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Evaluation of Rice Husk Ash and Bone Ash Mixed as Partial Replacement of Cement in Concrete

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Abstract- **The mixture of Rice Husk Ash (RHA) and Bone Ash (BA) were used as partial replacement for cement in concrete production. The percentage composition of (SiO_2 + Al_2O_3 + Fe_2O_3) of Rice Husk Ash and Bone Ash present is greater than 70% which makes the mixture suitable to be used as a pozzolana. In this paper, the replacement of cement by RHA and BA varied from 2% to 10% in a mix ratio of 1:2:4. Cubes cast comprise the control and specimen samples with various tests considered, and the results showed that workability were consistent within the described values for lightweight concrete. The maximum compressive strength was obtained to be 17.45N/mm^2 at 28 days for control (0%) while maximum value was obtained to be 13.78 N/mm^2 with 2% replacement of cement with rice husk ash and bone ash at 28 days curing with the mixed ash content. The value was found to be within the range acceptable for concrete; particularly light weight (lean mix) concrete. Substitution of the mixture should not be more than 10% for the best result in the concrete production for structures.**

Keyword: ***Bone Ash, Compressive Strength, Concrete, Concrete Cubes, Rice Husk Ash*.**

1. Introduction

The high cost of cement, used as binder, in the production of mortar, sandcrete blocks, sandcrete bricks and concrete has led to a search for alternative binding materials in the construction Industry. Apart from the cost, high energy demand and emission of CO_2 which is responsible for global warming, the depletion of lime stone deposits is also one of disadvantages associated with cement production. According to Badur and Chaudhary (2008), about 7% CO_2 is released into the atmosphere in the course of cement production contributed to the negative impact on ecology and life of human being which arises from global warming. Research on alternative materials locally available to replace cement, has been carried out on the partial replacement of cement with different materials. In advanced countries, partial replacement of cement with pozzolans is well documented and recommended. Pozzolans according to Arthanari et al (1981) are defined as siliceous material, which by itself possesses no cementitious properties but in processed form and finely divided form, react in the presence of water with lime, to form compounds of low solubility having cementitious properties. They are grouped into natural and artificial sources; clay and shale calcined to become active, volcanic tuff and pumicite are naturally occurring pozzolana, whereas good blast furnace slag and fly ash are the artificial varieties. The use of fly ash, a residue obtained from the combustion of pulverized coal in partial replacement of cement is recommended within the range of 10-30% by weight of cement.

A mixture of Portland cement and pozzolanic material is referred to as pozzolanic cements, such cement has the following advantages: good resistance to chemical attack, low evolution of heat of hydration, economy, improvement of workability, reduction of bleeding and greater impermeability. Its disadvantages being, slower rate of strength development and increased shrinkage. Various agro based materials and wastes has been used in some third world countries to replace cement in a partial manner due to their availability locally. Among these are Acha husk ash (AHA), Bambara groundnut shell ash (BGSA), Bone powder ash (BPA), Groundnut husk ash (GHA), Rice husk ash (RHA) and Wood Ash (WA). Others are Ashes from the burning of dried banana leaves, bagass, bamboo leaves, some timber species, sawdust and periwinkle shell ash (PSA). Advantages to be derived from the use of agro waste in the partial replacement of cement as presented by are low capital cost per ton production compared to cement, promotion of waste management at little cost, reduced pollution by these wastes and increased economy base of farmers when such waste are sold, thereby encouraging more production, conservation of limestone deposits and a reduction in CO_2 emission (Manasseh, 2010).

Rice Husk Ash is obtained from the combustion of rice husk, a by-product from rice milling operation which constitutes about 20-24% of the raw rice produced. The husk was burnt at a temperature of 438°C, before being grinded into fine particles. Using mortar and pestle (in the absence of ball mill) and made to pass through 212 micron BS sieve. In Nigeria, rice husk is produced in most northern and central states where rice is grown, some of the states are Osun, Niger, Kaduna, Kano, Benue, Nasarawa, Kogi, Kwara etc.

