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RESEARCH ARTICLE

EFFECTS OF VARIABILITY IN THE POZOLANNIC PROPERTIES OF RICE HUSK ASH (RHA) ON THE CONCRETE MODULUS OF RUPTURE

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ABSTRACT

Many s In this study, the effects of variability in the pozzolanic properties of Rice Husk Ash (RHA) gotten from four (4) different locations on the Flexural Properties of Concrete was reported. The different sources where RHA was gotten are; Ogoja, Abakaliki, Adani and Adikpo in Nigeria. It is discovered that the pozolanic properties of RHA varies based on their location. Samples from Ogoja where found to have the highest pozzolanic properties followed by Abakaliki, Adani, and Adikpo, their silica content was found to be 84.55, 76.3, 70.12 and 70.11%respectively. The percentages of RHA used to replace cement in concrete were 5, 10,15,20,25 and 30%.The compressive strength values at 28 day curing period was found to be in the range of 37-42N/mm^2 at 5%RHA, 35-39.5N/mm^2 at 10%RHA, 30-34.5N/mm^2 at 15%RHA, 27-29N/mm^2 at 20%RHA, 22-25.6N/mm^2 at 25% RHA and 21-24N/mm^2 at 30% RHA compared to the controlled sample with a strength value of 42.64N/mm^2. Beams of 500x100x100mm were cast and tested for flexural strength. The flexural values ranged from3.15-3.7N/mm^2 at 5%RHA, 2.61-3.03 N/mm^2 at 10% RHA, 2.16-2.30 N/mm^2 at 15% RHA, 1.7-2.0 N/mm^2 at 20% RHA, 0.86-1.4 N/mm^2 at 25% RHA and 0.62-0.85 N/mm^2 at 30% RHA while the results of the controlled sample is 3.84 N/mm^2.From the results above it can be deduced that there is a variability in the pozolanic properties of RHA based on location and this has a correlation on their efficacies as a concrete admixture.

INTRODUCTION

Flexural strength provides two useful parameters, namely; the first crack strength which is primarily controlled by matrix and the ultimate flexural strength or modulus of rupture which is determined by the maximum load that can be attained by the tested sample. In China, the flexural properties of cement-stabilized with macadam or pozzolans reinforced with polypropylene fibre have been studied by Zhang, (Sumrerng Rukzon *et al.,* 2009). Flexural properties of concrete are important to the design engineers to serve as a guide to the selection of appropriate construction materials. Ukpata, (Ramarao and Seshagiri Rao, 2003), studied the flexural properties of lateritic sand and quarry dust as fine aggregate. Their results compared favourably with normal concrete at 25-50 % replacements. The quality and strength desired in concrete is fundamentally related to its compressive strength. Compressive strength is the most convenient way of measuring and assessing the quality of hardened concrete using the equation (1)

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$$F = \frac{P}{A} \quad \text{.................................. (1)}$$

Where P is the crushing load and A is the cross-sectional area of the cube or cylinder.

The modulus of rupture of a material, f_{cf} (in N/mm^2) is expressed in equation (2)

$$f_{cf} = \frac{FL}{d1+d2^2}. \quad \text{.. (2)}$$

Where

F = the breaking load (in N)
d_1 and d_2 are the lateral dimensions of the cross-section (in mm).
L = the distance between the supporting rollers (in mm)
f_{cf} = Concrete modulus of rupture.
Flexural strength is expressed to the nearest 0.1N/mm.

