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Research Paper

Effect of Cow Dung Ash Calcined at Different Temperature on the Geotechnical Properties of Laterite Soil

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ABSTRACT
The need for construction of adequate transportation facilities and its maintenance is challenging in Nigeria due to increase in population. The conventional chemical stabilization technique is costly and there is need to intensify research work on finding alternative stabilizer. In this study, the effect of calcinatingtemperature on the pozzolanic characteristics of Cow Dung Ash (CDA) was investigated.
Cow-dungs werecollected at Attenda Abattoir, Ogbomoso,Oyo State. The dungs were sundried and calcinated at 600 and 800^{0}C and the chemical composition Silica (SiO_2), Alumina (Al_2O_3) and Iron Oxide (Fe_2O_3) were determined. Three lateritic soils A, B and C collected from 8^{0}24′ 46″N 4^{0}14′ 45″E, 8^0 10′ 55″N 4^0 24′ 47″E and 8^0 34′ 54″N 4^{0}29′ 10″E, respectivelywithin Ogbomoso were used in the study. The geotechnical properties which includeMoisture Content (MC), Specific Gravity (SG), Particle Size Analysis (Percentage passing Sieve No. 200) Plastic Index (PI), Optimum Moisture Content (OMC), Maximum Dry Density (MDD) and California Bearing Ratio (CBR)of lateritic soil samples were determined at natural state. The lateritic soils were stabilized with 0, 2, 4, 6, 8 and 10% of CDA by dry unit weight of the soil samples.The geotechnical propertiesLiquid Limit (LL), Plastic Index (PI), MDD, OMC and CBR (soaked and unsoaked) for other temperature.
TheSiO_2, Al_2O_3 and MgO of CDA at 600^{0}C and 800^{0}C are (51.54, 22.45 and 1.20%) and (43.64, 12.24 and 5.01%), respectively.The natural moisture content, specific gravity, PI, OMC, MDD and CBR of soil samples A, B and C were (10.1, 10.3 and 15.0%); (2.61, 2.71 and 2.55); (30.0, 16.1, 12.4%),(17.0, 16.5 and 15.5%); (1750, 1850, 1710kg/m^3) and (7.0, 21.0 and 17.0%),respectively. The LL, PL and PI of the stabilized soil ranged from (36 – 55%), (32 -42%) and plasticity index(4 -13%).For stabilized soil with CDA at 600 ^{0}C,MDD and OMC variedfrom (1.71 - 1.81g/cm^3) and(9 - 16.5%), respectively. For stabilized soil at 800^{o}C, MDD and OMC varied from (1.73 -1.82g/cm^3)and (13.5 – 17%), respectively.The CBR of stabilized soil at 600 ^{0}C varied from (15 - 26%)unsoaked and(5 -11%) for soaked. At 800 ^{0}C CDA,the values of unsoaked CBR varied from (20 - 27%)and the soaked CBR values varied from (7 – 14%).
Cow Dung Ash (CDA)had desirable pozzolanic properties and improved the geotechnical properties of the lateritic soil. Stabilization of weak lateritic soil with CDA is recommended for subgrade materials in highway pavement construction.
KEY WORDS: cow dung ash, temperature, calcined, laterite

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I. INTRODUCTION

The most causative factor of road failure in Nigeria is as a result of using poor materials for construction. This hitherto has continued to deter the underdeveloped and poor nations of the world from providing accessible roads to meet the need of their rural dwellers that constitute large percentage of their population. Lateritic soil as road construction material is said to be poor when it cannot satisfactorily sustain the stress imposed on it by adequate redistribution and withstand environmental deterioration effect. Hence, the need to improve the engineering properties of lateritic soil.

Dung waste is produced daily in most towns in the country, and the cost of modern waste disposal methods is enormous. Therefore, cow dung are commonly disposed by open burning which pollute the air, such crude disposal mechanism increases the concentration of carbon monoxide which in turn triggers global warming effect. There is no doubt, global warming is real and a major concern to all nations. The air pollution also poses threats to inhabitant that lives within the abattoir environment.

The over dependence on and the cost of conventional stabilizers, cement and lime, for stabilization have kept the cost of construction of stabilized road financially high. Therefore, this study is very important to find a sink for a waste like cow dung that is generated in large quantities across the nation.

Cow dung is cow poop. It is what is passed through the cow body and moved to the rectum. It is what is left over that the body does not need. It is then released from the body and onto the ground also known as cow pat, is the waste product of bovine animal species. These species include domestic cattle (cows), bison (buffalo), yak and water buffalo. Cow dung is the undigested residue of plant matter which has passed through the animal's gut. The resultant faecal matter is rich in minerals. Colour ranges from greenish to blackish, often darkening soon after exposure to air. Cow dung is basically the rejects of herbivorous matter which is acted upon by symbiotic bacteria residing within the animal's rumen. Cow/Cattle are mostly found in every part of Nigeria while they are mostly rear in the Northern states of the nation such as Plateau, Nassarawa, Kaduna, Jigawa among others (Olawale and Eniola, 2012)

In Egypt, dry animal dung (from cows & buffaloes) is mixed with straw or crop residues to make dry fuel called "Gella" dung cakes in modern times and ""khoroshtof"" in medieval times. Ancient Egyptians used the dry animal dung as a source of fuel. Dung cakes and building crop residues were the source of 76.4% of gross energy consumed in Egypt's rural area.

