Ordinary Portland Cement Stabilization of Amaoba-Umuahia Lateritic Soil using Snail Shell Ash, SSA as Admixture

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Abstract:- *The effect of Snail Shell Ash (SSA) on the engineering properties of ordinary Portland cement (OPC) stabilized Amaoba-Umuahia, Nigeria lateritic soil was investigated in the present research work. Geotechnical, chemical and phase analytical methods were used to characterize both the raw and treated laterite. Snail Shell Ash (SSA) was used in the present research as admixture. The compaction test, specific gravity, triaxial compressive strength test, Atterberg limit test and California bearing ratio test of the sample were carried out with varying proportions of SSA; 2%, 4%, 6%, 8% and 10%. The sieve analysis test conducted shows that the soil sample was retained at 1.18mm sieve size with the weight of soil retained obtained to be 15.2 grams and the soil classification shows the soil is silty clay i.e A-2-5 soil on the AASHTO soil classification system. Results showed that plasticity, percentage linear and volumetric drying shrinkages were reduced on the addition of the admixture. The specific gravity test result showed that the mean specific gravity of 2.65 was observed. There was an increase in dry density from1.655mg/m³ to 1.850 mg/m³ at 8% SSA and 6% OPC. The CBR value increased from 37 in its natural state to 81 at 8% SSA and 6% OPC. The Triaxial compressive strength test shows that the frictional angle increased from 24° at 0% to 27° at 2% SSA, 28° at 4% SSA and 29° at 8% SSA and the test maintained a considerable cohesion with the varied percentage of SSA. With the foregoing, SSA has been proved to be a good admixture on the improvement of the engineering properties of Amaoba lateritic soil for engineering works.*

Keywords:- *Ordinary Portland cement, stabilization, Amaoba-Umuahia, lateritic soil, SSA*

1. INTRODUCTION

Soil stabilization is the alteration of soils' engineering properties for use in relevant engineering works. Stabilization can increase the shear strength of soil and /or control the shrink swell properties of soil, thus improving the load bearing capacity of a sub –grade to support pavement and foundation. Reddish residues from rocks known as lateritic soil are mostly used for construction of road bases. Laterite is high in iron oxide and aluminium hydroxide content but low in silica content. The major concern of road engineers in the world is the incidence and frequency of road pavements failures on which researches such as this have been carried out and is carrying out ways to improve the bearing strength of road base (Brooks et al, 2011; Christopher et al, 2005)). Such improvement is known as soil stabilization which is concentrated on mixing two or more materials and compacting them to improve the strength of treated soil. In Nigeria as a case study, failure of most roads can be attributed to the use of laterite materials which do not satisfy load bearing requirements as sub-base and base materials. Pavement failure is usually associated with the lateral displacement of sub-grade as a result of pavement absorbing water and excessive deflection and differential settlement of material underneath the pavement (FMWT, 1997). In the construction of stabilized soil roads, cost of materials can be brought down considerably by selecting local available materials as in the case of snail shells. Once again, Soil stabilization is the process of improving the engineering property of soil and thus making it more stable. The objectives of this research work includes the following; (i) To evaluate and compute the amount of Ordinary Portland Cement and Snail Shell Ash admixture (SSA) that is required to meet or satisfy the optimum load bearing capacity requirements for lateritic soil in road construction or foundation, (ii) To determine the effect of stabilizer and admixture on the geotechnical properties of stabilized lateritic soil such as Atterberg limit, moisture-dry density relationship, California bearing ratio, cohesion etc.

