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The Engineering Analysis and Composition of Rice Husk Ash, Powdered Glass, and Cement as Stabilizers

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Abstract:
The stabilizing effects of three different compounds rice husk ash, glass powder, and cement on the properties of lateritic soil are contrasted in this study. First, the basic properties of the lateritic soil were ascertained by testing for color, moisture content, specific gravity, particle size distribution, and Atterberg limits. Then, by weight of the soil, varying amounts of each stabilizing agent were added to the lateritic soil: 2.5%, 5%, 7.5%, 10%, 12.5%, and 15%. Compaction tests and California bearing ratio (CBR) tests on the sample mixtures were then used to evaluate the effects of the components on the lateritic soil. To determine the samples' % oxide concentration, chemical tests were also performed on them. The results of the compaction test showed that the three mixed samples with the highest maximum dry densities (MDD) were 2.32 g/cm3 (at a 2.5% cement addition), 2.28 g/cm3, and 2.18 g/cm3 (at a 5% addition of rice husk ash), with corresponding optimum moisture contents (OMC) of 10.06%, 14.3%, and 12.31%, respectively. Cement and glass powder provided the highest values and closely resembled one another in dry conditions, according to the CBR trials, which showed that the CBR values rose in every case when more materials were added. The cement, powdered glass, and rice husk ash, respectively, included sizeable amounts of CaO (53.60%), SiO2 (68.45%), and SiO2 (89.84%) oxides, per the chemical analysis.

Keywords: Atterberg limits, optimum, compaction, California bearing ratio

INTRODUCTION

In many tropical nations, lateral soils are the most widely accessible and cost-effective building materials. Due to their wide-spread availability in the tropics and relative simplicity of manipulation on road surfaces, these soils are extremely cost-effective as base material for minor roads with low traffic volumes. However, a few years after construction, the surface of the pavement will begin to crack, stripe, and become uneven, which are the main issues with roads built with laterite [1]. Therefore, it becomes crucial to look into potential sub-base improvement. According to their morphological and chemical characteristics, laterite is a highly worn red subsoil that is abundant in secondary oxides of iron, aluminum, or both.

When subjected to wetting and drying, quartz and kaolinite are either hard or have the potential to get harder [2]. Laterite typically gets its color from the minerals that make up the material, and the different colors can be distinguished by the amount of hydrated iron oxide present.

Stabilization, which entails blending and mixing elements with the soils to either attain a desired gradation or to make them more stable, can be used to improve soils. In this study, the impacts of cement, powdered glass, and rice husk ash (RHA) on lateritic soil will be evaluated in comparison. The finest conventional stabilizer is cement, but it is pricey. As a result, it is necessary to find other stabilizers that are accessible, inexpensive, and made from materials that would otherwise be discarded as industrial waste. These materials are a nuisance to the environment, and, in the case of powdered glass, which is often non-biodegradable, even harmful. In order to assess how efficient, they are as stabilizers, these materials are processed into a usable form, added to the soil, and the resulting properties are compared to those of the soil containing cement.

Worldwide, the use of industrial waste in road construction has recently received consideration. For a nation like Nigeria, which typically offers a favorable climate for the manufacture and importation of glass materials as well as the production/processing of rice, the usage of such materials is based on technical, economic, and ecological reasons. Nigerian cities are currently facing environmental issues due to a subpar solid waste management system since the rate of solid waste generation has outpaced the capability of the relevant authorities. This heralds the beginning of a significant environmental problem that might be avoided or attenuated if these waste materials can be developed and used in the construction of highways in an appropriate manner.

LITERATURE REVIEW

The two main stabilizing techniques are mechanical and chemical techniques [1]. The mechanical techniques of stabilizing soil do not require chemical changes to the soil and either entail compaction or the addition of graded aggregate materials, fibers, and other non-biodegradable reinforcement to the soil [5]. The chemical approaches entail introducing substances to soils that react with them or alter their chemical properties, enhancing the soil's engineering properties. Cement, lime, fly ash, bitumen, calcium chloride, and resinous compounds are examples of such substances.

