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Performance Characteristic of Rice Husk Ash and Mining Tailing Waste Compressed Earth Blocks for Low Cost Housing

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--***ABSTRACT***--
Shelter is man's basic need after food and clothing. However, due to economic challenges and high cost of building materials such as cement, it became difficult for people to acquire affordable shelter in Nigeria. This led to research into finding ways of utilizing waste to serve as alternative to earth blocks stabilized with cement for low cost housing. Thus, this research study examined the performance evaluation of Compressed Earth Blocks (CEB) stabilized with rice husk ash (RHA) and mining tailing waste (MTW). In order to achieve this objective, geotechnical properties and compaction characteristic tests of lateritic soil used in the production of the blocks were determined. The blocks were produced with RHA and MTW as stabilizers at 0%, 2%, 6%, 8% and 10% by weight of laterite and cured for 14, 21 and 28 days respectively. The compressive strength, density and water absorption tests of the blocks were conducted after each curing regime. The results of the soil geotechnical properties revealed a plasticity index (PI) of 26.19% while particle size distribution test shows the percentage passing sieve size 0.075mm (No.200) to be less than 35%. Thus, the soil is classified (A – 2 – 6) according to AASHTO system of classification. The soil maximum dry density (MDD) and optimum moisture content (OMC) of 1.65kg/m^3 and 20.50% were obtained using standard proctor compaction method. The tests results at 28 days curing age revealed the highest compressive strength of 2.26N/mm^2 at 10% RHA/MTW stabilization; also water absorption of 12.12% and density of 1825.10kg/m^3 were obtained at 10% RHA/MTW at 28 days. From the results obtained, it was observed that the strength and density of the blocks increased with increase in RHA/MTW proportion. However, the water absorption test result revealed the blocks absorbs more water as the proportion of the stabilizers increases; some of the findings were acceptable within the possible experimental errors.

KEY WORDS: *CSEB****,*** *rice husk ash, mining tailing waste, compressive strength*

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I. INTRODUCTION

The built industry relies more on cement in the development of shelter and other infrastructural facilities. Over the years it has become more difficult for many a people in Nigeria to own houses or fix worn out buildings due to the ever increasing cost of cement. Thus, it became necessary that local raw materials are developed from waste and utilized to serve as an alternative to cement in the production of low cost building material.

The compressed earth block (CEB) is an improved version of molded earth block, also referred to adobe block. The initiative of stabilizing and compacting earth block was to improve its quality and performance. Since its emergence, the CEB production technology and application in building has been progressing and proved worthy scientifically and technically as well [4]. However, the trend in the technology of CEB has been the use of cement as stabilizer for lateritic soil during production. But, this method has proved to be an expensive venture due to the ever increasing cost of cement and transportation.

Now as the world is shifting towards utilization of recycled waste from different sources such as mineral, agricultural, industrial materials, for sustainable environment, a way out is to consider the utilization or converting this waste to suitable engineering materials. Thus, pozzolanic materials such as fly ash (FA), saw dust ash (SDA), rice husk ash (RHA) as well as industrial waste such as calcium carbide residue (CCR) and lime have also been used as stabilizers [10]; [12]; [9]; [7].

Research findings by [5] reported the differences in compressive strength developed between the common and improved (CEB) stabilized with rice husk ash at different percentage of (RHA) additions at 0%, 2.5%, 5.0%, 7.5%, 10.0% and 12.5% by weight of dry soil and 14, 21 and 28 days curing ages respectively. The findings revealed that, a CEB when stabilized with a RHA can be compared to other blocks in all aspects and can do well in general construction work and exhibits those properties required of an acceptable quality when compared with usual bricks especially in terms of strength and durability. Similarly, in an experimental study on use of RHA to stabilized mud blocks (SMB) investigated by [6], the blocks were examined for the engineering properties such as compressive strength, water affinity rate, and density. It was found out that, the target wet compressive strength for grade 30 category of SMB according to Indian standard was achieved by stabilizer proportion of 70% cement and 30% rice husk ash. However, for earth stabilization, utilizing the two wastes calcium carbide residue (CCR) and rice husk ash (RHA) reported by [7], to improve the performance of (CEBs). The CCR or ratio of CCR: RHA at 0 to 15% by weight of soil was used. The results showed that, with 15% CCR: RHA at 7:3, the compressive strength of CEBs 6.6N/mm^2 was 3 times that of the CEBs with 15% CCR which was only 2.2N/mm^2. This development was said to be related to the pozzolanic interaction between calcium carbide residue, clay and rice husk ash. They concluded that the compressed stabilized earth blocks meet the walling requirement for construction of two-storey housing. Nevertheless, continuous knowledge in this area justified the need for more research to be focused on ascertaining the required optimum mix design of local available material suitable for the production of compressed earth blocks in order to improve the strength and durability of the final product.

