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COMPARATIVE ASSESSMENT OF RICE HUSK ASH, POWDERED GLASS AND CEMENT AS LATERITIC SOIL STABILIZERS

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ABSTRACT

This paper compares the stabilizing effects of three different materials, namely: rice husk ash, powdered glass, and cement on the properties of lateritic soil. The basic properties of the lateritic soil were first obtained through colour, moisture content determination, specific gravity, particle size distribution and Atterberg limits tests. Each of the stabilizing materials was then mixed with the lateritic soil in varying percentages of 2.5%, 5%, 7.5%, 10%, 12.5% and 15% by weight of the soil. Thereafter, compaction and California bearing ratio (CBR) tests were carried out on the sample mixes to determine the effects of the materials on the lateritic soil. Chemical tests were also carried out on the samples to determine their percentage oxides composition. The compaction test showed that the highest maximum dry densities (MDD) obtained for the mixed samples were 2.32 g/cm^3 (at 2.5% cement addition), 2.28g/cm^3 (at 5% powdered glass (PG) addition) and 2.18 g/cm^3 (at 5% rice husk ash (RHA) addition) with corresponding optimum moisture contents (OMC) of 10.06%, 14.3% and 12.31% respectively. The CBR tests showed that the CBR values increased in all cases as the materials were added with those of the cement and powdered glass giving the highest values and showing close semblance under unsoaked conditions. The chemical test showed that the significant oxides present in the cement, powdered glass and rice husk ash were CaO (53.60%), SiO_2 (68.45%) and SiO_2 (89.84%) respectively.

KEYWORDS

Stabilizing, Atterberg limits, compaction, California bearing ratio, optimum

INTRODUCTION

Lateritic soils are the most readily available and the most economical construction materials found in many tropical countries. The availability of such soils over vast areas in the tropics and the relative ease of manipulation on road surfaces make their use very economical as low-cost road sub-base and base material for lightly trafficked secondary roads. However, the major problems associated with roads constructed with laterite include cracking of the surface pavement, stripping of the surface and waviness of the pavement surface a few years after construction [1]. Hence, the need to investigate possible sub-base improvement becomes paramount.

In terms of their morphological and chemical properties, laterite is a highly weathered red sub-soil, rich in secondary oxides of iron, aluminium or both and containing large amounts of

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quartz and kaolinite which are either hard or capable of hardening when exposed to wetting and drying [2]. Generally, laterite derives its colour from its mineral composition, while the various shades can be identified with various hydrated Iron Oxide content.

Improvement to soils can be achieved through stabilization which involves blending and mixing materials with the soils to either achieve a desired gradation or to make them more stable. This study seeks to comparatively assess the effects of rice husk ash (RHA), powdered glass (PG) and cement on lateritic soil. Cement is the best conventional stabilizer, however, it is expensive. Hence, there is a need to source for alternative stabilizers that are affordable and readily available from materials which would otherwise have been disposed of as waste from industries. These materials constitute a nuisance to the environment and could even be dangerous in the case of the powdered glass which is majorly non-biodegradable. Consequently, these materials are processed into suitable form, added to the soil and the resulting properties are compared to that of the soil containing cement to determine how effective they are as stabilizers.

Recently, industrial wastes have been considered for application in road construction across the world. The use of such materials is based on technical, economic and ecological criteria which are crucial for a country like Nigeria which normally provides a good environment for manufacture and importation of glass materials as well as the production/processing of rice. However, owing to a poor solid waste management system, Nigerian cities are experiencing environmental problems as the rate of solid waste generation has grown beyond the capacity of the authorities concerned. This portends a serious environmental crisis which could be forestalled or mitigated if these waste materials can be developed and suitably utilised in highway construction.

Background Literature

There are two major methods of stabilization namely mechanical and chemical methods. The mechanical methods of soil stabilization involve either compaction or the introduction of graded aggregate materials, fibrous and other non-biodegradable reinforcement to the soil without requiring chemical changes in the soil. The chemical methods involve adding chemicals or other additives to soils which react with or change the chemical properties of the soil thereby improving its engineering properties. Such chemicals include cement, lime, fly ash, bitumen, calcium chloride and resinous materials.

