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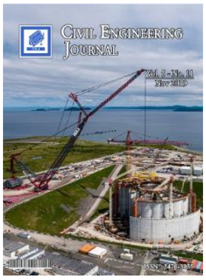

Effect of Compactive Efforts on Strength of Laterites Stabilized with Sawdust Ash

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Abstract

This study investigates the effects of different compactive efforts on the strength of laterites stabilized with sawdust ash (SDA). Laterites in the categories of A-7-5 and A-7-6 were considered because they are not suitable in the natural states as subgrade materials. The geotechnical properties of the laterites in their natural states were determined. The sawdust was burnt and sieved through 600micron. The sawdust ash (at 2%, 4%, 6%, 8% and 10%) was added to the laterites and the atterberg limits were determined, while the California bearing ratio and Unconfined compression test were determined using three compactive efforts (596, 1192 and 2682KN-m/m^3). It was generally observed that the maximum dry densities of the natural and stabilised laterites increase with increase in the compactive efforts, while the optimum moisture contents reduce. The plasticity indices of the laterites increased with the addition of SDA. The optimum values of the MDDs (2006 and 1878 kg/m^3) were observed at 4% and 6% SDA of 2682 kN-m/m^3 compactive effort for samples A and B, respectively. The soaked and unsoaked CBR values of the soils at natural state are 4.89 and 16.33%, and 3.4 and 5.62% for samples A and B, respectively. The results indicate that the higher the compactive efforts, the higher the CBR values of the two samples. Increase in SDA contents of soil samples A and B showed a non-predictable trend on their CBR values. The Unconfined Compressive Strength values at natural and treated states fell below the requirements. Generally, it was found that the use of sawdust ash alone as stabilizer was not effective. Therefore, it was concluded that future studies should consider the use of the sawdust ash in combination with cement or lime.

Keywords: Sawdust; Ash; Laterite; Compaction; Effort; Strength; Stabilisation.

1. Introduction

The economy of most nations in the world depends on their road network, since this is one of the major means of movement of freight and passengers. For an improved economy in the parts of the world where their major resource of transportation is through road, it is important that the road network of such nations is properly designed and constructed. Unfortunately, failures of road pavements have been so rampant in nations like Nigeria which had always resulted in the loss of life and properties [1]. Different reasons have been attributed as the causes of the failure. This includes the use of unsuitable materials, poor design, poor workmanship, unfriendly environmental conditions, heavy loadings, etc.

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This study focuses on laterites – a major material used in the construction of roads in the tropics. Laterite was given different definitions by various authors. It was defined as a product of in-situ weathering of igneous, sedimentary, and metamorphic rocks commonly found under unsaturated conditions [2]. Laterite was defined by Alexander and Cady (1963) and Thagesen (1996) [3, 4] as highly weathered material either hard or having potential of hardening on exposure to wetting and drying, possessing high contents of oxides of iron, aluminum, or both and low proportion of silica, nearly void of bases and primary silicates, which may contain large amounts of quartz and kaolinite. Laterite soil is used to describe all the reddish residual and non-residual tropically weathered soils, which genetically form a chain of materials ranging from decomposed rock through clays to sesquioxide-rich crusts. The ratio of silica (SiO_2) to sesquioxides (Fe_2O_3 + Al_2O_3) less than 1.33 is an indication of laterite, values between 1.33 and 2.0 indicate lateritic soil while a value greater than 2.0 is an indication of non-lateritic soil [5, 6]. Most samples of laterite available for use on site for road construction are inadequate in one aspect or the other (grading, plasticity, strength and freedom from deleterious chemical constituents) in terms of their properties. Inadequacy in the strength properties of available laterite or lateritic soil had posed a great challenge for the engineers, which has therefore led to looking for means of improving the strength of the soils. The major way of achieving this is by stabilization.

Stabilization is the process of blending and mixing materials with soil to improve the soil's strength and durability. Also, it is the process which may include blending soils to achieve a desired gradation or mixing commercially available additives that may alter the gradation, change the strength and durability, or act as a binder to cement the soil [7]. Stabilization is any process by which a natural soil is being treated in order to improve its engineering properties and make it more stable [4, 8]. Stabilization of soil has been regarded as a last hope for increasing the strength of substandard materials where the cost of getting other suitable soil material that will meet the specifications given is on the high side compare to the cost required to treat the soil [9]. Stabilization of soil was grouped into five major different methods, which are mechanical stabilization, cementitious stabilization, bituminous stabilization, chemical stabilization and specialized methods of stabilization [10].

Cement which is under the cementitious method of stabilization was found to be the most popular material used for stabilization in years past and it is still one of the best materials till this day. It was observed that apart from the cost of buying cement which is becoming unaffordable to common man, the CO2 (about 7% of the global value) released to the atmosphere during the period of production of cement posed a great threat to the society [11]. This fact has set many researchers on their toes in looking for alternative materials that will partially or totally replace the use of cement; some of the materials include sawdust ash, rice husk ash, bagasse ash, cassava peel ash, etc. This study focuses on the use of sawdust ash for the stabilization of weak laterite.

Sawdust is very common in most part of the world, although people may not recognize the importance of the sawdust generated within their town as they only use it in poultry farming, preservation of agricultural produce (e.g. potatoes), making briquettes for use as fuel, and also using it as fuel by burning directly [12]. Sawdust is a by-product of cutting, grinding, drilling, sanding, or otherwise pulverizing wood with a saw or other tool. It comprises of fine particles of wood and is also the by-products of certain animals, birds and insects which live in wood, such as the woodpecker and carpenter ant. The dust is usually used as domestic fuel. The resulting ash which is a form of pozzolana is known as sawdust ash (SDA). Clean Sawdust without a large amount of bark has proved to be satisfactory as it does upset the reactions of hydration [13].

Some researchers had work on the use of SDA as partial replacement for cement in different applications. Ogunribido [14] evaluated the effects of sawdust ash on the geotechnical properties of soil from three locations in Southwestern Nigeria. SDA of 2, 4, 6, 8 and 10% by weight of soil sample were added to the soil. The results show that sawdust ash improved the geotechnical properties of the soil samples. Effects of Palm Kernel Shell Ash (PKSA) and Sawdust Ash were monitored on geotechnical properties of soils from Efon Alaaye Local Government Area of Ekiti state [15]. Samples of soil obtained were subjected to compaction and Atterberg Limit tests. The additives were added to the soil samples at 2, 4, 6 and 8% proportions. The results showed that the LL, PI and MDD values decreased with increasing additives contents. It was found that the soil samples responded more to SDA additive than PKSA additive.

