Influence of Elemental Variants of Rice Husk Ash (RHA) On Concrete Strength and Modulus of Elasticity

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Abstract: - This paper presents the effects of differentials in the elemental composition of Rice Husk Ash (RHA) sourced from four (4) locations on the compressive strength and modulus of elasticity of Concrete. The modulus of elasticity of concrete is a measurement of the stiffness of the concrete which is a good indicator of strength. RHA was sourced from four locations of Ogoja, Abakaliki, Adani and Adikpo in Nigeria and their silica content 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 values at 28 days 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 while the controlled sample had a strength value of 42.64N/mm^2. Short Cylindrical columns were cast and tested for tensile strength. The values of the tensile test are as follows; 3.15-3.7N/mm^2 at 5%RHA, 2.41-2.75 N/mm^2 at 10% RHA, 2.0-2.40 N/mm^2 at 15% RHA, 1.9-2.0 N/mm^2 at 20%RHA, 1.26-1.85 N/mm^2 at 25% RHA and 0.90-1.2 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 the location source and the chemical elemental variants of RHA based on location affects the strength of concrete and its modulus of elasticity.

Key Words: — ***RHA, Elements, Variants, Strength, Modulus of Elasticity.***

I. INTRODUCTION

The modulus of elasticity of concrete is a measurement of the stiffness of the concrete which is a good indicator of strength or modulus which is determined by the maximum load that can be attained.

In China, the tensile properties of cement-stabilized with macadam or pozzolans reinforced with polypropylene fibre have been studied by Zhang, [1]. Tensile properties of concrete are important to the design engineers to serve as a measurement of the stiffness of the concrete which is a good indicator of strength.

Ukpata, [2]. Studied the tensile properties of Lateritic sand and quarry dust as fine aggregate and their results compared favourably with normal concrete at 25-50 % replacements.

Manuscript revised December 30, 2021; accepted December 31, 2021. Date of publication January 02, 2022.
This paper available online at www.ijprse.com
ISSN (Online): 2582-7898; SJIF: 5.494

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. The modulus of elasticity of a material is given by f_t (in N/mm2)

$$f_t = \frac{2F}{\pi L d} \quad (2)$$

Where:

F=The maximum breaking load (in N)

L=The length of the test specimen (in mm) and

d=The cross-sectional dimension of the test specimen (in mm)

Tensile strength is expressed to the nearest 0.1N/mm.

According to [3]. RHA is found in abundance globally and ways of disposing of this material are been sort.

[4] and [5], 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, [6] 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.

[7] 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 [9], 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, [10] 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 [11], 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, [12], 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 0.95 to 3.8 million tons, if volcanic ash or RHA were substituted for OPC at a 25% level, and from 240,000 to 874000 tons if diatomaceous earth was substituted for OPC at 6.25.

II. MATERIALS 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.

Fig.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.

2.5 Compressive Strength Test

2.5.1 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 15Nmm2 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.

2.5.2 Split Tension Test (BS1881-117 1983)

This test was carried out as specified in BS1881 0117 Cylindrical concrete specimens of size 100mm diameter by 200mm long were moulded and stored in water for 28 days before testing for tensile splitting strength. The automatic universal testing machine was used for the test. Three similar samples were prepared for each mix proportion used. The casting was made by filling each mould with freshly mixed concrete in two layers of approximately 100mm thickness. Each layer was compacted manually using a 25mm diameter steel rod to give 35 strokes of the tamping rod on each layer.

The hardened concrete specimen was then placed on the universal testing machine and supported longitudinally with hardboard packing strips carefully positioned along the top and bottom of the pan of loading of the specimen. The specimen was positioned centrally before application of load without shock at a rate of 400N/s. The tensile splitting strength was calculated as shown by Equation 3.2 in accordance with BS 1881-117.

$$f_t = \frac{2F}{\pi L d} \qquad (3)$$

Where:

F=The maximum breaking load (in N)

L=The length of the test specimen (in mm) and

d= The cross-sectional dimension of the test specimen (in mm)

The results of the above laboratory demonstration are shown on table 4.7 in chapter 4 of this research work.