Thus, in this research study, the performance characteristic of compressed earth blocks (CEB) stabilized with rice husk ash (RHA) and mining tailing waste (MTW) was evaluated. The compressive strength, density and rate of water absorption were investigated, preliminary investigation of the geotechnical and compaction characteristic of the soil (laterite) used in the production of the blocks was also examined. In addition, for the renewed interest in building with earth, this research is a way by which the methods and materials of stabilizing soil will continue to be assessed and improved upon in order that stabilized blocks of adequate quality can be continuously produced with local material.

II. MATERIALS

The lateritic soil was obtained from a site located in Jos south LGA, Plateau state, Nigeria. The representative soil sample was first tested to examine the basic geotechnical properties as suitability of soil for production of compressed stabilized earth blocks is concerned. Hence, various tests; Atterberg limit (liquid & plastic limits), gradation using sieve analysis and the compaction characteristic to determine the optimum moisture content (OMC) and maximum dry density (MDD) were conducted on the soil sample in accordance with [2].

The rice husk was obtained from a local rice milling industry also in Jos south LGA, Plateau state, Nigeria. It was converted into ash by a process performed in open air burning in order to depict the method of local production. The ash was then sieved through BS sieve 425µm size after allowing it to cool.

The mining tailing waste (MTW) is a waste product obtained from the site of local mining of Tin and other minerals in Jos south LGA, Plateau state. It was first dried to eliminate moisture, grounded and sieved through BS sieve 212µm size.

III. EXPERIMENTAL METHOD

The lateritic soil was spread, allowed to dry and then sieved by passing the bulk material through a wire mesh of 10 mm aperture to remove particles that are too coarse. The quantity of the materials required; RHA, MTW, and water were calculated and measured by dry weights of the soil. The blocks were prepared with the RHA and MTW additions at mix ratio of 1:1 at 0%, 4%, 6%, 8% and 10% respectively.

Dry mixing of the materials was first carried out before the gradual addition of water to ensure homogeneity. The wet mix was also turned over several times with shovel. The procedure was performed three times to ensure homogeneity. The mixture of sample was then served into an in-built mould of dimensions 220mm × 190mm × 110mm of a motorized hydraulic press interlocking earth block compression machine. The mixture fed into the mould was compacted by pressing the lever arm of the machine. After pressure, the block was ejected by lifting the lever arm which opened the lid and released the block which was carefully removed and kept in a shade. The process was repeated until all the blocks were produced.

Curing was performed on the produced block specimens by covering the stacked blocks with a polyethylene under a shade for 7 days. Afterwards the polyethylene was removed and the blocks allowed to air dried slowly until testing. A total of 54 blocks were produced and cured for 7, 14 and 28 days respectively.

The density, compressive strength and water absorption tests were carried out on the samples of the lateritic earth blocks stabilized with RHA/MTW after curing, in order to ascertain their engineering properties with respect to strength and durability performance. The test was carried out in accordance with [2].

The compressive strength is the failure load divided by the cross-sectional area resisting the load. The stabilized earth block samples were weighed and placed axially on a compression testing machine by switching between two flat steel plates in the machine, the load was applied gradually as the compressive strength machine was operated. The load at failure was recorded and the process repeated for the entire block samples.

The water absorption is dependent on the soil and stabilizer(s) content of the block. It is typically related to the strength and durability of the block as excessive water absorption causes a decrease in strength of the block. The block samples were first weighed and recorded. The blocks were then immersed completely in water for 24 hours, removed and reweighed. This method of total immersion depicts the worst condition of exposure to water.

The density of the compressed stabilized earth block is its mass per unit volume including its water content. The density of the stabilized laterite blocks is a measure of the effectiveness of the compression sample.

IV. RESULTS AND DISCUSSION

Table 1 shows the results of the geotechnical properties and compaction characteristic of the soil. Soil plasticity is a property that defines the extent to which a soil can be distorted without any significant elastic reaction, typically cracking or crumbling, occurring. The plasticity of a soil as well as its limits between different states of consistency is defined by measuring the Atterberg (liquid and plastic limit).