2. REVIEW

Soil is any uncemented or weakly cemented accumulation of material particles formed by the weathering of rocks and contains void spaces between particles, which are filled by water and air (Ranjan & Rao, 2011). Also Christopher (2005) defined soil as a material having three components which includes, solid particles ,air and weathering which can occur either chemically when the minerals of a rock are altered through climatic effect, such as freeze, thaw and erosion. Soil is said to be residual soil, if the present location of the soil is that in which the original weathering of the present rock occurred otherwise, the soil is referred to as transported. Laterite is a soil group which is formed under weathering systems productive of the process of laterization (decomposition of ferroailumino-silicate mineral, leaching of the combined silica and base, and the permanent deposition of sesquioxide within the prefilled (Brooks et al, 2011; Little, 2000). The silica that left unleached after laterization will form secondary clay silicate minerals. Laterites usually form a poor soil full of concretionary lumps and very unfertile because the potash and phosphate has been removed in solution, while only iron and silica are left behind (Muhammad et al, 2007). In the mass while excluded from the air, laterite is so soft that any instrument readily cuts it and its cut into square masses with pick axe and immediately cut into the shape wanted with a trowel or large knife. It's very soon becomes as hand as brick and resist the air and water much better than any bricks (Puppala et al, 1996; Ni et al, 2002). In civil engineering the confusion regarding laterite has been caused largely by the tendency to apply the term to any red soil or rock on the tropics. The concept of self-hardening has persisted but several theories have been advanced to account for the origin and formation of laterite. Lacroix divided laterite into true laterite, silicate laterite and laterite clays on the basis of the hydroxide content and this was developed further by (Christopher et al, 2005) with the application of a silicate -aluminia ratio. Rahman et al (2008) reintroduced the concept of hardened and its relationship to the crystallization of iron oxides and dehydration. A silica sesquoxide ratio $\{S_iO_2 /(AL_2O_3 + Fe_2o_3)\}$ with the ratio between 1.33 and 2 was therefore proposed for lateritic soils values greater than 2 indicated non-lateritic, tropically-weathering soil (Zhang & Tao, 2006). For engineering purposes, the term "Laterite" is confined to the coarse-grained vermicular concrete materials, including massive laterite. The term "lateritic soil" refers to the materials with lower concentration of oxides. Lateritic soil is formed in hot wet tropical regions with an annual rainfall between 750 to 3000mm (usually in areas with a significant dry season) on a variety of different types of rocks with high iron content. The location on the earth, that characterized these conditions fall between latitudes 35^{o}S and 35^{o}N (Werkmeister et al, 2001; Little, 2000). Laterization is the removal of silicon through hydrolysis and oxidation that result in the formation of laterite and lateritic soils. The degree of laterization is estimated by the Silica Susquoxides (S.S) ratio ($S_io_{2/}/Fe_2O_3 + AL_2O_3$). Laterization involves physical –chemical alteration of primary rocks forming mineral into material rich in 1.1 lactose clay mineral (Kaolinite) and laterite constituents (Fe, Al, Ti and Mn). In the first place Ca, Mg, Na and K are released, leaving behind a siliceous framework for the formation of clay minerals. During prolonged alkaline attack, the siliceous framework consisting silica tetrahedral and alumina octahedral is disintegrated. Silica will be leached slowly while alumina and Ferri Sesquioxide (Fe_2O_3, AL_2O_3 and Ti O_2) remain together with kaolinite as the end product of clay weathering. The end result is a "reddish matrix" made from kaolnite goethite and "fragment of the pisolitic iron crust"

2.1. Non –Cemetitious Additive Stabilization

There are lots of additive that have been experimented on with effect to improve the geophysical properties of soil at lower cost by replacing certain percentages of cemetitious stabilizers with non cementitious additives (Ettu et al, 2013; Sadeeq et al, 2015). Some of these non cemetitious stabilizers include; Snail Shell Ash obtained from burnt and pulverised snail shells which were used in this work, quarry dust obtained as waste in quarry site, egg-shell ash, palm kernel ash, palm bunch ash, coconut shell ash, saw dust ash etc.

2.2. Cementitious Stabilization

Cement is composed of calcium-silicates and calcium-aluminates that, when combined with water hydrates to form the cementing compounds of calcium-silicates-hydrates and calcium-aluminates-hydrates as well as excess calcium hydroxides (Salahudeen and Akiije, 2014. Because of cementitious material, as well as the calcium hydroxide (lime) formed, cement may be successful in stabilizing both granular and fine grained soil as well as aggregates and miscellaneous materials (Little et al, 2010; Rafat & Mohammad, 2011; Shafique et al, 2009, Umesha et al, 2009; Brooks et al, 2011; Okafor and Egbe, 2013). Portland cement, pozzolan, kaolin etc can be used either to modify and improve the quality of the soil or to transform the soil into a cemented mass with increased strength and durability. The amount of cement used will depend upon whether the soil is to be modified or stabilized.

2.3. Snail Shell Ash (SSA)

Snail Shell Ash (SSA) as an admixture is a material other than cement, water and aggregates that is used as an ingredient or filler in the production of concrete or as admixture in the stabilization of weak engineering soil and is added to the batch immediately before or during mixing. According to (Solanski et al, 2010; TDT, 2005) admixture in concrete as filler can improve its workability, hardening or strength characteristics and generally result in a reduction in the cost of concrete construction e.g. SSA.