According to (BS-1881-118), RHA is found in abundance globally and ways of disposing of this material are been sort. There is an increasing importance to preserve the environment in the present-day (Ajay Kumar *et al.,* 2012) and (Nevile, 1990). RHA from the parboiling plants is posing serious environmental threat and ways are being thought of to dispose them. This material is actually a super pozzolan rich in silica and has about 85% to 90% silica content. Narayan, (Mauro *et al.,* 2005) further proved that by utilizing these super-pozzolanic materials even in small amounts (5% to 10% cement replacements) can dramatically enhanced the workability, strength and impermeability of concrete mixes, as a result the concrete are highly durable to chemical attacks, abrasion and reinforcement corrosion. Pozzolans are not just "filler" but a strength and performance enhancing additive. (Narrayan, 2005) confirmed that RHA has a total percentage composition of Silicon Dioxide ($Si0_2$), Iron III Oxide (Fe_20_3) and Aluminium Oxide (Al_20_3) to be 73.15% which is above the minimum requirement of 70% by the American standard for testing materials (ASTM) C618-78 (1978). (Mihelcic *et al.,* 2005) further showed that by utilizing these super-pozzolanic materials even in small amounts (5% to 10% cement replacements) can dramatically enhanced the workability, strength and impermeability of concrete mixes, as a result the concrete are highly durable to chemical attacks, abrasion and reinforcement corrosion. Pozzolans are not just "filler" but a strength and performance enhancing additive.

According to (Obam, 2006), the principal binder in concrete is Portland cement, the production of which is a major contributor to greenhouse gas emissions with its negative effects on the atmosphere. Sumrerng, (Oyetola and Abdullahi, 2006) shows that environmental pollution caused by the emission of CO_2 into the atmosphere during the processing of clinker or limestone can be mitigated through the use of alternative fuels, the use of energy efficiency improvements in the cement plants, and the replacement of limestone-based clinker with other materials such as supplementary cementing materials (5cm) to reduce the use of Portland cements. One of the most suitable sources of pozzolanic material among agricultural waste components is rice husk, as it is available in large amount of silica.

The use of RHA in concrete lead to improved workability, reduced heat evolution, reduced permeability and increased strength. According to (Akeke, *et al.,* 2012), utilizing RHA as a construction material will solve the problem of waste management, enhance environmental protection and sustainability and improves the economic value of RHA. Mihelcic, (Habeeb and Fayyaah, 2009), estimated that if natural pozzolans were used to construct spring boxes or gravity fed water systems for the 1 billion people worldwide that do not have access to safe drinking water, the total anthropogenic CO_2 emissions could decrease from 3.8 to 0.95 million tons, if volcanic ash or RHA were substituted for OPC at a 25% level, and from 874,000 to 240,000 tons if diatomaceous earth was substituted for OPC at 6.25.

Table 1. Savings and reduction in global CO2 emissions if natural pozzolans were substituted for OPC in construction

Structure	Pozzolan Usage	Economic Savings	Reduction in CO_2 (Tons)
Spring Box	Volcanic ash or RHA @ 25%	$141,000,000	950,000
	Diatomaceous earth @ 6.25%	$ 37,000,000	240,000
Gravity Fed	Volcanic ash or RHA @ 25%	$451,000,000	3,800,000
Water system	Diatomaceous earth @ 6.25%	$102,000,000	874,000

MATERIALS AND METHODS

Rice Husk Ash

Rice Husk Ash (RHA) rich in silica was used in this project. The rice husks were gotten from four (4) different locations in Nigeria, Adani in Enugu State, Ogoja in Cross River State, Abakaliki in Ebonyi and Adikpo in Benue State. They were burnt in open air and the ash collected and stored in a dry area in the laboratory. Figure 1 shows the drying of RHAs. Chemical analysis was conducted on the ashes to determine the elemental composition of each ash in line with ASTM Standard C311.

Fig. 1. Drying of RHA from different locations in the Laboratory before analysis

Cement

Ordinary Portland cement (OPC) was used in which the composition and properties is in compliance with the defined standards of cement for concrete production. The cement was gotten from UNICEM factory.

Coarse Aggregate

In this research, granite of 5-20mm maximum size was used. Proper inspection was carried out to ensure that it was free from deleterious materials.

Water

Pipe borne water and free from contaminants was used in this study.

