Flexural Properties of Concrete Beam using Rice Husk Ash (RHA) a Partial Replacement of Cement

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***Abstract-* The research work examines the structural properties of concrete beam (flexural strength and deflection)under loading with partial replacement of cement with Rice Husk Ash (RHA).The Pozzolanic potential of RHA came to bear. Samples were made for various percentage of replacement (10%, 20%, 30% and 40%) with0% replacements for the control and tested at 7, 14 and 28 days. The results showed that there was an increase in flexural strength from 7 to 28 days with 6.0, 6.0, 3.6, 5.2 and 4.6 N/mm^2 for the 28days test and 30% replacement maintaining the same flexural strength for the entire test. It was also observed that there was a decrease in deflection value at rupture with progression in age with increase RHA content showing lesser capacity to carry imposed load. However, the water/cement ratio for the 30% AND 40% RHA/cement samples were increased to ensure a workable mix. These improved the result obtained when compared with the 20% RAH/cement having similar w/c the control and 10% RHA cement Samples. Setting time and slump test were also carried out and the results shows that with increase in RHA content in cement, lower values were obtained for the initial and setting time and for the slump test. It is recommended that 10% replacement can be used instead of the control and 20% and 30% can be used for non-structural concrete beam such as lintel.**

***Keywords* – Rice Husk, Concrete, Compressive strength, Pozzolan, Flexural**

I.INTRODUCTION

Rice milling industries generate a by-product acknowledged as husk which is the hard-protecting covering that surrounds the paddy grain. The husk is made up of about 75% organic unstable matter and the remaining 25% converted to ashes during the burning process [1]. When the rice husk is burnt under control temperature which is below 700^{0}C, the ash generated is amorphous in nature and becomes crystalline. In other clime, rice husk ash (RHA) is an agronomic waste made from the burning of the rice husk with the intention of producing heat for rice drying ovens. The RHA is enriched with silicon. Approximately one-fifth of a ton of husk are gotten from a ton of rice produced, out of which 40 kg of RHA is obtained when burnt.(Rajput et al, 2013) [2].

The RHA is a member of the pozzolan group which includes Pulverised Fuel Ash (PFA), Volcanic Ash etc. The American Society of Testing Materials (ASTM) defines pozzolan as a material containing siliceous or (and) aluminous components in a finely divided form which possess little or no cementitious properties. RHA is a great pozzolan, that is, a material having silica content above 85%. Other chemical constituents of RHA are Silicon dioxide (SiO2), Aluminum oxide (Al_2O_3), Ferric oxide (Fe_2O_3), Calcium oxide (CaO), Magnesium oxide (MgO), Sodium oxide (Na_2O), Potassium oxide (K_2O), Phosphorus oxide (P_2O_5), Titanium oxide (TiO_2), Sulfur trioxide (SO_3), and so on (Zhang & Malhotra, 1996 [3], Nuruddin, et. al., 2011 [4], Chao-Lung, et. al., 2011 [5]) [3-5]

Its usage in concrete has gained wide acceptance, particularly in areas where there is large cultivation of rice. This has also led to reduction in waste generated as a result of rice cultivation (Al-Khalaf & Yousif, 1984 [6];Hwang& Chandra,1996 [7];de Sensale, 2006 [8];Khan et.al., 2012[9]).The RHA can also be used as [i] a releasing agent in the ceramic industries, (Nagrale, 2012)[10],[ii] serves as insulation material for homes and refrigerants (Chel & Kaushik, 2018)[11], [iii] for soil stabilisation (Brooks, 2009)[12]. [iv] an absorbent for lubricant and chemicals (Feng et.al., 2004)[13], [v] biomass (Pode, 2016)[14],[vi]as filler in natural rubber vulcanizates (Sae-Oui, 2002)[15], [vii] as fertilizer (Tateda, 2016)[16] and many more applications.

II. REVIEW OF LITERATURE

Taylor (1977)[17] ascertain that when a pozzolan is mixed with cement, the calcium hydroxide combines slowly to give it cementitious properties that contribute to water tightness and long increase in strength for the concrete. The Portland-pozzolan cement produces reduction of segregation and bleeding, continuous gain in compressive and tensile strength, improve workability, reduction in the heat in hydration and apparently, saving the overall cost when compared with Portland cement.

cementitious properties along these lines adding to water snugness and long increase in quality of the solid.

RHA is highly pozzolanic and can supplement cementing material in the making of high-performance concrete. The test on RHA concrete came up with satisfactory slump, air content, and setting time (Zhang & Malhotra, 1996)[3]. The RHA can have as much as 87% silica, principally in unstructured form and a mean specific surface area of 36.47 m^2 /g (Ganesan, 2008)[18]. Antiohos, et. al., (2014)[19] found out that RHA is a substance that is very “sensitive” to changes in fineness; the lower the fineness, the less is the effect of RHA inclusion within mix and vice versa.

