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Effects of source location on the pozolannic properties of Rice Husk Ash (Rha) and strength properties of concrete

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Abstract

This paper presents the effects of variability in the chemical and elemental composition of Rice Husk Ash (RHA) sourced from four (4) different locations on Tensile Properties of Concrete. RHA is an agricultural waste gotten from rice mills after removal of rice paddy for food and burnt in open air or under controlled processes. RHA is found to be pozzolanic and can be used to partially replace cement to enhance the strength and quality of concrete. 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 source 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, 70.11, respectively. RHA was used to replace cement in concrete at 5, 10,15,20,25 and 30%. The compressive strength was determined and the values are as follows; And the compressive strength values at 28 days was found to be in the range of 37-42N/mm2 at 5%RHA, 35-39.5N/mm2 at 10%RHA, 30-34.5N/mm2 at 15%RHA, 27-29N/mm2 at 20%RHA, 22-25.6N/mm2 at 25% RHA and 21-24N/mm2 at 30% RHA compared to the controlled sample with a strength value of 42.64N/mm2. Cylindrical columns concrete of size 100mm diameter by 200mm long were moulded and stored in water for 28 days before testing for tensile splitting strength. The values determined from the split tensile test are as follows; 2.1-3.1N/mm2 at 5%RHA, 2.1-2.5N/mm2 at 10% RHA, 1.8-2.10 N/mm2 at 15% RHA, 1.2-1.7 N/mm2 at 20%RHA, 1.1-1.3 N/mm2 at 25% RHA and 0.62-0.9 N/mm2 at 30% RHA while the results of the controlled sample is 3.1 N/mm2.From the results above it can be deduced that source location influences the chemical properties of RHA strength characteristics of the Concrete with RHA as partial replacement.

Keywords: Rice Husk Ash (RHA); Pozolannic, strength; Concrete

1. Introduction

Tensile strength is the physical property of different building materials and how they can withstand tension or how a material resists being elongated of stretched by forces such as wind and gravity. Tensile strength is important because it guides professionals to build high rise buildings which subjected to more extreme weather conditions due to their heights in a safe and efficient manner. This happens because the higher the building, the more it interrupts wind currents that are not noticeable from the ground and in higher altitudes as well, the air current is much stronger and unimpeded, leading to harder and faster winds. To make sure that structures stand the test of time, gravity and wears-and-tears, engineers will choose materials with high tensile strength. Concrete is much cheaper and easier to source, and a high compressive strength its tensile strength is not the best because of its brittle nature therefore, when used in high rise buildings must be reinforce adequately. Hence, the need to study and investigate tensile strength of concrete.

Akeke [3] though static tensile loads on concrete members are avoided, it is difficult to isolate concrete members from dynamic tensile stresses. The propagation of tensile stress wave in structural members is generated by explosives,

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impingement of projectiles, earthquakes, and so on. At a time when a concrete structure comes under dynamic loading, two different modes of failure should be distinguished: local effects and the global effects on the structure.

The relationship between the tensile and compressive strength properties of roller compacted concrete (RCC) have been studied by Obam,[9]. In their study, the difference between the indirect tensile strengths of the RCC and those of the conventional concrete and the relationship equations to evaluate the compressive and tensile strengths was developed. More so, regression equations were developed to estimate the indirect tensile strengths, which are known as flexural and splitting tensile strengths, using the compressive strength of the RCC.

Mauro [5], Compressive and tensile strengths of concrete are important parameters utilised in the analysis and design of concrete members. Although, classification of concrete in most national and international design codes are often based on the compressive strength, while other mechanical properties such as tensile strength, modulus of elasticity and compressive strain are expressed as a function of the compressive strength. Several theoretical and empirical models have been developed to predict the splitting tensile strength of concrete based on its compressive strength.