As a mechanical stabilization technique, compaction entails exerting pressure from above to the soil to artificially increase its unit weight or density. This removes air from the soil mass, lowering the void ratio in the process [7]. The other mechanical stabilization techniques involve incorporating soil reinforcements into the soil, such as geotextiles and engineered plastic mesh, which are intended to hold soil in place while assisting in the regulation of soil permeability, moisture conditions, and erosion. Similarly, bigger aggregates like gravel, stones, and boulders are frequently added where more bulk and stiffness are needed to stop unintended soil migration or to enhance the soil's capacity for bearing loads [9].

According to research, stabilizing soils with modest amounts of insoluble binders including cement, lime, bitumen, and other resinous compounds significantly increased their water resistance and load bearing ability, which helped to slow the rate of cracking [3]. Additionally, for a wider variety of lateritic soils, cement stabilization has been found to be the most effective form of stabilization. Cement, though, is becoming more expensive. As a result, much work is being done to find and create substitute materials for highway construction, with products made from industrial waste like waste glass and rice husk serving as some examples.

Soil Stabilization with Glass Powder and Rice Husk Ash (RHA)

Investigated were the effects of RHA on the compaction properties, California bearing ratio (CBR), and unconfined compressive strength (UCS) tests of cement stabilized laterite soil [4]. The obtained results indicated that as the RHA content was increased from 2% to 8%, there was a general decrease in maximum dry density (MDD) and an increase in optimum moisture content (OMC). With an increase in the RHA content at the designated cement contents to their highest values at values between 4% and 6% RHA, the CBR and UCS likewise saw a significant improvement. With aging, the UCS values likewise increased.

The impacts of rice husk ash (RHA) on a lateritic soil designated as A-2-6 (0) or SW for sub-grade purposes were investigated [5]. These attributes included compaction, consistency limits, and strength. The results showed that an increase in RHA concentration increased the ideal moisture content but lowered the maximum dry density. The RHA levels used were 5%, 7.5%, 10%, and 12.5% by weight of the dry soil. Additionally, it was noted that an increase in RHA concentration, decreased flexibility, enhanced volume stability, and increased soil strength. The 10% RHA content level was the best one found.

On lateritic soil treated with up to 20% glass cullet content, experiments on grain-size distribution, consistency, specific gravity, compaction, California bearing ratio (CBR), unconfined compression, direct shear, and permeability were performed [6]. The results showed an increase in CBR and unconfined compressive strength (UCS), a decrease in cohesion-frictional angle relationship (lower cohesion (c) and higher angle of internal friction (), growth in co-efficient of permeability, k, with increased glass cullet treatment, and changes in moisture-density relationship (lower optimum moisture content (OMC) and higher maximum dry density (MDD). The glass cullet-lateritic soil blend is now possibly a suitable highway material, according to these studies, which also point to the blend's appropriateness for embankments, structural and non-structural fill, and retaining wall backfill.

On clay soil, the stabilizing impact of glass powder in various amounts, including 1%, 2%, 5%, 10%, and 15% (by weight of the soil), was evaluated [7]. The compaction test revealed that adding powdered glass improved maximum dry density values, which gradually increased up to 5% glass powder content before beginning to decline at 10% and 15% powdered glass content. For both the unsoaked and soaked treated samples, the greatest CBR values of 14.90% and 112.91%, respectively, were obtained at 5% glass powder concentration and 5mm penetration. At 10% glass powder content, the maximum cohesiveness and angle of internal friction values of 17.0 and 15.0, respectively, were obtained.

METHOD AND MATERIALS

The waste rice husk, waste glass, cement, lateritic soil, and water were the materials used to conduct this study. Glass is an optically transparent, fragile, non-crystalline, amorphous substance. Drinking glasses and window glass are two examples of the waste glass materials that are typically found in the environment. Most of them are soda-lime glasses, which contain Na_2O, CaO, and various chemicals in addition to roughly 75% silica (SiO_2) [8].

When it comes to its ingredients, silica, alkalis, and trace elements make up the majority of the organic material found in rice husk, which is an organic fiber that contains between 75 and 90 percent organic matter like cellulose and lignin. Additionally, it has a lot of ash in it (between 10% and 20%) [9]. Limestone, clay, and shale are combined to create cement, a substance that functions as both an adhesive and cohesive. The mixture is burned at 1450 degrees Celsius in a kiln, and the resulting clinker is cooled before being sent to the mills, where gypsum is added, and the cement powder is crushed [10]. Finally, water, a universal solvent, can be found in a variety of places (such wells and boreholes), but it must be unrestricted.

