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EFFECT OF PERCENTAGE REPLACEMENT OF CEMENT WITH RICE HUSK ASH ON THE COMPRESSIVE STRENGTH OF 56-DAYS AGED CONCRETE

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Abstract. This study investigates the effect of Rice Husk Ash (RHA) used in several proportions as partial replacement for cement on the concrete beyond normal curing age of 28 days. The RHA used in this study has a chemical composition of SiO_2 (63.28 %), Al_2O_3 (1.88 %) and Fe_2O_3 (0.54 %). Twelve (12) concrete cubes were cast for each 0, 5, 10, 15, 20, 25 and 30 % replacements by weight of RHA for OPC, in the proportion of 1:2:4 concrete mix and 0.5 water/cement ratio to achieve a total of eighty four (84) cubes. The cubes were cured and tested for the compressive strength at age 7, 28 and 56 days. It is observed that the use of RHA may reduce the compressive strength of concrete at an early age, but enhanced the strength from 28 days and beyond. A maximum compressive strength of 19.11 N/mm^2 at 56 days is higher than that obtained for the control (13.16 N/mm^2) at 28 days. A maximum of ten percent (10 %) RHA replacement of OPC is recommended in the production of lightweight concrete.

Keywords: Concrete, compressive strength, lightweight concrete, partial replacement of cement, RHA.

1.0 INTRODUCTION

In recent advances of concrete production, rice husk ash (RHA) is accepted as a good pozzolan when blended with cement in concrete production [1]. Conventional concrete is a composite material containing fine aggregate (sand), coarse aggregate (gravel), cement (ordinary Portland cement – OPC) and water in predefined mix proportion.

Exploration of alternative materials to partially replace aggregates and cement in concrete production is becoming increasingly important due to cost of conventional materials, environmental pollution caused by indecent ways of disposing agro-wastes such as rice husks, millet husks, groundnut shell and saw dust among others [2].

Partially replacing cement with rice husk ash (RHA) is not generally new [3]. According to [1], RHA blended concrete can decrease the total porosity of concrete and modifies the pore structure of the cement mortar and concrete, and significantly reduce the permeability which allows the influence of harmful ions leading to the deterioration of the concrete matrix.

In his study on the Effect of Rice Husk Ash (RHA) as partial replacement of cement on concrete properties, [4] and concluded that RHA concrete has potential to attain strength as conventional concrete at longer curing periods. Acording to [4], Rice Husk has the properties of lightweight aggregates and could be used as partial replacement of cement in the production of concrete.

The effect of Nigerian rice husk ash (NRHA) on engineering properties of concrete and sandcrete blocks is investigated by [3]. They observed that 10 % RHA content in the sand – cement mix is the optimum for improved structural performance while it is pointed out that RHA has the properties of lightweight aggregates and suggested that it should not be more than 10 % replacement for the best result in structural concrete production [2]. Studies by [5] have also focused on using RHA as a partial replacement of replacement of OPC in concrete production, proprieties of RHA and the effect of on compressive strength.

This paper seeks to investigate the effect of RHA percentage replacement for cement on the compressive strength of 56-days aged concrete other than the normal 28 days curing.

2.0 MATERIALS USED AND METHOD

2.1 Materials

The materials used in this study are cement, rice husk, fine and coarse aggregates and water. The cement brand is the Dangote Ordinary Portland Cement (OPC), 43 grade with typical properties and composition. Rice husk used was bought from a threshing site at Gidan Mangoro, Nigeria. River sand obtained from open market in Minna, Nigeria was used as fine aggregate in the laboratory experiments. The granite used in this work was 20 mm size. It was sourced from a local quarry in Gidan Mangoro in Nigeria. Sand passing through 5mm British Standard test Sieves Selection of aggregates conformed to [6]. Grading of fine and coarse aggregate is given in Table 1.

The water used was collected at Gidan Kwano borehole, main campus of Federal University of Technology Minna, Niger State, Nigeria. This water is potable and can be used for making concrete as per laboratory records. It conformed to requirements in [7]

2.2 Methods

The following tests were conducted: the chemical analysis of the rice husk ash, characterization of the aggregates that includes bulk density, particle size analysis and specific gravity. A sample of the Rice husk ash was analysed in the laboratory to determine the oxides composition. The results are presented in Tables 1 and 2.

2.3 Aggregate Characterization. The aggregates were tested for physical properties such as: specific gravity, particle distribution test and bulk density were conducted according to [8]. Absolute volume method was adopted in the calculation of this mix design.

2.4 Casting of samples and compressive strength test

A concrete mix of ratio 1:2:4 was adopted for the production of a total of eighty-four (84) concrete cubes of sizes 150x150x150 mm were cast at water/cement ratio of 0.5. Out of 84 cubes, twenty-eight (28) cubes were for each curing age, with four (4) cubes each at 0 %, 5 %, 10 %, 15 %, 20 %, 25 % and 30 % RHA replacements. The samples were demoulded after 24 hours of casting, and water tank to cure for 7, 28 and 56 days in accordance with specifications [9]. The cubes were tested for compressive strength using compressive testing machine [10] and the average compressive strength values were recorded.

3.0 RESULTS AND DISCUSSIONS

Results of the tests are summarized in Table 1, 2 and 3 respectively.

3.1 Aggregate Characterization

Table 1, show the summary of characteristics of aggregates. The aggregates are fine graded sand and granite. Specific gravity values in Table 1 are in agreement with specifications for fine aggregate and for coarse aggregate. Fineness Modulus of the RHA is 1.57. This is similar to the Fineness Modulus result of 1.38 suggested by [11]. RHA is finer than fine aggregate thus, the fineness modulus of 1.57 for RHA is less than Fineness Modulus of 2.3–3.1 for fine aggregate suggested by [12].