Compressive Strength Test

Cube Test

The test was carried out in accordance with (British American Institution, 2001), BSEN 206, 2001 Part 3. The samples were prepared by mixing the concrete constituents to achieve a homogenous mix, placed in the mould and vibrated in three layers. The samples were then demoulded after 24hrs and then cured at $20^{o}c$ for 7, 14, 21 and 28 days thereafter they were tested or crushed by a constant rate of stress increase of $15Nmm^2$ immediately after removal from the curing tank. The cube test gives information for the determination of the characteristic strength of concrete which is given as the strength below which not more than 5% of the tests results would fall.

Flexural Strength Test

The arrangement for flexural strength test is shown in Figure-2. Automatic universal testing machine was used for this test according to BS1881-118. Beam samples measuring 500X100X100mm were moulded and stored in water for 28 days before test for flexural strength. Three similar samples were prepared for each mix proportion. The casting was made by filling each mould with freshly mixed concrete in three layers. Each layer was compacted manually using a 25mm diameter steel tamping rod to give 150 strokes on a layer. The hardened beam was placed on the universal testing machine simply supported over a span 3times the beam depth on a pair of supporting rollers. Two additional loading rollers were placed on to the beam as shown in Figure 3. The load applied without shock at a rate of 200m/s.

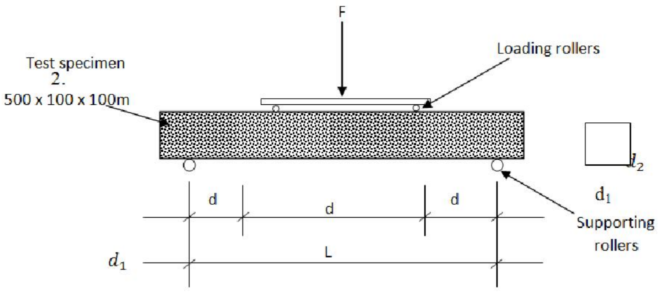
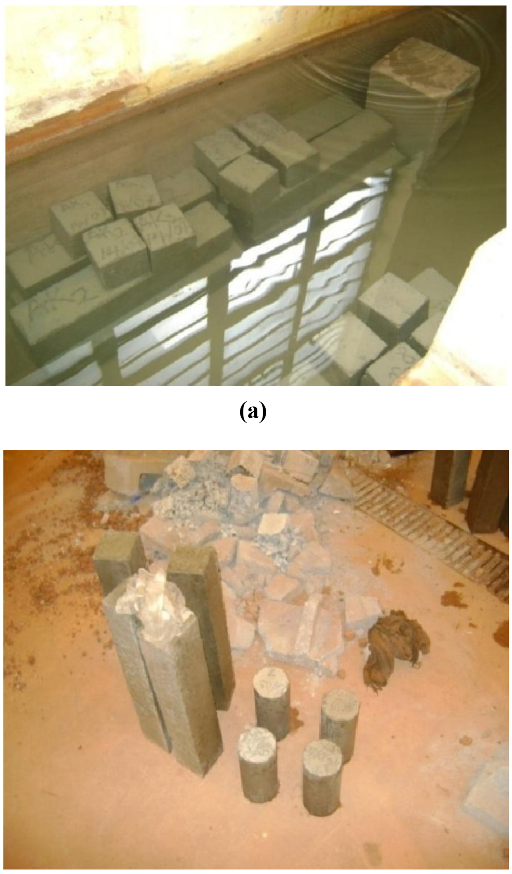


Figure 2. Arrangement of loading (2-point loading) for flexural strength

d_1 and d_2 = lateral dimensions of the cross sections (in 1 = distance between the supporting rollers (in mm).



(a)

(b)

Figure 3 (a) Test Samples in the curing Tank (b) Some of the Test Samples after removal from the curing Tank

Figure 4. A failed beam tested for the determination of the modulus of Rupture

The flexural strength is given by equation (3). Figure 4 shows the failure mood of specimen.

$$f_{cf} = \frac{FL}{d1 + d2^2}. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (3)$$

Where

F = is the breaking load (N)
d_1 and d_2 are the lateral dimensions of the cross-sections (mm)
L is the distance between the supporting rollers (mm)

RESULTS AND DISCUSSION

Physical properties of materials

Table 2 present the results of the specific gravity of the binder. The results showed that the specific gravity of RHA was found to be in the range of 1.67 to 1.94, sand (fine aggregate) was 2.4 while that of coarse aggregate was 2.89. The cement had a specific gravity of 3.15.