The Ogun Engineering Research Institute has a borrow pit where lateritic soil was gathered from depths ranging from 1.0 to 2.0 meters. The glass bottles utilized for this study were obtained from a petty trader's shop in the Ijebu East local government of Ogun state, Nigeria, using leftover brown bottles as a source material. They were crushed and examined via a sieve. The fractions that made it through a 212-mm sieve were utilized. To prevent pre-hydration during storage while left in the open air, it was immediately put in airtight containers.

The local rice milling factory in Ogun North local government of Oyo State, Nigeria, provided the rice husk ash (RHA) used in this investigation. To obtain the ash, it was burned outdoors (open air burning) at normal atmospheric pressure and temperature. The ash was then immediately stored in airtight containers. The fractions passing through the BS sieve 212m were employed for the testing after the rice husk ash was sieved through it. Ordinary Portland Cement (OPC), which was purchased from a trader with a storefront at the Ogun Engineering Research Institute, Ogun State, Nigeria, was the cement that was used. Samples of laterite, rice husk ash, powdered glass, and cement are shown in Figure 1 in that order.

Fig. 1: Laterite, rice husk ash, glass powder, and cement samples

ANALYSIS AND TESTING IN LABORATORIES.

Particle size distribution, specific gravity, and Atterberg limits tests are used to ascertain the characteristics of lateritic soil in its unaltered state. Compaction and California bearing ratio tests are used to ascertain the effects of stabilizing materials on the soil. The materials were also subjected to chemical tests to ascertain their makeup.

The liquid limit (LL), plastic limit (PL), shrinkage limit (SL), and plasticity index (PI) were all determined using the Atterberg limits tests. Based on its water content, which determines whether it exists in one of the four forms of solid, semi-solid, plastic, or liquid, these criteria describe the characteristics of a soil. The compaction test was conducted in a typical proctor mould to ascertain the maximum dry densities (MDD) and optimal moisture contents (OMC) of the soil samples. the ratio of force to weight in the California bearing ratio (CBR) test

Table: 1a

Component	Glass Powdered with Cement	Rice-Husk Ash
SiO2 (%)	28.70	68.45
Al2O3 (%)	13.50	5.21
Fe2O3 (%)	2.27	14.59
CaO (%)	53.60	13.99
MgO (%)	2.21	4.50
Ignition Loss (%)	2.05	9.11

The table presents the chemical composition of three different materials: Glass Powdered with Cement and Rice-Husk Ash. Each material is characterized by the percentage composition of specific components, including SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, and Ignition Loss.

The percentages indicate the relative presence of these components within each material. For instance, Glass Powdered with Cement has a significant amount of SiO_2 (28.70%), followed by Al_2O_3, Fe_2O_3, CaO, MgO, and a relatively low Ignition Loss. On the other hand, Rice-Husk Ash has a much higher concentration of SiO_2 (68.45%) along with varying percentages of other components. This data is crucial for understanding the elemental composition of these materials, which plays a significant role in their properties and potential applications in various fields such as construction, engineering, and materials science.

RESULTS ANALYSIS AND DISCUSSION

Chemical analysis was used to determine the stabilizing components in the lateritic soil, and the soil's classification was based on tests for natural moisture content, particle size distribution, specific gravity, and Atterberg limits. The compaction and California bearing ratio tests were used to evaluate the impacts of RHA, PG, and cement on lateritic soil.

Table: 1b

Molecular composition	
Sample	**Moisture Content**
Laterite	7.84
Cement	1.12
Powdered Glass	0.00
Rice Husk Ash	8.29

Using a Compact Energy Dispersive X-ray Spectrometer, the materials' chemical characteristics were discovered and are displayed in Table 1.

The table provides information about the moisture content of different samples: Laterite, Cement, Powdered Glass, and Rice Husk Ash.

- Laterite has a moisture content of 7.84%, indicating the presence of water within the sample.
- Cement has a relatively lower moisture content of 1.12%, suggesting minimal water content.
- Powdered Glass shows no detectable moisture content, with a value of 0.00%.
- Rice Husk Ash has a moisture content of 8.29%, implying a significant water presence.

Moisture content is a crucial factor in various applications, affecting material properties and behaviors. This data helps in understanding the water content in each sample, which can influence processes like drying, handling, and utilization in different industries.