Bone Ash was obtained from the incineration in a furnace at a temperature of more than 900°C of cattle bones. The bones were cleaned and sun-dried to reduce its oil content before incineration. The burnt bone was allowed to cool before it was ground in a hammer mill to fine powder. Cattle bones are readily available in commercial quantities in various abattoirs that litter the cities and villages in Nigeria (Manasseh, 2010).

2. Materials and Methods

2.1 *Materials collection*

The materials used for this research work i.e. Rice husk, Cattle bone, Cement, Fine Aggregate, Coarse Aggregate and water were obtained from Osogbo and Ede in Osun State of Nigeria.

2.2 Materials Used for the Study

2.2.1 Rice Husk Ash (RHA)

The Rice husk used for the study was obtained from Osogbo, Osun State and burned at a temperature of 438°C, before being grinded into fine particles, using mortar and pestle (in the absence of ball mill) and made to pass through 212 micron BS sieve (ASTM C136-06, 2006).

2.2.2 Bone Ash (BA)

The cattle bone used for the study was obtained from an abattoir at Ede, Osun State. The bones were cleaned and sun-dried to reduce its oil content before burning at a temperature of 900°C. The burnt bones were allowed to cool before it was grinded with mortar and pestle to fine powder.

2.2.3 Cement

The cement used was Elephant Portland cement which is available in Ede, Osun State and has properties conforming to the BS (1978) specification for Ordinary Portland cement.

2.2.4 Fine Aggregate

Sand was collected from a locally available river bed at Ede, Osun State and the aggregate was cleaned and freed from any matter that might affect the quality of the concrete.

2.2.5 Coarse Aggregate

The coarse aggregate (i.e. granite) used was obtained from natural depositor in Ede, and a maximum size of 19mm was used.

2.2.6 Water

Water used was collected from the well in the department, and it conformed to the water requirement for mixing of concrete which is natural water that is drinkable and has no pronounced taste or odour.

2.3 Experimentation

The experiments carried out using the basic apparatus and methods are: Sieve analysis, chemical composition determination, Slump test (workability test) and Compressive Strength test.

2.3.1 Test Procedures

(a) Sample preparation
   i. Collection and drying of samples
   ii. Burning, grinding and sieving of samples appropriately

(b) Mix preparation
   i. Batching of Concrete (by weight) was employed with mix ratio 1:2:4
   ii. Samples mixing with Portland cement (with the varying percentage of RHA and BA replacement)
   iii. De-moulding of concrete cubes after 24 hours and immersed in water for curing

(c) Testing of samples
   i. Sieve Analysis
   ii. Chemical composition test on ashes (RHA and BA)
   iii. Slump test
   iv. Compressive Strength test

The tests carried out were repeated after the control test represented by 0% RHA and BA (100% cement) with varying percentage of RHA and BA in equal quantities from 2% to 10%.

3. Results

Various qualities and quantities of materials required such as, mass of cement, fine aggregate, granite (coarse aggregate), rice husk ash and bone ash and mass of water required were calculated from the data obtained from the experiments carried out as tabulated in Tables and also represented in Figures.

Table 1: Sieve Analysis Test for Fine Aggregates

Sieve No (mm)	**Weight of empty sieve (g)**	**Weight of Sieve + sand (g)**	**Weight of sand Retained (g)**	**% retained**	**Cumulative % retained**	**% Passing**
2.00	555.60	599.79	44.19	8.84	8.84	91.16
1.00	371.40	489.79	118.39	23.68	32.52	67.48
0.850	380.40	406.69	26.29	5.26	37.78	62.22
0.600	325.60	384.49	58.89	11.78	49.56	50.44
0.425	339.70	397.19	57.49	11.49	61.05	38.95
0.300	321.60	384.69	63.09	12.62	73.67	26.33
0.212	417.20	468.79	51.59	10.32	83.99	16.01
0.150	358.40	370.09	11.69	2.34	86.33	13.67
0.075	266.90	323.79	56.89	11.38	97.71	2.29
Receiver	274.30	285.79	11.49	2.29	100	0.00
Total	3611.1	4111.1	500	100		