The use of SDA mixed with 45% slaked lime for production of sandcrete hollow blocks was investigated by Tyagher et al. [16] in order to determine the percentage of SDA-lime and water/cement ratio that would give the maximum 28-day strength. The ash mixed with 45% slaked lime was used to partially replace ordinary Portland cement (OPC) in various proportions. Fifteen blocks for each proportion were moulded using the mix of 1:8 and different water-cement ratio. It was concluded that for a mix of 1:8 of hydraulic binder and sand, 10% replacement of OPC by SDA-lime gave the maximum strength at water/cement ratio of 0.55 and was recommended for the production of sandcrete hollow blocks for low-income housing and non-load bearing walls. Gwarah et al. [17] investigated the use of sawdust ash as partial replacement of cement in concrete production. It was observed that 5 to 10% SDA when replaced with ordinary Portland cement can still give the desired strength of concrete.

Effect of the mixture sawdust ash and eggshell ash on engineering properties of lateralized bricks for low cost housing as compared with cement lateralized bricks was examined by Ayodele et al. [18]. The ash mixture was mixed with the laterite using 2, 4, 8 and 16% by weight of dry soil to produce bricks which was later subjected to compressive strength test. The results obtained showed that 2 and 4% SDA and eggshell ash is suitable as substitute for cement in low cost housing.

Nnochiri, et al. [19] assessed the geotechnical characteristics of lateritic soil and sawdust ash lime (SDAL) mixtures. The sawdust ash was mixed with lime for stabilization in the ratio 2:1 and was added to the soil in varying proportions of 2, 4, 6, 8 and 10% by weight of soil. Addition of SDAL increased the soil's optimum moisture content (OMC) from 17.0% at 0% SDAL to 26.5% at 10% SDAL and reduced its MDD from 2040 kg/m^3 at 0% SDAL to 1415 kg/m^3 at 10% SDAL. Values of unconfined compressive strength increased from 38.58kN/m^2 to highest value of 129.63kN/m^2 at 6% SDAL. The values of LL and PI of the soil were effectively reduced with the addition of the SDAL, from 54.0% at 0% SDAL to 49.0% at 10% SDAL and from 13.7% at 0% SDAL to 12.5% at 10% SDAL respectively.

The effects of compacted sawdust ash-lime (SDAL) stabilized soil as hydraulic barriers for waste contaminant was assessed by Ojuri and Oluwatuyi [20]. The study examined the impact of sawdust ash-lime stabilizer on the geotechnical characteristics of lateritic soil as an effective hydraulic barrier system for landfill liner application. SDAL mixtures in the ratio of 2:1 were added to the lateritic soil at varying percentages between 0 and 10%. The soil-SDAL mixtures were compacted using four integrative methods: reduced Proctor, standard Proctor, West African Standard and modified Proctor. The compacted soil-SDAL mixtures were subjected to hydraulic conductivity and unconfined compressive strength tests.it was observed from the results that increase in SDAL reduced the MDD and increased the soil's OMC. Increase in SDAL was also observed to reduce the hydraulic conductivity and increased the unconfined compressive strength of the soil mixture. Effects of compactive efforts on strength indices of laterite treated with calcium carbide waste, foundry sand treated with cement kiln dust, soil treated with cement-bagasse ash were examined by some scholars [21-24], while some looked into the effects of SDA as partial replacement of cement and lime.

Generally, the literature review shows that not much has been done in the use of sawdust ash to stabilize weak laterite and the effects of the compactive efforts on the stabilized soil. Therefore, this study investigates the possibility of using SDA to stabilize laterites and the effects of compactive efforts on the stabilized laterites.

2. Materials and Methods

2.1. Materials

The methodology for the research is as shown in Figure 2. The soils samples chosen for this investigation were laterites classified as A-7-5 and A-7-6. The laterites were sourced and found in two locations. The locations are shown in Figure 1 as locations A and B, respectively. Location A is located beside the main gate of the Federal Polytechnic, Ado-Ekiti on latitude 7º36'10"N and longitude 5º18'15"E, while location B is located at opposite Federal radio corporation junction along Ado-Iworoko road on latitude 7º41'18"N and longitude 5º15'09"E [25]. Soil samples were collected in disturbed state from the two locations at an average depth of 1.0m.

Sawdust was collected from a saw mill located at Oke-ureje, along Federal Polytechnic road, Ado-Ekiti, Ekiti state Nigeria. The sawdust collected was air-dried at room temperature for an average of two weeks and the deleterious materials were removed. The dried sawdust was converted into ash by open air burning. The dried sample of sawdust was placed in a metallic drum and burnt under atmospheric temperature and pressure. The resulting ash was made to pass through a sieve of 600 µm aperture before it was used. The procedure of burning was as shown in Figure 3.

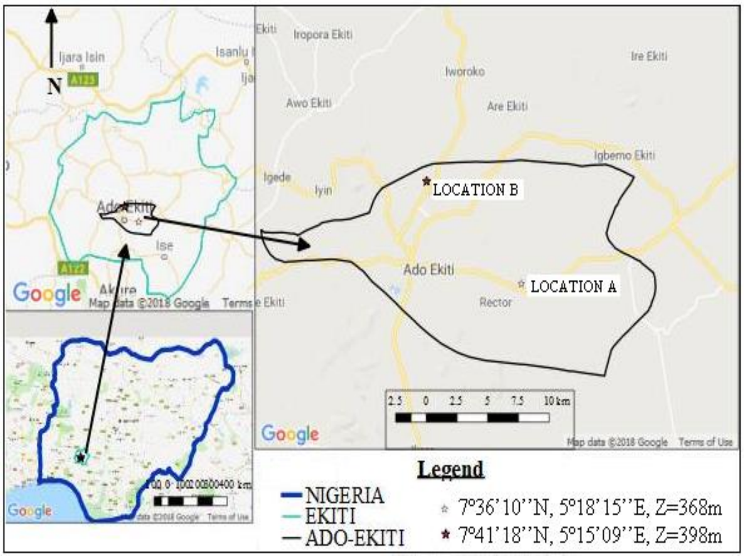

Figure 1. Location of the study areas [25]

