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Stabilization of Ikpayongu laterite using Cement, RHA and Carbide Waste Mixture for Road Subbase and Base Material

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ABSTRACT

This research work mainly focuses on stabilization of Ikpayongo laterite using cement blended with Rise Husk Ash (RHA) and Carbide Waste (CW) to promote its physical characteristics. The blending of cement with Rice Husk Ash (RHA) and carbide waste (CW) was done in proportion to determine the required proportion suitable for the stabilization of Ikpayongo laterite. Atterberg limit test, Compaction test, California Bearing Ratio (CBR) test, Specific Gravity, Unconfined Compressive Strength (UCS) test and Durability test were conducted on the laterite sample. The blend of cement with RHA and CW at interval of 0% to 10% displayed better results than the cement treated soil at some percentages. The result showed that at 2% and 10% cement content the MDD of the natural soil reduced from 2.015Mg/m3 to 1.917Mg/m3 and increased to 1.987Mg/m3 respectively, it also reduced to 1.870Mg/m3 when treated with 2% blend of 80% cement 10% RHA 10% CW and increased at 10% of the cement blend. The CBR value of the natural soil was gotten to be 9.66% but increased by 2% when treated with 100% cement. The blend of 80% Cement, 10% RHA and 10% CW yielded the most promising result as CBR value increased from 28% for the natural soil to 97.55% for stabilized soil while UCS increased from 1512.09KN/m2 to 1753.39KN/m2 by volume at 10% of the blends for 14 days cured sample. Based on the results, 80% Cement, 10% RHS and 10% CW is recommended for use in soil stabilization.

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1. Introduction

In many tropical countries the soil materials mostly employed for construction purposes as fill materials are Lateritic soils. These soils are subjected to high humidity and temperature which causes weathering of the soils with respect to alternative changes in seasons thereby resulting in dilapidated engineering qualities ranging from low strength, increased permeability, poor workability, high plasticity and high natural moisture content to tendency to retain moisture [1]. The efficiency in adequately adopting these lateritic soils as fill materials is often reduced as a result of the challenges in handling them particularly under moist and wet conditions as is the case in many tropical regions allowing it to be judiciously utilized only after it must have been stabilization. Lateritic soils that present such issues during construction are known as problematic laterites [2].

Numerous researches have been carried out on how to enhance the physical soil characteristic by introducing a wide variety of stabilizing agents, conditioners and additives and inorganic cementing agents have come to be accepted as the most widely applied method. The effect of cementing agent is largely dependent on bonding properties between the soil particles that makes up the system. There are two major cement stabilizing agents namely; cement and lime. Stabilization of soil has been widely recommended for construction of various pavement elements in under-developed countries as the application of locally available materials reduces construction cost [3]. A key understanding of the local conditions in any country is paramount before developing any soil stabilizing technique, as the weather conditions of the country can affect the construction process as well as the behaviour of the soil material that was stabilized. Researchers such as Gidley and Sack [4] suggested a number of techniques for making use of some industrial wastes in construction industry. Alternative investigations looked into the prospects of bettering soil characteristics such as augmenting shear strength, curtailing settlement, and downplay swelling problems by employing solid waste. Kamon and Nontananandh [5] mixed lime with industrial waste to stabilize soil. Attom and Al-Sharif [6] assessed the usage of burned olive waste as a soil stabilizer, which is a section that helps take care of the dilemma correlated with the escalation of olive waste in Jordan.

Liu et al. [7] analyzed the flexural and compressive strengths of rice husk ash (RHA) and calcium carbide residue (CCR) mortars in a bid to counter the geological menace caused by expansive soil. The research adopted mix ratio of 65:35 by weight for RHA/CCR as soil stabilizers. Results showed that the addition of RHA-CCR greatly improved the cohesion, internal friction angle and unconfined compressive strength. Zahemen et al. [8] examined the mechanical and physical properties of rice husk ash and rice husk ash blended with calcium carbide waste (RHA-CCW) when incorporated in concrete. Concrete cubes, beam and cylinder produced using RHA and RHA-CCW at 5, 10, 15 and 20% cement replacement where cured for 7, 14, 28 and 56 days. It was concluded that RHA-CCW has better effect on concrete mechanical properties as it yielded compressive strength higher than the control sample by 14.7% at 5% replacement. Quadric et al. [9][9] looked into subgrade stabilization using calcium carbide waste (CCW) in varying soil percentage replacements (0, 4, 8, 12, 16 & 20%). Reduction in maximum dry density (1.82-1.5 Mg/m^3) of the subgrade was recorded with corresponding increase in optimum moisture content. Results also showed increase in unconfined compressive strength (201.59-3525.8 KPa) and California bearing ratio for both soaked (6-456.6%) and unsoaked (1.12-555.4%). Phai and Eisazedeh [10] carried out compaction tests on soil mixed with 0, 10, 20, 30 and 50% of rice husk ash (RHA) replacement by dry weight adding lime by 0, 4, 8 and 12%. The research observations showed that the increase in the addition of RHA and Lime yielded increase in optimum moisture content implying that more water is required by the soil to reach its maximum dry density as more stabilizers are added to the mix. Quadric et al. [11] determined the correct blend of soil-lime for expansive subgrade material with calcium carbide waste (CCW) using pH test. From the result it was concluded that the subgrade-calcium carbide waste blend of 8% displayed the optimum reduction in plasticity index dropping from 14.8 to 8.7, thereby portraying it as the optimum subgrade lime blend.

Liu et al. [12] investigated the strength and deformation properties of expansive soil stabilized with blend of rice husk ash (RHA) and lime (RHA-Lime mortars) at a mix ratio of 4:1 varying from 0% to 20% replacements by weight. Increase in curing time and RHA-Lime content remarkably reduced the deformation properties and immensely increase the strength properties. It was concluded that initial water content of 1.2 times the value of optimum moisture content and mix ratio of 15% were the best for stabilizing expansive soil. Ganta [13] tried improving the engineering properties of clayey soil by incorporating rice husk ash and lime at 5%, 10%, 15% and 20% by soil mass. Test results showed that the addition of only rice husk ash reduced liquid limit and maximum dry density and that lime displayed better qualities as a stabilizer than rice husk ash. Kumar and Raju [14] looked into the utilization of calcium carbide residue (CCR) as a stabilizer so as to reduce its environmental disposal hazard. Test results showed that CBR value of treated and untreated soil samples were 1.29 and 14.85 respectively and also recorded increase in unconfined compressive strength of the treated soil up to 7% of CCR replacement. Sabat and Nayak [15] assess how fly ash-calcium carbide residue (CCR) could be used suitably as stabilizer for expansive soil liner material in engineered landfill. The experiment added fly ash and calcium carbide residue to the expansive soil in a ratio of 2:1 from 6% to 30% at progressive increment of 6%. From the laboratory analysis it was found that 24% fly ash-calcium carbide residue added to expansive soil stabilization qualifies it for use as a liner material in engineered landfill. Isah and Sharmila [16] utilized waste materials rich in calcium and silica for stabilization. The research employed calcium carbide residue (CCR) and coconut shell ash (CSA) as stabilizers for CH and CI soils. CSA proportions were 4, 9, 14& 19% while CCR had constant values of 4% and 6% in CH and CI soil. Values of optimum moisture content and unconfined compressive strength (UCS) increased with UCS showing improvement in soil strength of both soil up to 11.38 and 6.03 times the strength of the control soil at 7 days curing and also reduction in maximum dry density. Ayegbokiki et al. [17] studied the unconfined compressive strength of lateritic sand stabilized with a blend of rice husk ash (RHA) and calcium carbide waste (CCW). The study recommended that the combination of RHA and CCW as lateritic stabilizers should be in a percentage not exceeding 60:40 by weight of the dry soil i.e. 22.5% of RHA and 14.48% CCW. In addition, the moisture content of the mix should be dependent on the amount of CCW.