Akeke [1], studied the structural properties of Rice Husk Ash (RHA) Concrete, the Flexural strength studies indicate that there is a marginal improvement with 10 to 25% RHA replacement levels. Rice Husk Ash concrete possess a number of good qualities that make a durable and good structural concrete for both short-term and long-term considerations and good for structural concrete at 10% replacement level.

Ukpata [14] Studied the flexural properties of Lateritic sand and quarry dust as fine aggregate and 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 $F = \frac{P}{A}$ (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 is given by f_{cf} (in N/mm2)

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

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 [5]. RHA is found in abundance globally and ways of disposing of this material are been sort.

[2]and [10], there is an increasing importance to preserve the environment in the present day world. 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 since it is rich in Silica and has about 85% to 90% Silica content.

Narayan, [7] 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 is highly durable to chemical attacks, abrasion and reinforcement corrosion. Pozzolans are not just “filler” but a strength and performance enhancing additive.

[9] 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).

[8] 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.

According to [11], the principal binder in concrete is Portland cement, the production of which is a major contributor to greenhouse gas emissions that are implicated in 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.

Sumrerng, [12] 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.

According to [3], 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.

The tensile strength of concrete can be determined from three types of tests: direct pull tests on briquettes and bobbins, modulus of rupture tests on beams, and splitting tensile tests. There are many technical difficulties in executing a true tensile strength test. A uniform stress distribution which makes it possible to calculate the true tensile strength is difficult to obtain. The method commonly used to determine tensile properties of concrete is the flexural beam test by third-point loading on a beam over a span. The flexural strength is calculated from the bending moment at failure, assuming a straight line stress distribution according to Hooke's law. This is not entirely true; however, the calculated flexural strength may be about twice as high as the true tensile strength. The beam test has the advantage that the end pieces of the broken beam can be used to determine the compressive strength of the concrete. These compressive strength results, however, probably differ more from the actual strength of the field concrete than from the compressive strength based on standard cylindrical specimens.

2. Material and methods

2.1. 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 the country these are; Adani in Enugu state, Ogoja in CRS, Abakaliki in Ebonyi and Adikpo in Benue State. They were burnt in open air and the ash collected and stored in dry area in the laboratory. Chemical analysis was conducted on the ashes to determine the elemental composition of each ash

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

2.2. 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.

2.3. 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.

2.4. Water

Water plays an important role in concrete production (mix) in that it starts the reaction between the cement and the aggregates. It helps in the hydration of the mix. In this project, the water used was Pipe borne water and free from contaminants.

3. Compressive Strength Test.

3.1. Cube Test

The test was carried out in accordance with BSEN 206, 2001 Part 3. The samples were Prepared and concrete well mixed 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 (BS 1881-118; 1993).

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 500*100*100mm 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 3.3. The load applied without shock at a rate of 200m/

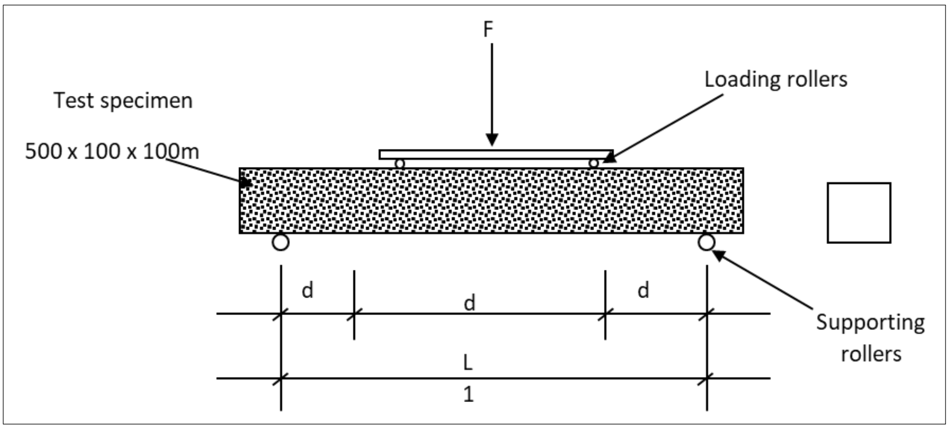

Figure 2 Arrangement of loading (2-point loading) for flexural strength

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

The flexural strength is given by

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

Where

F = Is the breaking load (N?)