Tab: 2

Component \ Sample	Cement	Rice Husk Ash	Powdered Glass
SiO2 (%)	28.70	68.45	89.84
Al2O3 (%)	13.50	5.21	8.43
Fe2O3 (%)	2.27	14.59	16.21
CaO (%)	53.60	13.99	12.17
MgO (%)	2.21	4.50	1.81
Ignition Loss (%)	2.05	9.11	17.78

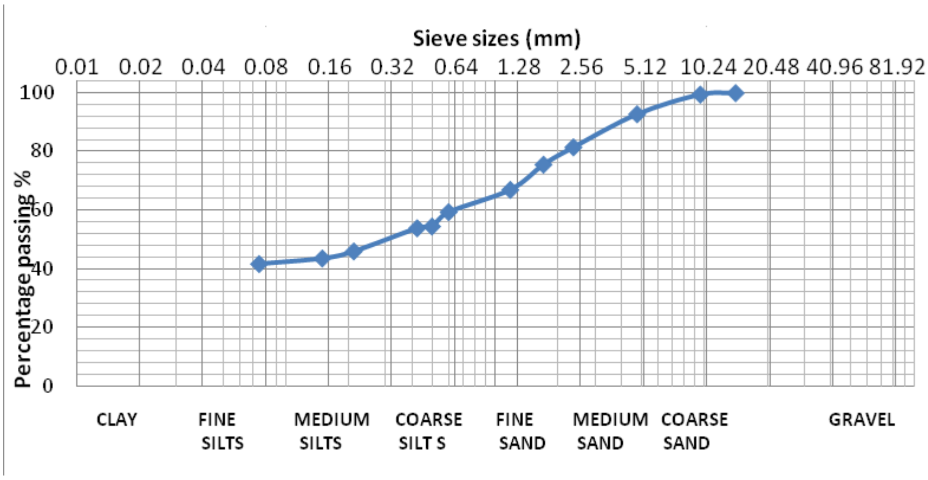

Fig. 2: Lateritic soil particle size distribution chart

SiO2 (silica) was found to be the main component in both powdered glass and rice husk ash, whereas CaO was found to be the main component in cement because lime was employed in its manufacturing. The fact that the total SiO2, Al2O3, and Fe2O3 percent composition of powdered glass and rice husk ash is greater than 70% indicates that they are effective stabilizers [11]. But cement has a notably high percentage of CaO, which is what gives it such strong stabilizing properties.

Moisture Content Naturally

The natural moisture content of the study's materials is displayed in Table 2 for your reference.

Tab. 3: The material specific gravity of the sample.

Sample	Moisture Content
Laterite	7.84
Cement	1.12
Powdered Glass	0.00
Rice Husk Ash	8.29

The study's materials' specific gravities are displayed in Table 3 for your reference.

Tab. 4: The sample materials' percentage of moisture content

Sample	Specific Gravity
Laerite	2.96
Cement	3.11
Glass Slivers	2.24
Rice Husk Ash	2.24

Atterberg Limit Evaluations

Table 4 displays the moisture content values acquired during the Atterberg limits tests. The natural soil sample's liquid limit, plastic limit, and plasticity index were determined to be 43.89, The shrinkage limit was determined to be 11.02% whereas the respective values were 41.0 and 2.89%.

Tab 4: Results for the liquid limit, plastic limit, and shrinkage limit

Maximum Liquid

No	Wet Sample (g)	Dry Sample (g)	Moisture	No. of Blows	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
M.C. on avg (%)		43.89			

Shrinking Range

Test Initial length (Lo), Final length (L1), Shrined length (cm), and Maximum shrinkage (%)
1 14.1 12.7 1.4 11.02

No	Wet Sample (g)	Dry Sample (g)	Moisture	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
M.C. on avg (%)		41.00		

Distribution of Particle Sizes

With the matching percentages kept on and passing through each of the sieves, Table 5 details the particle size distribution study of the lateritic soil. According to Figure 2, which depicts the particle size distribution curve, the soil is made up of 68% sand and 32% silt. It can be seen that 41.7% of the sample passed through the no. 200 sieve (0.075mm), which is higher than 30%, suggesting that the soil is silt and clay based. The soil is categorized as A-5 (with 'fair to poor' drainage characteristic) using the values of 43.89%, 41%, and 2.89% for the liquid limit, plastic limit, and plasticity index [12]. Therefore, stabilizing the soil is necessary.