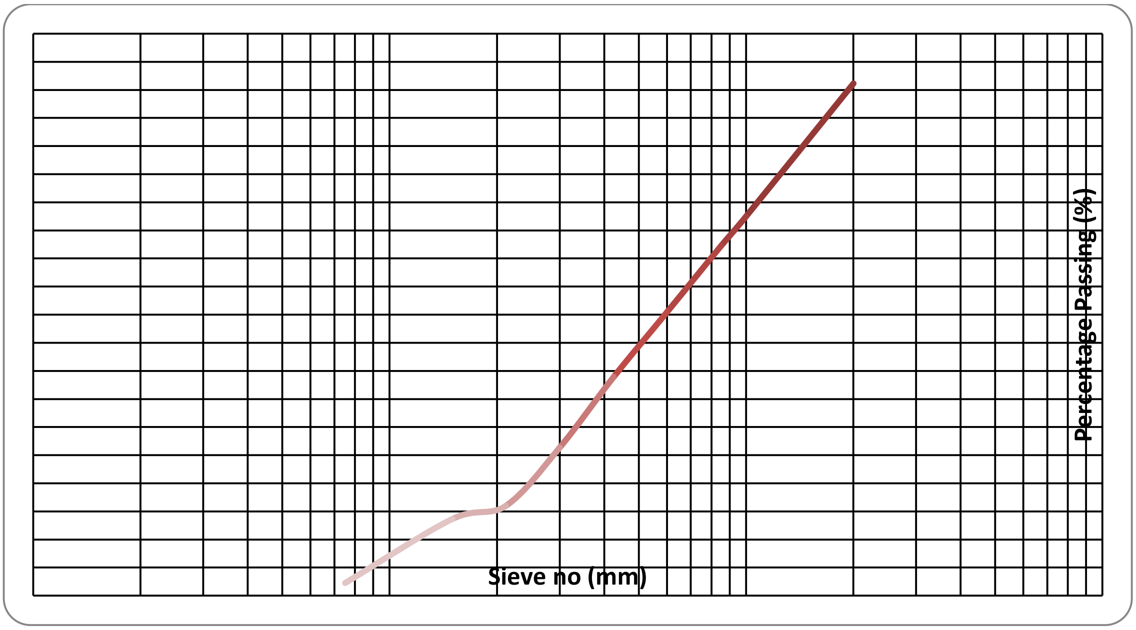

Figure 1**:** Sieve Analysis

Table 2: Table of the Proportion of the Fine (Silt), Sand and Gravel

Sample	**Fine (Silt) (%)**	**Sand (%)**	**Gravel (%)**	**Total (%)**
1	5.00	85.00	10.00	100