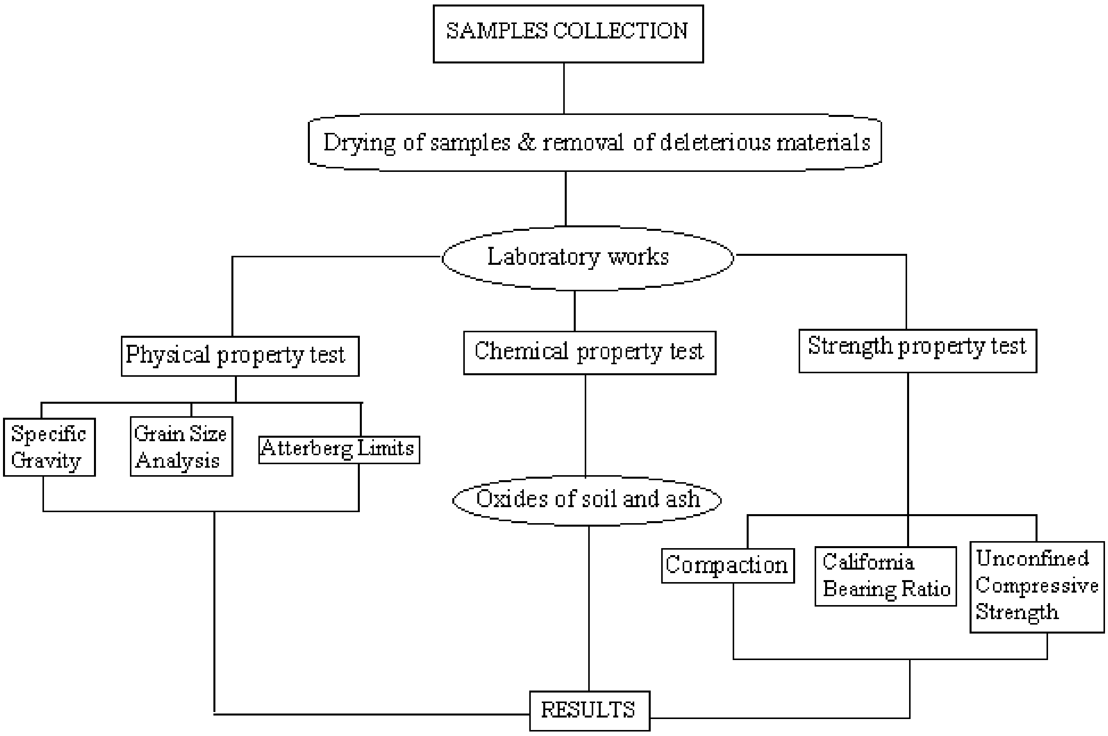

Figure 2. Flowchart of research methodology

Figure 3. Stages of converting sawdust to ash

2.2. Methods

The study involved the collection of the two laterite samples (A-7-5 and A-7-6) from two locations. The two samples were collected and their natural geotechnical properties determined, such as the particle size distribution, specific gravity, Atterberg limits tests (Liquid limit, Plastic limit and Shrinkage limit), compaction, California bearing ratio (CBR) and unconfined compressive test. The chemical compositions of the sawdust ash and the laterites were determined. The sawdust ash (SDA) at 2%, 4%, 6%, 8% and 10% by weight was added to the two laterites and stabilised in accordance with BS 1924(26) and the Atterberg limits (Liquid limit, Plastic limit and Shrinkage limit). Compaction, California bearing ratio (CBR) and unconfined compressive strength tests were carried out on the stabilised laterites using three different compactive efforts ((596, 1192 and 2682KN-m/m^3) representing Standard Proctor, West African Standard and Modified Proctor energies, respectively and the results were analysed.

2.2.1. Test Procedures

Particle Size Distribution (PSD): The test was done in accordance with BS 1377 [27] in order to analyse the grains that make up the soil. 1000 g of air-dried sample of soil was soaked in a bowl for 24 hours after which it was washed and sieved with a 75 µm sieve to remove silt/clay portions of the soil, until the water was clean. Soil particles retained on the sieve were oven dried for mechanical sifting by pouring the soil into the assemblage of sieves of various sizes.

The portions of sample passing through a 75 μm sieve in the form of liquid during the process of washing were subjected to hydrometer test by using hydrometer 152H in order to ascertain the silt and clay content in percentage that was present in the soil sample.

Specific Gravity Test*:* Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at the same temperature. The test gives an insight to how dense a soil sample is which in turn helps to distinguish between organic and inorganic soil. The test was performed by determining the ratio of the mass of soil occupying one third volume of 50 ml density bottles to the mass of water of the same volume. It was carried out in accordance with BS 1377 [27]. The result is expressed mathematically as shown in Equation 1.

$$\mathrm{Gs} = \frac{(W_2 - W_1)}{[(W_4 - W_1) - (W_3 - W_2)]} \tag{1}$$

Where: W_1 = weight of density bottle, W_2 = weight of bottle + soil, W_3 = weight of bottle + soil + water, and W_4 = weight of bottle + water

Chemical Analysis*:* Oxides of iron, aluminium, silicon, calcium, magnesium, potassium, etc. present in the soil samples and sawdust ash were tested using gravimetric method. The procedures were as stated in the Annual Book of the American Standard for Testing and Materials [28].

Atterberg Limits Test: This test encompasses determination of plastic, liquid and shrinkage limit of soil which is important in the process of monitoring soil-water behaviour used in soil classification. The lumps in an air-dried soil sample were broken in a mortar with a pestle and sieved through a 425 μm sieve size in preparation for the test. 200 g of fine soil that passed through the 425 μm sieve was soaked for 24 hours and tested in accordance with British standard [27]. The paste form was used for the tests and cone penetrometer method adopted for determining the liquid limit of the soils. Water content at which a sample of soil rolled on glass plate forming thread-like shape crumbles at 3 mm was determined to give its plastic limit while the water content at 20 mm penetration of the cone penetrometer gives the liquid limit of the samples. Shrinkage limit which is the water content at which further drying of soil will not result to further reduction in its length was determined using a linear shrinkage mould of 14.0 cm length. The shrinkage value is calculated as the ratio of change in length to the original length of the soil sample in percentage (Equation 2).

$$Linear\ Shrinkage\ (\%) = \frac{L_o - L_f}{L_o} \tag{2}$$

Where L_o = Length of wet soil bar and L_f = Length of dry soil bar.