Tab. 5: Analysis of the particle size distribution

	Dimensions (mm)	Mass Maintained (g)	Passing Percentage
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	0.0

Test for Compactness

On the lateritic soil with and without the additions, compaction tests were performed. Figure 3 illustrates the soil's MDD and OMC in its unstabilized natural state, which were 2.24g/cm3 and 11.65%, respectively. Each addition was incorporated into the soil at various rates of 2.5%, 5%, 7.5%, 10%, 12.5%, and 15% by soil weight. The compaction curves for the lateritic soil with RHA, PG, and cement concentration are shown in Figures 4, 5, and 6, which show

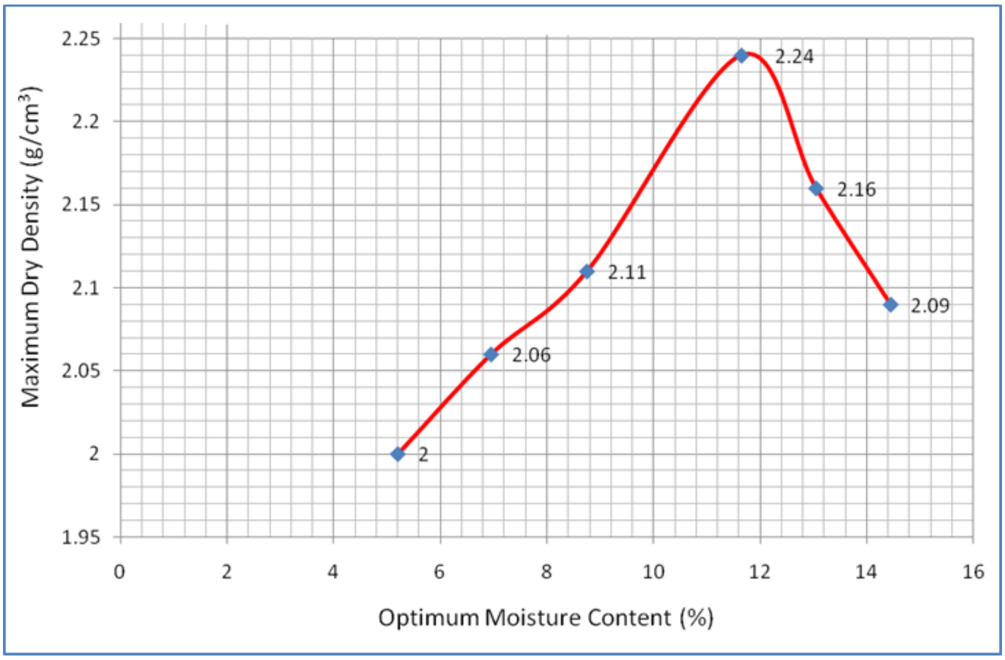

Fig. 3: The lateritic soil's inherent compaction curve