Compaction as a mechanical stabilization method involves artificially increasing the unit weight or density of the soil by applying pressure on it from above thereby expelling air from the soil mass and ultimately decreasing the void ratio. The other methods of mechanical stabilization involve introducing soil reinforcements in the soil such as geo-textiles and engineered plastic mesh which are designed to trap soils and help control erosion, moisture conditions and soil permeability. Likewise, larger aggregates such as gravels, stones and boulders are often introduced where additional mass and rigidity are required to prevent unwanted soil migration or to improve load-bearing properties of the soil.

Research has shown that stabilizing soils with small quantities of insoluble binders like cement, lime and bitumen and other resinous compounds greatly improved their load bearing capacity and water resistance properties which helped to reduce the rate of cracking [3]. In addition, cement stabilization has been shown as the most effective of all the methods of stabilization for the greater range of lateritic soils. However, the cost of cement is on increase. Hence, a lot of effort is being made to identify and develop alternative materials for highway construction and industrial waste products such as waste glass and rice husk are some examples.

Stabilization of soils with rice husk ash (RHA) and powdered glass (PG)

The effects of RHA on cement stabilized laterite soil with respect to compaction characteristics, California bearing ratio (CBR) and unconfined compressive strength (UCS) tests were investigated [4]. The results obtained showed a general decrease in maximum dry density (MDD) and increase in optimum moisture content (OMC), as the RHA content was increased from 2% to 8%. There was also a tremendous improvement in the CBR and UCS with increase in the RHA content at specified cement contents to their peak values at values between 4% and 6% RHA. The UCS values also improved with curing age.

The effects of rice husk ash (RHA) on some geotechnical properties (such as compaction, consistency limits and strength) of a lateritic soil classified as A-2-6 (0) or SW for sub-grade purposes were studied [5]. The RHA contents used were 5%, 7.5%, 10% and 12.5% by weight of the dry soil and the results obtained showed that an increase in RHA content heightened the optimum moisture content but decreased the maximum dry density. It was also observed that an increase in RHA content, reduced plasticity and increased volume stability as well as the strength of the soil. The optimum RHA content observed was at 10%.

Grain-size distribution, consistency, specific gravity, compaction, California bearing ratio (CBR), unconfined compression, direct shear and permeability tests were conducted on lateritic soil treated with up to 20% glass cullet content [6]. The results showed growth in grain sizes resulting in coarser soil, changes in moisture-density relationship, resulting in lower optimum moisture content (OMC) and higher maximum dry density (MDD), an increase in CBR and in unconfined compressive strength (UCS), changes in cohesion-frictional angle relationship resulting in lower cohesion (c) and higher angle of internal friction (Φ) and growth in co-efficient of permeability, k, with increased glass cullet treatment. These results showed an improvement in geotechnical properties, making glass cullet-lateritic soil blend a potentially good highway material and suggesting the suitability of the blend for embankments, structural and non-structural fill and retaining wall backfill.

The stabilizing effect of powdered glass in varying proportions namely 1%, 2%, 5%, 10% and 15% (by weight of the soil) on clay soil was assessed [7]. The compaction test showed that there was an improvement in the maximum dry density values on addition of the powdered glass with corresponding gradual increase up to 5% glass powder content after which it started to decrease at 10% and 15% powdered glass content. The highest CBR values of 14.90% and 112.91% were obtained at 5% glass powder content and 5mm penetration for both the unsoaked and soaked treated samples respectively. The maximum cohesion and angle of internal friction values of 17.0 and 15.0 respectively were obtained at 10% glass powder content

MATERIALS AND METHODS

The materials used in carrying out this study included waste rice husk, waste glass, cement, lateritic soil and water. Glass is a brittle, optically transparent and amorphous non crystalline material. The type of waste glass materials commonly found in the environment are drinking containers and window glass. Most of them are soda-lime glass composed of about 75% silica ($Si0_2$) plus Na_2O, CaO, and several additives [8].