1.1 Composition of Cow Dung

The composition of cow dung depends on what the cow has just eaten. Grazing cows will have a lot of plant fibres in their dung. Cows housed in barns and fed with special diet will have different materials in their dung;it starts in the rumen, where microorganisms break down the feed by fermentation. These microorganisms eventually pass through the gut and are expelled, mainly dead, in the faeces. The reticulum works to sort the contents of the rumen, passing on digested feed to the third stomach. The stems of plants and grasses contain fibre for rigidity and are composed of complex sugars such as cellulose and hemicelluloses. These are mostly digestible, but cells walls also contain lignin, mainly insoluble, that is passed into the faeces(Wattiaux and Howard, 2000).

The composition of cow dung is basically digested grass and grain. The grass and grain which they eat is not easily digested and remain up to some extent in their residue. The grass has the high cellulose content, although there are some species of microorganisms found in the guts of these animals. They actively work upon the grass and other substrate material to break it into their simpler compounds. The part which is not digested here is forwarded to stomach where in presence digestive juice its gets digested. It has the high roughage content. Cow dung provides high levels of organic materials and rich in nutrients. It contains about 3 percent Nitrogen, 2 percent Phosphorous, and 1 percent Potassium (3-2-1: NPK).

In addition, one of the other advantages is, it contains high levels of ammonia which is potentially dangerous for pathogens. The growth of the pathogens is almost ceased due to its use (Smith, 2005). Cow dung is comprised of organic matter including fibrous material that passed through the cow's digestive system, among other liquid digesta that has been left after the fermentation, absorption and filtration, then acidified, then absorbed again. Exact chemical composition is of mostly carbon, nitrogen, hydrogen, oxygen, phosphorus, etc. with salts, cells sloughed off as the digester went through the digestive tract, some urea, mucus, as well as cellulose, lignin and hemicelluloses (Pavan *et al*, 2012).

Laterites and lateritic soils form a group comprising a wide variety of red, brown, and yellow, fine-grained residual soils of light texture as well as nodular gravels and cemented soils (Yudhbir and Honjo 1991). They contain iron and aluminum oxides or hydroxides, particularly those of iron, which give the colors to the soils.

Lateritic soils are all products of tropical weathering with red, reddish brown or dark brown colour, with or without nodules or concretions. They are mostly found below hardened ferruginous crusts or hard pan. Ola (1983) used the ratio of silica to sesquioxide represented by $SiO_2/(Fe_2O_3 + Al_2O_3)$ as a criterion to distinguish between laterite and lateritic soils. Those with less than 1.33 are indicative of laterites, those between 1.33 and 2 are lateritic soils, while those greater than 2 are non lateritic.

II. MATERIALS AND METHODS

Based on the objectives of this study, the materials needed were sourced and geotechnical properties of natural and stabilized soil were assessed using soil properties which include liquid limit (LL), plastic limit (PL), plasticity index (PI), compaction and California bearing ratio (CBR)

2.1 Materials and Equipment's

The main materials used were lateritic soil samples, CDA, and water. Materials and equipment used for the calcinations are Lithium tetrabromate, Lithium metaborate, Integrated X-ray Analyzer, Oven, Electric furnace, Desiccator and Box –resistance heating electric furnace)

2.2 Soil Sampling

Three lateritic soil samples labeled A, B, C were collected from three different locations in Ogbomoso.sample A was collected from Ile ewe (8º24′46″N, 4º14′45″E); sample B from LadokeAkintola University of Technology farm (8º10′55″N, 4º24′47″E) and sample C from RCC borrow pit(8º34′54″N, 4º29′10″E)along old Ogbomoso-Ilorin road, all in Ogbomoso North Local Government Area.

2.3 Collection and Calcination of Cow Dung

The cow dung for this study was collected from Attenda abattoir, Ogbomoso, Oyo state. The dung was sun-dried for 7 days after which it was burnt under controlled condition for 45 minutes. Cow dung ashes from the combustion of the dried cow dung were obtained from a Box-resistance heating furnace, at two different calcinations temperatures (600^0C and 800^0C).The ashes obtained from these varying temperatures were labelled Ash A and Ash B, respectively. It was weighed using a weighing balance and placed inside a desiccator for cooling.

2.4 Characterization of the cow dung ash (CDA)

Fusion method was used for analyzing the samples, the chemicals used for fusing the samples were Lithium Tetraborate and Lithium Metaborate at ratio 66% to 34%, respectively.The chemicals were weighed and put inside an oven for 1hour at 110^0C and then mixed with 2g of each of samples inside a crucible with the aid of a glass rod. 1ml of Lithium Bromite was added to the mixture and placed inside an automatic fusion machine for 20mins. The samples were then placed inside an Integrated X-ray analyzer to obtain the general oxides.

2.5 Methods

Soil sample prepared by passing the soil through sieve No. 4 (4.75mm aperture) was admixed with varying percentages of CDA up to 10 % in 2% successive increments and geotechnical testswere carried out to ascertain its classification and strength.