Other notable researchers have conducted researches on stabilization of laterite, but much is yet to be done on Ikpayongo laterite, incorporating the combination of Rice Husk Ash (RHA) and Carbide Waste (CW) as admixtures in stabilizing laterite. Ikpayongo laterite has been stabilized in the past with sand and cement but not very little contributions were recorded. These nominal admixtures can yield the minimum acceptable strength for durable highway construction but are not viable economically. This research therefore focuses on the formulation of a material composition which satisfies not only strength but also is economically viable. For the purpose of its availability and easy accessibility, Carbide Waste (CW) and Rice Husk Ash (RHA) were picked for this research as a suitable admixture, to a combination of cement and laterite. Over the years, the application of admixture modification has increased as a result of its enhanced strength and economy of composite materials. Recently, the trends in soil stabilization have evolved innovating technologies of using industrial and environmental wastes that are locally available as materials for stabilizing deficient soil.

Rice Husk Ash (RHA) and Carbide Waste (CW), as an additive, add several advantages to the engineering properties of such soil; including reduced plasticity of the soil and its potential to shrink swell in addition to promoting the strength properties of the soil. The use of Rice Husk Ash (RHA) and Carbide Waste (CW) mostly brings environmental and economic benefits. Rice husk ash is a by-product of rice and for every four tons of rice produced, one ton is sieved as rice husk. In most cases, the rice husk is disposed off by burning them which generates close to 20% of its weight as ash. Due to the light weight of the ash it can be easily carried by water or wind in its dry state. It is difficult to gel in this state and hence pollutes the water and air, the same thing is applicable to carbide waste. These materials are disposed off and become a threat to our environment. Utilizing Rice Husk Ash and Carbide Waste by efficiently using their inbuilt qualities to promote construction is the best way to proffer solution to the environmental and disposal menace of these materials.

Rice Husk Ash and Carbide Waste cannot be used alone for stabilization of soil due to their non possession of cementitious properties. This necessitated the introduction of cement to the mixture. Rice Husk Ash and Carbide Waste can be found in many parts of the world. The availability of these materials in these areas as waste necessitated the need for the research**.** This project investigated the effect of blended cement obtain from a mixture of RHA – CW – Cement mixture in the improvement of engineering properties of laterite by to determine the change in strength properties (CBR and UCS) of stabilized Ikpayongo laterite, using cement and blended cement and the durability of the stabilized soil.

2. Experimental programme

2.1. Materials

2.1.1. Laterite

The lateriteused was collected from Hajaig borrow pit in Ikpayongo, between latitude 7º30′ and 7º35′ N longitude 8º35′ E a distance at km 22 from Makurdithe capital Benue State of Nigeria, along Makurdi – Otukpo road and at an angle of 90º from the road and the borrow pit distance is about 1.8km from the road.Table 1 shows the summary of the geotechnical Properties of Ikpayongo laterite.

Table 1
Some Geotechnical Properties of Ikpayongo Laterite.

	Sample 1		Sample 2		Sample 3	
Liquid limit (%)	35.0		33.0		42.00	
Plastic limits (%)	20.0		19.1		24.6	
Plasticity index (%)	15.0		13.9		17.4	
Maximum dry density (MDD)	1.83		1.90		1.78	
Optimum moisture content	13.6		11.6		12.0	
California Bearing Ratio (CBR)	Soaked 17.1	Unsoaked 23.0	Soaked 18.4	Unsoaked 25.0	Soaked 20.5	Unsoaked 25.5
Maximum Dry Density (heavy) MDD	1.93		2.01		2.01	
Specific Gravity	2.70		2.69		2.69	
Gravel (%)	82.00		78.00		55.0	
Sand (%)	11.00		15.00		39.00	
Fine (%)	7.00		7.00		6.00	

Adopted from Adele [18]

Several attempts have been made by researchers to determine and ascertain the engineering properties of Ikpayongo laterite. According to Adele [18] Ikpayongo laterite is sandy gravel clay, while classification test confirm the soil status as A-2-6 using AASHTO system of classification. The specific gravities of Ikpayongo laterite, calcium carbide waste and cement were determined as 2.61, 1.92, and 3.11 respectively. Dallah [19] establishes that the laterite from Ikpayongo could become a good base and sub-base material if improved upon by adding little percentage of additive like cement.

2.1.2. Rice Husk Ash (RHA)

The rice husk ashused for this study was obtained from Otukpo Rice Mill Otukpo, Nigeria. Table 2 shows the Chemical Composition of Dry Rice Husk. From table 2, it is clear that silica is the major constituent of rice husk ash.

Table 2
Chemical Composition of Rice Husk on Dry Basis.

Element	Mass fraction %	Element	Mass fraction %
Carbon	41.44	Silica (SiO_2)	80 – 90%
Hydrogen	4.94	Alumina	1 – 25%
Oxygen	37.32	Ferric Oxide	0.5%
Nitrogen	0.57	Titanium	
Silicon	14.66	Dioxide	Nil
Potassium	0.59	Calcium Oxide	1 – 2%
Sodium	0.035	Magnesium Oxide	0.5 – 2.0%
Sulphur	0.3	Sodium Oxide	0.2 -0.5%
Phosphorous	0.07	Potash	0.2%
Calcium	0.06	Loss on ignition	10 – 20%
Magnesium	0.003		

Source: Grist [20]

2.1.3. Cement

The cementused as additive is the BCC ordinary Portland cement produced at Yandev, Gboko, Local Government Area of Benue State Nigeria, obtained from the open market at

North Bank Makurdi, Benue State. The cement complies with the requirement in BS EN 197-1 [21], composition, specification and conformity criteria for a common cement. Table 3 shows the chemical constituent of Portland cement.

Table 3
Chemical Constituent of Portland cement.

Chemical Constituent	Percentage Content (%)
Lime (CaO)	60 to 67
Silica (SiO_2)	17 to 25
Alumina (Al_2O_3)	3 to 8
Iron oxide (Fe_2O_3)	0.5 to 6
Magnesia (MgO)	0.1 to 4
Sulphur trioxide (SO_3)	1 to 3
Soda and/or Potash (Na_2O+K_2O)	0.5 to 1.3

Source: https//theconstructor.org [22]

2.1.4. Carbide waste

The carbide wasteused in this testwas obtained from Makurdi Mechanic village at North bank.

Carbide wastes are the residues of industrial processed which are not used. It is a by-product obtained from the production of acetylene gas (C_2H_2). Carbide waste or calcium hydroxide [Ca (OH) $_2$] is obtained from the reaction between water and calcium carbide (CaC_2) as shown in equation 1:

$$CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2 \tag{1}$$

CaC_2 is prepared by burning limestone ($CaCO_3$) to yield lime (CaO) and carbon dioxide (CO_2).

$$\mathrm{CaCO_3 \rightarrow CaO + CO_2} \tag{2}$$

After that, CaO reacts with coal (C) and CaC_2 with carbon dioxide (CO) are obtained.

$$\mathrm{CaO + 3C \rightarrow CaC_2 + CO} \tag{3}$$

Table 4.
Chemical Composition of Carbide Waste.

