Vol-05 Issue 12, December - 2021 ISSN: 2456-9348
Impact Factor: 5.004

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International Journal of Engineering Technology Research & Management

STRENGTH PROPERTIES OF MOUND SOIL – RICE HUSK ASH CONCRETE

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Abstract:
As a result of the increasing price implications and health risks associated with the production and usage of cement in concrete, it has become increasingly imperative to produce concrete from locally available and eco-friendly materials that can either partially or fully replace cement in concrete, and still be structurally viable for construction. This paper therefore focuses on determining optimized replacement percentages of a three-component binder concrete – Rice Husk Ash (RHA), Mound Soil (MS) and Ordinary Portland Cement (OPC) – for achieving the most viable and structurally compliant compressive strengths values. The outcome of the study showed that for 28 days curing, at 50% cement and 25% each of RHA and MS soil, an average compressive strength of 15.01 N/mm^2 was achieved; at 60% cement and 20% each of RHA and MS, 21.05 N/mm^2 average compressive strength was achieved; at 70% cement content and replacement of 15% each of RHA and MS, 24.55 N/mm^2 average compressive was recorded; at 80% cement and 10% each of RHA and MS, an average compressive strength of 32.25 N/mm^2 was reached; and finally, for 90% cement content and 5% each of RHA and MS, an average compressive strength of 34.99 N/mm^2 was attained.

Keywords:
Compressive strength, concrete, Optimized mixes, three-variant binder,

1. INTRODUCTION

A growing concern in construction among material engineers in developing countries is the development and use of alternative, indigenous construction materials [1]. This challenge has resulted in a higher consumption of natural resources for cement manufacture, leading to an investigation into the pozzolanic properties of cementitious materials in the industrial and agricultural sectors [2]. An estimated 10 billion cubic meters of concrete is produced every year, with Cement being a very important constituent and produced to an approximate tune of 4180 million tons globally as at globally [3]. Rice husk is an agricultural residue from the rice milling process. The estimated annual production of rice worldwide for year 2007, according to the United Nations FAO (2008), was kept at 649.7million tons, with the husk constituting approximately 20%. [4]. Rice Husk Ash (RHA) is an agricultural waste obtained from rice husks which are the outer coatings of rice paddy burned in open air in rice mills. It is estimated that global rice production has reached 700 million tons with countries like China and India being notable farmers of the grain.

According to [5], the chemical composition of rice husk is 50% of cellulose, 25 – 30% of lignin, 15 – 20% of silica, 30 – 50% organic carbon, and 10 – 15% of water (or moisture) and that by percentage of weight, the rice husk contributes 20% to the total weight of rice with a low bulk density of 90 – 150kg/m^3. The disposal of RHA is a problem to waste managers but if RHA, which is a proven pozzolan, and a more natural, local and affordable material is used in concrete to partially replace the more expensive cement, then the problem of its disposal will be significantly solved [6].

The influence of various RHA sources on the properties of road subgrade materials has been investigated by [7]. It has been reported that RHA obtained from various states of Nigeria can be used for sub-grade stabilization because of their pozzolanic properties.
Replacing OPC with up to 30% RHA reduces chloride penetration, decreases permeability, and improves strength and corrosion resistance properties at an optimal replacement proportion of 25% [8]. According to [9], compressive strength is converted to their corresponding tensile strength by multiplying them with a conversion factor 0.8, and available literature provide that the tensile strength of concrete is about 10 – 12% of the compressive strength, or computed from empirical formulas.

ISSN: 2456-9348
Impact Factor: 5.004

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Mound-building termites are largely considered to be a threat, especially to the agroindustry. They are known to be destructive to crops, trees, and general manmade structures. However, research has further revealed that not all species of termites pose negative impacts on humans' socio-economic activities [10]. A termite mound is a mixture of clay components and organic carbon cemented by secretions, excreta, or saliva deposited by the termites. The mounds could be conical, lenticular cathedral or mushroom-like, depending on the species, temperature, clay availability, level of termite presence in an area and general site conditions [11]. Mound soils result from termite activities over time and serve as shelter for the termites and are predominantly clay. This clay is exceptionally improved by the secretions from the termites in building the mound [12]. These secretions improve on the plasticity of the mound soil, making it a better moulding material than the surrounding soil. Mound clay has been reported to perform better at dam construction than ordinary clay without the termite secretions [13]. Following the need for affordable materials for construction of functional, adequate and low-cost housing for the teeming populace, the search is now for local materials to serve as alternatives for the more expensive conventional building materials [14]. Hence, with a view to decreasing the cost of building construction, effective steps are now being taken to partially replace cement with industrial waste [15], agricultural waste [16] and plastic waste materials [17].