2.5.1 Preliminary geotechnical analysis of natural and stabilized lateritic soils

All geotechnical tests on the both the natural and the stabilized samples were carried out in accordance with the procedural steps BS 1377 part 2-4 (1990) and BS on 1924 (1990). For the stabilized lateritic soil samples, the CDA was introduced in incremental order of 2, 4, 6, 8 and 10% by dry unit weight of the soil samples.
Soil classification tests which included natural moisture, specific gravity , particle size analysis and Atterberg limits tests were performed on the soil samples.

(a) Natural Moisture Content

The natural moisture content of each of the soil samples was determined by crumbled 20g of the soil and placed it loosely in a clean can. The weight of the can was measured to the nearest 0.1g and recorded as M_1. The can and its content was weighed and recorded as M_2, and then placed in the oven to dry at 105°C to 110°C for 1 day. After the drying, the can with its content was removed from the oven and allow cooling down. The can with its content was weighed and recorded as M_3.The moisture content of the soil sample was determined and expressed as percentage of the dry soil sample. The moisture content (w) is derived using equations 3.1 and 3.2

$$w = \frac{Weight\ of\ water}{Weight\ of\ drysoil} x\ 100\% \quad (1)$$

$$w = \frac{M_2 - M_3}{M_3 - M_1} x\ 100\% \quad (2)$$

where:
M_1= weight of the empty can
M_2 = weight of wet soil + can
M_3 = weight of dry soil + can

(b) Specific Gravity

In determining the specific gravity of the soil samples, 100g of dried soil samples that passed through 425μm opening were used for this test. A density bottle of 1 litre capacity with a rubber cork was cleaned, dried, weighed and recorded as W_1. The cork was removed, and 100g of the sample was poured into the bottle, the cork was replaced, weighed and recorded as W_2. Distilled water was poured into the bottle until it was half-filled with the water and topped by the cork. The bottle was shaken vigorously to remove all air-bubbles in the soil mass, and finally the bottle was filled to the brim with the water, the density bottle with the rubber cork was then wiped dry, weighed and recorded as W_3.
The density bottle content was emptied and rinsed with distilled water, it was then filled with distilled water only and rubber cork replaced, wiped dry, weighed and recorded as W_4 and the specific gravity was computed using equation 3.5. The procedure was repeated for each of the three soil samples

$$Specificgravityofsoil = \frac{Density\ of\ water\ at\ 27°C}{Weight\ of\ water\ of\ equal\ volume} (3)$$

$$= \frac{(W_2 - W_1)}{(W_4 - W_1) - (W_3 - W_2)} \quad (4)$$

$$= \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)} \quad (5)$$

where:
W_1= weight of the empty density bottle
W_2 = weight of dry soil + density bottle
W_3 = weight of soil + water + density
W_4 = weight of water + density

(c) Particle Size Distribution

Particle size analysis test was carried out by shaking the soil sample through a set ofsieves having progressively smaller openings. First, 300 g of the soil was weighed and washed through BSsieve No. 200 (75 µm aperture). The content remained on the sieve was thoroughly oven dried before passing it through the set of sieves. The following sieves numbers was stacked in descending order. These sieves used were: 4, 10, 16, 20, 40, 60, 100 and 200 as well as a receiving pan and their respective weights were taken and recorded. The washed oven dried soil sample were placed on the first sieve on top (i.e BS sieve No. 4) and electrically vibrated for 10 minutes. Each sieve together with its content was then weighed and recorded. The test was carried out in accordance with the procedure outlined in BS 1377-2 1990.

(d) Atterberg Limit

Atterberg limits measure the nature of fine grained fraction of a soil which passes through sieve size 425µm.The liquid limit (LL), the plastic limit (PL) and the plasticity index for the natural soil samples of all the three samples were determined in accordance with BS 1377-2 1990.

For the liquid limit test, 150g of the soil samples passing 425µm were mixed thoroughly with distilled water using spatula until the mix formed a uniform paste. A small sample of the mixed soil was placed in the LL device. Using a cutting groove to cut through the centre of the placed soil sample in the cup, the LL device was run and the number of blows (N) required to close this groove through a distance of 13mm was counted and recorded. About 10g of the paste was then taken from the two sides of the paste in the cup into the can and oven dried for 24 hours to determine the moisture content. The test was repeated three times [N~(10-20), N~(20-30) and N~(35-45)] and the logarithmic graph of number of blows against moisture content for the three soil samples were plotted, and the liquid limits (LL) were determined at moisture content at 25 blows.

A representative sample of about 50g was taken from the remainder of soil sample used in the liquid limit determination. This was thoroughly mixed with distilled water on a glass plate until it became sufficiently plastic enough to be moulded into ball. The ball of soil was then rolled between the palms until slight hair-line cracks appeared at the surface. The ball sample was splited into two samples. These two samples were further divided into four equal parts and each part being rolled into a 3mm diameter thread. Two cans of rolled soil samples were used to determine the moisture content of the cracked soil sample.