Rice husk is an organic fibre containing about 75 to 90% organic matter such as cellulose and lignin while the rest of its constituents are mineral components such as silica, alkalis and trace elements. It also contains high amount of ash (about 10 to 20%) [9]. Cement is both an adhesive and cohesive material which is manufactured from a mixture of limestone, clay and shale. The mixture is burnt in a kiln at 1450°C and the resulting clinker is cooled, passed unto the mills where gypsum is added and ground to the cement powder [10]. Lastly, water which is a universal solvent, can be obtained from different sources (such as boreholes and wells) but it must be free from suspended particles like organic matter and silt which might affect the hydration process of cement.

Collection and processing of materials

The lateritic soil used for this study was collected from a borrow pit located within the Federal University of Technology, Akure, Ondo state, Nigeria at depths ranging between 1.0m to 2.0m. The glass bottles used for this research were sourced from the discarded brown bottles at a petty trader's shop located in Ilesha East local government of Osun state, Nigeria. They were ground and subjected to sieve analysis. The fractions that passed through sieve 212μm was used. It was immediately stored in air tight containers to avoid pre-hydration during storage when left in open air.

The rice husk ash (RHA) used in this study was obtained from a local rice milling factory located in Ibadan North local government of Oyo State, Nigeria. It was burnt under normal atmospheric temperature and pressure (open air burning) to obtain the ash which was immediately stored in air tight containers. The rice husk ash was sieved through BS sieve 212μm and the fractions passing through the sieve were used throughout the tests. The cement used was ordinary Portland cement (OPC) obtained from a retailer whose shop was located at the Federal University of Technology, Akure, Ondo State, Nigeria. Figure 1 shows samples of laterite, rice husk ash, powdered glass and cement used in that order.

Fig. 1. - Samples of laterite, rice husk ash, powdered glass and cement

Laboratory tests and analysis

The tests carried out to determine the properties of the lateritic soil in its natural form are the particle size distribution, specific gravity and Atterberg limits tests while the tests to determine the effects of the stabilizing materials on the soil include compaction and California bearing ratio tests. Chemical tests were also carried out on the materials to determine their composition.

The Atterberg limits tests were carried out to determine the liquid limit (LL), plastic limit (PL), shrinkage limit (SL) and Plasticity index (PI). These parameters characterise the nature of a soil based on the water content which determines whether it exists in some of the four following states, namely: solid, semi-solid, plastic and liquid states. The compaction test was carried out in a standard proctor mould to determine the optimum moisture contents (OMC) and maximum dry densities (MDD) of the soil samples. The California bearing ratio (CBR) test is the ratio of force per unit area required to penetrate the soil mass with standard circular piston at the rate of 1.25mm per minute to that required for the corresponding penetration of a standard material (well graded crushed stone).

ANALYSIS AND DISCUSSION OF RESULTS

The stabilizing agents in the lateritic soil were identified through chemical analysis while the soil was classified through the natural moisture content, particle size distribution, specific gravity and the Atterberg limits tests. The effects of RHA, PG and cement on the lateritic soil were assessed through the compaction and the California bearing ratio tests.

Chemical properties

The chemical properties of the materials were obtained by using a Compact Energy Dispersive X-ray Spectrometer and are as shown in Table 1.

Tab 1. - Chemical properties of the sample materials

Component	Concentration (%)		
	Cement	Powdered glass	Rice husk ash
SiO_2	28.70	68.45	89.84
Al_2O_3	13.50	5.21	8.43
Fe_2O_3	2.27	14.59	16.21
CaO	53.60	13.99	12.17
MgO	2.21	4.50	1.81
Loss on ignition	2.05	9.11	17.78

It was observed that SiO_2 (silica) was the major component present in powdered glass and rice husk ash while CaO was the major component present in cement as a result of lime used in its production. The combined percent composition of SiO_2, Al_2O_3 and Fe_2O_3 in the powdered glass and rice husk ash is more than 70 which shows that they are good stabilizers [11]. However, cement has a distinctly high concentration of CaO which is responsible for its high stabilizing property.

Natural moisture content

Table 2 shows the natural moisture content of the materials used in the study.

Tab. 2. - Specific gravity of sample materials

Sample	Moisture content (%)
Laterite	7.84
Cement	1.12
Powdered glass	0
Rice husk ash	8.29

Specific gravity

Table 3 shows the specific gravity of the materials used in the study.