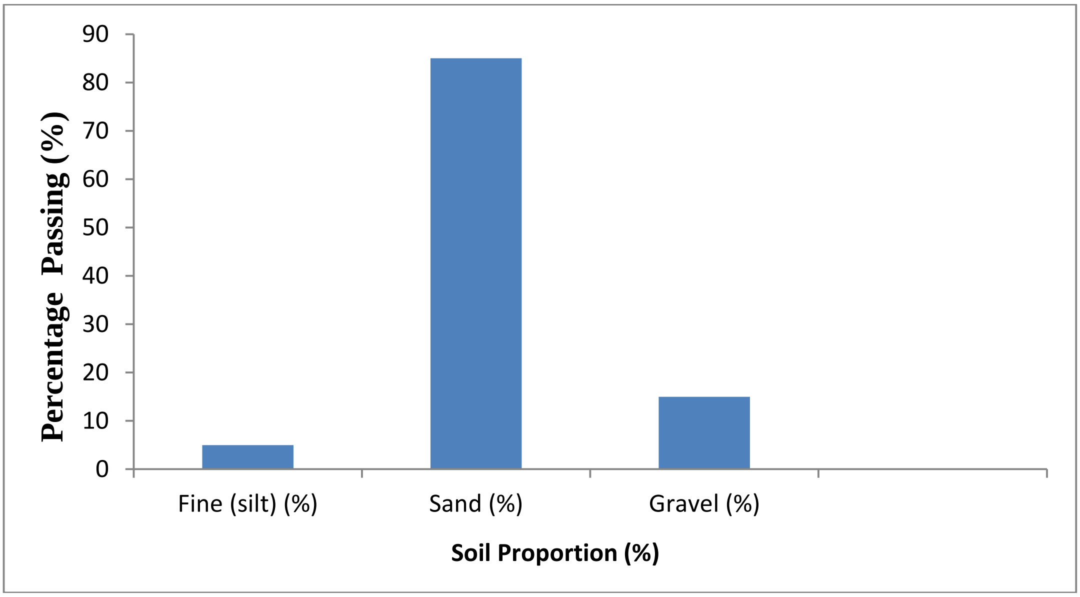

Figure 2**:** Soil Sample Composition

Table 3: Slump Test Result

Sample identification with mix ratio 1:2:4	Height of Cone (mm)	Height of concrete (mm)	Slump Value (mm)	Type of Slump	Degree of workability
0% rice husk and bone ash / 100% cement	300	272	28	TS	Medium
2% rice husk and bone ash / 98% cement	300	275	25	TS	Medium
4% rice husk and bone ash / 96% cement	300	280	20	TS	Low
6% rice husk and bone ash / 94% cement	300	282	18	TS	Low
8% rice husk and bone ash / 92% cement	300	284	16	TS	Low
10% rice husk and bone ash / 90% cement	300	285	15	TS	Low

Note: TS = True Slump, SS = Shear Slump

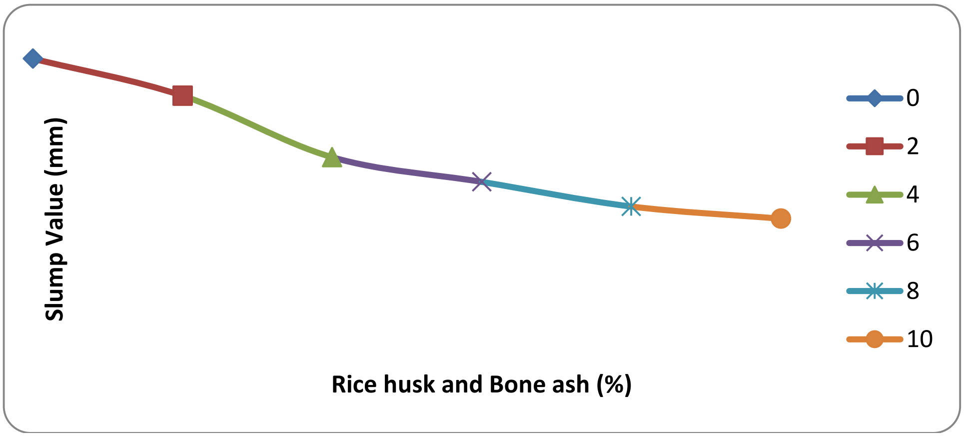

Figure 3: Slump Test

Table 4: Summary of Average Compressive Strength with varying percentage of Cement with RHA and BA at varying curing Ages.

Percentages replacement of Ashes	Average Compressive Strength (N/mm^2) / Ages of Curing (Days)			
	7	14	21	28
0% (RHA/BA)	15.08	15.16	16.44	17.45
2% (RHA/BA)	11.17	11.79	13.36	13.78
4% (RHA/BA)	9.42	10.43	11.85	12.14
6% (RHA/BA)	9.10	9.37	10.70	11.44
8% (RHA/BA)	9.07	9.27	10.34	10.37
10% (RHA/BA)	7.29	7.94	8.12	8.59