The cone penetrometer method was used to determine the Atterberg limit of the soil. The result of the liquid limit (LL), plastic limit (PL) and plasticity index (PI) of the soil was found to be 36.53%, 10.34% and 26.19% respectively as shown in Table 1.

Figure 1 shows the plot of the sieve analysis gradation test performed in accordance with B.S. 1377: (1990) for soils. From the result it can be observed that percentage passing sieve size 0.075mm (No. 200) is less than 35%. Thus, the soil is classified as A – 2 – 6 (silty or clayey, gravel and sand) according to the [1] classification. Figure 2 shows the plot of the compaction characteristic of the lateritic soil. The maximum dry density of 1.65kg/m^3 and optimum moisture content of 20.5% of the soil was obtained from the laboratory mechanical compaction test. The result of maximum dry density MDD and optimum moisture content OMC are presented in Table 1.

Table 1: Geotechnical properties of lateritic soil

S/no.	Properties	Results
1.	**Bulk density (kg/m^3)**	1670
2.	**Particle density**	2.55
3.	**Moisture content (%)**	1.71
4.	**Liquid limit (%)**	36.53
5.	**Plastic limit (%)**	10.34
6.	**Plasticity index (%)**	26.19
7.	**Maximum dry density (MDD) (kg/m^3)**	20.50
8.	**Optimum moisture content (%)**	1.65

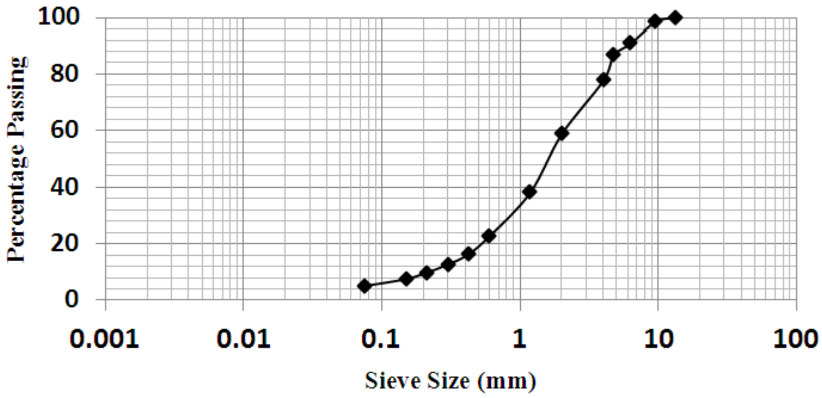

Figure 1: Particle size distribution of lateritic soil

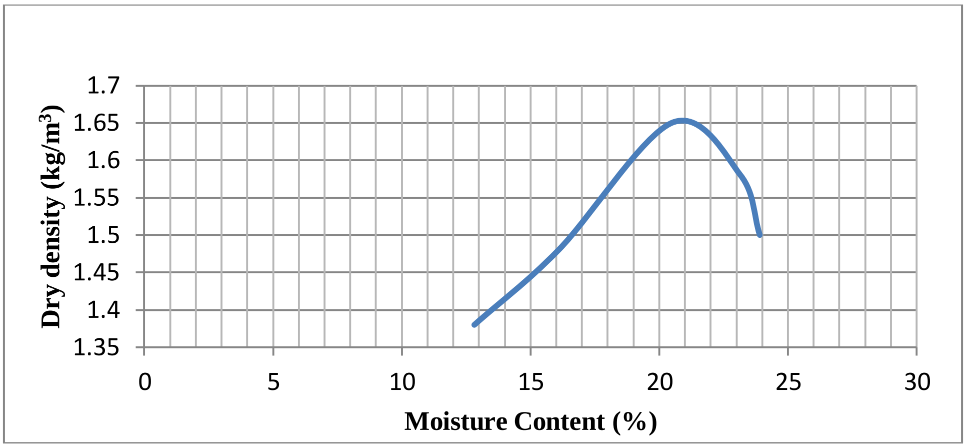

Figure 2: Compaction characteristic of lateritic soil

The performance characteristics of CSEBs as walling materials were determined with respect to their compressive strength, water absorption and density. The results are shown in Tables 2, 3 and 4 respectively. The compressive strength is the most universally accepted value for determining the quality of bricks [8]. Nevertheless, it is related with the soil type and the content of stabilizer. Compressive strength tests were conducted on the blocks at different curing ages to indicate the rate of strength gain and the strength at a point in time.