Tab. 3. - Percentage moisture content of sample materials

Sample	Specific gravity (g/cm³)
Laterite	2.96
Cement	3.11
Powdered glass	2.24
Rice husk ash	1.34

Atterberg limits tests

The moisture content values obtained under the Atterberg limits tests are shown in Table 4. The liquid limit, plastic limit and plasticity index of the natural soil sample were obtained as 43.89, 41.0 and 2.89% respectively while the shrinkage limit was obtained as 11.02%.

Tab 4. - Liquid limit, plastic limit and shrinkage limit results

Liquid limit					
Test	Number of blows	Mass of wet sample (g)	Mass of dry sample (g)	Moisture (g)	M.C. %
1	40	7.3	5.3	2.0	37.74
2	30	13.5	9.5	4.0	42.11
3	21	10.2	7.0	3.2	45.71
4	14	7.8	5.2	2.6	50.00
				Average M.C (%)	43.89

Plastic limit				
Test	Mass of wet sample (g)	Mass of dry sample (g)	Moisture (g)	M.C %
1	1.0	0.70	0.30	45.85
2	1.6	1.15	0.45	39.13
3	1.3	0.93	0.37	38.02
			Average M.C (%)	41.00

Shrinkage limit				
Test	Initial length (L_o) (cm)	Final length (L_1) (cm)	Shrinked length (cm)	Shrinkage limit (%)
1	14.1	12.7	1.4	11.02

Particle size distribution

Table 5 shows the details of the particle size distribution analysis of the lateritic soil with the corresponding percentages retained on and passing through each of the sieves. Figure 2 shows the particle size distribution curve indicating that the soil comprises of 32% silt fraction and 68% sand fraction. It can be observed that the percentage passing through the no. 200 sieve (0.075mm) was 41.7% which was more than 30% indicating the soil is composed of silt and clay. Using the liquid limit, plastic limit and plasticity index values of 43.89%, 41% and 2.89%, the soil is classified as A-5 (with 'fair to poor 'drainage characteristic) [12]. Hence, the soil needs to be stabilized.

Tab. 5. - Particle Size Distribution Analysis

Diameter (mm)	Mass retained (g)	% retained	% passing
14	0	0	100
9.5	2.6	0.5	99.5
4.75	33.4	6.7	92.8
2.36	56.7	11.3	81.5
1.7	29.7	5.9	75.6
1.18	43.0	8.6	67.0
0.6	38.1	7.6	59.9
0.5	24.3	4.9	54.5
0.425	2.9	0.6	53.9
0.212	39.3	7.9	46.0
0.150	12.0	2.4	43.6
0.075	9.7	1.9	41.7
Pan	1.6	0.3	0

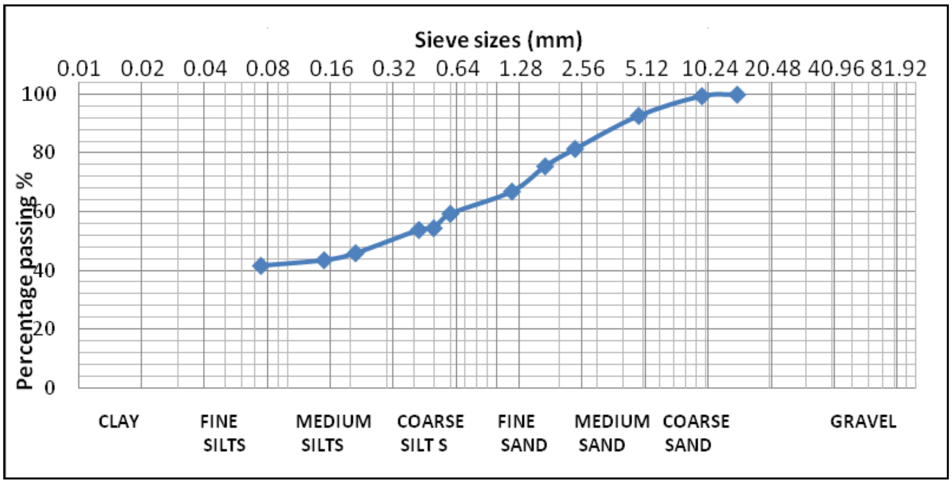

Fig. 2. - Particle Size Distribution chart for the lateritic soil

Compaction test

Compaction tests were carried out on the lateritic soil with and without the additives. The MDD and OMC of the soil in its natural form before stabilization were 2.24g/cm^3 and 11.65% respectively as shown in Figure 3. Each of the additives was added to the soil in varying percentages of 2.5%, 5%, 7.5%, 10%, 12.5% and 15% by weight of the soil. Figures 4, 5 and 6 show the compaction curves for the lateritic soil with RHA, PG and cement content which indicate