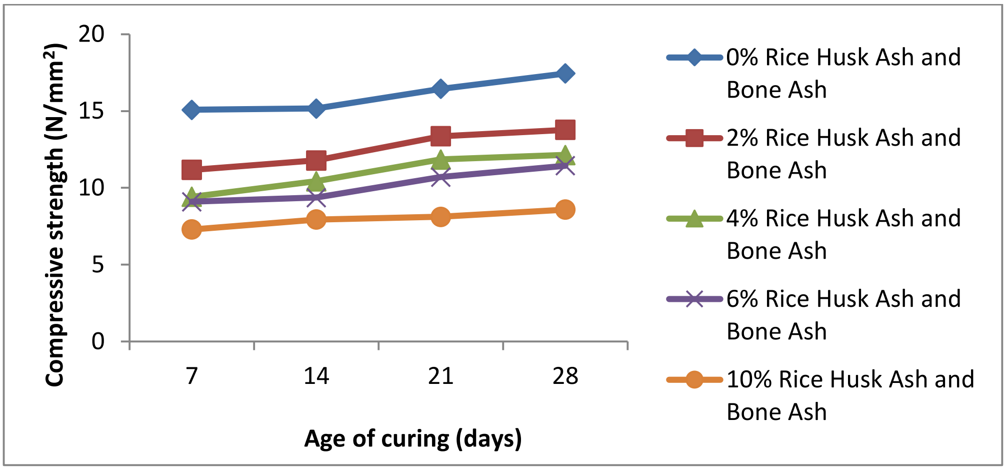

Figure 4: Compressive Strength Against Age of Curing

Table 5: Laboratory Result for Percentage Composition of Oxides in Ash Samples

Elements	RHA	BA	Unit
P_2O_5	-	4.96	wt.%
SO_3	2.64	-	wt.%
MgO	1.92	1.18	wt.%
K_2O	-	0.16	wt.%
CaO	1.67	47.77	wt.%
SiO_2	68.12	3.04	wt.%
Al_2O_3	4.82	3.22	wt.%
Fe_2O_3	0.87	0.52	wt.%
CO_3	-	-	wt.%
Na_2O	-	0.36	wt.%
CuO	-	0.18	wt.%

RHA – Rice Husk Ash, BA – Bone Ash

4. Discussion of Results

4.1 Sieve Analysis Test Result

The soil sample has less amount of fine (silt), approximate amount of gravel and contains large amount of sand. The granular composition of the soil sample is Sand (5-90) %, Gravel (90-100) % and Silt (0-5) %. These are shown in Tables 1 and 2 and Figures 1 and 2.

4.2 Workability Test Result

The slump test value decreased upon the inclusion of rice husk ash and bone ash as partial replacement of cement as shown in Table 3 and Figure 3. Thus, it can be inferred that to attain the required workability, mixes containing rice husk ash and bone ash will require higher water content than the corresponding conventional mixes (America's Cement Manufacturers, 2015).

4.3 Chemical Composition Test Result

The laboratory analysis shows that the percentage of Calcium oxide present in the ash samples makes it usable as replacement for cement in concrete production. This is presented in Table 5.

4.4 Compressive Strength Test Result

From the results shown in Table 4 and Figure 4, based on the compressive strength of the cubes, the following can be deduced: –

i. As the curing days' increase, the compressive strength of the various percentages of the cubes also increases but decreases with the increase in percentages of rice husk ash and bone ash mixed.

ii. The highest compressive strength, 17.45N/mm^2 was achieved at the control 28days of curing while a closer value of 13.78N/mm^2 was obtained at 2% replacement of cement with rice husk and bone ash content.

iii. The addition of rice husk ash and bone ash mixed as partial replacement of cement yielded an increase in strength with increase in curing ages which is in conformity with the pattern followed by control samples.

Conclusions

Based on the study carried out on the strength behaviour of rice husk and bone ash, the following conclusions are drawn:

- As the curing days and the replacement level of rice husk ash and bone ash mixed increase the compressive strength also increases.
- Using rice husk ash and bone ash as partial replacement of ordinary Portland cement in concrete, the emission of greenhouse gases can be reduced up to a meaningful extent.
- Ordinary Portland cement replacement by rice husk ash and bone ash mixed results in reduction of cost of production of concrete and can be used in the range of 2 to 10% for concrete production.
- Ordinary Portland cement replacement by rice husk ash and bone ash is environmental friendly due to utilization of waste and replacement of cement

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