2.4. Ordinary Portland Cement (OPC)

Ordinary Portland Cement is the most common type of cement in general use around the world, used as a basic ingredient in the production of concrete, mortar and stucco. It developed from other types of hydraulic lime gotten from limestone (Boyd). The major chemical components of OPC are Tricalcium silicate $(CaO)_2.SiO_2)$, and tricalcium aluminate $[(CaO)_3.Al_2O_3Fe_2O_3]$. The most common use of OPC is in the production of concrete as a cohesive material of structural elements such as panels, beans, stairs, damns, foundations and column (Okafor and Egbe, 2013).

3. MATERIALS AND METHODS

3.1. Materials

Materials used for the research work include Amoaba lateritic soil, OPC and Snail Shell Ash (SSA) as admixture. Laterite samples were gotten from amaoba borrow pit site situated along latitude 05° 26^{1} 44.288^{11} N and longitude 07° 32^{1} 33.229^{11} E (www.google.com, 2015) used as a source of laterite for civil engineering works within IKWUANO Umuahia, South Eastern Nigeria was investigated under normal laboratory condition. The laterite was obtained having little content of moisture in it i.e. semi-solid state and it was reddish brown in colour. Snail Shells were collected from dump site at Umuahia ultra modern market. The snail shell was washed thoroughly to remove the droppings of the snail. The snail shell was then sun dried for 3 weeks and then burnt without gasoline or fuel on a clear dried surface. The crushing of the burnt snail shell was carried out immediately on that same clear and dried surface. The ash was sieved using the 0.75µm BS TEST sieve to achieve a smooth, uniform and fine particle. The ash was found to be hygroscopic hence the ash was stored in an air-tight container. Ordinary Portland cement was gotten from Dangote Cement at the Umuahia ultra-modern industrial and building materials market. The cement was preserved to prevent contact with water in a dry place.

3.2. Methods

The physical characteristics of Amaoba laterite was determined which includes; particle size distribution, Atterberg limit, compaction/moisture content, specific gravity, CBR, and unconfined compressive strength (ASTM D-1632; ASTM D-1633; ASTM D-5102-09; ASTM D-2166-06; IS: 2720-Part XVI, 1990).

Particle Size Distribution

Orderly arranged British Standard Sieves to BS1377 (1990); 4.36mm, 2.36mm, 1.18mm, 600µm, 425µm, 300µm, 212µm, 150µm, 75µm; Lid and receiver; balance readable and accurate to 0.1g, drying oven, sieve brush and the mechanical shaker were the apparatuses used for the PSD test.

Atterberg Limit (Plastic Limit, Liquid Limit & Plasticity Index)

A flat glass plate (10mm thick and 500mm square); two palette knives (200mm long and 30mm wide); Cassagrande liquid limit apparatus; a grooving tool and gauge; an evaporating dish or a damp cloth; a beaker containing distilled water; and a non-corrodible air tight container large enough to take about 250g of wet soil and the material soil sample were the apparatuses use for the above examination.

Soil Compaction/Moisture Content Test

A cylindrical metal mould having an internal diameter of 105mm, internal effective height of 115.5mm and a volume of 1000cm^3 (the mould shall be fitted with a detachable base plate and a removable extension 50mm high); a metal rammer having a 50mm diameter circular face and weighing 2.5Kg (the hammer was equipped with a suitable arrangement for controlling the height of drop to 300mm); a balance readable and accurate to 1g; a palette knife (100mm long and 20mm wide); a straight edge steel strip 300mm long, 25mm wide and 3mm thick with one bevelled edge; 20mm BS test sieve and a receiver; large metal tray (600mmx500mm with sides 80mm deep) were apparatuses used for moisture content and MDD examination.

Specific Gravity Test

The apparatuses used for this examination are; two density bottles (pycnometers) of approximately 50ml capacity with stoppers; water bath maintained at constant temperature of 20^{o}C within +0.2^{o}C; vacuum desiccators; thermostatically controlled drying oven (105-110^{o}C); balance readable and accurate 0.001g; a vacuum pump, spatula (150mm long, 3mm wide); plastic wash bottle containing air-free distilled water; sample divider of the multiple slot type (riffle box) with 7mm width of opening; and a length of rubber tubing to fit the vacuum pump and the desiccators.

