EFFECTS OF RICE HUSK ASH ON STRENGTH AND SHRINKAGE PROPERTIES OF CONCRETE

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ABSTRACT

This study investigates the effects of Rice Husk Ash (RHA) on the strength and shrinkage properties of Concrete. Rice Husk is an agro- waste which when burnt under a controlled temperature, the ash produced owing to its rich content in silica is used as a super-pozzolanic material for the partial replacement of Ordinary Portland Cement (OPC) in concrete. Concrete mix proportion of 1:1.5:3 by weight with a constant water-cement ratio of 0.5 was used. The compressive strength was found to increase from 22.37N/mm^2 at 7- day to 32.12 N/mm^2 at 28 -day (i.e. 43.6 % increment) for the control mix. The flexural strength results obtained at 28-day were 3.38, 3.44, 3.67, 3.50, 3.25, 2.96, 2.90 N/mm^2 at replacement percentages of 0, 5, 10, 15, 20, 25 and 30% respectively. Results of tests on the drying shrinkage of RHA concrete revealed that the 30% replacement level exhibited the highest shrinkage strain value of 440 microstrain compared to the control experiment with 380 microstrain at the 90-day period. This study suggests that up to 10% OPC replacement with RHA has the potential to be used for the partial replacement of cement in concrete for structural applications.

KEYWORDS: Strength, Shrinkage, Ordinary Portland cement, Rice Husk Ash and Concrete.

1. INTRODUCTION

The rising cost of housing and construction in Nigeria and other developing nations of the world is a major concern. This has been attributed amongst many factors to the rise in the cost of cement which is a major constituent of concrete used in the construction industry (Arum et al., 2013). According to the Pan African Capital Industry Report (2011) on the Nigerian Cement Industry, the increase in the cost of Portland cement was attributed to the influence of the market forces of demand and supply, unstable power supply, sheer monopoly of production and importation of cement by a few players, huge cost of transportation of cement from factory, high tax burden, high capital cost, unfavourable government policies and many others. This has posed a lot of hardship on Nigerian citizens because of poor access to affordable housing.

In view of the high and increasing cost of Portland cement, considerable efforts have been and are being made to search for suitable and effective alternative to the use of cement in the short and long term in the construction industry. Rice husks are agro-waste produced in significant large quantities in the world and are often disposed of by dumping or open heap burning, although some quantity has been used as a low- grade fuel (Marthong, 2012). This open heap burning and disposal into river is a big concern causing serious environmental problems. Due to the increasing importance of preserving our environment in this present day world, considerable efforts have been made to burn rice husk under controlled conditions and to utilize the ash produced as a building material. Rice Husk Ash (RHA) is highly rich in silica containing about 85-90% of silica content and it has been used as a super-pozzolanic material for the partial replacement of cement in concrete. (Godwin et al., 2013).

The extent to which Portland cement can be acceptably replaced by RHA for its use as a construction material has been investigated by different researchers. Al-Khalaf and Yousif (1984) findings showed that up to 40% replacement of cement with RHA can be made with no significant change in the compressive strength compared to a controlled mix under optimum temperature condition. Ismail and Walludin (1996) showed that 10 – 20% optimum replacement of cement with RHA can be achieved on high strength concrete. Jayasankar et al. (2010) investigated the partial replacement of Ordinary Portland Cement (OPC) with RHA and reported that the amount of replacement varies from 0 to 20% without varying the Grade of concrete of OPC.

The objectives of this study are to investigate the effects of partially replacing Ordinary Portland Cement with rice husk ash on the strength development and shrinkage of concrete.

2.0 MATERIALS AND METHODOLOGY

2.1 Materials Preparation

The Rice Husk used for this research was obtained from the rice threshing floor at Ifo, Ifo Local Government Area, Ogun State. The RHA was made in the laboratory by burning the husk using an Electric furnace, with the temperatures of the furnace at about 700°C. The resulting ash was collected and sieved through BS standard sieve size 45μm and its colour was grey. Batching was done by weight with the replacement percentages at 5% interval from 0 to 30%.