2.5. 2 Determination Strength Properties of the Lateritic Soils

The strength property tests determined in this research work were compaction and California Bearing Ratio (Soaked/Unsoaked)

(a) Compaction

West African Standard (WAS) Compaction method was used in this study and carried out in accordance to BS 1377 – Part 4 -90. A 6kg of air dried soil sample passing through 4.75mm BS sieve was weighed. This soil sample mixed with suitable amount of water (8% by weight of the dry soil sample) was compacted in the CBR mould in five different layers with each layer receiving a total number of 27 blows using 4.5kg rammer. The optimum moisture content (OMC) and maximum dry density (MDD) for the natural soil were determined. The same procedure was repeated for each of the stabilized soil samples.

(b) California Bearing Ratio (CBR)

The CBR mould was assembled with its base plate and weighed. The collar fitted and a filter paper placed at the bottom. 6kg of the soil sample was thoroughly mixed with the OMC as determined from the compaction test. The mix was divided into five parts and the soil was compacted inside the mould in five layers with each layer receiving 27 blowsof4.5kg rammer.. The collar was then removed and the edge of the mould trimmed off to flush with the top of the mould. The mould containing the sample was placed in the CBR machine with the top facing the plunger. The plunger was made to penetrate the specimen at a uniform rate of 1mm/min and readings were taken at intervals of 0.25mm penetration. The base plate was removed from the mould and the bottom face of the specimen was placed under the plunger and the reading taken as was done for the top surface. For soaked

CBR, the compacted soil was soaked in water for 48 hours before subjecting it to CBR test as described above. The above procedure was repeated for the samples stabilized with CDA calcined at different temperatures.

III. RESULTS AND DISCUSSION

The results of the various tests carried out on CDA, natural and stabilized lateritic soil samples collected from three borrow pits in Ogbomoso, North Local Government Area of Oyo State, Nigeria are presented and discussed in this section. Table 1 gives the general description of the three soil samples and their coordinates of the sampling points.

3.1 Chemical Properties of CDA at Varying Temperature

Results of the chemical compositions of CDA shows that pozzolanic activity at any temperature is a function of the material used. From Tables 2-3, the silica content was 51.54%and 43.64% at 600 and 800 ^{0}C, respectively. Of the active oxides, silica is normally considered as the most important and should not fall below 40% of the total ASTM C618 (2005). The silica content at 600 ^{0}C was higher compare to 800 ^{0}C.The alumina content was 22.45% at 600 ^{0}C and 12.24% at 800 ^{0}C. Ferric oxide content was 2.40% at 600^{0}C and 2.74% at 800^{0}C. The total content of Silica, Alumina and Ferric oxide was 76.39% and 58.62% at 800^{0}C. ASTM C618 (2005) specifies that any pozzolans to be used as cement binder in concrete requires a minimum of 70% for SiO_2, Al_2O_3 and Fe_2O_3.

Also, CDA at 800^{0}C has higher percentages of Maganesium (MgO), Ferric (Fe_2O_3), Manganese (MnO) and Tin Oxide (TiO_2) compared to CDA produced at 600^{0}C. The Silicate and the Aluminate layers of laterite can accommodate the cations from theses oxides which can altered their geotechnical properties.

Table 1: Description of Soil Samples from Selected Locations

S/N	Soil Identification	Geographic Location	Latitude (N)	Longitude (E)	Remark
1	A	Ile ewe	8º24′46″N	4º14′45″E	Borrow Material
2	B	Lautech Farm	8º10′55″N	4º24′47″E	Borrow Material
3	C	RCC borrow pit	8º34′54″N	4º29′10″E	Borrow Material

Table 2: Analysis of the Cow Dung Ash Success/Failure rate at 600^{o}C

Compound	IUPAC Symbols	Percentages (%)
Calcium Oxide	CaO	15.63
Silicon(iv)Oxide	SiO_2	51.54
Aluminum Oxide	Al_2O_3	22.45
Magnesium Oxide	MgO	1.20
Iron Oxide	Fe_2O_3	2.40
Potassium Oxide	K_2O	-
Manganese Oxide	MnO	0.05
Sodium Oxide	Na_2O	-
Phosphorous pentoxide	P_2O_5	0.06
Sulphur Oxide	SO_3	0.94
Tin Oxide	TiO_2	0.13
Loss on Ignition	LOI	5.60

Table 3: Analysis of the Cow Dung Ash Success/Failure rate at 800^{o}C

Compounds	IUPAC Symbols	Percentages (%)
Calcium Oxide	CaO	10.64
Silicon(iv)Oxide	SiO_2	43.64
Aluminum Oxide	Al_2O_3	12.24
Magnesium Oxide	MgO	5.01
Iron Oxide	Fe_2O_3	2.74
Potassium Oxide	K_2O	-
Manganese Oxide	MnO	0.14

Sodium Oxide	Na_2O	-
Phosphorous pentoxide	P_2O_5	0.08
Sulphur Oxide	SO_3	0.37
Tin Oxide	TiO_2	0.31
Loss on Ignition	LOI	24.83

3.2 Result of Preliminary Analysis of the unstabilized Soil Samples

The results of all preliminary tests, natural moisture content, specific gravity, soil classification, and Atterberg limits, carried out on the three natural soil samples.

