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Optimization of the Structural Properties of RHA-Concrete Using Osadebe's Mathematical Program

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Abstract

This research work focused on the analyses of the compressive strength, modulus of rupture and elasticity of RHA-concrete that was gathered from four states in Nigeria (Cross River, Ebonyi, Enugu, and Benue). The results were calculated and compared geographically by using Osadebe's mathematical program. They had corresponding relative silica values of 85, 75, 1, 65, 2, and 60.1. In place of cement, RHA was utilized in concrete at different percentages of replacement in the concrete. The results showed that strength values increased as RHA replacement increased by 5% - 15% and decreased as the percentages of RHA in the concrete increased. When RHA is utilized to partially replace cement in concrete, the strength is improved. RHA is a yearly supply of silica and a naturally occurring pozzolan. The Compressive strength values varied between 37 and 42 N/mm^2. The elastic modulus of a short cylinder obtained was between 3.15 and 3.7 N/mm^2. It was discovered that the rupture modulus ranged from 0.6 to 4.2 N/mm^2. Mathematical prediction models employing Osadebe's method were created. The findings confirmed that there were differentials in the results and laboratory responses of RHA concrete based on spatial properties, Fisher's statistical tool was used to confirm the adequacy of the model and the mean values, variance and critical values were found satisfactory for the 10 observation points.

Keywords

Compression, Flexure, Tension, Optimization, Pozzolans

1. Introduction

The structural properties of concrete are of great concern to engineers and members of the building industry globally and ways are sought how to improve the performance of concrete as well as new approaches to its preparation and possible eco-friendly and naturally occurring additives to enhance concrete performability. The compression strength of concrete determines its ability to resist forces that pressurize it. Concrete specimens were prepared and tested for compression, tension and flexure this was to evaluate their strength properties. RHA samples from several places were used to produce concrete, which had a variety of strengths and properties. Okere *et al.* [1] examined the models used to calculate the flexural strength of concrete. To create the model for their study's optimization of the concrete's modulus of rupture, Osadebe's mathematical software was utilized. One of the agricultural wastes, rice husk, contains a significant amount of silica and is used in concrete to increase strength, decrease permeability, minimize heat evolution, and increase production. Portland cement, the primary binder in concrete, is a significant source of greenhouse gas emissions during production [2].

In their investigation of the impact of RHA on the geotechnical features of lateritic soils, Okafor and Ugochuku [3] showed that the addition of RHA to soils is beneficial for sub-grade applications because it decreases flexibility, increases volume stability, and increases the strength of the soil. They proposed that 10% RHA would offer the best replacement percentage in lateritic soil. In a suitable environment, adding RHA to cement will improve the properties of residual soil.

RHA is utilized by Ajay *et al.* [4] to control insect pests in stored food products, to purify water, to deodorize flue gases, and as absorbent. Additionally, it has been investigated for its possible use in water filtration, and attempts have been made to use RHA in the vulcanization of rubber. The effectiveness of RHA as an oil spill absorbent, flame retardant, waterproofing agent, pesticide, insecticide, and in industrial applications has been demonstrated.

Anya *et al.* [5] constructed statistical models that predicted the compressive strength and water absorption of sand-quarry dust blocks using Scheffe's simplex lattice design. They expressed the components' pseudoratios, which had to be transformed to their actual component ratios, and utilized the models to examine how the mixture components interacted with one another.

Obam [6] discovered that the third-degree polynomial predicts strength with an accuracy that is roughly 21% higher than the second-degree polynomial. This suggests that higher-order polynomials, which are laborious and time- consuming, are not required unless more accurate results are required. As a result of its great accuracy, the second-degree polynomial can be used in the majority of situations.

Orie and Osadebe [7] showed that concrete can be a five-component material with mound soil selected at random as the fifth component, and it is one of the most adaptable materials used in the construction industry today. Its constituents, which always decide the price, are primarily comprised of aggregates.