D1 and d_2 are the lateral dimensions of the cross-sections (mm)

L is the distance between the supporting rollers (mm)

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

4. Results and discussion

4.1. Physical properties of materials.

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.

Table 1 Particle Size Distribution Results of the Various RHA and Cement

Sieve Size	%Passing Adani	%Passing Abakaliki	% Passing Ogoja	% Passing Obubra	% Passing Adikpo	% Passing Vandikiya	% Passing Makurdi	% Passing OPC
2.36	100	100	100	100	100	100	100	100
1.18	100	100	100	100	100	100	100	100
600	94	98	93.2	90	100	100	98	100
425	80	90	85	85	90	95	82	100
300	50	55	55	60	60	52	51	80
212	45	45	43.6	40	50	49.5	41	35
150	25	30	27.4	25	30	35	30	22
63	5	4	7.4	8	9	7.5	5.5	4
Pan	0	0	0	0	0	0	0	0

4.2. Rsults of the Chemical Analysis on Rha and Cement Is Shown In

Table 2 Chemical Composition of Rha

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	0.75	84.5	0.3	0.25	0.69	0.43	0.45	0.51
	E0477210, N0729822								
4	VANDIKYA	0.6	68.4	0.23	0.21	0.73	0.6	0.5	0.25
	E0507062, N0750072								
5	RHA-ABAKALIKI	0.2	76.3	0.25	0.09	0.27	0.2	0.03	0.16
	E0405465, N0697514								
6	ADIKPO	0.37	70.1	0.28	0.18	0.41	0.27	0.2	0.22
	E0525472, N0760211								
7	OBUBRA	0.45	74.7	0.31	0.23	0.48	0.32	0.44	0.38
	E0418329, N0661377								
8	MAKURDI	0.54	70.6	0.34	0.15	0.44	0.52	0.36	0.41

4.3. RESULTS OF THE DENSITIES.

4.3.1. Density

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 3-5

Table 3 Density Values for Various RHA Concrete Mixes from Ogoja, CRS

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

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

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

Table 5 Density Values for Various RHA Concrete Mixes from Adani, EBS

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

4.4. Results of compressive strengths

Concrete cubes were prepared from different samples of RHA concrete using 5, 10,15,20,25 and 30% replacements of ordinary Portland cement. The results are graphically presented in the figures 6A-D

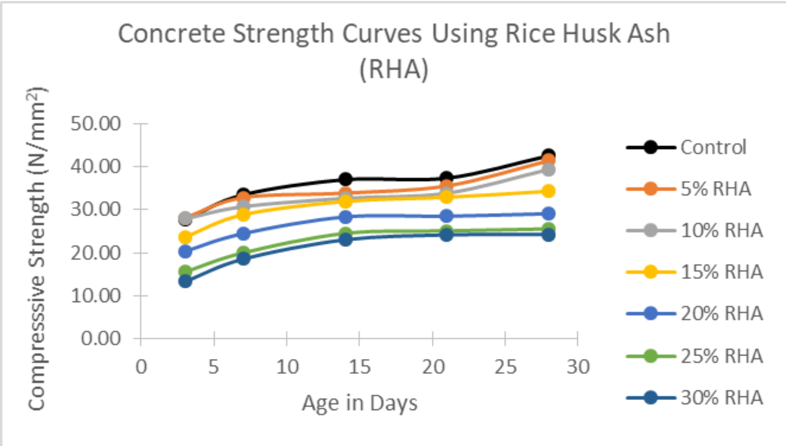

Figure 5 the relationship between compressive strength and age for RHA concrete from Ogoja CRS