3.2.1 Natural moisture content of the soil samples

The natural moisture content of the selected soil samples A, B and C were 10.1, 10.3 and 15.0%, respectively. This connotes that the soil samples still contain some amount of moisture, which is largely influenced by temperature and rainfall intensity.

3.2.2 Specific gravity of the soil samples

The specific gravity of sample A, B and C are 2.61, 2.71 and 2.55, respectively. These values ranged within the reported values in Das (2010) for clay minerals, as montmorillonite (2.65 to 2.8), Biotite (2.8 to 3.2) and Halloysites (2.0 to 2.55), respectively.

3.2.3 Particle size distribution

The particle size distribution curves analysis for Sample A, B and C shown in Figure 1. The percentage passing sieve No. 200 were 62.0, 38.1 and 36.5% for Sample A, B and C, respectively.

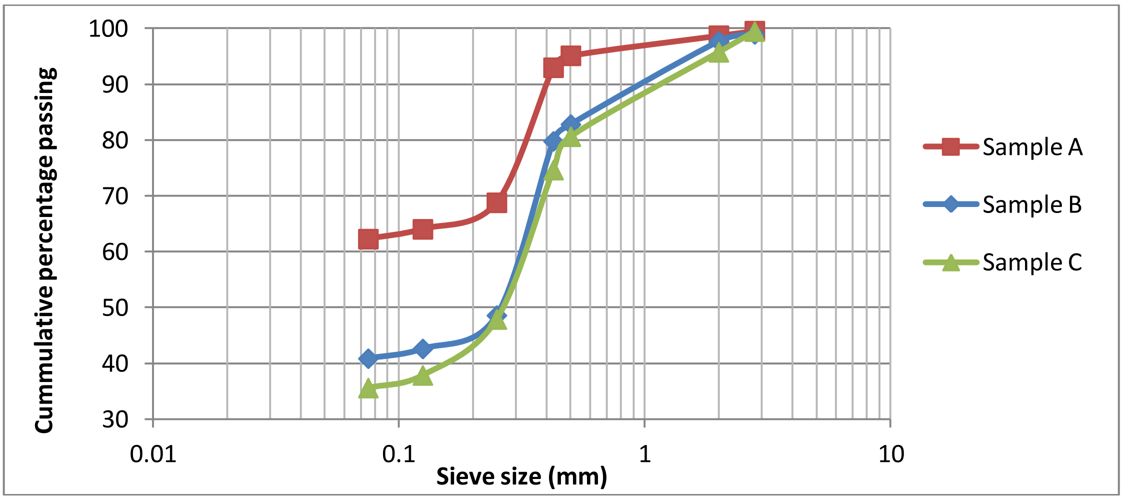

Figure 1: Particle Size Distribution Curve for Sample A, B and C

Table 4: Summary of the Preliminary Analysis of Soil Samples

ITEM	A	B	C
Natural Water Content (%)	10.1	10.3	15.0
pH	4.8	5.8	4.2
Specific Gravity	2.61	2.71	2.55
Percentage Passing Sieve No. 200 (%)	62.0	38.1	36.5
Liquid Limit (LI) %	64.0	46.2	35.8
Plastic Limit (PI) %	34.0	30.1	23.33
Plasticity Index (PI) %	30.0	16.1	12.4
Optimum moisture content, OMC (%)	17.0	16.5	15.5
Maximum dry density, MDD (kg/m^3)	1750	1850	1710
California bearing ratio, CBR (%)	7.0	21.0	17.0
AASHTO Classification	A-4	A-7-5	A-7-5

3.2.4 Atterberg limits of the natural and stabilized soil samples

The Atterberg limits (Liquid limits, LL and plastic limits, PL) results of the soil samples in their natural states are presented in Figures 1 and 3, for sample A admixed with CDA calcined at 600 and 800 ^{0}C, respectively.

For CDA calcined at 600^{0}C, the LL and PI decreased as the percentage of CDA increased. The LL decreased from 64 to 36 % due to decrease in clay content. The PL on the other hand tends to increased from 34 to 42% because of the pozolanic properties of CDA as a result, PI decreased from 30 to 4%. The PL tends to drop at 6% CDA from 38 to 32.

Similarly, for CDA calcined at 800^{0}C, LL and PI decreased as the percentage of CDA increased. The LL decreased from 64 to 44% due to decrease in clay content. The plastic limit on the other hand increased from 34 to 47 because of the pozolanic properties of CDA with consequential decrease in the PI from 30 to 7%. The highest value of PL was obtained at 6%CDA. The Optimum percentage of CDA is 4% which give PI of 13

However, the Atterberg limit for stabilized Sample B and C were performed at 4% optimum percentage of CDA and presented in Table 4 and 5. The PI of sample B and C at 800 ^{0}C are 14 and 15, respectively. The PI of sample B and C at 600 ^{0}C are 11 and 12. From the compaction, CBR and Atterberg results of the stabilized soil, it is clear that the pozolanic properties at 800 ^{0}C is higher than 600^{o}C.

Table 4 is the summary of the tests carried out on the three natural soil samples A, B and C used in this study.