For over fifty years, the utilization of pozzolanic and cementitious materials,(for example, silica smoke, granulated heater slag, fly ash, and regular pozzolan) has risen significantly and have benefited immensely the economy, engineering, and ecology particularly the construction industry. This goes with the rise in demand for cement in the world. Apart from the materials listed above, the usage of RHA in concrete is a work in progress. (Qing-ge, et.al., 2004)[20]. Pozzolanic materials are the fundamental siliceous that produce calcium silicate hydrate in the process of responding with water and lime.From studies, it has been seen that RHA contains high amorphous silica and enormous inner surface area which areexceptionally responsive pozzolanic material that can improve the quality and strength of concrete.

It has been contemplated that high substance of nebulous silica and enormous inner surface zone can make RHA an exceptionally responsive pozzolanic material that can improve the quality and strength of cement.

The RHA was used to enhance the compressive strength of OPC sandcrete blocks. The strength decreases as the percentage of RHA increases above the optimal but increases with age at curing. The optimal replacement of cement with 20% RHA was achieved in the study (Oyetola & Abdullahi, 2006)[21]. Other pozzolanic materials from agriculture waste are cassava (Soyemi and Ogunfayo, 2015)[22], eggshell (Yerramala, 2014)[23], zeolite (Najimi et. al., 2012)[24] and so on.

III. METHODOLOGY (EXPERIMENT)

The Rice Husk was obtained and burnt. The process employed was open burning method. The combustion of the rice husk in the open takes place in the presence of air (oxygen). Three days of uninterrupted burning were required to completely burn the husk into ashes. After cooling, it was then sieve using sieve size 300µm. The setting time test was carried out on the cement paste to determine the initial and final setting time.

The weight batching method was deployed in the mix proportioning. The mix ratio (1:2:4) was used to determine the quantity of each materials required. The washed river sands are retained by 0.06mm sieve with maximum diameter being 2.0mm, free from mud and iron particles. The granites are free from dust and measured an average diameter of 12mm. For a design mix of 1:2:4, the compositions are in Table 1.

Table 1: Material Composition for OPC/RHA Concrete

% RHA Replacement	Cement	RHA	Sand	Granite
0	1.0	0.0	2	4
10	0.9	0.1	2	4
20	0.8	0.2	2	4
30	0.7	0.3	2	4
40	0.6	0.4	2	4

Having gotten various mix constituents, a water cement (w/c) ratio of 0.55 was used for up to 20% replacement while for 30% and 40%, a w/c ratio of 0.92 for good workability of concrete. These were determined by the slump test carried out in accordance toBritish Standard 1881 (1983)[25]. This clearly indicates that an increase in the replacement of cement with RHA will eventually lead to a rise in the demand for water required to produce a workable concrete. The mixed concrete was then placed in the formwork and compacted.

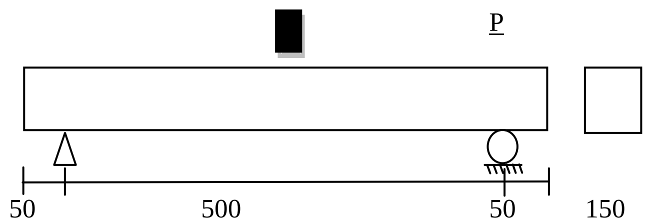

Figure 1: Schematic Diagram of Beam

To obtain the compressive strength of the mix, the OPC/RHA concrete were placed in plastic moulds (150mm x 150mm x 150mm) and demoulded after 24 hours. They were then placed in the curing tank until the day of crushing. The compression testing machine used has a drive speed of 0.5mm per second. The cubes were crushed on the 7th, 14th and 28th day. The beams cross-sectional are 150mm x 150mm and an overall length of 600mm and spans 500mm over two supports (Figure 1). The beam samples were de-moulded after 24hours and covered by sacks and watered daily for a period 28 days. the flexural response of the beam was determine using the three-point loading test. At the end of the 28th day, the beam samples were loaded at mid-span to destruction to determine the maximum load and the mid-span displacement using the Magnus frame with manually applied load of 0-60bars. The piston moves at a speed of 0.5 mm per minute. This gives a gentle time to monitor the displacement and cracks formation.

IV. RESULTS

Tests were carried out on the OPC/RHA enhanced concrete. Table 2 gives the outcome of the slump test for individual mix and are shown below:

Table 2: Slump Test and water/cement ratio

w/c ratio	RHA/Cement content (%)	Slump (mm)
0.55	0	12.0
0.55	10	9.0
0.55	20	8.5
0.92	30	13.0
0.92	40	11

It was observed that when the percentage replacement of RHA increases, the workability was poor which led to an increase in the w/c ratio. This became necessary as there was no true slump after 20% replacement of cement with RHA. The slump of 30% replacement is as good as that of the control specimen with increase in w/c ratio.

Table 3 shows the result of the initial and final setting times for the ordinary Portland cement (OPC) and the RHA/OPC. The setting times are close with the lowest at 40% replacement. These indicate that all the concrete will set about the same time.