Chemical Composition	**Carbide Waste (%wt)**
SiO_2	6.49
Al_2O_3	2.00
Fe_2O_3	1.87
CaO	56.41
MgO	0.70
SO_3	0.36
Na_3O	0.18
K_2O	0.10
TiO_2	n.d
P_2O_5	n.d
Total cl content	n.d
LOI	31.74

n.d: Non – detectable due to zero or very small concentration

LOI: Loss on Ignition

Source: Krammart [23]

Carbide waste obtained from producing acetylene gas is normally disposed off by land filling, which may create further problems, that is, the leaching of harmful compounds and alkali to ground water. On the other hand, if carbide waste can be used in stabilizing a poor laterite, it will not only reduce the consumption of cement but also solve the carbide waste disposal problems. Table 4 shows the chemical composition of carbide waste.

2.2. Experimental tests

The laboratory tests were carried out in accordance with the procedures in BS EN ISO 17892-12 [24]. Soil classification test was carried out on samples of natural laterite and of soil treated with cement and blended cement.The percentage proportions of the samples for the different tests are: 100% cement blended with 0% RHA 0% CW by volume, 90% cement blended with 5% RHA 5% CW, 80% cement blended with 10% RHA 10% CW and 70% cement blended with 15% RHA 15% CW by volume.The following tests were performed on the samples treated with 0%, 2%, 4%, 6%, 8% and 10%.

Specific gravity test

Grain size analysis

Atterberg (Consistency) limit test.

Compaction Test.

California Bearing Ratio (CBR) Test.

Unconfined Compressive Strength Test (UCS)

Durability test.

3. Discussion of results

Ikpayongo laterite was stabilized with Cement, RHA, Carbide Waste (CW) mixture at 0% to 10% interval of these constituent mixture.Stabilizing to these different percentages, it was observed that the sample responded to the introduction of these stabilizers, thereby improving some of the properties of the soil.The replacement was adequate up to some percentage proportion after which there was a reduction in the stabilizing potentials of these percentage proportions. Some improvements in the properties are discussed.

3.1. Grain size analysis

Sieve analysis result showing the percentage of Ikpayongo laterite passing different sieve sizes is as shown in Table 5.

Table 5
Percentage Passing Some BS Sieves Diameters.

Sieve size (mm)	**20**	**14**	**10**	**6.30**	**5.0**	**3.35**	**2.65**	**1.70**	**1.18**	**0.85**	**0.60**	**0.425**	**0.300**	**0.15**	**0.075**
Percentage passing	95.2	87.5	78.9	62.65	54.1	43.4	37.8	32.2	26.1	24.0	14.2	9.2	5.8	2.1	1.0

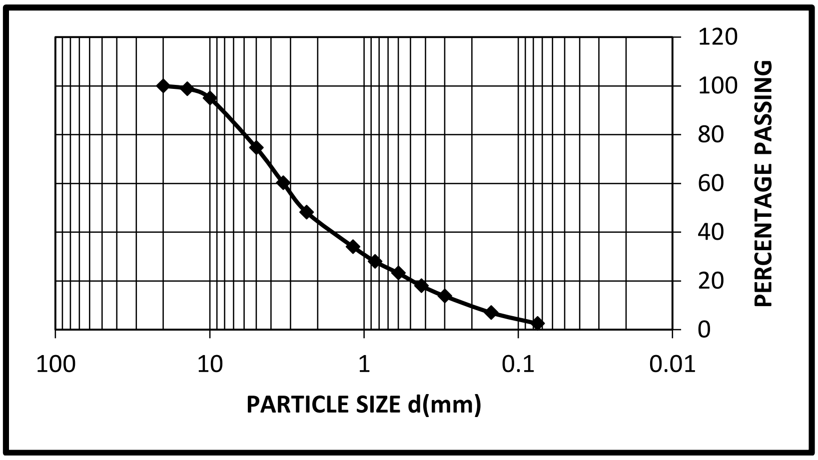

Fig. 1. Grain Size Distribution of Ikpayongo Laterite.

The coefficient of uniformity (CU) and Coefficient of Concavity (CC) are 22.12 1.24 respectively

From the analysis carried out on the sample of the soil, it was discovered that, Ikpayongo laterite is sandy gravel, and from the values of CC and CU, it can be said that the sample is well graded, these made Ikpayongo laterite meet the requirement for laterite used for base and sub-base materials in pavement construction.

3.2. Atterberg limits

The atterberg limits basically measures the critical contents of waterof a soil that is fine-grained; it can also be used to differentiate between clay and silt. The test includes liquid limit (LL), plastic limit (PL) and shrinkage limit (SL) which were conducted in accordance with BS EN ISO 17892-12 [24]. Depending on the water content of the soil, the soil may exist in different states: soild, semi-soild, plastic and liquid states displaying different behaviour and consistency thus engineering properties in each different state. Responses of the Atterberg limits of Ikpayongo laterite to cement and blend of cement – CW – RHA are reflected in figures 2 to 5.

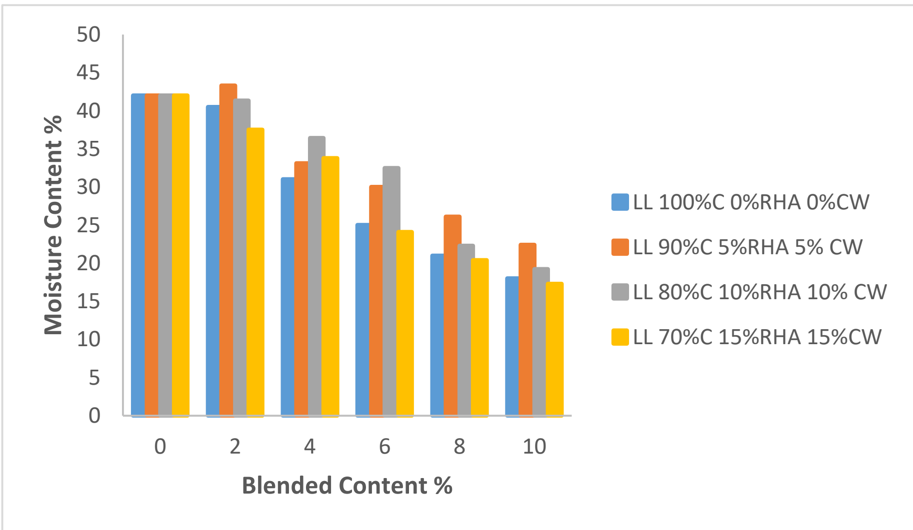

Fig. 2. Relationship between the LL of (100%C 0%RHA 0%CW), (90%C 5%RHA 5%CW),(80%C 10%RHA 10%CW)& (70%C 15%RHA 15%CW).