Table 2: Compressive strength of RHA-MTW Compressed Stabilized Earth Blocks

Curing period (days)	Compressive strength N/mm^2					
	0%	2%	4%	6%	8%	10%
14	0.44	1.24	1.32	1.42	1.56	1.71
21	0.57	1.33	1.35	1.44	1.75	1.99
28	0.40	1.63	1.65	1.66	2.00	2.20

Table 3: Water Absorption Capacity of RHA-MTW Compressed Stabilized Earth Blocks

Curing period (days)	Water Absorption Capacity (%)					
	0%	2%	4%	6%	8%	10%
14	0	11.08	11.76	12.18	14.19	15.10
21	0	9.65	10.34	10.34	12.78	14.19
28	0	8.81	9.83	10.59	11.59	12.12

Table 4: Density of RHA-MTW Compressed Stabilized Earth Blocks

Curing period (days)	Density Kg/m^3					
	0%	2%	4%	6%	8%	10%
14	1794.67	1886.09	1903.88	1802.26	1936.89	1950.36
21	1806.21	1828.52	1888.13	1858.19	1967.72	2055.69
28	1856.75	1858.35	1795.80	1828.41	1846.81	1825.10

Figure 3 shows plot of the relationship between compressive strength and percentages of stabilizers content at different curing period. The result shows compressive strength increase with increase stabilizers content and curing period respectively. The highest compressive strength of 2.26N/mm^2 was obtained at 10% RHA/MTW stabilization at 28 days curing period, and the minimum compressive strength of 0.4N/mm^2 was obtained at 0% (control), at 28 days curing period. Although, the minimum compressive strength of earth blocks specified by codes is 2.5N/mm^2, the maximum compressive strength of 2.26N/mm^2 obtained in this study can be acceptable within experimental error.

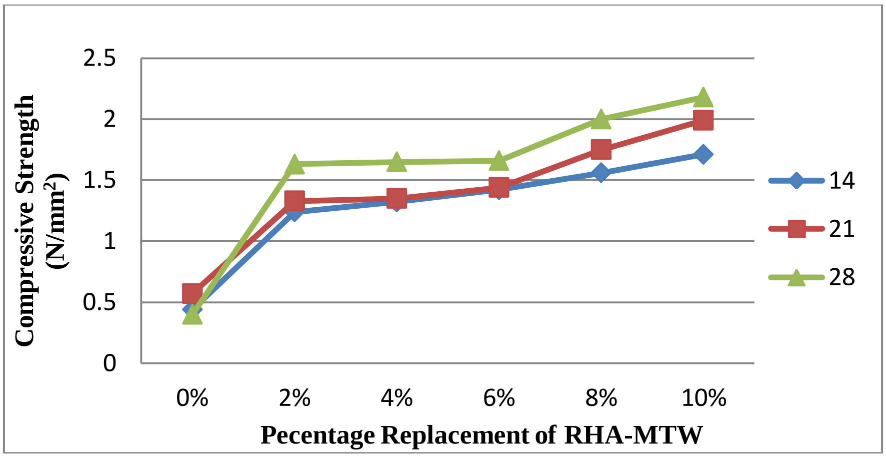

Figure 3: Compressive Strength of RHA/MTW Stabilized Compressed Earth Blocks.

The rate of water absorption is given in terms of percentage absorption of water gained after immersion in cold water for 24 hrs. Test procedure followed is in accordance with BS EN 12390 Part 7(2000). Maximum water absorption for masonry units should not be more than 12%, according to the standard. Figure 4 shows plot of the rate of water absorption of the RHA/MTW compressed stabilized earth blocks. The results show an increase in rate the of water absorption with increasing percentage of RHA/MTW contents and decreases with curing period. The minimum rate of water absorption of 8.81% was obtained at 2% stabilizer content and 28 days curing period. The highest rates of water absorption obtained were 12.12%, 14.19% and 15.10% at 10% RHA/MTW content, 14, 21 and 28 days curing respectively. The control (0%) specimens of the blocks all dissolved when immersed in water for 24 hours.