Ordinary Portland Cement (OPC) manufactured by Dangote Cement Plc in Nigeria was used. It was purchased in sealed 50kg bags with its properties conforming to Standard BS 12: (1996). The cement was sieved through BS standard sieve size 75µm for fineness test in accordance with BS 4550: Part 3: Section

3.3:1978.The fine aggregate used was sharp sand obtained from river bed in Ogun State. The fine aggregate was free from clay/silt content. Sharp Sand of sizes that pass through sieve size 4.75mm was used as fine aggregates. The coarse aggregate used was crushed granite. It was of high quality and free of deleterious organic matter and passed through 20mm maximum sieve size. The potable water used for this experiment was obtained from the taps available in the laboratory.

2.2 Methodology

Experimental tests were carried out in two phases, namely:

a) Assessment of the properties of the aggregates used in the concrete

b) Assessment of the fresh and hardened properties of concrete.

1) Properties of Fine and Coarse Aggregate Tests:

a) Sieve analysis – Particle size distribution of coarse, fine aggregate, cement and RHA. b) Specific Gravity on RHA, cement, fine and coarse aggregates.

2) Tests on concrete:

a) Concrete workability (slump test)

b) Compressive strength of concrete (cubes)

c) Flexural strength test on concrete containing RHA and control concrete (cubes)

d) Drying shrinkage.

2.3 Mix Proportion

The control concrete was designed to achieve Grade 25 using the DOE method (1975). Based on this design method, a constant water to cement ratio of 0.5, free-water content of 210 kg/m^3, cement content of 420 kg/m^3, fine aggregate of 477.9 kg/m^3 and coarse aggregate of 1292.1 kg/m^3 were used.

2.4 Casting, Curing and Testing of Specimens

Fifteen concrete 150mm cubes of BS standard sizes were cast for each of the different percentages of replacement of cement with RHA and the control experiment. The cubes were demoulded after 24 ± ½hrs and then cured in curing tanks by complete immersion in clean water for periods of 7, 14, 28, 60 and 90 days. After which they were crushed in compression machine to determine their compressive strengths. Water absorption test was also carried out on three concrete cube specimens for each of the replacement levels of cement with RHA and control experiment. They were completely immersed in the curing tank containing clean water at room temperature for 6, 12, 18 and 24 hours. And then were heated in an oven at 100-1150°C for 24 hours and weighed.

Three beams of size 150 x 150 x 750 mm were cast for each of the different percentages of replacement of cement with RHA and control concrete. The specimens were cured in clean water under controlled conditions for 7, 14 and 28 days respectively. Flexural strength test was carried out on the three samples and the cross-section at each end and at the center was measured.

Three concrete prisms of sizes 100 x 100 x 500mm were also cast each for the different replacement levels of cement with RHA and controlled experiment for the drying shrinkage test of the hardened concrete. The changes in length of the concrete prisms were measured and recorded with the dial gauges after 24 hours under room temperature of 24-30ºC for a period of 90 days.

3.0 RESULTS AND DISCUSSION

3.1 Physical Properties of RHA, Cement, Fine and Coarse Aggregates

The specific gravity results showed that for the RHA it was 1.99, cement 3.06, sand 2.63 while granite was 2.66. The results of the moisture content tests were 6.82% for RHA, 0.50% for cement, 0.46% for sand and 0.05% for granite. Fig. 1a, 1b and 1c show the results of the particle size distribution carried out on the sand, granite, cement and

RHA.