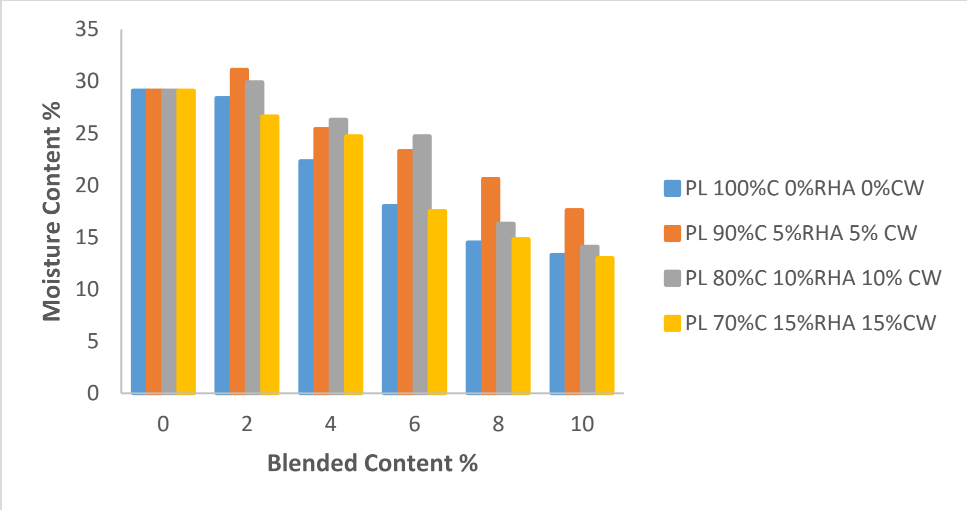

Fig. 3. Relationship between the PL of laterite treated with (100%C 0%RHA 0%CW), (90%C 5%RHA 5%CW),(80%C 10%RHA 10%CW)& (70%C 15%RHA 15%CW) blended cement.

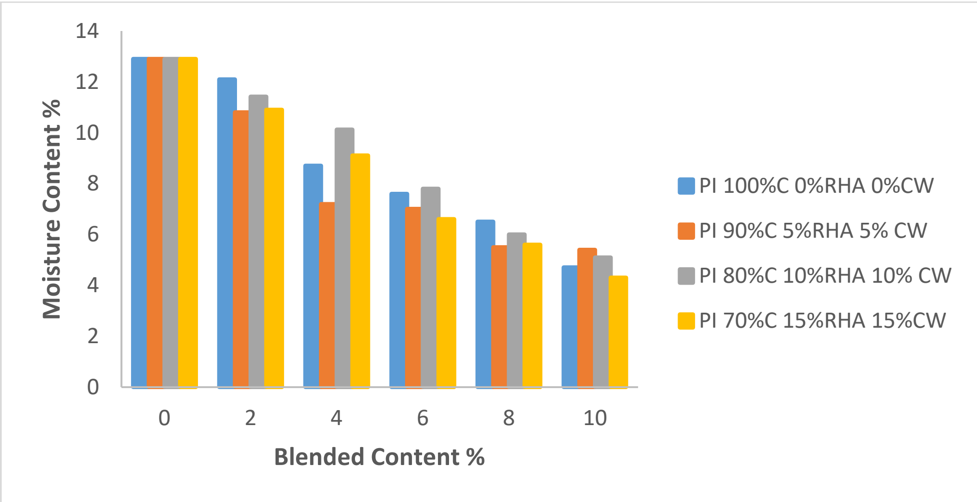

Fig. 4. Relationship between the PI of laterite treated with (100%C 0%RHA 0%CW), (90%C 5%RHA 5%CW),(80%C 10%RHA 10%CW)& (70%C 15%RHA 15%CW) blended cement.

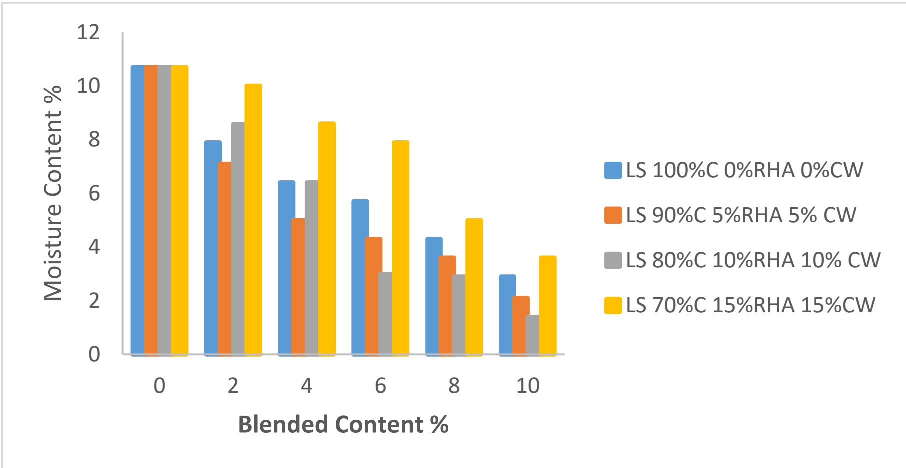

Fig. 5. Relationship between the LS of laterite treated with (100%C 0%RHA 0%CW), (90%C 5%RHA 5%CW),(80%C 10%RHA 10%CW)& (70%C 15%RHA 15%CW) blended content.

According to BS EN ISO 17892-12 [24], the following requirements in table 6 are to be met before any material can be used for sub-base course pavement construction.

Table 6
Requirement for base and sub-base materials.

	Properties	**Range**
	Liquid Limit (LL)	0-45%
Materials for Sub-base	Plastic Limit (PL)	0-15%
	Linear Shrinkage (LS)	0-18%
Materials for base	Properties	Range
	Liquid Limit (LL)	0-25%
	Plastic Limit (PL)	0-10%
	Linear Shrinkage (LS)	0-6%

According to the requirements in table 5, and the properties of the Atterberg Limits summarized in Figures 2 to 5, it can be discovered that Ikpayongo laterite can be used for a sub-base material.

The liquid limit of the cement treated soil decreased as the percentage of treatment increases and so do the blended cement. For example the natural soil has its liquid limit to be 42.0% but at 10% cement treated soil it was observed to be 18.0% for the blend of cement, the 70% C 15%RHA 15%CWblends has the least which was 17.3%, while that of the 80%C 10%RHA 10%CW was 19.21% and that of the 90%C 5%RHA 5%CW was found to be 22.40%. The PL, PI and LS also decreased as the percentage of stabilization increased. The reduction observed may be as a result of swell potential reduction of cement and RHA. The CW present also contributed to this reduction by the action of the cation exchange reaction because it posses calcium ion which resulted in increased inter-particle attraction.In Basha et al [25] report it was observed that reduction in plasticity of soil can be attributed to the presence of RHA and cement. Cement and RHA of 6–8% and 10–15% respectively displayed the optimum amount in reducing soil plasticity. Reduction in plasticity index of stabilized soil proves that the inclusion of CW to soil increase the workability of the soil [26,27]. Reduction in the PI denotes enhancement in the soil characteristics.

3.3. Compaction test

The standard proctor compaction test is an experiment that determines the optimal moisture content at which a certain type of soil will become most dense and attain its maximum dry density. The test was conducted in accordance with BS EN ISO 17892-12 [24]; soil samples with and without additives were thoroughly mixed with varying moisture contents ranging from 0% to 10% and leftfor 24 hrs to counterpoise before to compaction. The compaction properties of unstabilized soil was first determined followed by soil stabilized with varying percentage of cement, RHA and calcium carbide.