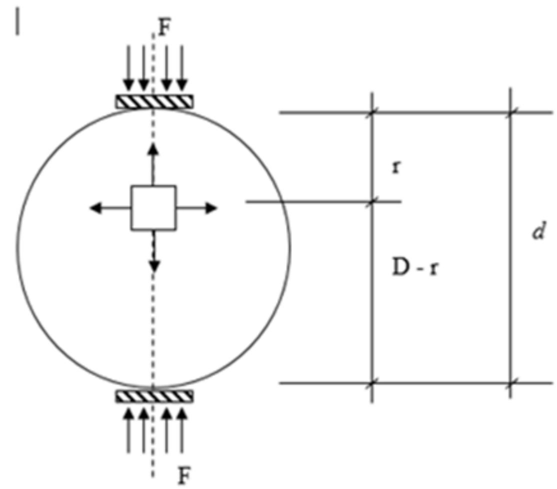

Fig.2. Arrangement of loading for splitting test

The vertical compressive strength can also be calculated from

$$f_c = \frac{2FL}{\pi}\left(\frac{d^2}{r(d-r)}\right) \qquad (4)$$

Where

F= Compressive load on the cylinder

L = Length of Cylinder

D=diameter of the cylinder

R and (d-r)=distances of the element from the two loads

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

Fig.4. Experimental set up for Split Tension Test

III. RESULTS AND DISCUSSION

3.1 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

Results Of The Chemical Analysis On Rha And Cement Is Shown In Figures 4 To 11.

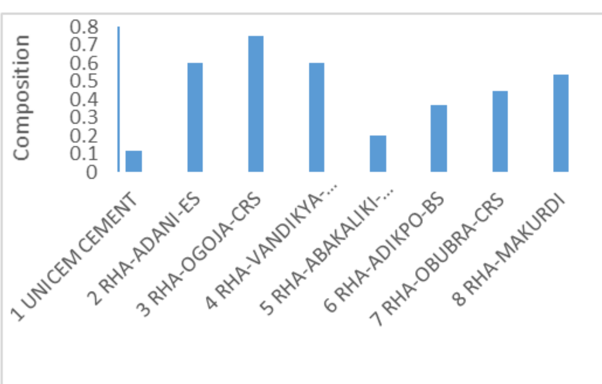

Fig.5. Percentage composition of zinc oxide in cement and RHA from the seven locations

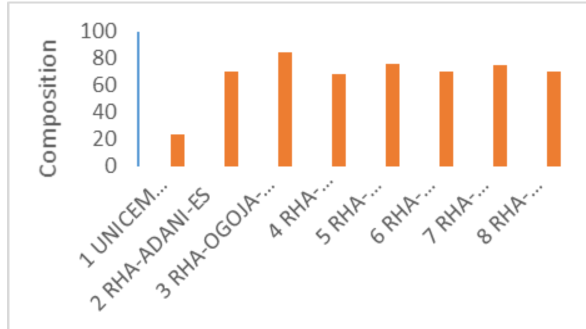

Fig.6. Percentage composition of silicon oxide in cement and RHA from the seven locations

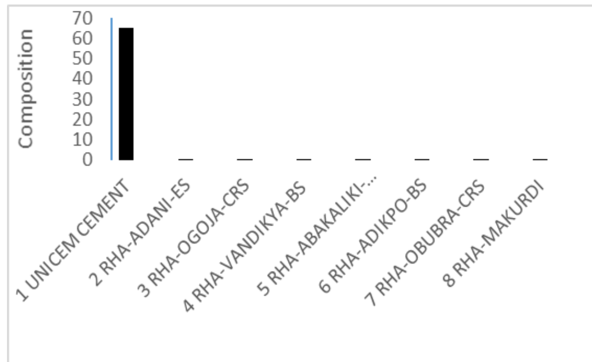

Fig.7. Percentage composition of calcium oxide in cement and RHA from the seven locations