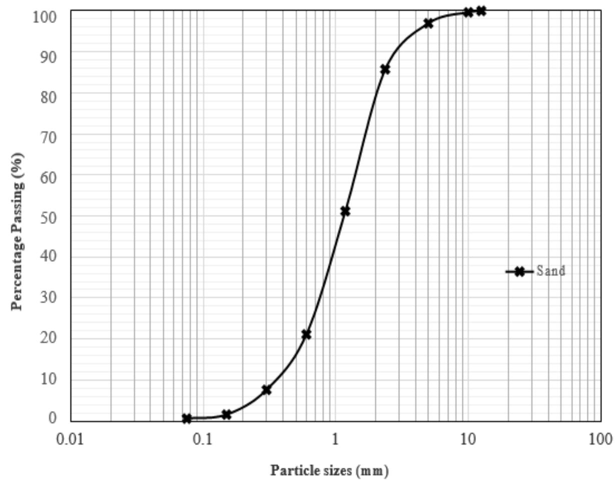

Fig 1a: Sieve Analysis Results of Sand

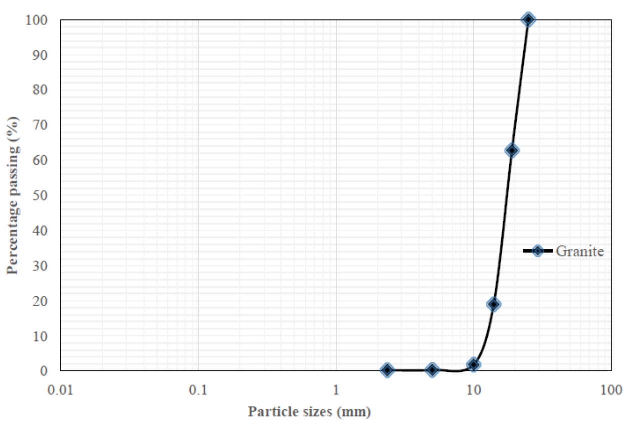

Fig 1b: Sieve Analysis Result of Granite

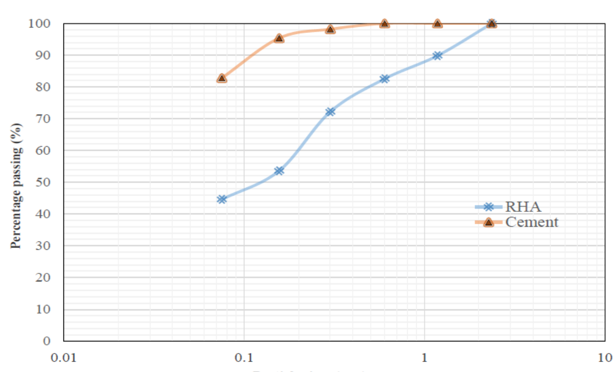

Fig 1c: Sieve Analysis Result of Cement and RHA

3.2 Chemical Properties of RHA and Cement

Table 1 shows the results of the chemical composition of the RHA and the cement used. From the results, the silica content of the RHA was found to be 88.29% which indicate higher silica content than in cement. This value is higher than the minimum required value of 70% for the combined proportion of silica oxide, aluminium oxide and iron oxide for natural pozzolanas (ASTM C618, 1978).

Table 1: Chemical Composition of the RHA and Cement

S/ No	Chemical Components	RHA	Dangote 3x
1	Silica Oxide (SiO_2)	88.29 %	19.16 %
2	Sodium Oxide (NaO_2)	0.10 %	0.40 %
3	Potassium Oxide (K_2O)	2.90 %	0.35 %
4	Calcium Oxide (CaO)	0.63 %	64.25 %
5	Magnesium Oxide (MgO)	0.46 %	2.17 %
6	Aluminium Oxide (Al_2O_3)	0.44 %	4.92 %
7	Iron Oxide (Fe_2O_3)	0.65 %	0.75 %
8	Sulphur Oxide (SO_3)	0.00 %	1.02 %
9	Loss on Ignition (LOI)	5.35 %	0.005 %

3.3 Setting Times of Cement Pastes

Table 2 shows the results of the setting times test on the cement and the RHA used for the concrete production. From the results, the initial and final setting times increased with increase in rice husk ash content. This may be attributed to the slower heat-induced evaporation of water from the cement/RHA paste due to the reduced content of cement.