Compaction Test: This test is aimed at determining the relationship between moisture content and dry density of soil for a specified compactive effort. Gradual increase in the volume of water added to any given soil at a specified compactive effort tends to remove the voids present in the soil sample thereby increasing its dry density. This phenomenon continues and the density will attain its maximum value at a particular water content before it starts to decrease with further increase of the water content. That density and the corresponding moisture content are called maximum dry density (MDD) and optimum moisture content (OMC). The compactive effort (E) was calculated as the ratio of the product of the number of blows per layer, number of layers, weight of rammer and height of drop of the rammer to the volume of mould used for the compaction test as shown in equation 3. Samples of laterite were compacted in accordance with Part 4 of British standard [27], using three different compactive efforts 596, 1192 and 2682KN-m/m^3 (representing Standard Proctor, West African Standard and Modified Proctor energies) to evaluate the compaction characteristics of the soils at natural and treated states. Compactive effort of 596 kN-m/m^3 was achieved by dividing the soil into three layers in a 1000 cm^3 mould. Each layer of the soil received 27 blows of a 2.5 kg rammer falling through a height of 300 mm. The energy derived from a 4.5 kg rammer falling through a height of 450 mm into a 1000 cm^3 mould was used to achieve the compactive efforts of 1192 and 2682 kN-m/m^3. The soil was divided into five layers with each layer receiving 12 blows and 27 blows for compactive efforts, respectively.

$$E = \frac{\left[\begin{pmatrix} Number\ of \\ blows\ per\ layer \end{pmatrix} \times \begin{pmatrix} Number\ of \\ layers \end{pmatrix} \times \begin{pmatrix} Weight\ of \\ Rammer \end{pmatrix} \times \begin{pmatrix} Height\ of \\ drop \end{pmatrix}\right]}{Volume\ of\ mould} \tag{3}$$

Where E = Compactive effort (KN-m/m^3).

California Bearing Ratio (CBR): The test was carried out in accordance with Part 4 of British standard [27] in order to determine the suitability of a soil for use as sub-base or base material. This test is an indirect way of measuring the shear strength of soil for use as subgrade or base material in flexible pavement construction. It involves measuring the resistance offered by the soil under controlled moisture content and density conditions to the penetration of a cylindrical plunger of cross-sectional area 1935 mm^2. The CBR is calculated as the ratio of the force required to push the plunger to a certain depth into the soil to that force required to push the same plunger to the depth into a standard sample of compacted crushed stone. The soil samples used were compacted in a CBR mould using the three selected compactive efforts and were run in soaked and unsoaked states and calculated as shown in Equation 4.

$$CBR\ (\%) = (Test\ load/Standard\ load) \times 100 \tag{4}$$

Unconfined compressive strength (UCS): The test is used to determine the compressive strength of soil in an unconfined state which in turn is used to calculate for the unconsolidated undrained shear strength of cohesive soil. The unconfined compressive strength (q_u) of a soil specimen is the ratio of failure load to the cross-sectional area of the specimen (at failure) when it is not subjected to any confining pressure. The soil samples used were pulverized and compacted with sand compacting apparatus. The sand compacting apparatus consists of a rammer of mass 6.6 kg, falling through the height of 5 cm, with an attached mould of 197 cm^3. The soil samples in control and stabilized states were compacted using the three different compactive efforts adopted and mixed with the optimum moisture contents of the compaction tests. Compacted specimens were trimmed to the ratio provided in British standard [27] (1:2-2½, B: D respectively). The specimens were oven dried at 70ºC for 24 hours and cured by covering them with polythene in compliance with method A14 of the materials manual [29] for 14days. UCS values of the soil samples were determined by as the average value while subjecting three specimens representing each additive content to unconfined pressure by using a compressive machine of known proving ring factor at 7 days interval in order to monitor the effect of SDA on them with respect to curing age. The typical failed specimens are shown in Figure 4.

Figure 4. UCS specimens after testing until failure

3. Results and Discussion

3.1. Particle Size Distribution

The soil samples were subjected to the wet sieving method of the particle size distribution test in accordance with the British standard [26] in other to ascertain the percentage by fraction, of various grains (gravel, sand, silts and clay) making up the soil samples. The gradation curves are presented in Figure 5. Adopting the Unified Classification system, the soil samples A and B are fine grained since the fraction of soil passing 75 µm sieve is greater than 50%. The soil samples having more than 35% of their grain fractions passing through the 75 µm sieve are classified as silt-clay materials according to the American Association of State Highway and Transportation Officials (AASHTO) [30]. The gradation curves show that soil samples A and B are well graded. The AASHTO Classification also shows that the laterites (Sample A and B) are in the categories of A-7-5 and A-7-6 with group index number of 31 and 13, respectively, which indicates they are not suitable in their natural state as subgrade materials.

According to clause 6201 of the Federal Ministry of Works and Housing [31], it was recommended that the percentage by weight of soil sample passing 75 µm sieve must not be greater than 35% for the soil to be fit as subgrade and base materials. The soil samples did not meet the requirement because of the high content of fines present in them; hence, treatment of the soils was necessary.

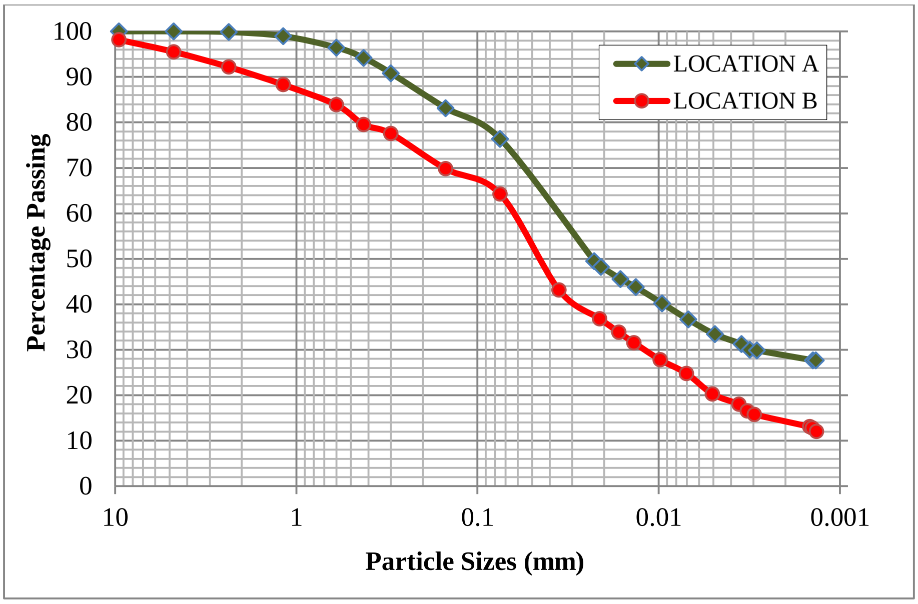

Figure 5. Particle size distribution curve of the natural soil samples studied

3.2. Specific Gravity

The specific gravity helps in classifying soil and to know the likely mineral present therein. Specific gravity of the soil samples was determined using density bottles and results of 2.17 were gotten for both samples A and B. The low value is an indication of the likely presence of organic substance in the soil samples.