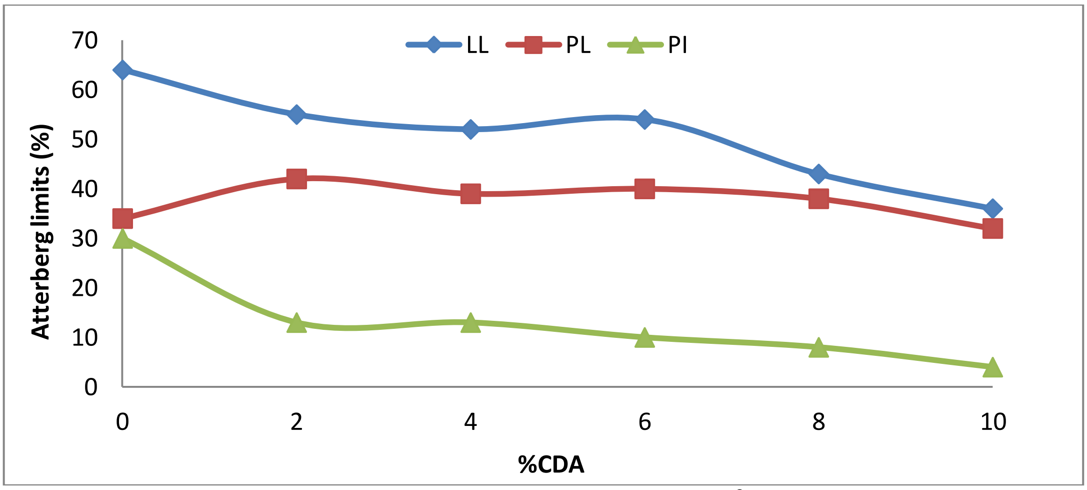

Figure 2: Atterberg Limit of Stabilized Soil at 600^{o}C for Sample A

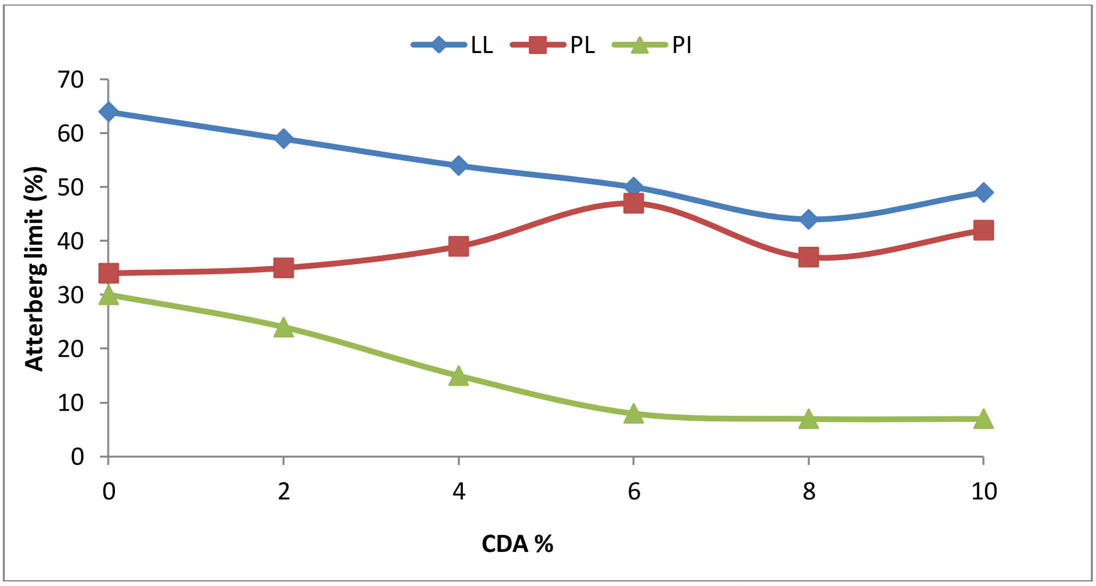

Figure 3: Atterberg Limit of Stabilized Soilat 800^{o}C for Sample A

Table 5: Atterberg Limit of Stabilized Soil with 4% CDA at 600°C

Sample	Liquid Limits, LL(%)	Plastic Limits, PL (%)	Plasticity index, PI(%)
B	50	39	11
C	49	37	12

Table 6: Atterberg Limit of Stabilized Soil with 4% CDA at 800°C

Sample	Liquid Limits, LL(%)	Plastic Limits, PL (%)	Plasticity index ,PI(%)
B	51	37	14
C	53	38	15

Sample A has the highest LL compared to sample A and C. This implies that the three soil samples contain kaolinite. Whitlow (1995) opined that, liquid limit less than 35% indicates low plasticity; those between 35% and 50% indicates intermediate plasticity; those between 50% and 70% indicates high plasticity; and those between 70% and 100% very high plasticity and that kaolinite soils have liquid limits values ranging from 35 to 100% and plastic limit values ranging from 20 to 40%.. Based on this, Sample B and C have intermediate plasticity while sample A is highly plastic.