The results from the compaction test using a light compactive effort (2.5kg rammer) are as shown inFigures 6 and 7.

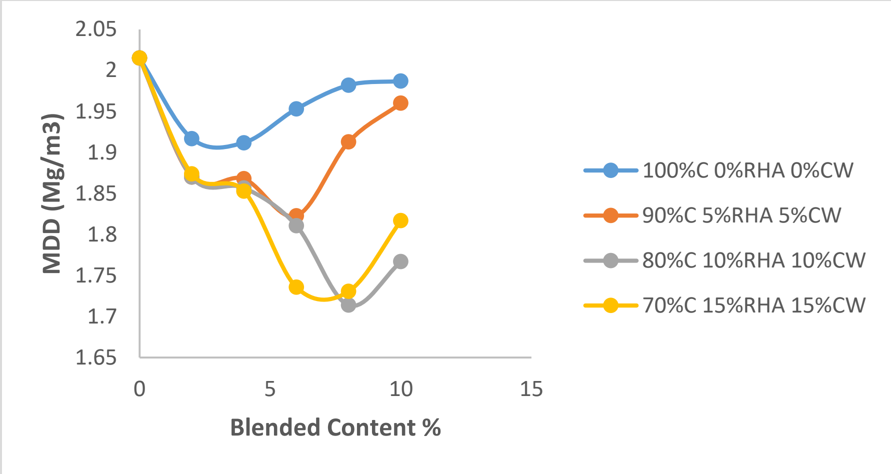

Fig. 6. Relationship between the MDD of laterite treated with (100%C 0%RHA 0%CW), **(**90%C 5%RHA 5%CW),(80%C 10%RHA 10%CW)& (70%C 15%RHA 15%CW)blended cement.

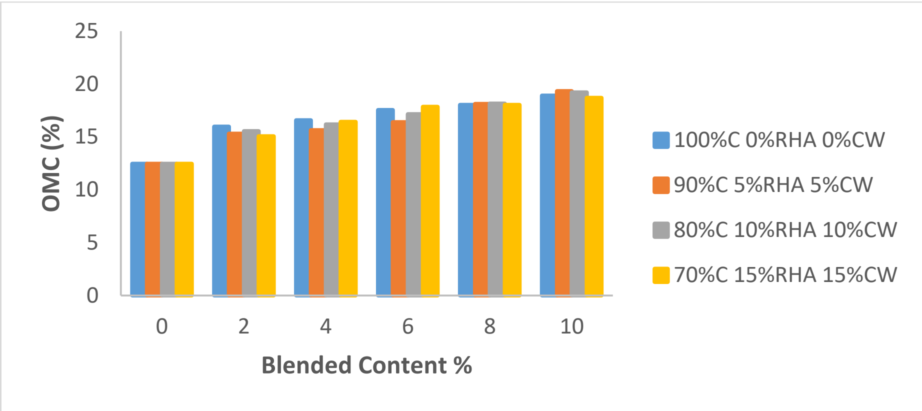

Fig. 7. Relationship between the OMC of laterite treated with (100%C 0%RHA 0%CW), **(**90%C 5%RHA 5%CW),(80%C 10%RHA 10%CW)& (70%C 15%RHA 15%CW) blend of cement.

Using British Standard Light (BSL) compactive effort, the Maximum Dry Density (MDD) for each of the mix followed a particular trend in which as the percentage of replacement increased so did the MDD decreased to some percentage of treatment after which it started increasing.

From the results shown in figure 6, it was discovered that for 100% cement treated laterite, the MDD gotten was higher than the blended cement treated soil. At 2% of the percentage proportion, the MDD for the 100% cement was gotten to be 1.917Mg/m^3 while for 90%C 5%RHA 5%CW, 80%C 10%RHA 10%CW and 70%C 15%RHA 15%CW were 1.870Mg/m^3, 1.870Mg/m^3, 1.874Mg/m^3 respectively. But at 10% of this proportion the MDD of 100% cement treated laterite was gotten to be 1.987Mg/m^3 while for the blended cement were: 1.960Mg/m^3, 1.767Mg/m^3, 1.817Mg/m^3 respectively from the 10% proportion of stabilization, the MDD decreased as the blends increased and the least MDD was observed at 80%C 10%RHA 10%CW which was 1.767Mg/m^3 after which it started increasing. The initial decrease in the MDD can be attributed to the replacement of soil by the cement, RHA, and CW in the mixture which has relatively lower specific gravity compared to that of the soil [28,29]. The decrease in the MDD may also be explained by considering these materials as filler (with lower specific gravity) in the soil voids. However when quite a bit of the percentage has been added to increase the specific gravity of the mixture, the Maximum Dry Density (MDD) starts to increase appreciably, this increase in the maximum dry density

(MDD) observed may be attributed to more densely packing due to the finer particles of the stabilizers used in the test. Another explanation could be that since cement with a specific gravity of 3.15 is added to the Ikpayongo laterite of specific gravity of 2.61, a resulting mixture with a higher specific gravity emerged, which in turn gives rise to an increase in the maximum dry density (MDD) of the entire mixture. From Rahman [3] investigation it was revealed that the change-down in dry density was as a result of specific gravity and particles size of both the stabilizer and soil particles. Reduction in dry density implies that low compaction energy is required to achieve its MDD thereby making compaction more economical, as also agreed by Muntohar [30].

The OMC also followed a particular trend in which as the percentage of stabilization increases so did the OMC, for example it was observed that at 100% cement, the OMC of the 2% treatment was 15.95%, it increased at an interval down to 10% stabilization in which the OMC was 18.89%. The same trend was observed in the blended cement, but had values higher than the 100% cement treatment. At 10% stabilization of soil treated with 80%C 10%RHA 10%CW blend of cement, the OMC was 19.32%. The increase in the OMC for the blends may be due to the presence of more fine particles which has more surface area and the absorbent properties of the blends (RHA and CW). Increase in the optimum moisture content (OMC) with increase in the quantity of cement, RHA and CW could possibly be due to increase in the surface area needed to be coated as the quantity of these materials increased, which made the mix to require more water for hydration and further pozzolanic reactions. In addition, the inclusion of the stabilizers helps in reducing the free silt content and fractions of clay thereby forming materials that are coarser with larger surface area. These processes take place in the presence of water. Zhang et al. [31] reported that there are two probably reasons for increase in OMC. Firstly, excess absorption of water by RHA due to the porous characteristics. Secondly, the added water clasped with the fluffy soil structure as a result of cement interplay. If no flow of water from the CW paste, the hydration reaction utilizes a large amount of the water till very small is left to saturate the soil surfaces thereby reducing the relative humidity within the paste [32].

3.4. California bearing ration (CBR) test

This is a penetration test that evaluates the strength of sub-grade material for pavements and roads. The tests results form a curve that is used to decide pavement thickness and the thickness of its integral layers. This method has been already described in BS EN ISO 17892-12 [24]. The CBR results for the cement treated soil and blend of cement are shown inFigures 8 and 9.

The California Bearing Ratio (CBR) values of Ikpayongo laterite treated with cement, RHA and CW ranging from 0% to 10% at BSL compactive effort shows an increased improvement in the CBR value of the soil as the percentage of treatment increased.