California Bearing Ratio (CBR)

The apparatuses used for this examination are; Compressive machine, proving ring, dial gauge, stopwatch, sampling tube, split mould, vernier caliper, and balance.

Undrained Triaxial Test

The apparatus used for the unconfined triaxial test on the studied sample is as shown in Fig. 1 below.

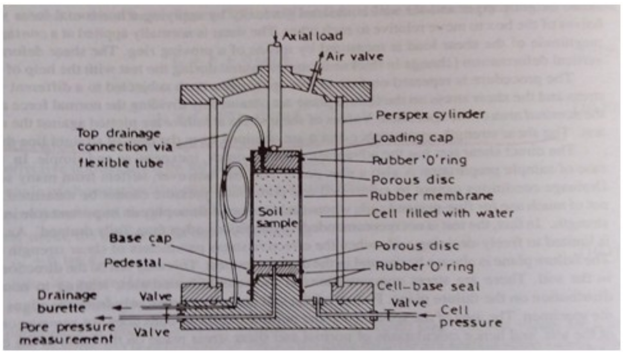

Figure 1: *Triaxial test apparatus set up (Ranjan and Rao, 2011)*

4. RESULTS AND DISCUSSIONS

The chemical analysis was done by adopting X-ray fluorescence technique in which the snail shell ash is made into standard tablet from the samples of cement to get the chemical analysis of the snail shell ash. The chemical investigation of snail shell ash gives us a conclusion that the SSA has the same properties as that of the OPC nearly satisfying all the requirements. Table 1 shows that the snail shell ash contains the main chemical constituents of cement which are CaO, SiO_2, Al_2O_3, MgO etc that present in the ordinary Portland cement

Table 1: *Chemical Composition of Snail Shell Ash*

Constituent	Description	% in Snail Shell Ash
LOI	Loss on ignition	40.54
Sio_2	Silica	0.60
AL_2O_3	Alumina	0.51
Fe_2O_3	Ferrous oxide	0.56
CaO	Calcium oxide	51.09
MgO	Magnesium oxide	0.69
80_3	Sulphur oxide	0.19
Na_2O	Sodium oxide	1.20
K_2O	Potassium oxide	0.12
TiO_2	Titanium dioxide	0.03
P_2O_5	Phosphorus perioxide	0.21
Mn_2O_3	Manganese oxide	0.02
CL	Chlorine	0.034
Total		95.79

This test determines the relative portions of different sizes of particles present in a soil sample. Two separate procedures are used in order to span the very wide range of particle size which are encountered. These are sieving and the sedimentation methods. Sieving is used for gravels and coarse sand particles which can be separated into different size ranges with a series of standard sieves. The particle size distribution data is presented graphically as the particle size distribution (PSD) curve or the grading curves, for the material. This enables engineers to recognize instantly the grading characteristics of a soil. Fig.2 represents the particle graphically as the particle size distribution of Amaoba lateritic soil. It is associated with small grain size which affects inter-particle packing level and shrinkage level. The particle size distribution classification of soil was determined and obtained to be A-2-5 and A-2-6 which is silty clay soil (AASHTO, 1982).

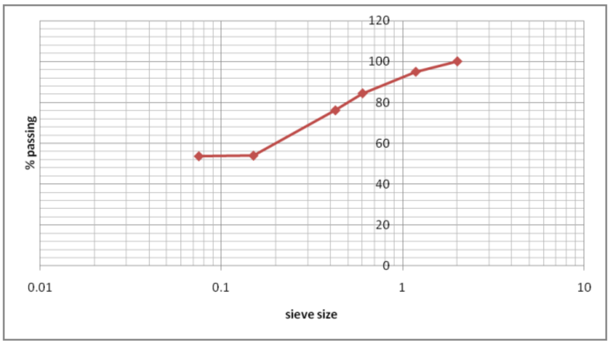

Fig 2: *Sieve Analysis Graph*

The specific gravity test was conducted using separate distilled bottles, the weights of the bottles were recorded at different bottle content i.e. bottle filled with water only, bottle filled with soil sample and water, and bottle when empty. The analysis was conducted as well and the result of each bottle obtained. Bottle 1 was obtained as 2.65 and bottle 2 as 2.64 which gave rise to the mean specific gravity (MSG) of 2.65 which falls between 2.6 and 2.7 which is the specified value by (Brooks et al, 2011) for natural aggregate.