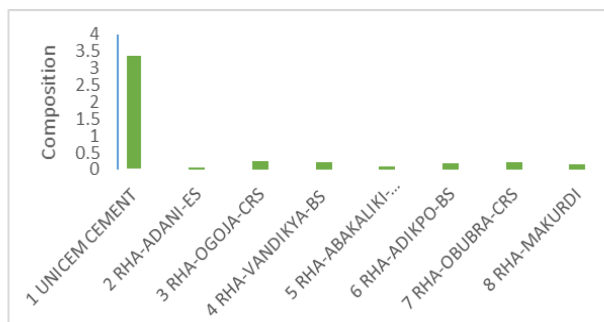

Fig.8. Percentage composition of iron oxide in cement and RHA from the seven locations

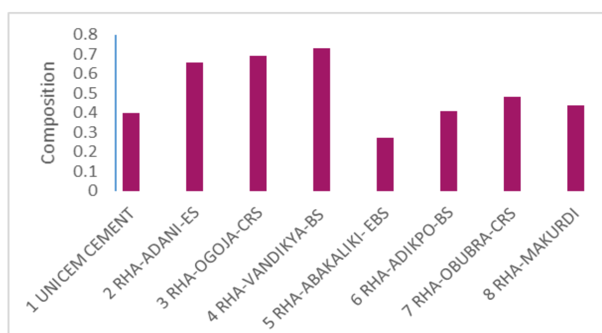

Fig.9. Percentage composition of potassium oxide in cement and RHA from the seven locations

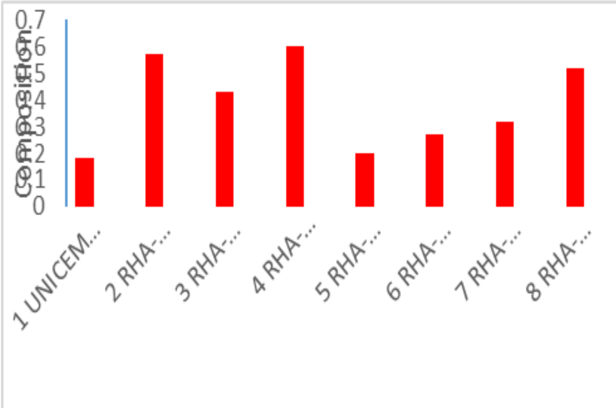

Fig.10. Percentage composition of manganese oxide in cement and RHA from the seven locations

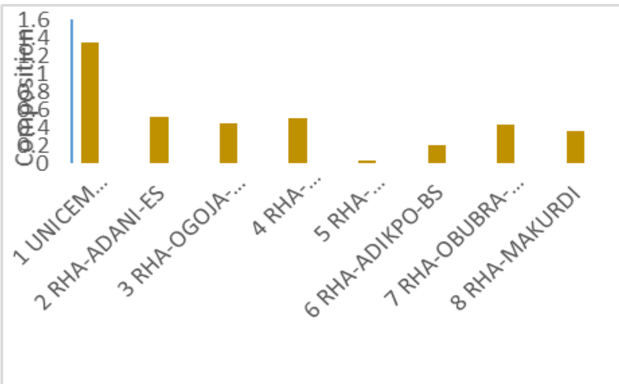

Fig.11. Percentage composition of Magnesium Oxide in Cement and RHA from the seven locations

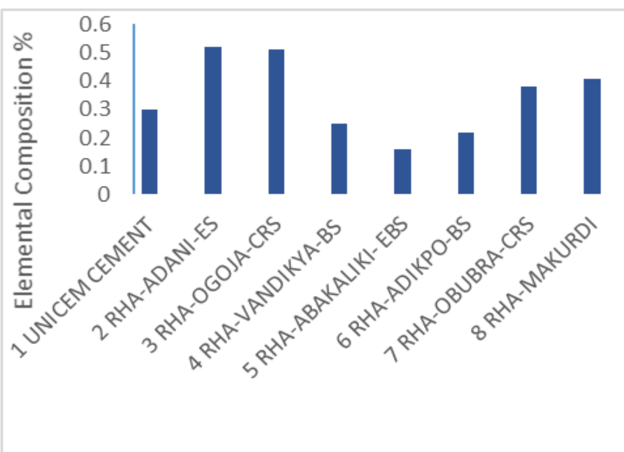

Fig.12. Percentage composition of Magnesium Oxide in Cement and RHA from the seven locations.