The CBR value of the natural soil was gotten to be 9.66% but increased by 2% when treated with 100%cement. The CBR value for the immediately compacted soil was found to be 24.87%, after been soakedthere was a reduction in the value which was gotten to be 17.97%. The same trend of increase was noticed as the percentage of stabilization increased to 4% treatment and for 100% cement, there was a further improvement in the strength characteristics of the soil which may be attributed to the hydration of cement. The blended cement showed better results from 8% to 10% of the this treatment when compared to the cement treated laterite, for example at 90%C 5%RHA 5%CW, the results gotten immediately after compaction were 45.39% and 49.31% respectively. The soaked values were found to be 74.30% and 88.91% respectively. For the 80%C 10%RHA 10%CW blend, the improvement when compared with the cement treated soil is higher, at 10% percent replacement, the values gotten were 55.20%and 65.41% respectively immediately after compaction. When soaked, the values further increased to 77.31% and 97.55% respectively in comparison with the cement treated laterite which had its values as 61.14% and 88.14% respectively. The further improvement in strength may be due to further reaction which took place between the cement and the calcium component of the CW and the silica component of the RHA which further enhanced the hydration of the cement, hence increasing the strength of the soil.

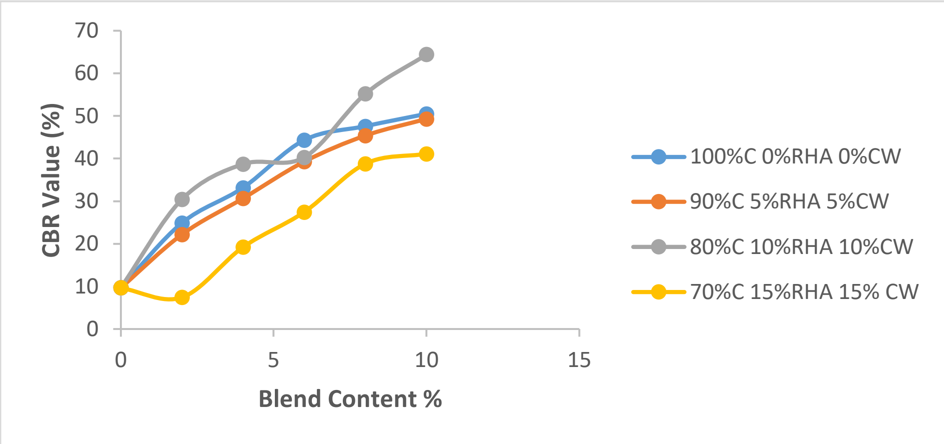

Fig. 8. Relationship between the CBR values immediately after compaction of (100%C 0%RHA 0%CW), **(**90%C 5%RHA 5%CW),(80%C 10%RHA 10%CW)& (70%C 15%RHA 15%CW).

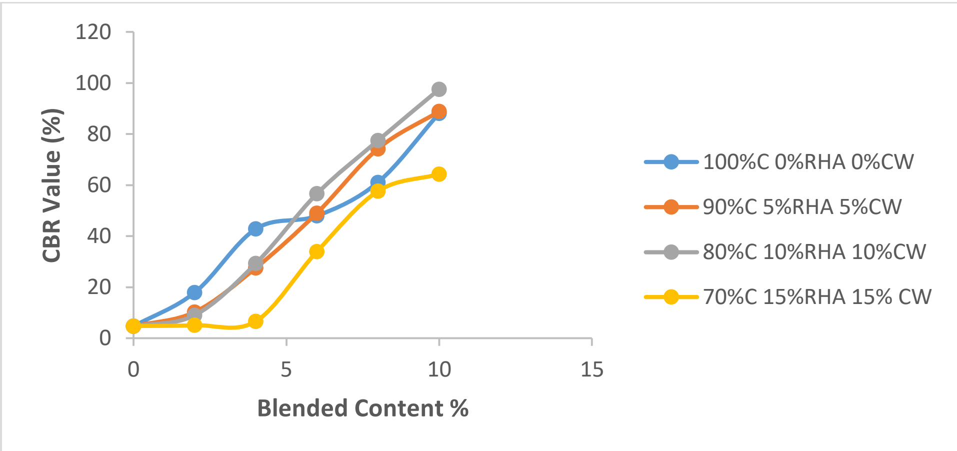

Fig. 9. Relationship between the soaked CBR value of (100%C 0%RHA 0%CW), **(**90%C 5%RHA 5%CW),(80%C 10%RHA 10%CW)& (70%C 15%RHA 15%CW).

The 70%C 15RHA 15CW blend showed a reduction in the strength, for example at the 10% treatment of the this blend, a value of 41.10% was gotten immediately after compaction while that of the cement treated soil was found to be 50.47%, when soaked, the CBR value of the blend was found to be 64.33%, while that of the cement treated soil was gotten to be 88.14%. The reduction in strength may be due to the excess presence of this calcium and silica component in the CW and RHA respectively with insufficient cement to bond these materials.

In summary, from the figures 8 and 9, it can be observed that addition of cement increased the CBR value considerably, which increased further under soaked condition from 6% to 10%

of the treated. The addition of RHA and CW further enhanced the CBR value. The increase in CBR value after the addition of RHA and CW and cement may be due to the formation of various cementing agent.

3.5. Unconfined compression strength (ucs) test

This test is employed to ascertain the strength of stabilized soils. It is mostly used to determine the amount of material required in soil stabilization. The Unconfined Compression Strength (UCS) Test was carried out on the various samples in accordance with BS 1924-1:2018 [33] of which the samples each had an initial height of 80mm, initial area 11.34cm^2 and initial diameter of 3.8cm and initial volume of 90.75cm^3. After taking the deformation dial reading the unconfined compressive strength (Qu) and the corresponding cohesion of the sample were determined from $^{Qu}/_2$. The results obtained are as shown in Figures 10, 11 and 12.

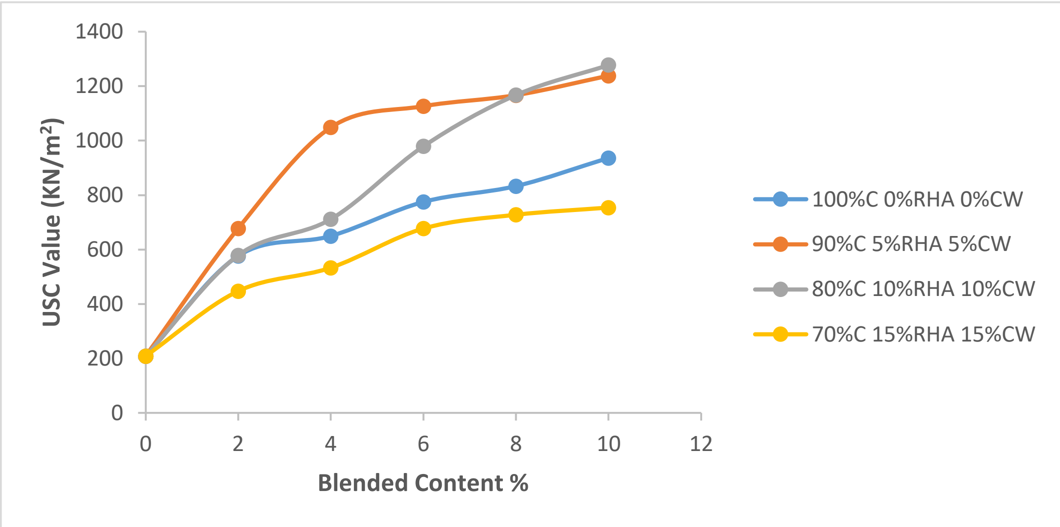

Fig. 10. Relationship between the 7 days UCS values of laterite treated with (100%C 0%RHA 0%CW), **(**90%C 5%RHA 5%CW),(80%C 10%RHA 10%CW)& (70%C 15%RHA 15%CW) blend of cement