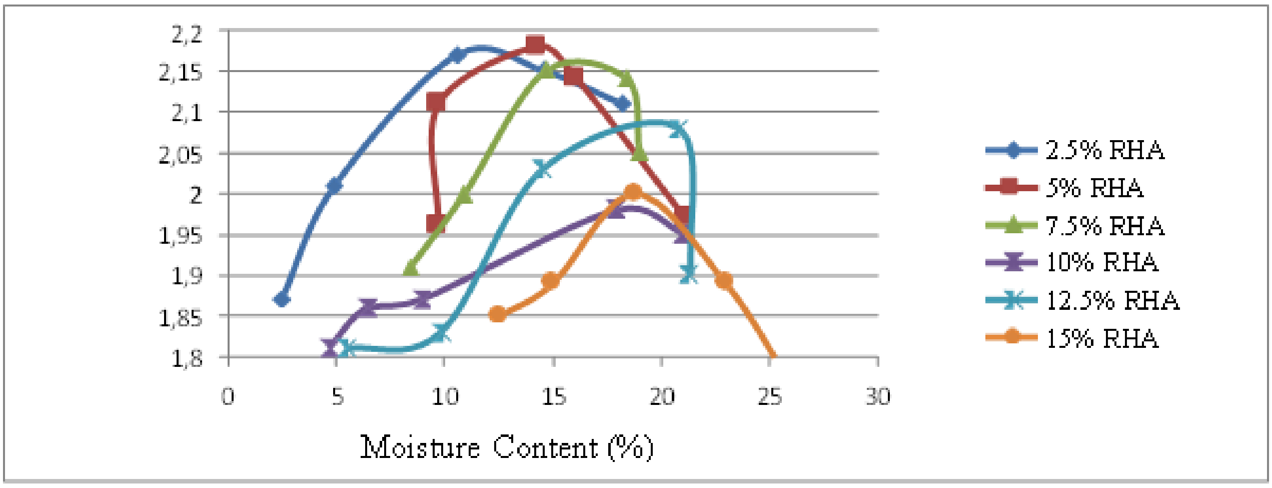

Fig. 4: Compaction curves for soils with various levels of RHA

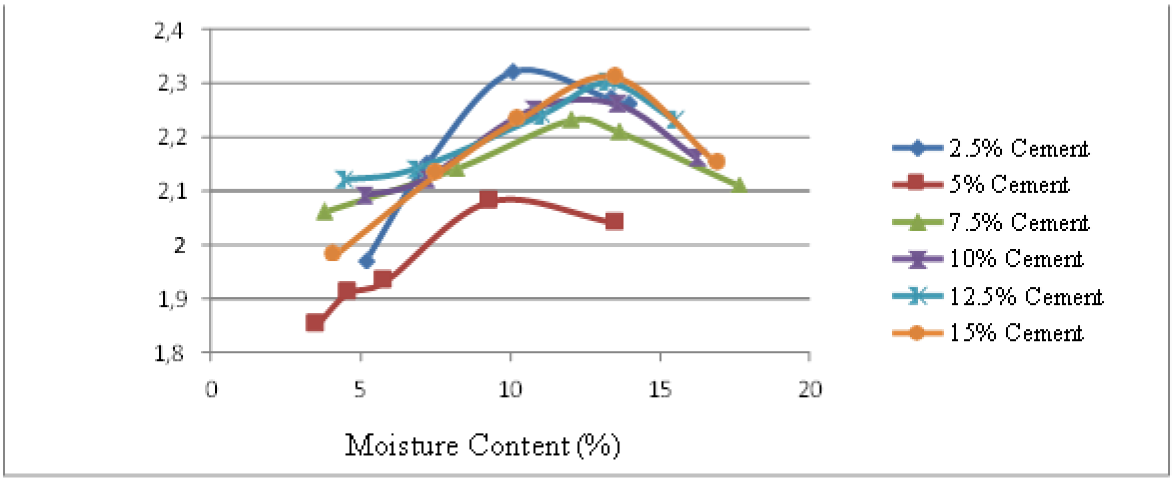

Fig. 5: Compaction curves for soils with increasing amounts of cement.

Th figures revealed the soil's MDD increased from 2.24g/cm3 in its natural state to 2.28g/cm3 (OMC = 12.31%) at 5% glass powder content and to 2.32g/cm3 (OMC = 10.06%) at 2.5% cement concentration. At 5% RHA content, it decreased, reaching a maximum of 2.18 g/cm3 (OMC = 14.3%).

Los Angeles Bearing Ratio

Figures 6 and 7 show the CBR graphs for lateritic soil that contains additives in varying percentages of 2.5%, 5%, 7.5%, 10%, 12.5%, and 15% by weight of the soil when unsoaked and soaked, respectively.