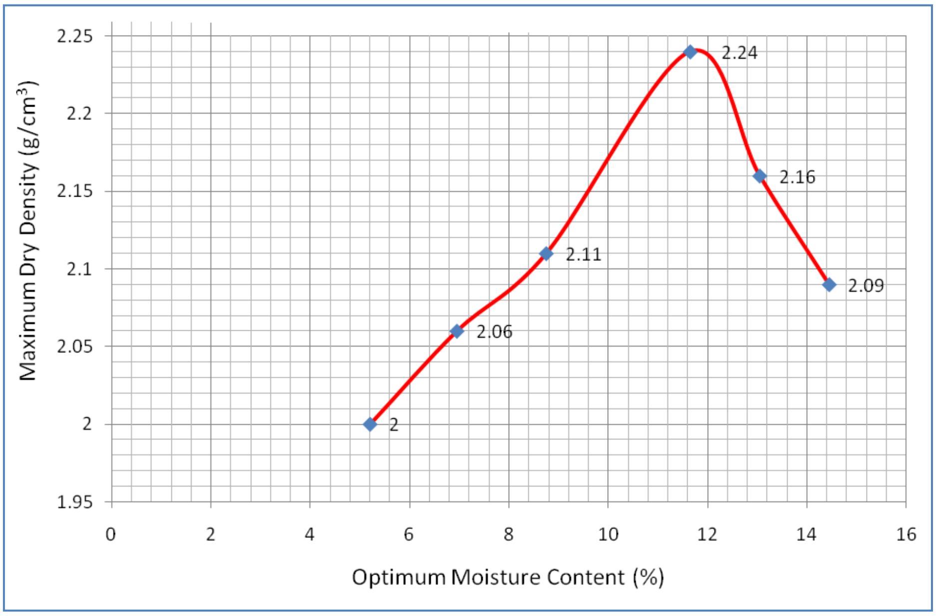

Fig. 3 - Compaction curve for the natural lateritic soil

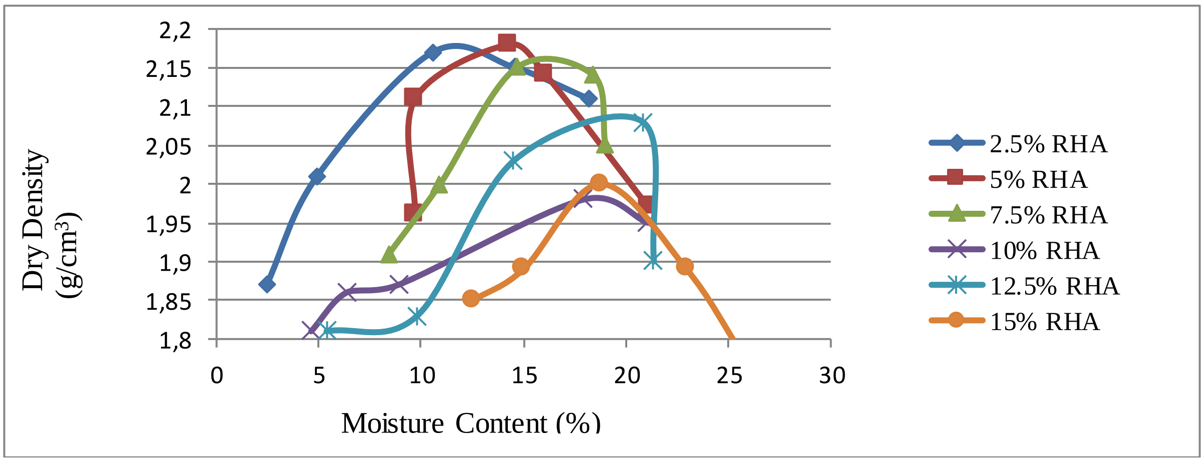

Fig. 4. - Compaction curves for the soil with varying RHA content

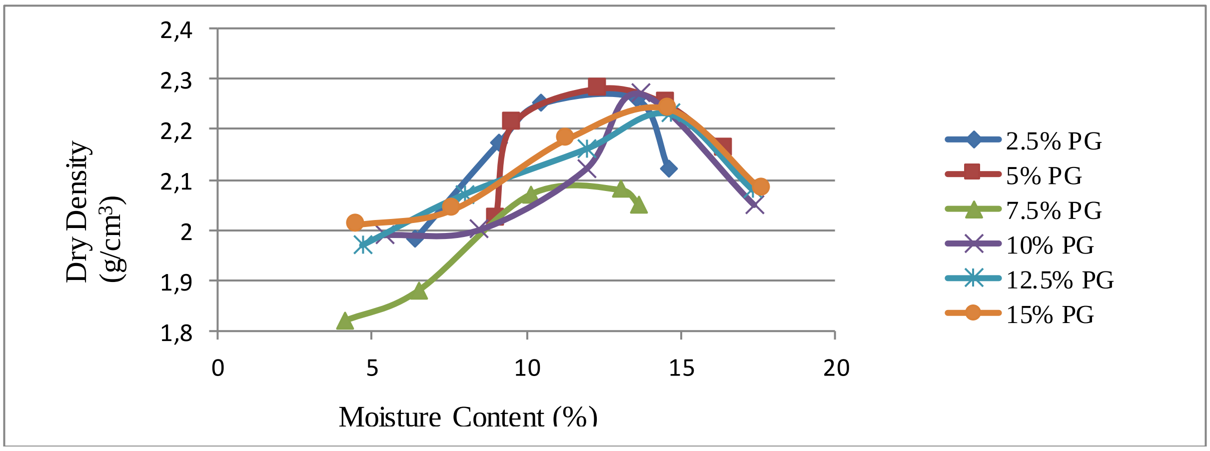

Fig. 5. - Compaction curves for the soil with varying PG content

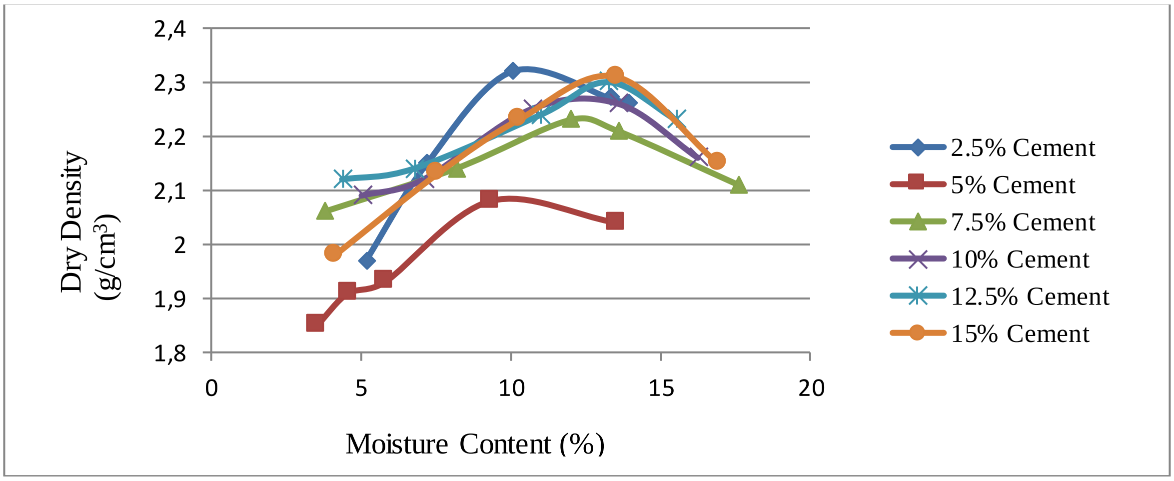

Fig. 6. - Compaction curves for the soil with varying cement content

that the MDD of the soil increased from a value of 2.24g/cm³ in the natural form to 2.28 g/cm³ (OMC = 12.31%) at 5% powdered glass content and to 2.32 g/cm³ (OMC = 10.06%) at 2.5% cement content. However, it dropped to its maximum value of 2.18 g/cm³ (OMC = 14.3%) at 5% RHA content.