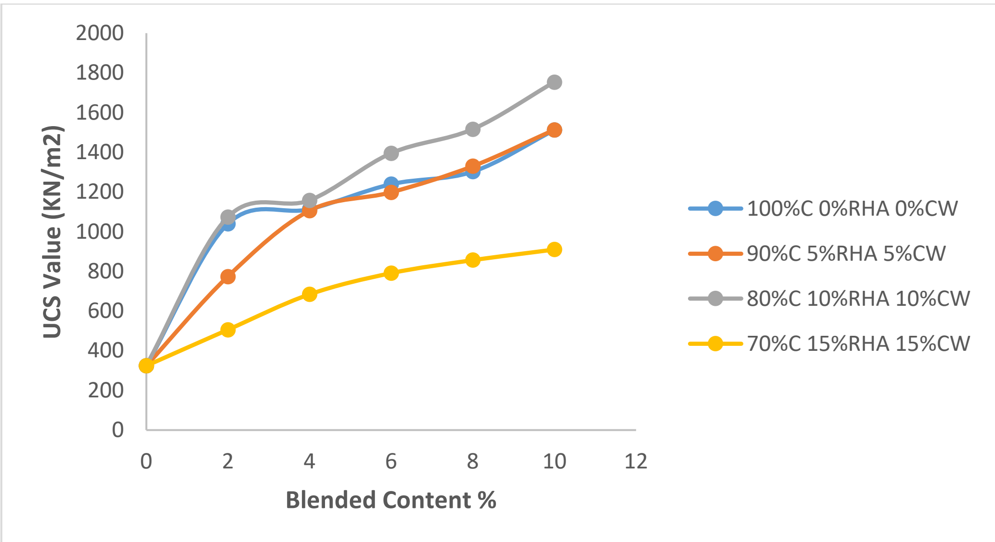

Fig. 11. Relationship between the 14days UCS values of laterite treated with (100%C 0%RHA 0%CW), **(**90%C 5%RHA 5%CW),(80%C 10%RHA 10%CW)& (70%C 15%RHA 15%CW) blend of cement.

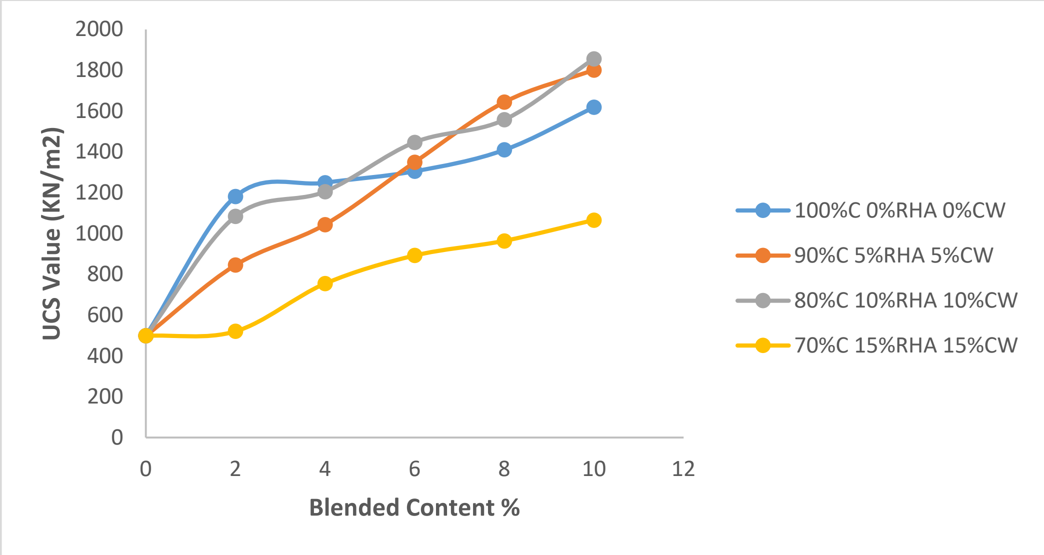

Fig. 12. Relationship between the 28days UCS values of laterite treated with (100%C 0%RHA 0%CW), **(**90%C 5%RHA 5%CW),(80%C 10%RHA 10%CW)& (70%C 15%RHA 15%CW) blend of cement.

The effects of RHA and CW mixture in the various proportions on the Unconfined Compressive Strength of cement soil mixture after 7, 14 and 28 days of curing are shown in the various figures above. A general pattern was observed in which the strength developed rapidly with addition of RHA and Carbide Waste (CW) until an optimum condition was reached which was observed at (90%Cement 5%RHA 5%CW) and (80%Cement 10%RHA 10%CW) beyond which there was a marginal decrease in strength. The optimum RHA and CW contents were observed to be about 10% in all the cases. Furthermore, it was also observed that curing period marked an influence on the unconfined compressive strength and for the given constituent content, unconfined compressive strength increased with increase in curing period. Although treatment with cement improved the strength characteristics of soil, the addition of RHA and CW further improved the strength of cement stabilized soil.

Table 7
Oxide Composition of Lateritic Soil.

Oxide	**Concentration (%) Lateritic soil**
CaO	0.28
SiO_2	35.60
Al_2O_3	27.40
Fe_2O_3	24.0
MgO	0.22
SO_3	0.85
MnO_2	2.00
Na_2O	ND
K_2O	ND
Loss on ignition	146.00

Adapted from Osinubi K.J. [34]

At 10% cement content and 28days curing period, the maximum strength of RHA and CW treated sample was higher than that without this mixture. This indicates that in cement – RHA – CW soil mixture, a lesser amount of cement is required to achieve a given strength as compared with cement – soil mixture. The gain in strength of blended cement – stabilized soil is primarily due to pozzolanic reactions between silica and alumina from the soil as shown in Table 7and CW and cement to form various types of cementing agents. By introducing RHA to the soil, additional amounts of silica are available for reaction with cement resulting in further increase in strength. But the presence of this silica in excess reduced the strength of the cement – soil mixture which was observed in the 70% Cement 15%RHA 15%CW, and this maybe as a result of insufficient availability of cement for pozzolanic reaction. Basha et al [17] and Hossain [32] showed that cement is unarguably an effectual additive for strength enhancement. In polarity with RHA–soil mixtures, there is little increase in strength because RHA does not have a cementitious quality which means only RHA cannot be employed for soil stabilization. A smaller quantity of cement is needed to wangle a desired strength as compared to soil stabilized with cement, since RHA and CW are cheaper than cement this leads to reduction in cost of construction. But when higher compactive effort is used, a better result can be gotten and may meet the requirement of a road base material.