Table 1. Specific gravity results of the soil samples.

	SAMPLE	A			B		
	TRIAL	1	2	3	1	2	3
W1	WT OF DENSITY BOTTLE	26.2	27.0	24.5	24.8	26.1	25.8
W2	WT OF BOTTLE + SOIL	46.9	47.8	46.1	47.6	49.3	46.4
W3	WT OF BOTTLE + SOIL + WATER	90.1	91.0	90.6	89.3	90.9	89.3
W4	WT OF BOTTLE + WATER	79.4	79.3	79.1	77.0	78.6	78.0
	G_S = W2-W1/[(W4-W1)-(W3-W2)]	2.07	2.29	2.14	2.17	2.13	2.22
	AVERAGE VALUE	**2.17**			**2.17**		

3.3. Chemical Composition

Soil samples A and B were subjected to gravimetric method to determine the chemical constituents in order to ascertain the silica sesquioxides ratio of the soil samples and for proper classification of the type of soils they were. The ratio of silica-sesquioxides [SiO_2/ (Al_2O_3 + Fe_2O_3)] for the soils as shown in Table 2 were calculated to be 0.71 and 1.32 for samples A and B respectively, which is an indication that the soils are laterites. According to Schellmann scheme for classification of weathering products [32], soil samples A and B are from weak laterisation and kaolinized profile, respectively. Chemical constituents of sawdust ash were also determined using gravimetric method in order to determine its pozzolanicity. The oxides of silicon, iron and aluminium present in the ash are as shown in Table 3 which is greater than 70 percent and clearly indicates that sawdust ash is pozzolan.

Table 2. Chemical constituents and their percentage in the soil samples

Chemical Constituents	Location A	Location B
SiO_2	38.11	52.06
Fe_2O_3	29.40	16.86
Al_2O_3	24.09	22.68
$SiO_2/(Fe_2O_3 + Al_2O_3)$	0.71	1.32

Table 3. Chemical Constituents of Sawdust Ash

Chemical Constituents	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3	K_2O	$SiO_2 + Al_2O_3 + Fe_2O_3$	Average
Percentage Composition	64.43	2.01	4.31	9.15	3.98	1.00	2.76	70.75	**71.13**
	65.21	2.03	4.27	8.97	4.01	1.20	2.81	71.51	

3.4. Atterberg Limits

The Liquid Limit (LL), Plastic Limit (PL) and Shrinkage limit give the indication of the rate of change of soil from one phase to the other. Sawdust ash was added to the soil samples in steps of 2% by weight of soil sample until it reaches 10%. The liquid limit values for soil samples A and B at natural states are 68.5 and 49.4%, while their plasticity indices are 36.31 and 21.75% respectively. Values of liquid limit and plasticity index greater than 41 and 11% respectively shows that the samples belong to the group of A-7 soil [30]. This shows that the samples are subject to high volume change. Further classification with AASHTO [30] shows that samples A and B are A-7-5 and A-7-6 soils respectively, which are rated as 'poor' materials for subgrade layer in road construction. Plasticity indices of samples A and B are greater than 7% and plotted above 'A' line as shown in Figure 6. It shows that samples A and B are silty-clayey soil of fat clay and lean clay with traces of sand, respectively. The soils are of group symbols CH and CL for A and B respectively [33-34]. The effects of SDA on the plasticity characteristics of the soil samples were monitored as shown in Figure 7 and it was observed that increase in SDA generally increases the liquid limit and plasticity index of the samples.