Table 1.

Characteristics of aggregates

S.No.	Test	Fine aggregate		Coarse aggregate		Rice husk ash	
		Result	**BS requirement**	**Result**	**BS requirement**	**Result**	**BS requirement**
1	Specific Gravity	2.62	2.6 – 3.0 [13]	2.67	2.4 – 2.8 [3]	1.90	2.6 – 3.0 [13]
2	Bulk Density (kg/m^3)	1530	1500 – 1700 [14]	1556.5	1300 – 1800 [14]	568.343	1500 – 1700 [14]
3	Fineness modulus (FM) from standard sieves only	2.85	2.0 - 3.3 [6]			1.57	2.3 - 3.1 [12]

3.2 Chemical Composition of the Rice Husk Ash (RHA)

Table 2 consists of silicon dioxide (SiO_2), aluminium oxide (Al_2O_3) and iron oxide (Fe_2O_3), and when summed up is 65.70 %, which is slightly below the 70 % specified by [12] for pozzolana.

Table 2.

Composition of Elemental oxides of the rice husk ash

Constituents	RHA % by weight	OPC % by weight
SiO_2	63.28	20.70
Al_2O_3	1.88	5.75
Fe_2O_3	0.54	2.5
CaO	0.37	64.0
MgO	3.59	1.00
MnO	0.13	0.05
Na_2O	3.78	0.20
K_2O	3.14	0.60
P_2O_5	0.16	0.15
Total $SiO_2 + Fe_2O_3 + Al_2O_3$	65.70	28.95

3.3 Workability

The slump and the compacting factor decreased upon the inclusion of RHA as partial replacement of OPC. It was observed that the slump for the OPC concrete cubes varies between 30 mm and 50 mm, while the OPC-RHA varies between 16 mm to 0.0 mm. The compacting factor for the RHA – OPC fresh concrete was between 0.78 and 0.85.

The results indicate that the compacting factor values reduce as the RHA content increases from 0 % to 30 %. Since the compaction factor for medium workability is about 0.9 it implies that to attain the required workability, mixes containing RHA will require higher water content than the corresponding conventional mixes. The high demand for water as the RHA content increases is due to increased amount of silica in the mixture. This is typical of pozzolana-cement concrete, as the silica-lime reaction requires more water in addition to water required during hydration of cement [15].

3.4 Effect of RHA on Compressive Strength of Concrete

The result of table 3 shows that at 7 days curing, the control (0 %) concrete developed compressive strength of 11.57 N/mm^2. With the inclusion of RHA, there was a drop in compressive strength at 5 % (9.53 N/mm^2) then a slight increase at 10 % (10.84 N/mm^2) which is still lower than the control. The 15 % replacement showed a significant reduction in strength. The reason for the reduction at 5 % replacement could be due to insufficient *silica oxide* that could react with all the lime produced from the hydration of 95 % OPC used, resulting in low production of the calcium silicate compound that enhances the compressive strength of the concrete.

Table 3.

Compressive strength (N/mm^2)

% RHA	After 7 days	After 28 days	After 56 days
0	11.57	13.16	16.71
5	9.53	14.33	17.12
10	10.84	14.67	19.11
15	5.87	8.61	11.2
20	5.63	8.55	10.81
25	4.09	7.63	10.1
30	2.02	5.82	7.76

Addition of 5 % RHA (10 % RHA +90 % OPC) showed an increment in compressive strength. However, further addition of RHA above 10 % resulted in decrease of strength. A better compressive strength is achieve at ages 28 and 56 days where the strength obtained at 5 % and 10 % RHA replacement were higher than the control values. The maximum compressive strength of 19.11 N/mm^2 at 56 days obtained with 10 % RHA replacement of OPC is higher than the control (13.16 N/mm^2) at 28 days representing a 45 % increment in strength. The compressive strength however, declines for replacements of RHA for cement made above 10 %. This suggests that the optimum RHA replacement for cement is 10 %. The presence of RHA in the concrete in the right proportion tends to increase the strength through micro filler effect.as the RHA finer particles react to block the large voids in the hydrated cement paste through pozzolanic reaction This reduces large pores and porosity resulting very low permeability. The results obtained here are in agreement with the submissions of [5].

4.0 CONCLUSIONS AND RECOMMENDATION

The following conclusions are drawn from this study:

The RHA used in this work contains about 63.28 % of silicon oxide (SiO_2) which enables it to react well with the lime from hydrated OPC to form calcium silicate compound that enhanced the compressive strength of concrete.

It is observed that when OPC is replaced by 5–10 % of RHA in concrete, a high compressive strength is achieved. A maximum of ten percent (10 %) RHA replacement of OPC should be employed in the production of lightweight concrete.

The compressive strength of the concrete decreased as the percentage RHA content in the mix increased above 10 %. It is not recommended to replace OPC in light concrete production with more than 10 % RHA.

The use of RHA may reduce the compressive strength of concrete at an early age and enhanced the strength from 28days and beyond. Curing the blended RHA-Cement in proportions (0 % – 10 %) concrete beyond 28 days but up to 56-days will significantly improve the compressive strength of the concrete. Thus, the RHA percentage replacements up to 10 % has affected the concrete positively.

While the use of local materials like RHA as pozzolanas should be encouraged in concrete production, curing the blended RHA-Cement in proportions 0 % – 10 % be done beyond 28 days, up to 56 days will significantly improve the compressive strength of the concrete as demonstrated in this study.

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