Table 2: Initial and Final Setting Times of Cement Pastes

Setting Times	RHA replacement of OPC (%)						
	0	5	10	15	20	25	30
Initial setting time	156	187	250	320	355	403	435
Final setting time	240	287	400	512	568	730	802

3.4 Workability of fresh concrete (Slump test)

Fig. 2 shows the results of the slump test indicating the workability of the fresh concrete for the different percentages of replacement of cement with RHA. From the results, it was observed that the slump decreased as the percentage replacement of cement with RHA increases. This can be attributed to the water absorptive character of RHA and its high fineness (increased surface area) having specific gravity of 1.99. For the control experiment, a shear slump type was observed with a value of 100mm while for the 5% to 30% replacements with RHA, a true slump type was observed.

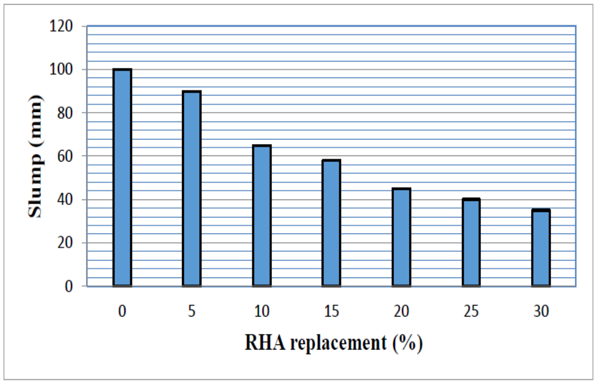

Fig. 2: Variation of slump of the concrete at different replacement levels of RHA.

3.5 Water Absorption of Hardened Concrete Cubes

Fig. 3 shows the results of the water absorption test of the RHA concrete conducted at 6, 12, 18 and 24 hours respectively. The result shows an increase in water absorption with time for the replacement levels of OPC with RHA. It was also observed that the water absorption increased as the percentage replacement of RHA increases. However, 30% RHA replacement gave the highest water absorption of 1.28% after 24 hours compared with the control concrete with water absorption of 0.83% after 24 hours. This may be attributed to the high water-binder ratio and the pore structure of the RHA in which water occupies the space in concrete and as it evaporates it leaves voids thus increasing the absorption value.

3.6 Compressive strength

Fig. 4 and 5 show the results of the variations of the cube compressive strength of the different percentages of replacement with RHA at 7, 14, 28, 60 and 90 days respectively. It was observed that the compressive strengths reduced as the percentage replacement of RHA increased. However, the compressive strengths increased as the number of days of curing increased for each percentage replacement of OPC with RHA. It was also observed that for the control experiment, the compressive strength increased from 22.37 N/mm^2 at 7 days to 32.12 N/mm^2 at 28 days (i.e. 43.6 % increment). For the 5% RHA replacement, it showed an increase in compressive strength from 21.70 N/mm^2 at 7 days to 28.15 N/mm^2 at 28 days (29.72% increment). The 28-day strength was also above the specified value of 25 N/mm^2 for the characteristics strength of grade 25 concrete. The strength of the 10% RHA replacement showed an increase in compressive strength from 20.67 N/mm^2 at 7 days to 26.82 N/mm^2 at 28 days (29.75% increment). The 28-day strength was also higher than the specified value of 25N/mm^2 for the characteristic strength of Grade 25 concrete. However, the 28-day strength for the 15%, 20%, 25% and 30% RHA replacement gave 22.37 N/mm^2, 20.44 N/mm^2, 18.67 N/mm^2 and 18.22N/mm^2 respectively.