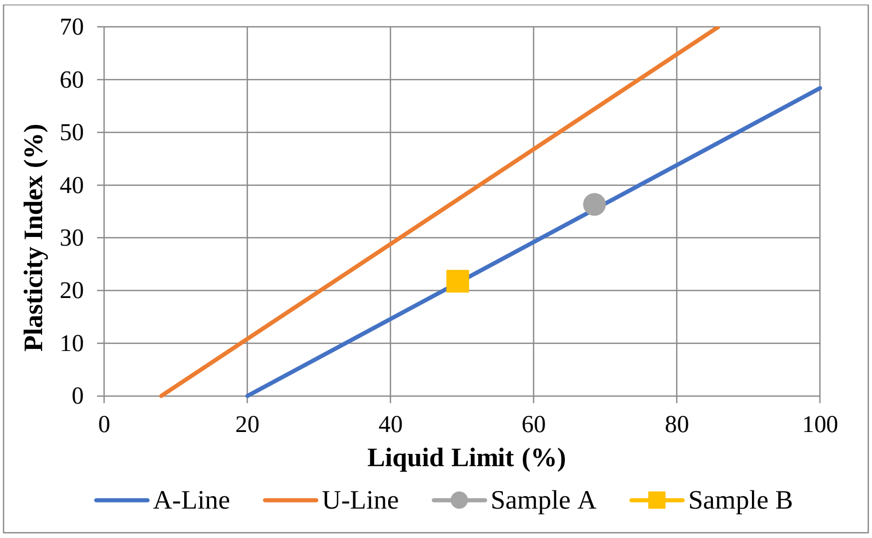

Figure 6. Plasticity chart showing the soils' group

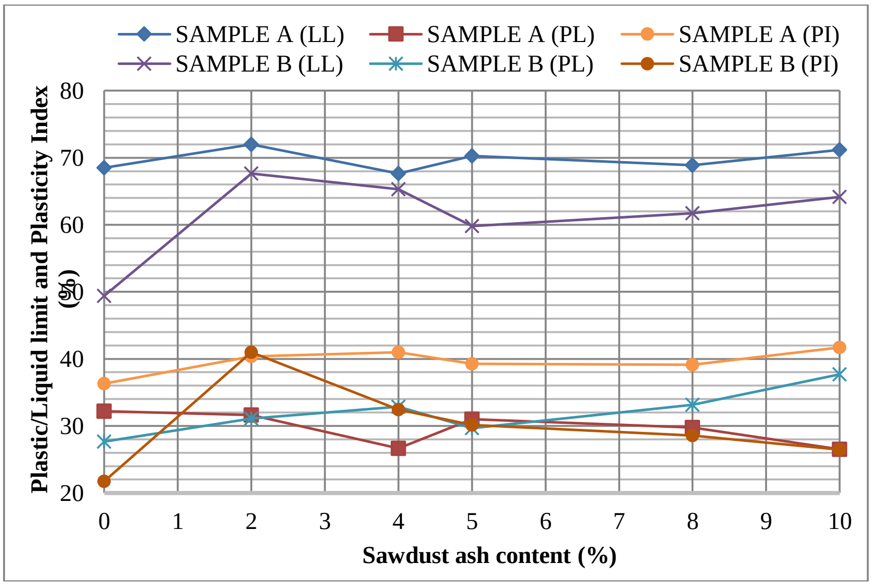

Figure 7. Effect of SDA on Atterberg limits of samples A and B

3.5. Compaction Test

Compaction characteristics of the soil samples (MDD and OMC) were monitored at natural and stabilized states using compactive efforts of 596, 1192 and 2682KN-m/m^3. The results as presented in Figures. 8a and 8b show that increases in compactive efforts generally increase MDDs and reduce OMC of natural soil samples. It was observed that an increase in compactive efforts increases the MDD of the soil irrespective of the quantity of SDA present. The optimum values of the MDDs (2006 and 1878 kg/m^3) were observed at 4% and 6% SDA for 2682 kN-m/m^3 compactive effort for samples A and B, respectively. Also, it was observed that the compactive effort of 596 kN-m/m^3 is not effective on the soil samples when treated with SDA. This was noted majorly on sample A as an increase in SDA content reduces the MDD of the soil. Increase in SDA content shows an erratic behaviour on the trend of the soil's OMC. The optimum moisture contents of the soil samples range from 17.5 to 28%. This was noted to be on the high side and it tends to reduce the workability of the samples [35-37]. Reduction in MDD of the soil samples with an increase in SDA content can be attributed to the low value of specific gravity (1.80) of the ash compared with that of natural soil sample. Increase in OMC could also be attributed to the affinity of SDA to water.