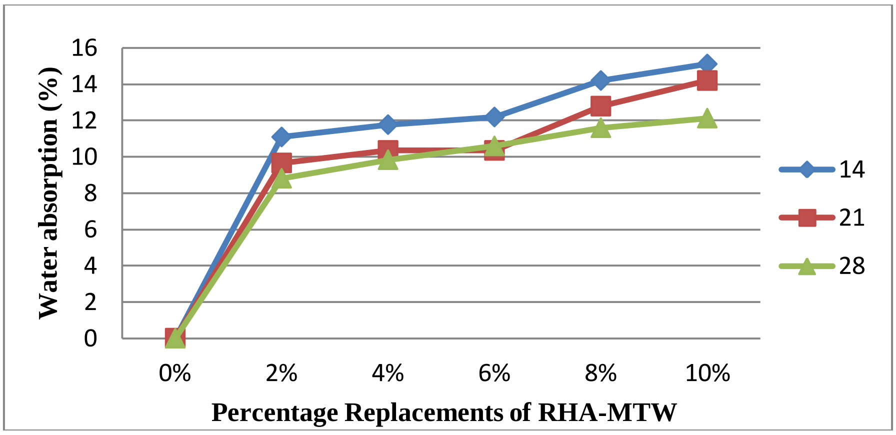

Figure 4: Water Absorption of RHA/MTW Compressed Earth Block Stabilized

Figure 5 shows the plot of the densities of the CSEB produced with RHA/MTW contents. According to [11], the density of CSEBs is typically ranging from of 1500 – 2000kg/m^3.The highest density of 2055.69 kg/m^3 was obtained at 10% stabilizers content at 21days curing. There was an obvious reduction in density with the value 1825.10 kg/m^3 at 10 % content of 28days curing age compared to 21 days at the same stabilizer content. The lowest density obtained was 1806.21 kg/m^3 at 0%. The results also indicate a decrease in density of blocks with increase in percentage addition of stabilizer and curing period. However, all results fell within the typical range of densities.

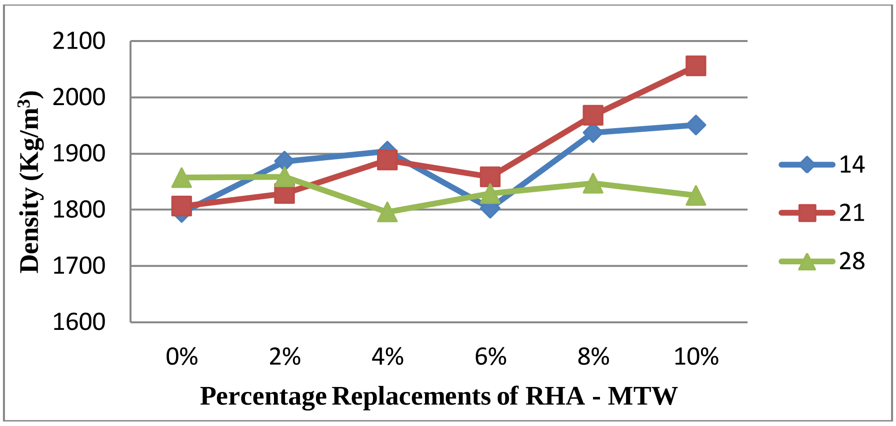

Figure 5: Density of RHA/ MTW Compressed Earth Block Stabilized

V. CONCLUSION AND RECOMMENDATION

i. The soil is classified as $A-2-6$ (gravel and sand, silty or clayey) according to the AASHTO classification based on the laboratory results of the test carried out on the soil sample.
ii. The plasticity index of 26.19% obtained falls within the range of values stated in BS 1377 (1990).
iii. The compressive strengths results of stabilized earth blocks 1.71 N/mm^2, 1.99 N/mm^2 and 2.26 N/mm^2 at 10% stabilizers content, 14, 21 and 28days curing, were higher compared to the control blocks 0.44 N/mm^2, 0.57 N/mm^2 and 0.40 N/mm^2 respectively.
iv. The strength characteristics of the compressed earth block stabilized with RHA-MTW shows increased in strength with increase in stabilizers content and curing age.
v. The maximum values of the compressive strengths obtained for different content of RHA-MTW were obtained at 10% replacements.
vi. The densities of the RHA-MTW stabilized earth blocks met the standard requirement for compress earth blocks.
vii. Increased rate of water absorption was observed with increase in stabilizers content.
viii. Incorporating RHA/MTW contents above 10% as stabilizer may be considered in the production of compressed earth blocks as the case may be.
ix. In the case where the blocks stabilized with RHA/MTW may be utilized, it should not be used in environment susceptible to high water areas, due to the increase in rate of water absorption with increase in stabilizer.
x. The strength of the RHA-MTW CSEB can be increased by adding natural fibres which can improve the ductility in tension.

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