California bearing ratio

Figures 7 and 8 show the unsoaked and soaked CBR graphs for the lateritic soil containing the additives in varying percentages of 2.5%, 5%, 7.5%, 10%, 12.5% and 15% by weight of the soil.

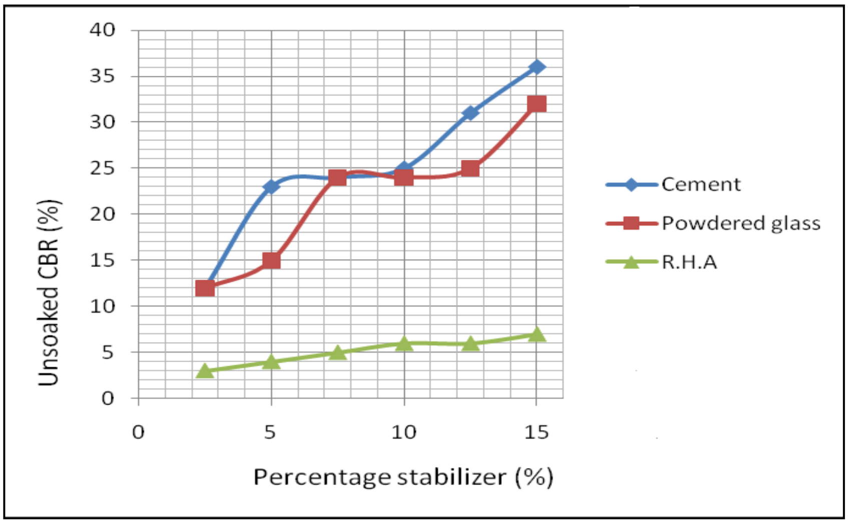

Fig. 7. - Unsoaked CBR curves for the soil with varying additives

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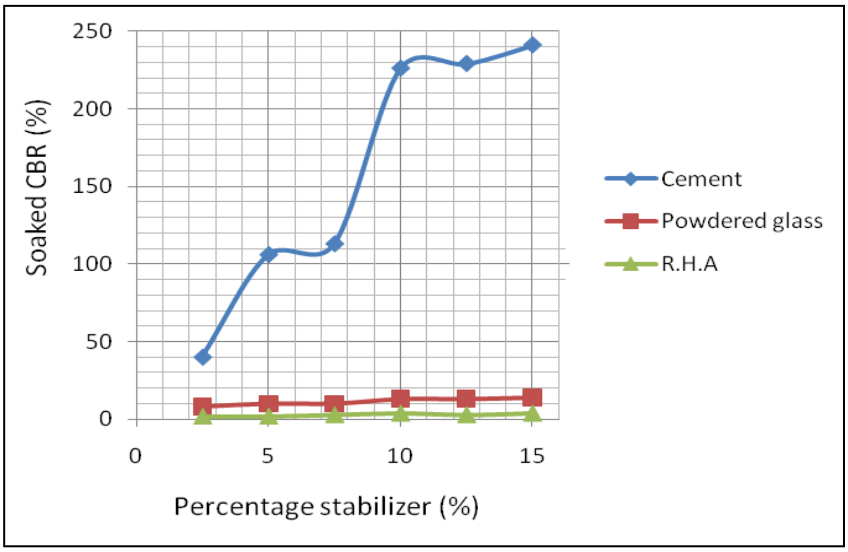

Fig. 8. - Soaked CBR curves for the soil with varying additives

The unsoaked CBR curves show that the values continued to increase as both the cement and powdered glass content were increased likewise the soil containing RHA but only slightly. The explanation for this is that cement has a very high flexural strength which translates to the high strength of the soil-cement mix. In the case of the soil-powdered glass mix, the glass acts as a pozzolana (siliceous or aluminous material) which reacts with calcium hydroxide in the presence of water at room temperature to form insoluble calcium silicate hydrate and calcium aluminate hydrate compounds which possess cementitious properties that strengthen the soil.