Results of the chemical analysis

Table 3 shows the chemical compositions of the analysis done on the RHA and cement. The silica contents of the pozzolans are 84.55, 76.3, 70.12 and 70.11% for Ogoja, Abakaliki, Adani and Adikpo respectively.

Results of the densities

The density of RHA was investigated, results analysed and presented as a ratio of the mass to that of the volume are given in Tables 4A to 4D. Density values generally decreased with increased in the RHA content. The low specific gravity of RHA compared to that of cement is responsible for this decrease, as the latter is heavier than the former.

Results of the effects of RHA on concrete modulus of rupture

The flexural strength properties of RHA concrete was investigated in the laboratory and the results of this investigation are presented in Table 5. From the results, it can be seen that the flexural strength increased at 5-10% with values of 2-4.1N/mm^2, 1.9-3.2N/mm^2, 1.9-3.0N/mm^2 for the various locations and 15-20% replacement gives acceptable strength values, thereafter a decline in the strength values is experienced.

Table 2. Particle Size Distribution Results of the Various RHA and Cement

Sieve Size	%Passing Adani	%Passing Abakaliki	% Passing Ogoja	% Passing Adikpo	% Passing OPC
2.36	100	100	100	100	100
1.18	100	100	100	100	100
600	94	98	93.2	100	100
425	80	90	85	90	100
300	50	55	55	60	80
212	45	45	43.6	50	35
150	25	30	27.4	30	22
63	5	4	7.4	9	4
Pan	0	0	0	0	0

Table 3. The chemical compositions of the analysis done on the RHA and cement. The silica contents of the pozzolans are 84.55, 76.3, 70.12 and 70.11% for Ogoja, Abakaliki, Adani and Adikpo respectively

S/N	SAMPLE/LOCATIONZ	ELEMENTAL COMPOSITION IN %							
		ZnO	SiO_2	CaO	Fe_2O_3	K_2O	MnO	MgO	Na_2O
1	UNICEM CEMENT	0.12	23.5	652	3.4	0.4	0.18	1.35	0.3
2	ADANI	0.6	70.2	0.2	0.05	0.66	0.57	0.52	0.52
3	OGOJA E0477210, N0729822	0.75	84.5	0.3	0.25	0.69	0.43	0.45	0.51
4.	RHA-ABAKALIKI E0405465, N0697514	0.2	76.3	0.25	0.09	0.27	0.2	0.03	0.16
5.	ADIKPO E0525472, N0760211	0.37	70.1	0.28	0.18	0.41	0.27	0.2	0.22

Table 4A. Density Values for Various RHA Concrete Mixes from Ogoja, CRS

	Age	Percentage Replacement with RHA					
		5%	10%	15%	20%	25%	30%
Average	3	2346.27	2290.96	2306.67	2282.86	2269.63	2269.63
Densities	7	2342.91	2304.59	2266.57	2272.59	2214.62	2214.62
of RHA	14	2364.74	2317.33	2316.44	2288.69	2262.12	2262.12
Concrete in	21	2357.43	2335.70	2331.26	2317.04	2272.10	2272.10
KN/m^3	28	2326.22	2350.72	2343.70	2274.17	2296.20	2296.20

Table 4B. Density Values for Various RHA Concrete Mixes from Abakaliki, EBS

	Age	Percentage Replacement with RHA					
		5%	10%	15%	20%	25%	30%
Average	3	2326.91	2315.56	2347.95	2284.44	2282.47	2222.72
Densities	7	2338.27	2301.73	2378.37	2271.80	2215.80	2234.07
of RHA	14	2365.33	2325.73	2328.69	2357.83	2283.46	2241.48
Concrete in	21	2359.41	2341.04	2333.83	2335.21	2300.84	2257.78
KN/m^3	28	2340.64	2371.65	2339.06	2307.75	2324.74	2258.47