IV. RESULTS OF THE DENSITIES

4.1 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 2 to 5.

Table.2. 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/m³	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.3. Density Values for Various RHA Concrete Mixes from Abakaliki

	Age	Percentage Replacement with RHA					
		5%	**10%**	**15%**	**20%**	**25%**	**30%**
Average Densities of RHA Concrete in KN/m³	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.4. Density Values for Various RHA Concrete Mixes from Adani.

	Age	Percentage Replacement with RHA					
		5%	**10%**	**15%**	**20%**	**25%**	**30%**
Average Densities of RHA Concrete in KN/m³	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

Table.5. Density Values for Various RHA Concrete Mixes from Adikpo, BS.

	Age	Percentage Replacement with RHA					
		5%	10%	15%	20%	25%	30%
Average Densities of RHA Concrete in KN/m³	3	2344.30	2293.73	2307.36	2282.86	2269.63	2223.41
	7	2340.94	2301.93	2267.06	2272.59	2214.62	2228.84
	14	2362.57	2319.01	2318.42	2288.69	2262.12	2242.57
	21	2356.44	2335.31	2331.65	2317.04	2272.10	2253.53
	28	2324.25	2345.68	2344.69	2274.17	2296.20	2263.70

V. 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 13 to 16.

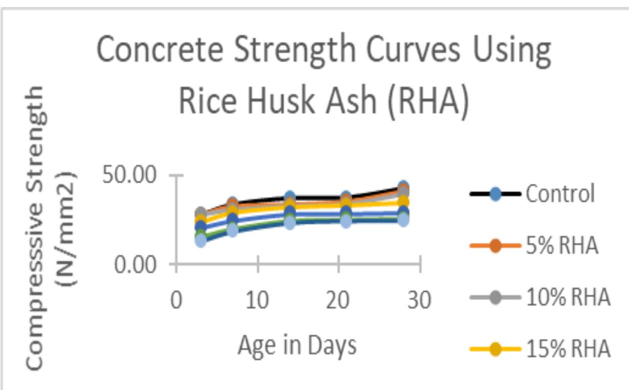

Fig.13. The relationship between compressive strength and age for RHA concrete from Ogoja.

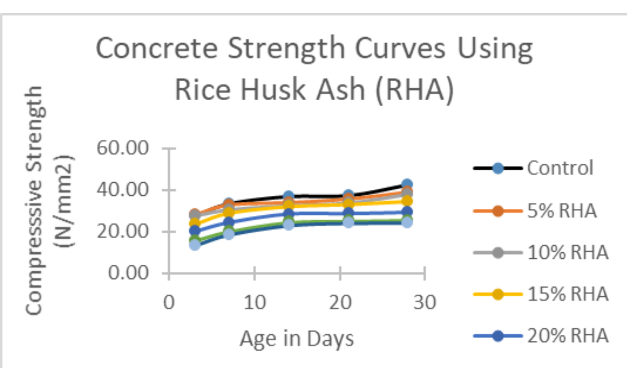

Fig.14. The relationship between compressive strength and age for RHA concrete from Abakaliki.

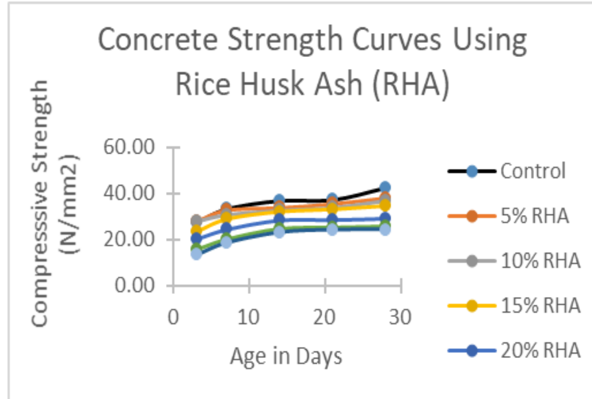

Fig.15. The relationship between compressive strength and age for RHA concrete from Adani.