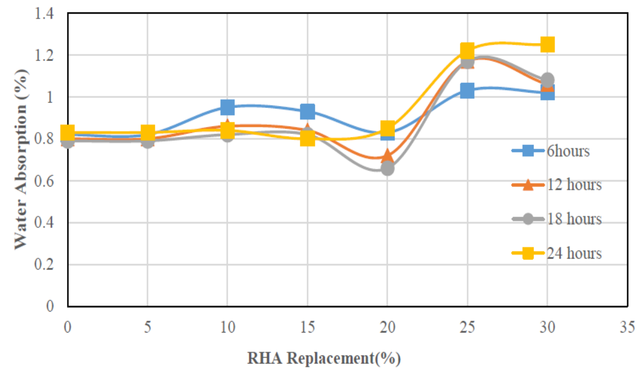

Fig. 3: Variation of water absorption of Grade 25 concrete

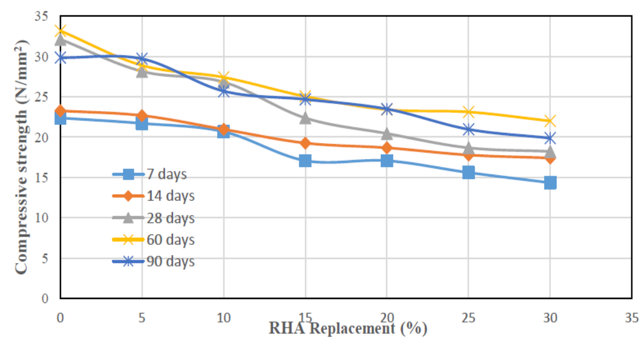

Fig. 4: Variation of compressive strength of Grade 25 concrete with percentage replacement

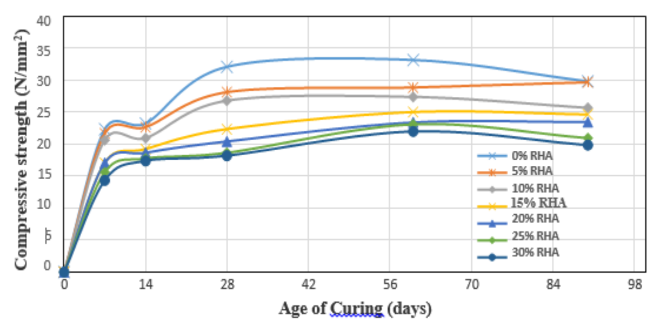

Fig. 5: Variation of compressive strength of Grade 25 concrete with age of curing.

Table 3: Percentage increase or decrease in compressive strength of Grade 25 RHA Concrete with age.

RHA Replacement (%)	% Increase between 7 -14 days	% Increase between 14 -28 days	% Increase between 28 -60 days	% Increase between 60 -90 days
0	3.98	38.09	3.30	2.83
5	4.47	24.17	2.63	2.80
10	1.40	27.96	2.20	3.25
15	12.76	16.15	11.94	6.51
20	9.37	9.48	14.53	4.57
25	13.97	5.01	23.78	3.60
30	21.41	4.65	20.75	6.45

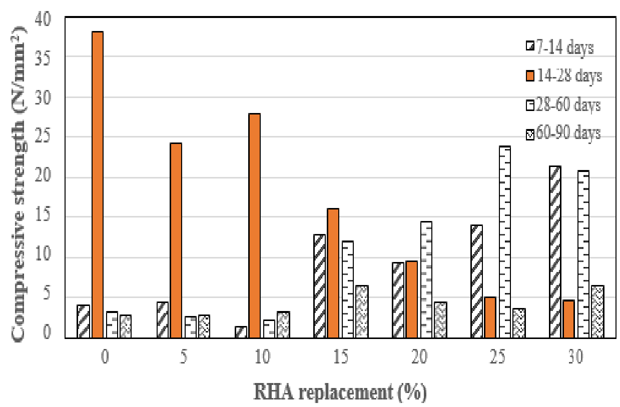

Fig. 6: Bar chart showing percentage increase in compressive strength of Grade 25 concrete.