The assessment of the performance of Termite-Mound Powder (TMP) as partial replacement for cement in the production of lateritic blocks was studied by [18].

(a)

(b)

Fig. 1: (a) Termite mound (b) some termite mound clusters in Ikot Eneobong, Calabar

The concern of the researchers was clearly on the over-dependence on cement, increase in construction costs, health concerns with the toxic emissions of cement production and usage. The results of the research showed that the compressive strength of the bricks increased with curing, reaching an optimum value at 10%, but decreased with increase in percentage TMP.

The spatial variation of the chemical properties of Rice Husk Ash has been investigated using X-ray fluorescence (XRF) technology [19]. The results of the study showed that Rice Husk Ash (RHA) varies in pozzolanic properties depending on the location they are found, and that RHA can be used as a partial replacement to OPC due to its chemical composition.

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This present study attempts to utilize termite mound powder and rice husk ash as partial replacement to Portland cement. Figure 1 shows the abundance of termite mounds in a small area of Ikot Eneobong in Calabar, Nigeria.

2. MATERIALS AND METHODS

The mound soil (MS) was obtained as a disturbed sample from a termite mound in an open field in Ikot Eneobong located in Calabar Municipality, Cross River State Nigeria, shown in Figure 1.

A digger was used to claw open the hard termite mound and the mound clods were collected in an airtight nylon bag for the avoidance of moisture loss. In all, 15kg of the sample was collected and taken to the laboratory. 31g of the collected sample was weighed, oven-dried and reweighed to determine its natural moisture content and the rest of it was crushed and spread out on a pan in a damp-free area to air-dry under room temperature. To obtain the finest particle sizes, the crushed, air-dried mound soil was passed through the smallest aperture-sized sieve and the residue collected in the pan was kept ready for the concrete still under damp-free condition.

The RHA sample was also collected as a disturbed sample from a heap in the Obubra rice mill in Cross River State of Nigeria as shown in Figure 2.

Fig. 2: Rice mill from where RHA was obtained

It was transported under airtight condition to the laboratory where 29g of it was oven-dried to determine its natural moisture content. The rest of it, 10.5kg, was sieved to remove all unwanted materials contained in the sample before being used for the research work.

OPC was obtained from the Lafarge cement producing company in Akamkpa Local Government Area of Cross River State, Nigeria, and the fine and coarse aggregates were respectively obtained from the dredged Calabar river and Saturn Quarry, all in Cross River State, Nigeria. 15-22mm average coarse aggregate size was adopted for this research work, and fine aggregate classified as fine sand with particle size range of 125-250µm.

The procedure for producing this three-binder concrete followed the usual concrete production procedure except for the use of three distinct materials as binder in the same concrete mix. To achieve this three-binder concrete, OPC was replaced with both RHA and MS, simultaneously, in predetermined percentages. Adopting the provision of 1:2:4 concrete mix ratio for this study, the binder constituent of the concrete matrix was split to accommodate OPC,

RHA and MS such that 10, 20, 30, 40, and 50% of OPC was replaced by equal amounts each of RHA and MS. These percentages were measured out volumetrically using a calibrated container. The conventional concrete with 100%OPC was also produced to serve as the standard basis for comparison, giving a sum total of six (6) different batches of concrete.

A. Pozzolanic properties of the constituent binder materials

The pozzolanic characteristic of the binder materials – RHA, OPC and MS – are revealed in their chemical composition as shown in the table below. This elemental chemical composition was achieved using the X-Ray fluorescence technique, which is a non-destructive analytical technique used to determine the elemental composition of materials. It works by measuring the fluorescent (or secondary) X-ray the sample emits when excited by a primary X-ray source. This technique basically thrives

ISSN: 2456-9348
Impact Factor: 5.004

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on the basis of unique fluorescent rays (“fingerprint”) produced by the individual elements. The result of the X-ray fluorescence (XRF) process carried out for the binders is as presented in Table 1.