The result of the Atterberg limit test showed that at 0% SSA + 0% OPC which is the control state, that the Liquid Limit(LL) was very high i.e. 45.6% and PL was 25.2, which eventually accounted for high plasticity. However, the addition of admixture i.e. SSA to the lateritic soil sample reduced the Liquid Limit (LL) and Plastic Limit (PL) as shown in Table 2 and Figures 3, 4, 5, 6, 7 and 8. From the table and figures, it is observed that the properties of the Atterberg limit decreased considerably with increased amount of SSA and the lowest plasticity of 13.35% was recorded at 10% SSA.

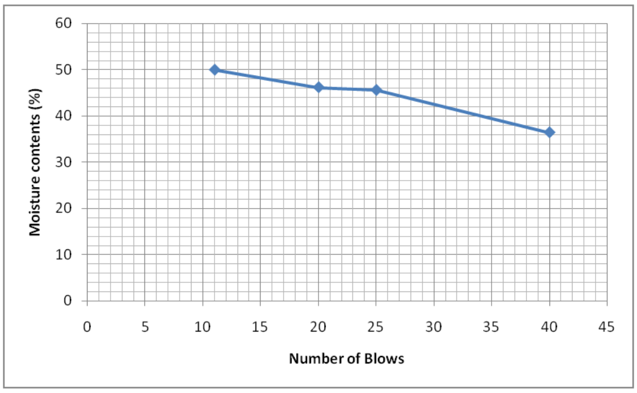

Fig 3: *Atterberg Graph for 0% SSA*

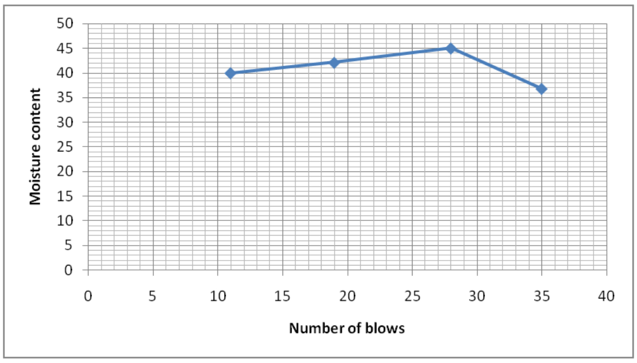

Fig 4: *Atterberg limit Test graph for 2% SSA*

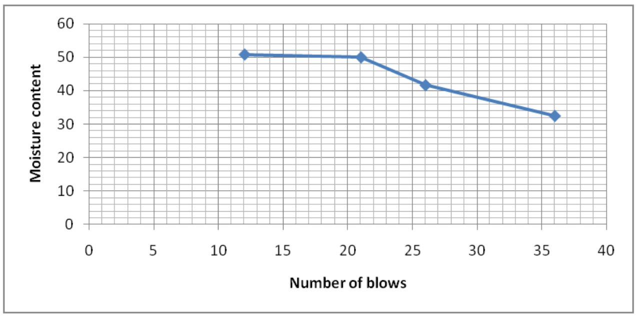

Fig 5: *Atterberg limit Test graph for 4% SSA*

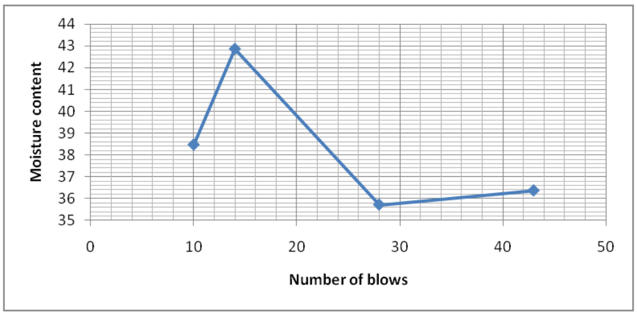

Fig 6: *Atterberg limit Test graph for 6% SSA*

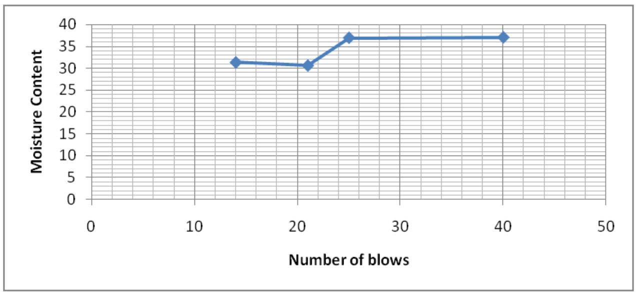

Fig 7: *Atterberg limit Test for 8% SSA*

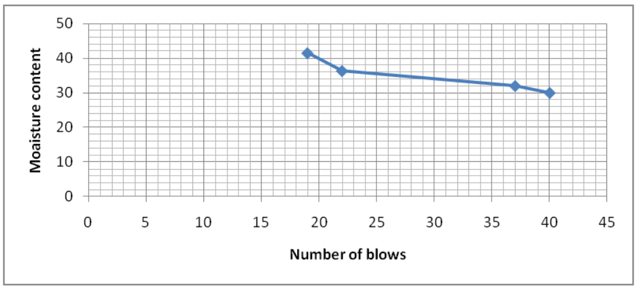

Fig 8: *Atterberg limit Test graph for 10% SSA*

Table 2: *Effect of SSA% on the Atterberg limit condition of the studied sample*

SSA%	0	2	4	6	8	10
LL %	45.60	44.80	42.5	37.01	36.94	35.02
PL %	25.20	26.11	21.48	22.50	23.04	21.67
PI %	20.40	18.69	21.02	14.51	13.90	13.35

From Table 3 and Figures 9, 10, 11, 12, 13 and 14, the compaction test rests have shown that at 0% Snail Shell Ash (SSA) with 6% cement stabilizer at various percentages of water which include 8%, 10%, 12%, 14%, 16%, the optimum moisture content was determined as 13.10 and the maximum dry density, MDD as 1.778mg/m^3. At 2% admixture and 6% cement there was an increase in the MDD to 1.852mg/m^3, and further addition of admixture at 4%, the OMC was obtained as 14.56% and MDD as 1.714mg/m^3. Furthermore, at 6% admixture, the highest value of MDD was obtained to be 1.849mg/m^3 at OMC of 10.03%. Finally, at 8% and 10% SSA, there was an increase in the OMC property and a reduction in MDD respectively.