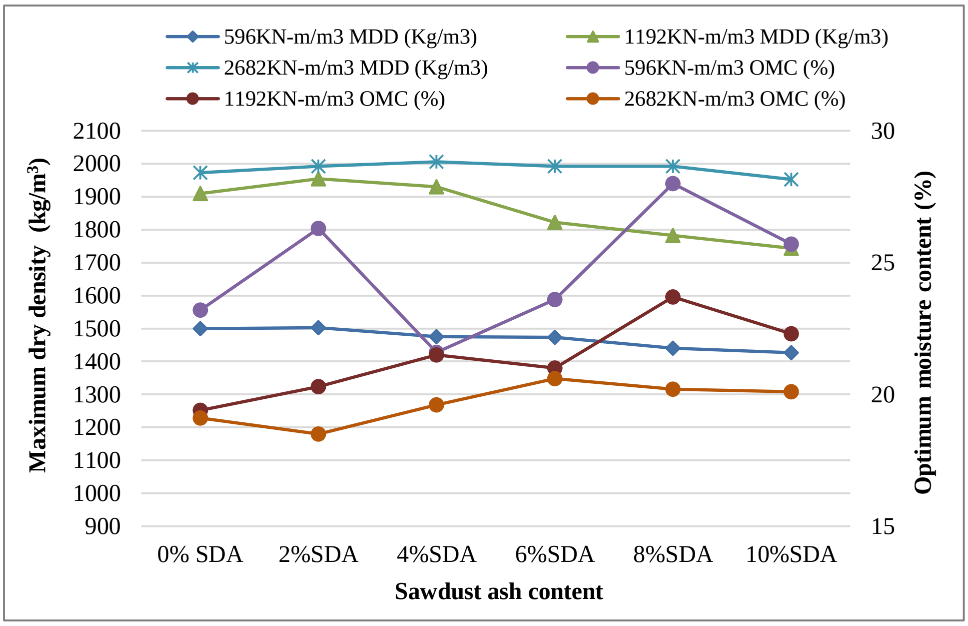

Figure 8a. Effects of SDA and compactive effort on MDD and OMC of sample A

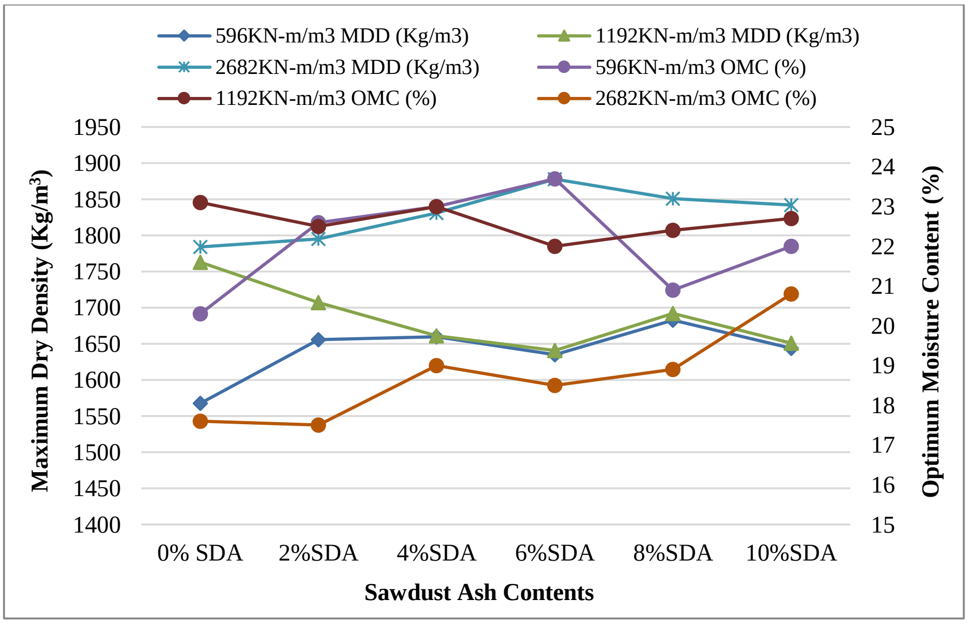

Figure 8b. Effects of SDA and compactive efforts on MDD and OMC of sample B

3.6. California Bearing Ratio

The strength of road subgrade is commonly assessed in terms of the California Bearing Ratio (CBR) and this is dependent on the type of soil, its density, and its moisture content. The variations of unsoaked and soaked CBR values of the soils at natural and stabilized states are shown in Figures 9 and 10. The CBR test was performed on the soils compacted at the specified compactive efforts used for the compaction test and mixed with the OMC derived from the compaction. The soaked and unsoaked CBR values of the soils at natural state are 4.89 and 16.33%, and 3.4 and 5.62% for sample A and B respectively. Generally, the results indicate that the higher the compactive efforts, the higher the CBR values of the two samples. Increase in SDA contents on soil sample A and B showed a non-predictable movement on their CBR values. This could be as a result of inconsistency in the OMC of the soils. The results further affirmed that 2682 kN-m/m^3 compactive effort was more effective at 6% SDA for soil sample A, while compactive effort of 1192 kN-m/m^3 was more effective on soil sample B at 4% SDA. According to clause 6201 of the Nigeria General Specification by Federal Ministry of Works and Housing [31], the minimum strength of base and sub-base course materials shall not be less than 80% and 20% (light traffic) CBR (unsoaked) while minimum strength for subgrade/fill shall not be less than 8% after at least 48 hours soaking. The clause makes only soil sample A stabilized with 2% SDA at compactive effort of 1192KN-m/m^3 suitable as subgrade material while it rendered soil samples from both locations unsuitable for use as sub-base and base materials both at natural and stabilized states.

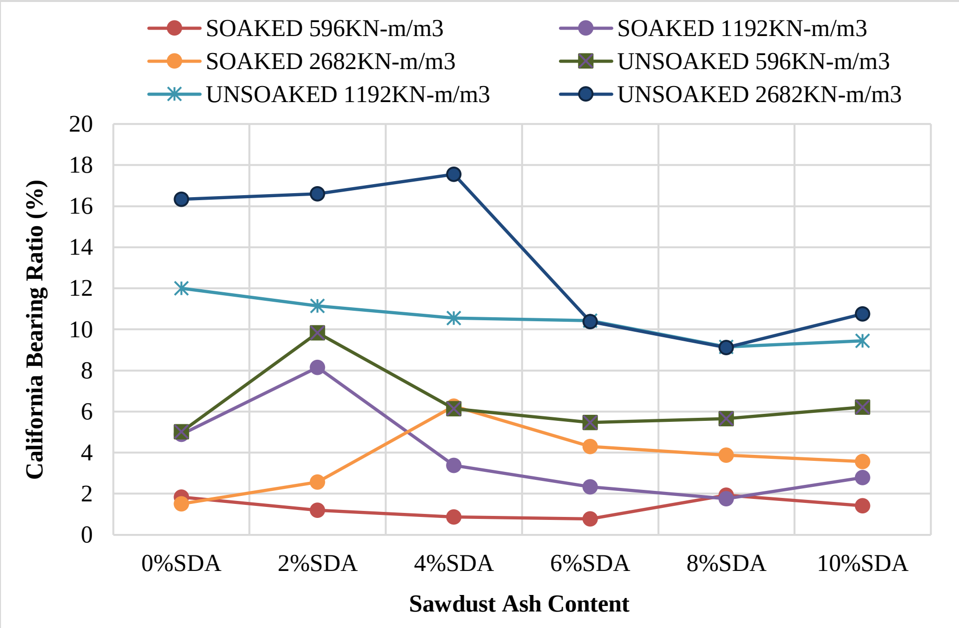

Figure 9. Effects of SDA and compactive effort on CBR of sample A

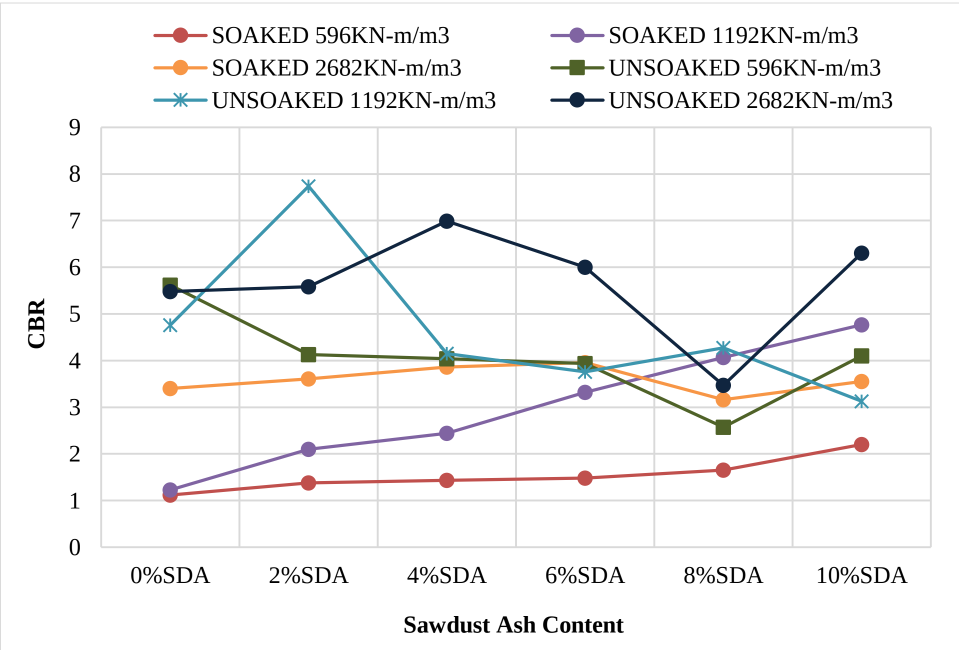

Figure 10. Effects of SDA and compactive effort on CBR of sample B

3.7. Unconfined Compressive Strength

Unconfined compressive strength values of soil samples A and B at different percentages of sawdust ash compacted at 596, 1192 and 2682 kN-m/m^3 are shown in Figures. 11 and 12 respectively. The UCS values of both samples were found to be increasing with the increase in compactive efforts. UCS value of soil sample A rose from 186.45 kN/m^2 to 592.98 kN/m^2, while that of sample B rose from 210.56 kN/m^2 to 279.25 kN/m^2. The UCS values of stabilized soils were found ranging between 101.25 and 645.86 kN/m^2. SDA was found to be most effective on the UCS for both samples at 4% composition. Furthermore, the UCS values for soil sample A increases with the increase in curing age, while the strength of sample B increases up to 7 days curing after which the values begins to drop. The drop in UCS values of sample B after 7 days could be due to weakening in bonds of the soil as a result of the reaction of the additive with soils. The UCS values at natural and treated states falls below the requirements of 1710KN/m^2 [38].