3.2.5 Soil Classification

The soil samples were classified using the AASHTO and USCS soil classification system as presented in Table 2.Based on AASHTO classification, samples A was classified as A-7-5 while B and C were A-4. They are grouped as silty-clay materials because more than 35%of their soil materials were finer than 75µm.All the three samples are clayey because PI>11% is clayey according to AASHTO.

3.2.6 Compaction properties of natural and stabilized soil samples

The results of maximum dry densities and optimum moisture contents (OMC) for lateritic soils samples stabilized with varying contents of CDA calcined at 600 ^{0}C and 800 ^{0}C were presented in Table 5 and 6, respectively. The MDD of lateritic soil stabilized with CDA calcined at 600^{0}C ranged from 1.71 to 1.81g/cm^3 with OMC ranged from 9 to 17%. For soil sample stabilized with CDA calcined at 800^{0}C,the MDD ranged from 1.73 to 1.82g/cm^3 with OMC ranged from 13.5 to 17%.For both ashes calcined at 600^{0}Cand 800^{0}C, the maximum dry densities of 1.82 and 1.83 were obtained, respectively at 6% CDA content. This implies that this two degrees of temperature at which the CDA was calcined have little or no effect on the attainment of desirable degree of compaction.

3.3 California Bearing Ratio of Stabilized Soil

The California Bearing Ratio (CBR) soaked and unsoaked for 600 ^{0}C and 800 ^{0}C at varying percentages of CDA replacement are presented in Table 8 and 9. The Soaked and Unsoaked CBR at 600 ^{0}C and 800 ^{0}C are presented in Figures 2 and 3. The pozolanic properties of CDA increases at higher temperature. The maximum CBR value at 800 ^{0}C for unsoaked condition was 27 while at 600 ^{0}C, the maximum value was 26 . Similarly, the maximum CBR value at 80^{0}C for soaked condition was 14 while at 600^{0}C, the maximum value was 11. The pore water pressure account for the relatively smaller value of soaked CBR as compared to the unsoaked CBR.

However, the Optimum percentage of CDA was 4% which give unsoaked CBR values of 21 and 27 at 600 ^{0}Cand 800 ^{0}C, respectively. Similarly, the Optimum percentage of CDA was 4% which give soaked CBR values of 7 and 14 at 600^{0}C and 800^{0}C, respectively. Beyond the optimum percentage of CDA, The CBR fell for both soaked and unsoaked CBR. The Optimum percentage of CDA was used to stabilize sample B and Cat 600^{0}Cand 800^{0}Cand the result are presented in Tables 10 and 11. The soaked CBR value at 800^{0}C is twice the value at 600^{0}C as shown in Tables 10 and 11. The result agrees with Moses (2008); Oriola and Moses (2010) and Osinubi and Eberemu (2005) that posit the optimum percentage of replacement at (4-6) %.

Table 7: Summary of Compaction Test Results for sample A at600°C CDA

Percentage of CDA %	Maximum Dry density MDD (g/cm^3)	Optimum Moisture Content OMC(%)
0	1.75	17.0
2	1.72	16.5
4	1.75	15.0
6	1.81	14.6
8	1.71	16.0
10	1.73	9.0

Table 8: Summary of Compaction Test Result for sample A at 800°C CDA

Percentage of CDA %	Maximum Dry density MDD (g/cm^3)	Optimum Moisture Content OMC(%)
0	1.75	17.0
2	1.79	17.0
4	1.80	16.0

6	1.82	15.3
8	1.74	14.0
10	1.73	13.5

Table 9: CBR Results at 600°C for Soaked and Unsoaked conditions (Sample A)

Percentage of CDA %	Unsoaked CBR (%)	Soaked CBR (%)
0	25	7.0
2	26	5
4	21	7
6	15	11
8	15	9
10	16	6

Table 10: CBR Results at 800°C for Soaked and Unsoaked conditions (Sample A)

Percentage of CDA %	Unsoaked CBR values(%)	Soaked CBR (%)
0	25	7
2	22	7
4	27	14
6	21	12
8	21	10
10	20	9