TABLE I: CHEMICAL COMPOSITION OF CONSTITUENT CONCRETE BINDER MATERIALS

S/N	**Sample/Location**	**Elements and % Composition**							
		ZnO	**SiO_2**	**CaO**	**Fe_2O_3**	**K_2O**	**MnO_3**	**MgO**	**Na_2O**
1	Ordinary Limestone Cement	0.18	28.5	65.2	3.4	0.4	0.2	1.55	0.38
2	RHA-Obubra-CRS	0.55	76.7	0.51	0.43	0.50	0.52	0.54	0.38
3	Termite Mound Soil	-	67.74	1.79	5.15	4.12	0.07	0.59	0.23

B. Laboratory methods

The tests carried out were to determine the workability of the concrete, determine water absorption percentages, and determine compressive strength. Workability was assessed by conducting slump tests on fresh mixes of the conventional and test concrete in accordance with BS EN 12350-2:2009. The mix ration table is as shown in Table 2.

TABLE II: MIX PROPORTION TABLE

SN	**Portland cement**	**MS**	**RHA**
1	100	0	0
2	90	5	5
3	80	10	10
4	70	15	15
5	60	20	20
6	50	25	25

For determination of percentage water absorption, the fresh concrete was cast into $150m^3$ moulds, demoulded and weighed after setting, and then cured in a water tank. Each batch of concrete had 15 cubes cast, 3 cubes for 5 curing ages, in order to have an average value. The curing ages were 3, 7, 14, 21 and 28 days. Water absorption tests assess the capillary action of concrete and is basically the difference in dry and wet weights of the concrete cubes before and immediately after curing. It therefore serves as a durability check on concrete to predict the rate of possible ingress of corrosive fluids into concrete.

The compressive strength of a material is basically its ability to carry the loads on its surface without any crack or deflection. This procedure was carried out on the hardened concrete cubes of 150mm x 150mm x 150mm dimensions in accordance with the provisions of BS EN 12390-3:2019. The procedure was conducted such that the moulds were first cleaned and oiled internally and then the freshly mixed concrete was placed in the moulds in approximately 5cm thick layers. Each layer of concrete was compacted with 35 strokes using a tamping rod of 16mm diameter, 60cm in length and bullet-pointed at lower end and top surface of concrete was always smoothened with a trowel before being left to harden. The cast concrete cubes were left to harden for 24 hours after which they were cured and tested for 3, 7, 14, 21 and 28 days using a Universal Test Machine (UTM), from which loading was generated across the entire surface area of two opposite faces of the test sample. The loading was in such a manner as to flatten the sample, tending to shorten the sample in the direction of the applied load, while expanding it in the direction perpendicular to the load. Loading was applied on each sample gradually at the rate of 140 kg/cm^2 per minute until it failed. Compressive strength for each cube sample was then computed as the load at failure divided by the area of the cube sample, expressed mathematically as:

$$\sigma = \frac{F}{A} \tag{1}$$

where *F* is the applied load in Newton, *N* and *A* the cross-sectional area in mm^2.

3. RESULTS AND DISCUSSIONS

A. Workability and Water absorption

Figure 3 shows workability of MS-RHA concrete. With the W/C ratio kept relatively constant, the results of the slump tests show a massive difference in slump height between the control and the optimum percentage replacement. From the results obtained it can be seen that the control sample has a slump height of 105mm while the three-binder concrete sample has a value of 50mm at 20% OPC replacement. This can be compared with works of [16] and [17] who carried out studies on the use of fly ash and POFA as pozzolans in concrete.

ISSN: 2456-9348
Impact Factor: 5.004

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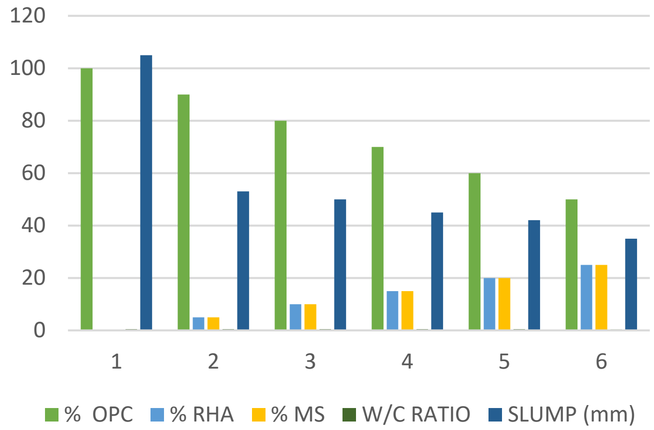