Table 4C. Density Values for Various RHA Concrete Mixes from Adani, EBS

	Age	Percentage Replacement with RHA					
		5%	10%	15%	20%	25%	30%
Average	3	2325.43	2239.60	2286.62	2282.86	2269.63	2223.41
Densities	7	2305.28	2238.02	2292.74	2273.58	2214.62	2228.84
of RHA	14	2360.59	2359.90	2342.32	2288.69	2262.12	2242.57
Concrete in	21	2324.05	2277.33	2327.31	2317.04	2272.10	2253.53
KN/m^3	28	2347.75	2364.15	2345.88	2284.05	2299.16	2263.70

Table 4D. Density Values for Various RHA Concrete Mixes from Adikpo, BS

	Age	Percentage Replacement with RHA					
		5%	10%	15%	20%	25%	30%
Average	3	2344.30	2293.73	2307.36	2282.86	2269.63	2223.41
Densities	7	2340.94	2301.93	2267.06	2272.59	2214.62	2228.84
of RHA	14	2362.57	2319.01	2318.42	2288.69	2262.12	2242.57
Concrete in	21	2356.44	2335.31	2331.65	2317.04	2272.10	2253.53
KN/m^3	28	2324.25	2345.68	2344.69	2274.17	2296.20	2263.70

Table 5. Flexural Strength Values of RHA Concrete from the four different locations

Sample/Location	% of RHA	Results Values			
		F_{cu}	F_{Cf}	SLUMP	W/C
CTRL	0	42.64	3.84	105.00	0.44
OGOJA	5	41.48	3.68	100.00	0.44
	10	39.56	3.03	80.00	0.44
	15	34.37	2.27	60.00	0.44
	20	29.10	1.95	50.00	0.44
	25	25.56	1.36	60.00	0.46
	30	24.27	0.85	35.00	0.47
ABAKALIKI	5	38.98	3.29	100.00	0.45
	10	38.00	2.62	85.00	0.44
	15	33.41	2.10	65.00	0.44
	20	27.93	1.28	48.00	0.45
	25	24.37	0.83	50.00	0.48
	30	22.90	0.60	30.00	0.5
ADANI	5	38.13	3.12	100.00	0.45
	10	37.04	2.37	90.00	0.45
	15	31.48	1.95	70.00	0.45
	20	27.93	1.22	60.00	0.47
	25	23.79	0.82	65.00	0.48
	30	22.30	0.66	40.00	0.48
ADIKPO	5	37.01	3.15	90.00	0.44
	10	35.16	2.61	75.00	0.44
	15	30.15	2.16	60.00	0.51
	20	27.04	1.70	60.00	0.48
	25	22.00	0.86	45.00	0.49
	30	21.26	0.62	40.00	0.55

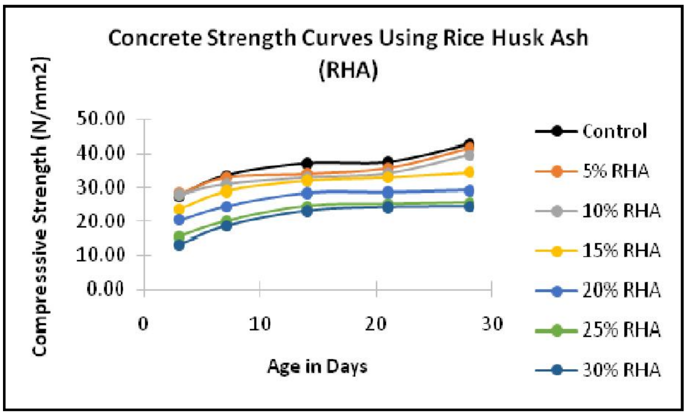


Fig. 6A. The relationship between compressive strength and age for RHA concrete from Ogoja CRS