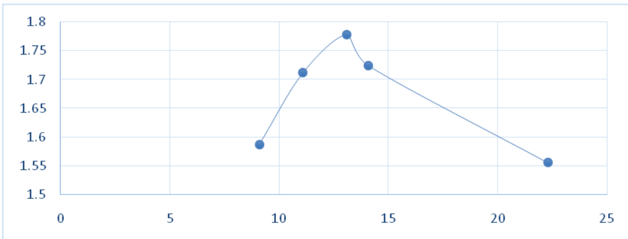

Figure 9: *Compaction curve at 0% SSA*

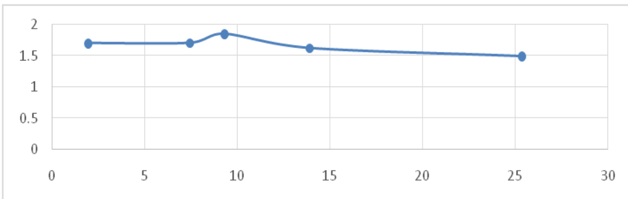

Figure 10: *Compaction curve at 2% SSA*

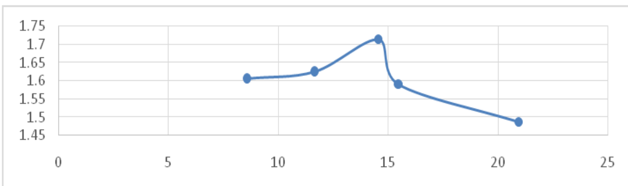

Figure 11: *Compaction curve at 4% SSA*

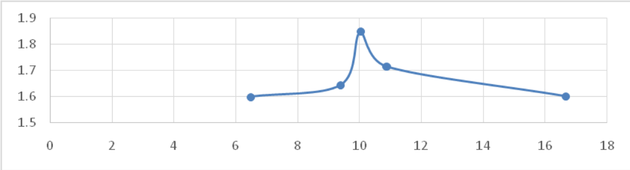

Figure 12: *Compaction curve at 6% SSA*

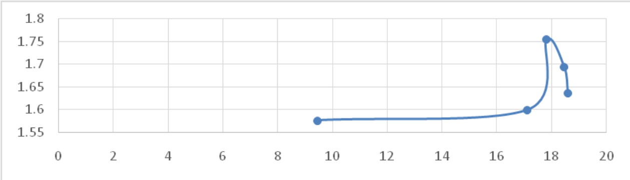

Figure 13: *Compaction curve at 8% SSA*

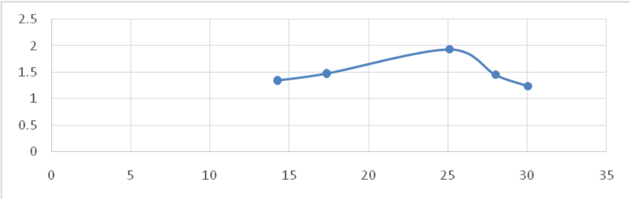

Figure 14: *Compaction curve at 10% SSA*

Table 3: *Effect of SSA % on the compaction properties of studied sample*

SSA %	0	2	4	6	8	10
OMC %	13.10	9.32	14.56	10.03	17.81	25.13
MDD mg/m³	1.78	1.84	1.71	1.85	1.76	1.45

From Figure 15, it is observed that the California Bearing Ratio (CBR) for the natural soil was determined as 37.98, at 2.5mm and 44.12 at 5.0mm respectively which is a poor value for road pavement work. At various percentages of admixture additive which includes 2%, 4%, 6%, there was an increase of CBR values of 44.49 (2.5mm), 50.63 (5.0mm) for 2%, 61.85 (2.5mm), 57.14 (5.0mm) for 4% and for the 6%, 66.19% and 58.59% were recorded respectively and the CBR value 81 (2.5mm) was recorded, at 8% of SSA and 6% OPC as specified by the Nigeria specification.

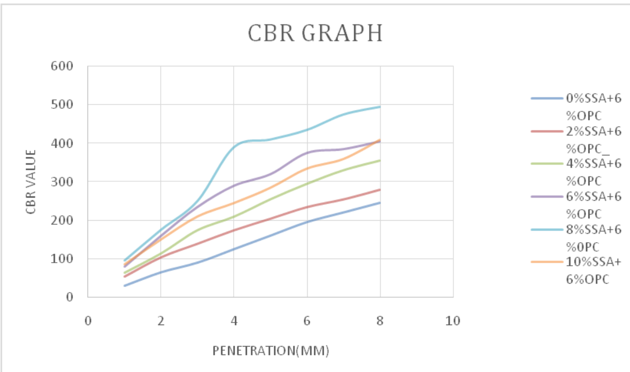

Figure 15: *Effect of SSA % on the CBR of the studied sample*

From Table 4, the result of the triaxial compressive strength test has shown that at 8% SSA + 6% OPC, the cohesion of the stabilized sample was low at the highest angle of internal friction 29° which makes soil very plastic. At 0%, 2%, 4%, 6%, and 10% the cohesion of the soil was recorded to be 20, 11, 11, 16 and 19 respectively and the angle of internal friction recorded was 24°, 27°, 28°, 21° and 27° respectively. 10% SSA have an ideal Cu and Ø which are 19KN/m² and 27°.

Table 4: *Effect of SSA % on the triaxial properties of the studied sample*

SSA (%)	0	2	4	6	8	10
Cu (KN/m²)	20	11	11	16	12	19
Ø (°)	24	27	28	21	29	27

5. CONCLUSION

It could be noticed that formation of reaction products, such as hydration, contribute to strength development of the stabilized soil; and that the formation of these reaction products are influenced by the addition of admixture (SSA). A cement quantity of as small as 6% and 8% SSA admixture additive is found to be sufficient for stabilizing the lateritic sample to the required strength of CBR of 81 which is greater than that recommended by the Nigerian specification for construction of minimum value 80 which points to the economics and advantages of the method, lower cost as well as its concomitant environmental benefits are characteristics that make this method attractive.

Finally, the use of locally, affordable and economical materials as is the case of snail shell ash was adopted to be used for stabilization of clays to improve structural properties such as compaction of lateritic and volumetric change properties. Considering the various test carried out on Amaoba lateritic soil, it is recommended that the stabilized with 8% of SSA and 6%by weight of ordinary Portland cement. This will go a long way in ensuring the durability of the road way base-coarse.

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