Table 3: Setting time of cement

RHA/Cement content (%)	Setting Time (mins)	
	Initial	Final
0	40	550
10	38	535
20	37	535
30	45	515
40	35	500

The average compressive strength measured during crushing are presented in Table 3. For each sample, six (6) tests were carried out and the average calculated. The compressive strength of the 10% RHA replacement gives the same answer as the control. This is significant as it means they can be used for the same structural purpose as the control.

Table 4: Compressive Strength of OPC/RHA Concrete

% RHA Replacement	Mean Strength (N/mm^2) at		
	7th Day	14th Day	28th Day
0	19.80	20.11	20.40
10	19.80	20.08	20.38
20	15.95	16.48	16.85
30	17.87	18.00	18.55
40	16.42	16.84	17.02

The maximum average strength attained by the control was 20.40 N/mm^2 (20.40MPa) while that of the 10% RHA replacement was 20.38 N/mm^2. The least compressive strength is from 20% RHA replacement, which is 17.4% lesser than the control. This also indicate that the concrete with 20% RHA replacement can be used for non-structural members.

The flexural strength (measured as stress at rupture) and displacement at which rupture occurs were taken at the 28th day and given in Table 5 and Figure 2:

Table 5: Flexural strength and Displacement at 28 days

RHA/Cement Content (%)	28 Days	
	Stress at Rupture (N/mm^2)	Displacement at Rupture (mm)
0	6.0	5.50
10	6.0	5.50
20	3.2	3.60
30	5.2	4.50
40	4.6	3.00

The stress at rupture for the control and 10% replacement are the same on all the days of testing. This connotes that the 10% replacement is suitable for use in all structural elements that the control is suitable for. The 30% replacements also give an appreciable response like the control (86.7%).

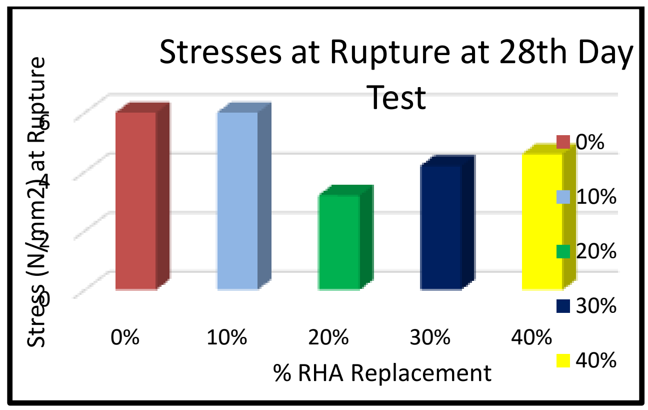

Figure 2: Bar Chart showing Stress at Rupture on Test Days

The displacement at rupture was also measured. This gives the maximum deflection at the middle of the beam. It was observed that the response of the beam with 10% cement replacement with RHA responded closely like the control beam (Table 4 and Figure 3). The response of the beam with 20% RHA replacement was the poorest.

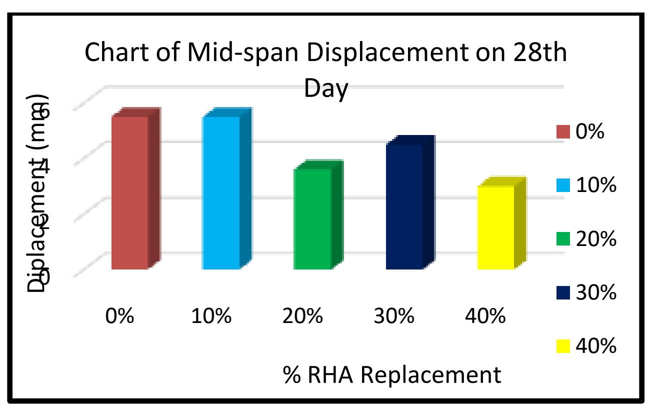

Figure 3: Bar Chart showing Displacement at the Mid-span on Test Days

The response of the OPC/RHA concrete maintains a significant compressive strength at the 28th day test compared to that of the control concrete. At noticed the control and 10% replacement provided the same flexural properties and deflected at the same rate, while 20% and above has a reduction in strength from 14% to 46%.

V.CONCLUSION

Replacement of cement with Rice Husk Ash (RHA) has many benefits. It can reduce the environmental pollution caused by cement industries by reducing the consumption of the cement and reduce the waste generated during milling of rice. Moreover, with high replacement with RHA, it can be used in the construction of non-structural element. The addition of RHA below the optimal improves the properties of concrete. The workability of the mix also reduces as the quantity of RHA increases.This investigation has shown that a rise in the replacement of cement with RHA result in considerable rise in the quantity of water needed to make a workable concrete. The 10% RHA replaced mix attained a comparable compressive strength and displacement as that of the control mix. Hence 10 % RHA replacement by volume of cement is recommended for structural elements. The 30% and 40% can be used for non-structural members.

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