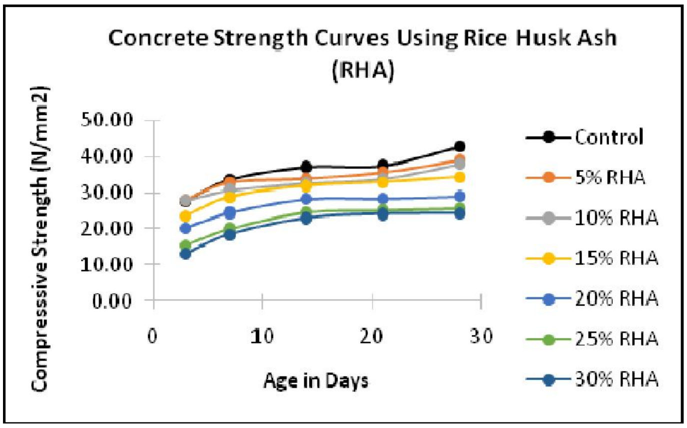


Fig. 6B. The relationship between compressive strength and age for RHA concrete from Abakaliki EBS

It can also be seen that the addition of RHA to concrete improves its flexural strength but excess percentage replacement decreases the strength of the concrete.

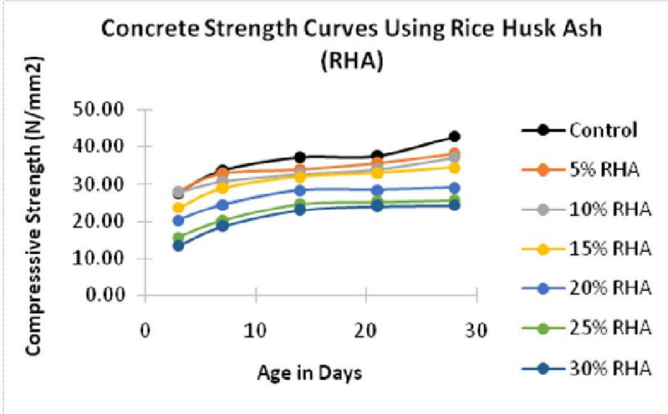


Fig. 6C. The relationship between compressive strength and age for RHA concrete from Adani ES

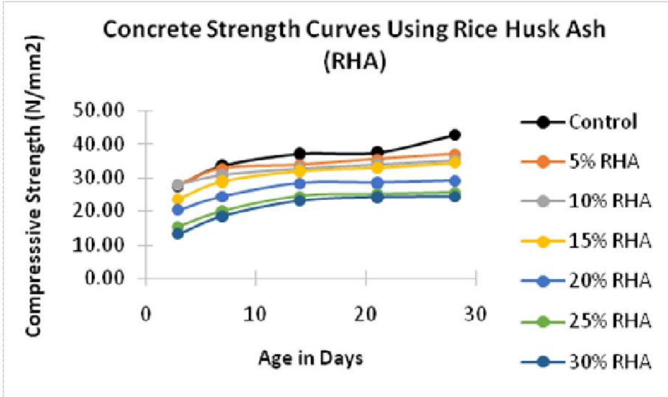


Fig. 6D. The relationship between compressive strength and age for RHA concrete from Adikpo

Conclusion

From the results and values obtained, the Flexural strength properties were found to compare favourably with those obtained for the controlled concrete. Therefore, it can be deduced that concrete with RHA as an admixture can be used for structural purposes provided the proportion or percentage replacement is followed as confirmed from the Laboratory work. From the findings, the strength values were found to increase with an addition of 5 to 15% RHA replacements and decreases with an increase in the percentage of RHA from 25-30% replacements. RHA enhances the strength of concrete when used to partially replace cement. RHA is a natural pozzolan and an annual renewable source of silica. The strength values are affected by the efficacy of RHA which is believed to be primarily due to the variability in their pozzolanic properties based on the locations they are found.

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