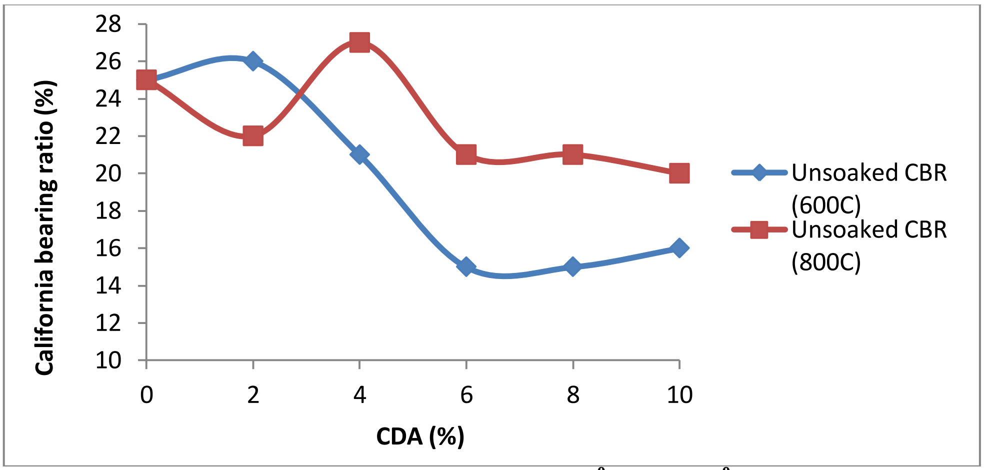

Figure 4: Unsoaked CBR at 600°C and 800°C

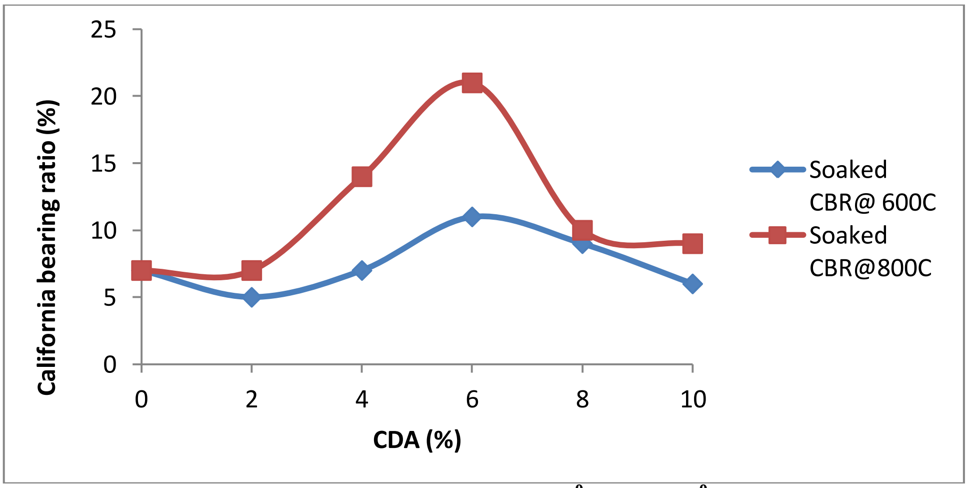

Figure 5: Soaked CBR at 600°C and 800°C

Table 11: CBR Results at 4% CDA at 600°C for Sample B and C

Sample	Unsoaked CBR values (%)	Soaked CBR (%)
B	22	6
C	23	7

Table 12: CBR Results at 4% CDA at 800^{0}C for Sample B and C

Sample	Unsoaked CBR values (%)	Soaked CBR (%)
B	29	14
C	26	13

IV. CONCLUSION

The following conclusions are drawn based on the result from this study

(i) All the soil samples at their natural state show a weak strength as they all range in A-7 in the AASHTO classification. This requires soil stabilization so as to increase its strength in geological properties. Sample A, B and C are not suitable for road construction according to the guideline of the Federal Ministry of Works Specifications for sub grade, sub base and base course material.

(ii) CDA at 600^{0}C has higher pozzolanic properties compare to CDA at 800^{0}C. This properties is shown when $CAO+SIO_2+AL2O_3>70$. This shows that as the temperature increases, the pozzollanic properties reduce (Okunade, 2010).

(iii) Stabilized soil shows higher strength in geotechnical properties at 4% replacement of CDA. There is reduction in the plasticity index of the soil with the addition of CDA.

(iv) The Atterberg results of stabilized soil at 800^{0}C CDA, shows the liquid limits ranges from (44 to 59) %, plastic limits ranges from (35 to 42) % and the plasticity index ranges from (7 -24) %. The Plasticity index of the soil reduces as compared with the natural soil. There is decrease in values of LL, increase in the values of PL and decrease in the value of PI at 600^{0}C and 800^{0}C, respectively.

(v) The compaction test results for the natural soil samples which produced Maximum Dry Density(MDD) and OMC of (1.75g/cm^3, 17%); (1.85, 16.5%) and (1.71, 15.5%) in Sample A, B and C, respectively. For stabilized soil with CDA at ^{0}C,MDD and OMC varied from (1.71 - 1.81) g/cm^3 and(9 - 16.5) %, respectively. For stabilized soil with CDA at 800^{0}C, MDD and OMC varied from (1.73 -1.82) g/cm^{3}and (13.5 – 17) %, respectively. There is an increase in MDD and decrease in OMC throughout the stabilization processes when compared with natural soil.

(vi) The CBR for the natural soil sample A is 25% and 7% for unsoaked and soaked conditions, respectively. The values of the stabilized CBR for CDA at 600^{o}C varied from (15 - 26) % unsoaked and(5 -11) % for soaked.

(vii) At 800^{0}C CDA, the values of unsoaked CBR varied from (20 - 27) %and the soaked CBR values varied from (7 – 14) %. This shows an increase in CBR values at 2% CDA for 600^{0}C and 4% CDA for 800^{0}C at unsoaked conditions. There is increase in the values CBR for stabilized soil at 600^{0}C and 800^{0}C CDA except or 2 and 10% for 600^{0}C when compared with natural soil. Cow Dung Ash (CDA) can be used to increase the density of the natural soil at 6% for 600^{0}C and 2 to 6% CDA for 800^{0}C.

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