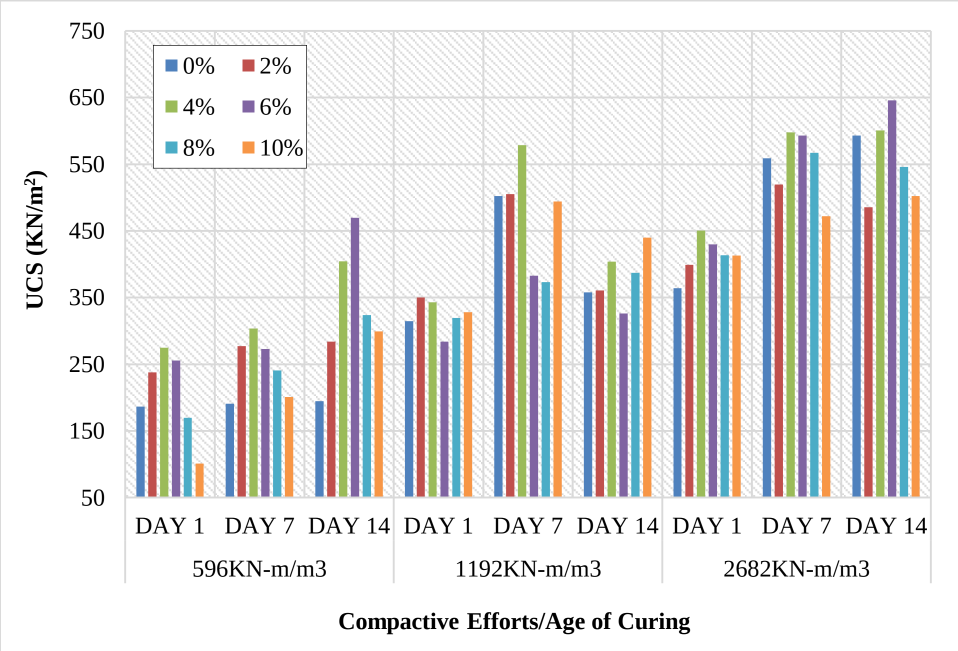

Figure 11. Effects of SDA and compactive effort on UCS of sample A

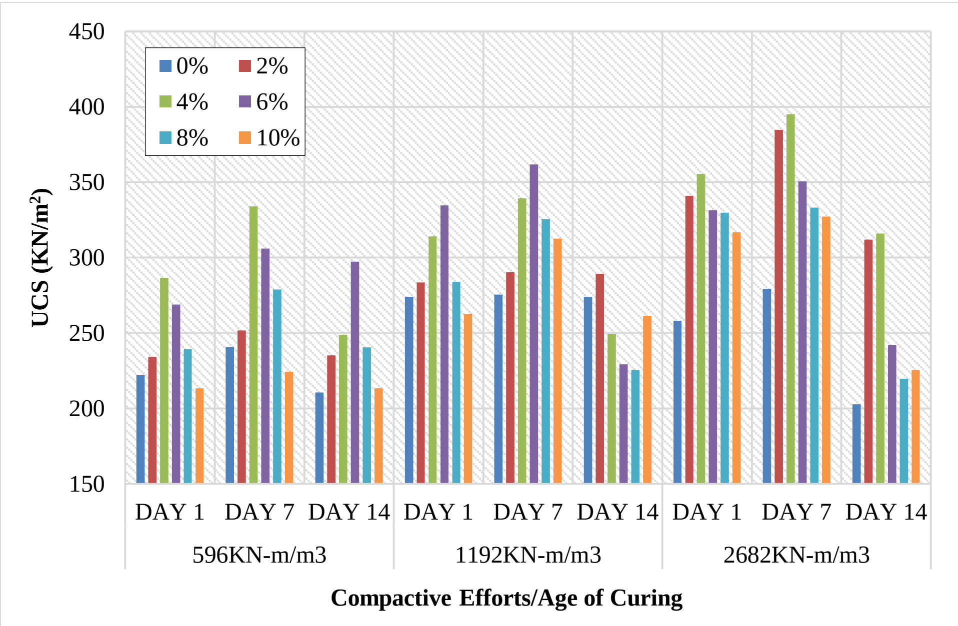

Figure 12. Effects of SDA and compactive effort on UCS of sample B

4. Conclusion

The soils were subjected to various laboratory tests in accordance with BS 1377 (1990) and BS 1924 (1990) [26, 27] and were classified as A-7-5(31) and A-7-6(13). The effects of compactive efforts were monitored on the strength properties of the soil and was realized that increase in compactive effort leads to an increase in the strength properties of the soil. Addition of SDA increases the plasticity indices of the two samples of laterite considered which is due to the high fine contents of the laterites. The maximum dry densities of sample A and B are at optimum with 2% and 4% SDA respectively. It was observed that the CBR values of the soil samples only satisfied the requirement for subgrade materials in road pavement, though SDA contents of 4% and 2% boost the CBR values of samples A and B respectively.

The compressive strength of the soil samples in an unconfined state is at maximum when stabilised with 4% SDA each. It was generally observed that an increase in the compactive effort resulted in an increase in the strength properties of the soil with compactive efforts 1192 and 2682 kN-m/m^3 recommended as the minimum when confronted with these types of soils. Generally, it was found that the use of sawdust ash alone as stabilizer was not effective. Therefore, it was recommended that future studies should consider the use of the sawdust ash in combination with cement or lime.

5. Acknowledgement

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6. Conflicts of Interest

The authors declare no conflict of interest.

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