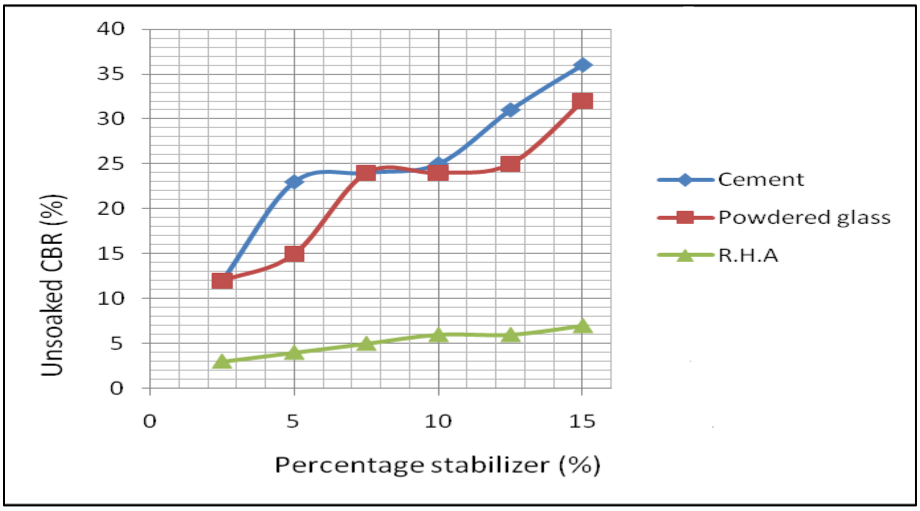

Fig. 6: CBR curves for soil with various additions that haven't been soaked

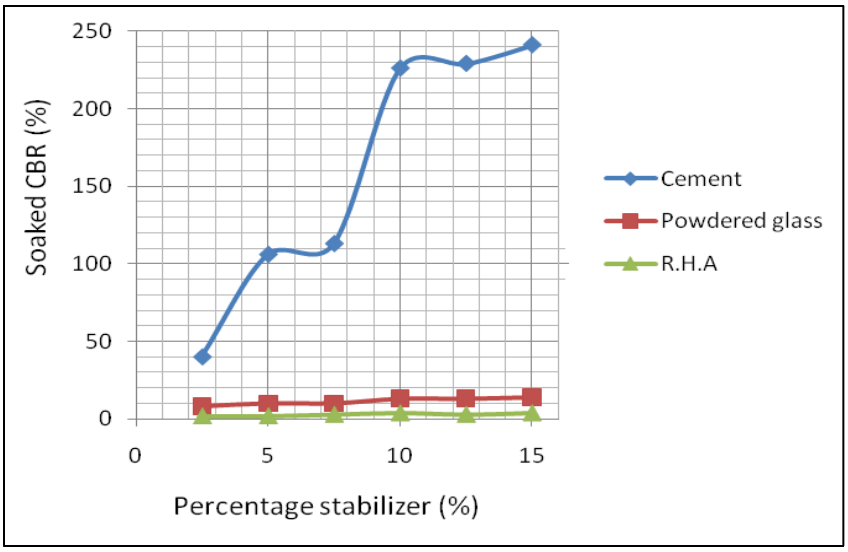

Fig. 7: Curves for the soil's soaked CBR with various additions

The unsoaked CBR curves demonstrate that values increased as the content of cement, powdered glass, and, to a lesser extent, RHA-containing soil increased. This is explained by cement's extremely high flexural strength, which correlates to the mix's high strength of soil and cement. In the soil-powdered glass mixture, the glass functions as a pozzolana (siliceous or aluminous material) that combines with calcium hydroxide in the presence of water at room temperature to form insoluble calcium silicate hydrate and calcium aluminate hydrate compounds that have cementitious properties that make the soil stronger.

Additionally, it can be shown that the unsoaked CBR of cement-rich soil (36%), as opposed to natural soil's (34%), was higher. Additionally, when compared favorably to those of the soil containing cement, the CBR values of the soil containing powdered glass (with the maximum CBR value at 32%) performed well.

The soaked CBR curves reveal that only the cement additive, whose greatest value is 241% and which stands in stark contrast to the native soil's CBR value of 21%, has a very significant positive effect on the CBR of the soil. In this instance, the RHA and powdered glass generate hardly perceptible improvements in the soil's CBR. It appears that when exposed to moisture, powdered glass loses strength.

CONCLUSION

The natural lateritic soil utilized for the study was categorized as A-5 soil utilizing the AASHTO soil classification system based on the Atterberg limits test and the particle size distribution analysis. A-5 soils are a kind of soils that must be stabilized before they can be used as subgrade material for roads.

According to the results of the compaction tests, the lateritic soil treated with cement, powdered glass, and rice husk ash can reach its maximum dry densities at OMCs of 10.06 percent, 14.3 percent, and 12.31 percent, respectively. The soil will be stronger as a result, and it will also be less vulnerable to variations in moisture content that could cause swelling and shrinkage.

The CBR experiments show that, as their percentage contents are increased beyond 15%, the CBR values of soil treated with cement and powdered glass may further rise. The CBR tests also indicate that soil treated with powdered glass will only give outcomes similar to cement. The treated soils in a dry environment. Therefore, in dry conditions, glass powder can be used in place of cement.

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