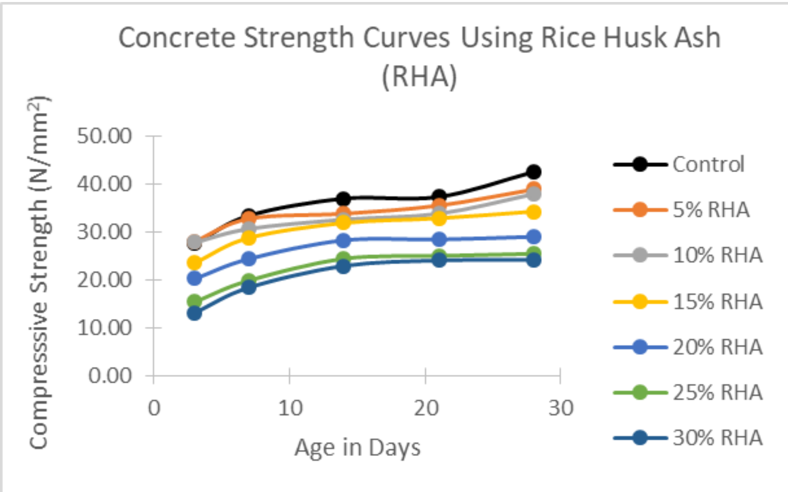

Figure 6 The relationship between compressive strength and age for RHA concrete from Abakaliki EBS

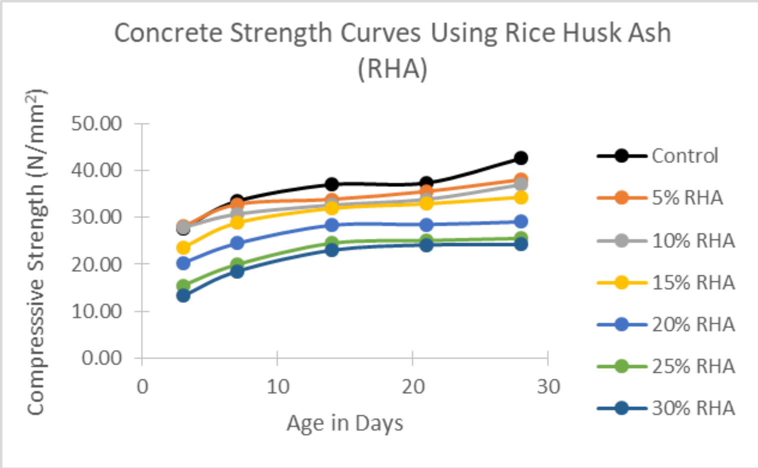

Figure 7 The relationship between compressive strength and age for RHA concrete from Adani ES

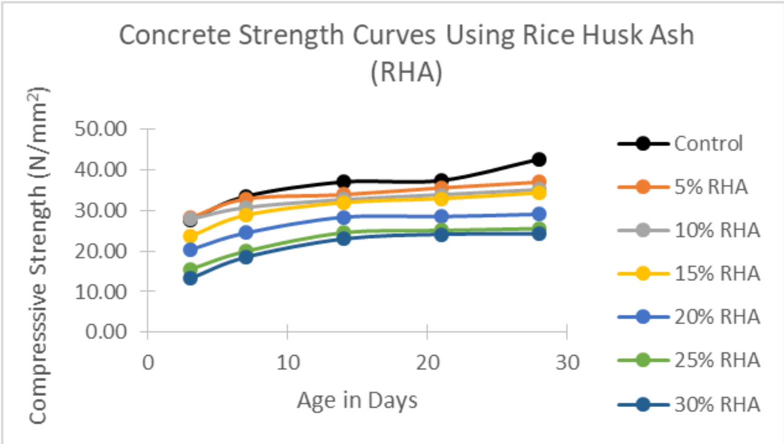

Figure 8 The relationship between compressive strength and age for RHA concrete from Adikpo BS

4.5. 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 6

From the results above 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. 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.

Table 6 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

5. 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.

Compliance with ethical standards

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