Fig. 3: Graph showing workability of RHA-MS concrete

The result of durability in terms of water absorption is as presented in Figure 4. The pattern of the water absorption test results was such that it was incremental after 3 days of curing, attaining a peak value and then falling before the 28th day of curing. Again, with increase in percentage replacement of OPC with the pozzolanic materials, the peak values of percentage average water absorption steadily dropped, tending back to what obtained with 100% OPC and no pozzolans

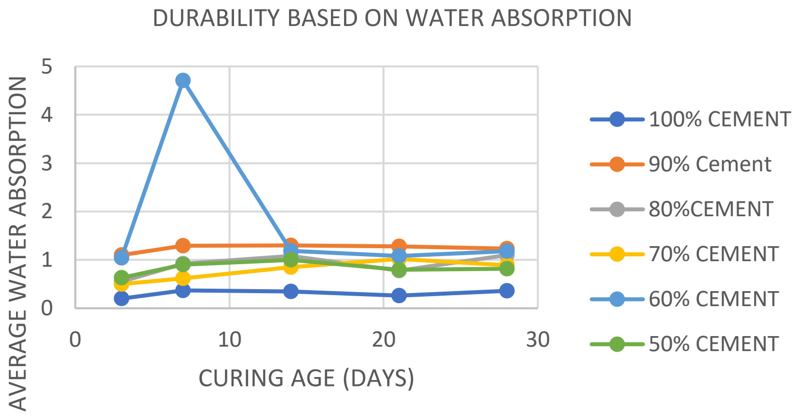

Fig. 4: Variation of water absorption with curing age for RHA-MS Concrete

B. Compressive Strength

The results of the compressive strength which was done using 3 cubes of 150mm x 150mm x 150mm for each curing cycle showed that at optimal replacement a strength value of 32.25N/mm^2 was achieved which is classified under structural concrete. This is compared to the control with a strength value of 42.64N/mm^2. Other replacement percentages show favourable results for the concrete quality that can be used for other purposes. Generally, the increment in strength values is dependent on the percentages of the pozzolans in the concrete and water-cement ratio. These results generally conform with results of previous works in similar areas of study, therefore RHA-MS concrete can be used for construction purposes. Figure 5 shows the relationship between compressive strength and age.

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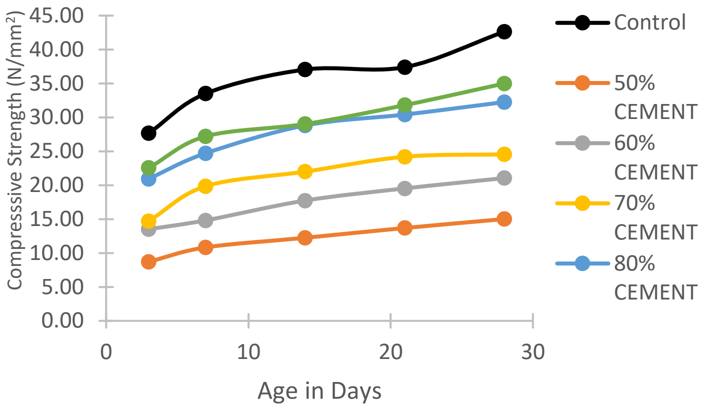

Fig. 5: Variation of Compressive strength with % OPC replaced with RHA and MS

TABLE III: SUMMARY OF OPTIMUM RESULTS OF THIS RESEARCH

Replacement fraction (%)	Percentage difference from OPC concrete: Compressive Strength (N/mm^2)	Maximum Dry Density (g/cm^3)	Water Absorption (%)
100		2.391	0.37
90	42.64	2.284	1.30
80	34.99	2.296	1.10
70	32.25	2.276	1.02
60	24.55	2.238	4.71
50	21.05	2.211	
	15.01		1.00

4. CONCLUSION AND RECOMMENDATION

The research shows that RHA and MS are pozzolans and can be used as partial replacements to OPC at an optimum replacement of 20% (10% RHA, 10%MS and 80%OPC) for structural concrete while other percentages can be used for mass concrete as can be seen from the results presented in section 3 of this work. The implication of the foregoing is that a cost saving of 20% can be achieved for OPC in concrete works.

Furthermore, it has been established from this work that structural concrete can be achieved from a multivariant binder using more natural occurring and eco-friendly admixtures while maintaining the same strength and ensuring environmental sustainability. Durability of RHA-MS concrete was investigated in terms of water absorption and the result shows that this multivariant binder concrete is more durable, therefore recommended for use in the building industry as contained in this research work.

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