It can be also observed that the unsoaked CBR of the natural soil (34%) was exceeded by that of the soil with cement content (36%). In addition, the CBR values of the soil with powdered glass content (with the highest CBR value at 32%) compared favourably with those of the soil containing cement.

The soaked CBR curves show that only the cement additive has very noticeable positive effect on the CBR of the soil with its highest value at 241% which is a sharp contrast to the CBR value of the natural soil at 21%. In this case, the powdered glass and RHA produce barely noticeable positive changes in the CBR of the soil. It appears that the powdered glass loses its strength under soaked conditions.

CONCLUSION

Based on the Atterberg limits test and the particle size distribution analysis, the natural lateritic soil used for the study was classified using the AASHTO soil classification system as A-5 soil. A-5 soils are a group of soils that cannot be used as subgrade material in road construction unless they are stabilized.

The compaction tests show that the maximum dry densities are obtainable for the lateritic soil treated with cement, powdered glass and rice husk ash at OMCs of 10.06%, 14.3% and 12.31% respectively. This will ensure greater strength of the soil as well as ensure that it is less susceptible to changes in moisture content which may lead to swelling and shrinkage.

The CBR tests indicate that the CBR values of the soil treated with cement and powdered glass may further increase on increasing their percentage content beyond 15%. The CBR tests also suggest that powdered glass treated soil will only produce results comparable to cement treated soils under dry conditions. Hence, powdered glass can be used as an alternative to cement under unsoaked conditions.

REFERENCES

[1] Morin, W.J. and Todor, P.C. 1975. *"Laterite and Lateritic Soils and other Problem Soils of the Tropics"*. An Engineering Evaluation and Highway Design Study for *United States Agency for International Development.* Vol. 1. Lyon Associates, Baltimore, Maryland.

[2] Alexander, L.T. and Cady, J.G. 1992. Genesis and Hardening of Laterite Soils. *Technology Bull*, 1: 82-88.

[3] Ola, S.A. 1983. Geotechnical Properties and Behaviour of some Nigerian Lateritic Soils in Ola, S.A. Tropical Soils of Nigeria in Engineering Practice. A. A. Balkema: Rotterdam, The Netherlands: 61-84.

[4] Alhassan M., Mustapha M., 2007. Effects of Rice Husk Ash on Cement Stabilized Laterite. Leonardo Rlectronic Journal of Practices and Technologies, vol. 11: 47-58.

[5] Okafor F.O., Okonkwo U.N., 2009. Effects of Rice Husk Ash on some Geotechnical Properties of Lateritic Soil. Nigerian Journal of Technology, vol. 28, no. 1: 46-52.

[6] Eberemu A.O., Edeh J.E.,Gbolokun A.O., 2013. The Geotechnical Properties of Lateritic Soil Treated with Crushed Glass Cullet. Advance Materials Research, vol. 824: 21-28.

[7] Olufowobi J., Ogundoju A., Michael B., Aderinlewo O., 2014. Clay Soil Stabilisation using Powdered Glass. Journal of Engineering Science and Technology, vol. 9, no. 5: 541-558.

[8] El-Kheshen A. A., 2012. Glass as Radiation Sensor. Current Topics in Ionizing Radiation Research, edited by Mitsuru Nenoi (InTech) 579-602

[9] Kumar S., Sangwan P., Dhankhar R., Mor V., Bidra S., 2013. Utilization of Rice Husk and their Ash: A Review. Research Journal of Chemical and Environmental Sciences, vol. 1, no. 5: 126-129.

[10] ELC, 2015. Cement. The Environmental Literacy Council website: http://www.enviroliteracy.org/ environment-society/materials-use/cement/ (April 22, 2016)

[11] Tashima M.M., Silva C.A., Akasaki J.L., Barbosa M.B., 2004. The possibility of adding rice husk ash (RHA) to concrete. In: Proceedings of the 2004 inter-national RILEM Conference on the Use of Recycled Materials in Building and Structures. Barcelona, 778-786.

[12] AASHTO, 1986. Standard specifications for transportation materials and methods of sampling and testing. American Association for State Highway and Transportation Officials. Washington D.C.