3.6. Durability test

A material is said to be durable if it can remain strong and compact when subjected to catastrophic weathering forces over a long period of time. It is paramount for a stabilized soil to be durable so as to remain strong under all unfavourable conditions. A good stabilizer promotes soil strength and also retains a firm bond with the soil during changes in seasons. Durability test is basically of two types namely; the freezing and thawing test and the wetting and drying test [33].

The durability of the samples was measured in percentages obtained after curing the sample for 7days and soaking for another 7days compared with that only cured for 14days with immersion in water. The test was carried out in accordance to BS 1924-1 [32], results obtained are as shown in Figure 13.

$$Durability = \frac{UCS\ values\ for\ 7days\ cured\ and\ 7days\ soaked}{Value\ of\ 14days\ cured\ with\ immersion} x100\%$$

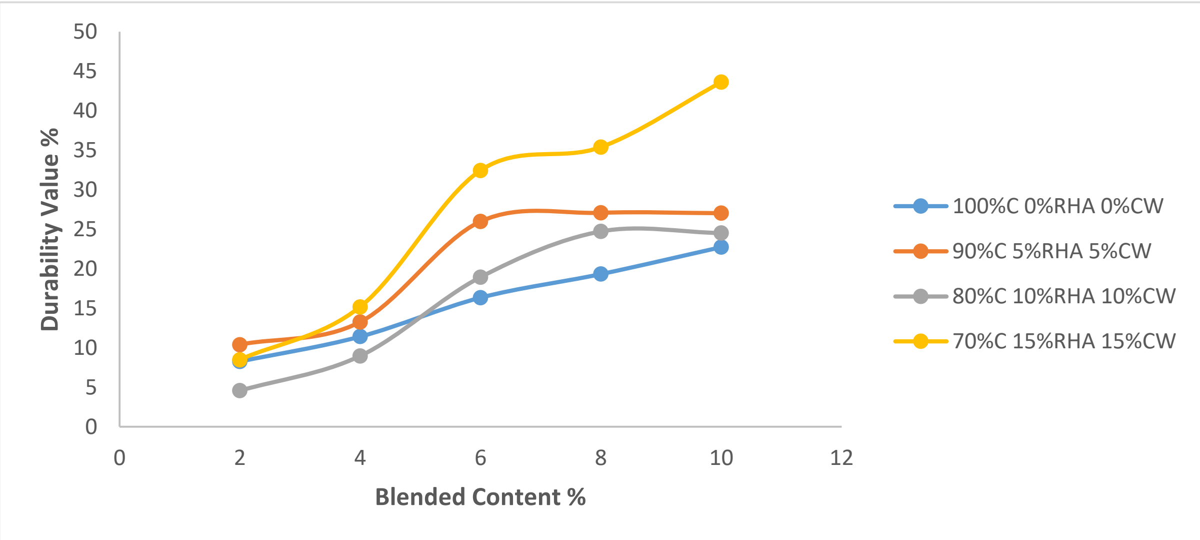

Fig. 13. Relationship between the durability values of laterite treated with (100%C 0%RHA 0%CW), (90%C 5%RHA 5%CW),(80%C 10%RHA 10%CW)& (70%C 15%RHA 15%CW) blend of cement.

The conventional criterion of a maximum allowable loss in strength of 20%, which translates to 80% resistance to loss in strength was adopted for the stabilization of the laterite and from the result above, it can be said that, there is an improvement in the strength of the soil when the cement was blended with RHA and CW, although result did not meet strength requirements specified for soil. Marathe et al. [35] investigated durability properties of cement stabilized lateritic soil by alternate freezing-thawing and wetting-drying tests and recorded that most of the specimens withstood not less than 200000 cycles prior to failure which indicated high endurance limit.

4. Conclusion and recommendation

4.1. Conclusion

From the results of the test carried out on the natural Ikpayongo laterite,it is a well graded sandy gravel soil which showed good and desired engineering properties in its natural state that can be used as a fill material for pavement.

The use of cement as a stabilizing agent shows a progressive enhancement in its engineering properties. Blending this cement with Rice Husk Ash (RHA) and Carbide Waste (CW) in the percentage proportion of (90%Cement 5%RHA 5%CW), (80%Cement 10%RHA 10%CW) and (70%Cement 15%RHA 15%CW) at interval of 0% to 10% showed good results than the cement treated soil at some percentage of treatment.

MDD of the natural soil reduced from 2.015Mg/m^{3}to 1.917Mg/m^{3}at 2% cement content, and increased at 10% cement content to 1.987Mg/m^3. MDD of the natural soil reduced from 2.015Mg/m^3 to 1.875Mg/m^3 when treated with 2% blend of 90% cement 5% RHA 5% CW, but increased to 1.950Mg/m^3 at 10% of the cement blend. The MDD of the natural soil also reduced to 1.870Mg/m^3 when treated with 2% blend of 80% cement 10% RHA 10% CW and increased at 10% of the cement blend.

The CBR value of the natural soil was gotten to be 9.66% but increased by 2% when treated with 100% cement. The CBR value for the immediately compacted soil was found to be 24.87%, after been soaked there was a reduction in the value which was gotten to be 17.97%.

For the 80%C 10%RHA 10%CW blend, the improvement when compared with the cement treated soil is higher, at 10% percent replacement, the values gotten were 55.20% and 65.41% respectively immediately after compaction. When soaked, the values further increased to 77.31% and 97.55% respectively in comparison with the cement treated laterite which had its values as 61.14% and 88.14% respectively.

The UCS value of the cement treated soil increased from 1512.82KN/m^2 to 1512.90KN/m^2 for the blend of 90% cement 5% RHA 5% CW by volume at 10% of the blend for the 14 days cured sample. It also increased from 1512.09KN/m^2 to 1753.39KN/m^2 for the blend of 80% cement 10% RHA 10% CW by volume at 10% of the blends for 14 days cured sample. It reduced at 70% cement 15% RHA 15 CW. This particular trend was observed for the 28 days cured sample, but its values were higher than that of the 14 days cured samples. The 10% of the cement blends for the proportion of 90% cement, 5% RHA 5% CW and 80% cement 10% RHA 10% CW were able to meet the Nigerian minimum requirement for road base material, which is 1720KN/m^2 for both the 14 days and 28 days cured samples.

The durability of a cement stabilized soil increased as the percentage of stabilization increased. When this was compared with that gotten from the blended cement, it was observed that, the 80%C 10%RHA 10%CW and 70%C 15%RHA 15%CW showed better result than the cement treated soil.

4.2. Recommendations

Based on the laboratory tests and observations during this work, the following recommendations have been suggested:

Ikpayongo laterite can be used as sub-base course material when stabilized with constituent mixtures to meet economy and strength requirements, since with low compactive effort, the desired CBR of ≥30% can be achieved.

Ikpayongo laterite cannot be used as a base material even when stabilized to10% cement and blended cement, at the BS light compactive effort. But when a higher compactive effort is used, a better result can be gotten and may meet the requirement of a road base material.

The use of Cement, Rice Husk Ash(RHA) and Carbide Waste (CW) as a stabilizing agent in laterite should be widely employed in Base/Sub-base materials because its readily availability and the economic quantity, which can produce desires properties as compared to other stabilizing agents, and the high cost of obtaining stone base rock.

More research works should be carried out on further replacement of the cement with RHA, CW to get the further substantial effect of these replacements.

Summary statement

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