3.7 Bulk Density

The results of the bulk density of the concrete cubes presented as a ratio of the mass of the cube to its volume at different percentages of replacement of RHA with curing age. It was observed that the density value of the RHA concrete was in the range of 2338-2543 Kg/m^3 for all the replacement level of RHA. This could be due to the high specific gravity of the RHA which led to increase in the mass per unit volume. Also, it was observed that the density value of the RHA concrete decreased with the age of curing. According to BS 377, the RHA concrete can be classified as a normal and heavy weight concrete.

3.8 Flexural Strength

Fig. 7 shows the results of the flexural strength test for each of the percentage replacement of OPC with RHA at ages of 7, 14 and 28 days respectively. From the result of the flexural strength, the rate of development of the flexural strength was found to be higher between the 7 and 14-day period. However, there was a marginal increase at 28 days. It was observed that the flexural strength increased as the percentage replacement of the RHA increased up to 10% (3.67 N/mm^2) at the 28-day period and afterwards the flexural strength decreased gradually. The flexural strength for the control concrete beam at the 28-day period was found to be 3.38 N/mm^2.

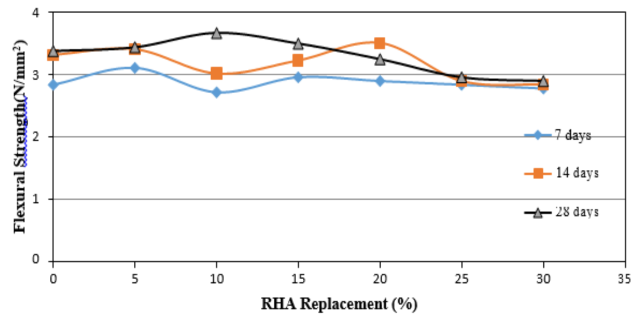

Fig. 7: Variation of the flexural strength of Grade 25 concrete beam with age of curing.

3.9 Drying Shrinkage

The results of the drying shrinkage test for the varying percentage of replacements of cement with RHA showed that the Rice Husk Ash had a significant effect on the drying shrinkage with the 30% RHA replacement exhibiting the highest shrinkage strain value of 440 microstrain (4.4 x10^{-4}) compared to control experiment with 380 microstrain (3.8 x10^{-4}) at the 90 day period. It was however observed that the shrinkage value of the 5%, 10 % and 15% RHA replacement were lower compared to the control experiment. This could be attributed to the reduction in the RHA particle size which increased pozzolanic activity and contributed to the pore refinement of the RHA concrete paste matrix. This further shows that using pozzolanic material like Rice Husk Ash will help reduce the shrinkage of concrete.

4.0 CONCLUSION

From the experimental investigation carried out, the following inferences on the RHA concrete are made:

i. The chemical analysis done on the RHA indicated high amount of silica oxide content (88.29%). This shows that RHA has a high chemical composition that encourages its use as a pozzolana.
ii. The setting times of the cement increased as the percentage replacement of the ash increased.
iii. The slump decreased upon the inclusion of RHA as partial replacement of OPC in the concrete.
iv. The compressive strength of the concrete cubes increased at all the replacement level of the RHA as the number of days of curing increased. However, the strength reduced as the percentage replacement of RHA in concrete increased.

v. The bulk density of the concrete cubes decreased with age of curing and was found to be in the range of 2338 - 2543 Kg/m^3 for all the replacement levels with RHA.
vi. The flexural strength also improved on addition of Rice Hush Ash with marginal increase in flexural strength up to the 10% replacement of RHA. The 28-day flexural strength of the 10% RHA replacement had the highest value of 3.67N/mm^2.
vii. The values of the drying shrinkage strain of the concrete was lower for the 5-15% RHA replacement compared with the control experiment. However, at the 90-day period the 30% RHA Replacement had the highest shrinkage value of 440 microstrain.

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