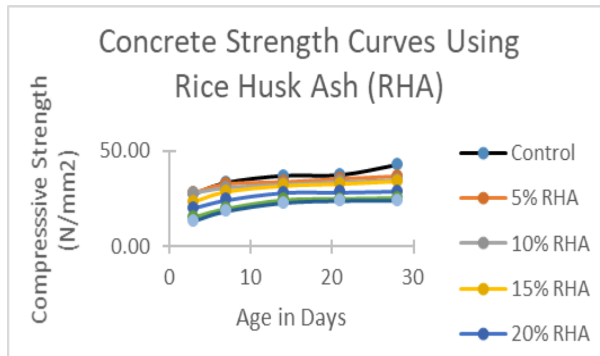

Fig.16. The relationship between compressive strength and age for RHA concrete from Adikpo.

VI. SPLIT TENSION TEST RESULTS

The results of our investigations on the 28days RHA concrete are presented in Tables 6 to 9 below. From the results, it can be seen that the tensile strength results are similar at all replacement percentages which is in line with the projections of [8]. The failure mode of the split tension test described in section 3 is vertical through the centre of the plane of testing which is an indication of the concentration of the tension force on the sample.

Table.6. Results of the split tension test on samples of Ogoja RHA Concrete.

%	P(N)	P_{ct} (N/mm^2)
control 0	95000	3.023943919
control 0	96600	3.074873501
control 0	84600	2.692901637
5	96800	3.081239698
5	89000	2.832957987
5	89700	2.855239679
10	66000	2.100845249
10	77500	2.466901618
10	77200	2.457352321

15	68100	2.167690325
15	58100	1.849380439
15	67300	2.142225534
20	42100	1.340084621
20	52100	1.658394507
20	51800	1.64884521
25	40200	1.279605742
25	41000	1.305070533
25	40000	1.273239545
30	18300	0.582507092
30	28800	0.916732472

Table.7. Results of the split tension test on samples of Abakaliki RHA Concrete.

% Composition of RHA	P(N)	$P_{ct}(N/mm^2)$
control 0	95000	3.023944
control 0	96600	3.074874
control 0	84600	2.692902
5	75000	2.387324
5	71350	2.271141
5	87800	2.794761
10	66810	2.126628
10	69500	2.212254
10	68500	2.180423
15	58100	1.84938
15	58100	1.84938
15	66300	2.110395
20	38100	1.212761
20	41800	1.330535
25	38200	1.215944
25	40000	1.27324
30	28800	0.916732
30	29000	0.923099

Table.8. Results of the split tension test on samples of Adani RHA Concrete

% Composition of RHA	P(N)	$P_{ct}(N/mm^2)$
control 0	95000	3.023943919
control 0	96600	3.074873501
5	75000	2.387324146
5	87800	2.794760801
10	66810	2.12662835
10	68500	2.18042272
15	58100	1.849380439
15	58100	1.849380439
15	66300	2.110394545
20	42100	1.340084621
20	41800	1.330535324
25	38200	1.215943765
25	40000	1.273239545
30	20300	0.646169069
30	29000	0.92309867

Table.9. Results of the split tension test on samples of Adikpo RHA Concrete

% Composition of RHA	P(N)	$P_{ct}(N/mm^2)$
control 0	95000	3.023944
control 0	84600	2.692902
5	65000	2.069014
5	64500	2.053099
10	60000	1.909859
10	68600	2.183606
15	60000	1.909859
15	59700	1.90031
20	41200	1.311437
20	41800	1.330535
25	38200	1.215944
25	40000	1.27324
30	21800	0.693916
30	29000	0.923099

VII. CONCLUSION

From the results and values obtained, the Tensile strength properties were found to compare favorably 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 location of RHA which is believed to be primarily due to the differential in their elemental composition and properties.

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