In the work of Akeke [8] asserted that using RHA as a building material would help with waste management, increase environmental sustainability and protection, and raise RHA's economic value. Additionally, [9] when the tensile properties of lateritic sand and quarry dust as fine aggregates were examined, the researchers found that the results were good and within the acceptable range when 25% - 50% of conventional concrete was altered.

According to Akeke [10], RHA is widely dispersed around the world, although removal techniques have been created. The need to preserve the environment and people from harm is growing in importance in the modern world [11] [12]. RHA from the parboiling facilities poses a serious environmental risk. Hence disposal options are being examined. This stuff is a real super pozzolan. It contains between 85% and 90% silica. The workability, strength, and imperviousness of concrete mixtures can be significantly increased by adding these super-pozzolanic materials, even in small amounts (5% to 10% replacements for cement). As a result, the concrete is very resistant to chemical deterioration, abrasion, and corrosion of the reinforcing steel. There are numerous additional benefits to using these super-pozzolanic materials. Pozzolans are not only "filler", but rather a supplement that boosts strength and efficiency.

The total composition of RHA, according to Padma Rao [13], is 73.15% silicon dioxide (SiO_2), iron III oxide (Fe_2O_3), and aluminum oxide (Al_2O_3), which is higher than the minimum of 70% needed by American standard for testing materials (ASTM) C618-78 (1978).

The functionality, strength, and impermeability of concrete mixtures can be significantly improved by adding even small amounts of these super-pozzolanic elements (5% to 10% replacement of cement), according to a study by Narrayan [11]. Concrete is hence particularly resistant to abrasion, chemical attacks, and corrosion of the reinforcing metal. Pozzolans are not only "fillers", but also supplements that boost strength and efficiency.

Due to its accessibility and high silica content, rice husk is one of the agricultural waste products that are most suited for usage as a pozzolanic material, according to Tashima [12]. Portland cement serves as the main binder in concrete, and its manufacture contributes significantly to greenhouse gas emissions related to the construction industry. By adding RHA to concrete, workability, heat evolution, permeability, and strength were all increased.

Padma Rao [13] claimed that using alternative fuels, improving the energy efficiency of cement plants, and using materials other than limestone-based clinker (5 cm) can reduce environmental pollution brought on by the emission of CO_2 into the atmosphere during the production of clinker or limestone.

According to Oyetola, *et al.* [14], the total anthropomorphic CO_2 emissions could be reduced from 0.95 to 3.8 million tons if volcanic ash or RHA were substituted for OPC at a 25% level; from 240,000 to 874,000 tons if diatomaceous earth was substituted for OPC at a 6.25 level and if natural pozzolans were used to build spring boxes or gravity-fed water systems for the billion people without access to clean drinking water worldwide.

Again, according to Niville and Brooks [15], the form of the aggregate affects the quality of concrete and the tension at which substantial cracking starts.

Smooth gravel cracks more easily than crushed aggregate that is angular and rough. Therefore, crushed aggregate was chosen for this project.

According to [16], the minimal amount required to be regarded as successful in limiting expansion to the level produced by the control sample with Lime Stone cement, test mixtures with various percentages of the natural pozzolan (RHA) were created. Natural pozzolan should make up at least 15% of the weight of the cementitious material.

In order to address some research gaps. This research aims to determine the potential structural applications of concrete made with RHA as a partial substitute for LSC. RHA is suitable for use in construction due to its effectiveness as a concrete filler. To transform agricultural waste into beneficial forms will improve the economy and address the issue of excessive building costs by reducing the cost of concrete. The models that are created will simplify mix designs by addressing issues with trial mixes, eliminating experimental errors, improving precision in experimental work, giving communities where RHA have located a source of income, and giving the local populace jobs.

2. Materials and Methods

RHA: Rice Husk Ash (RHA) with a high silica content was used in this investigation. Four different locations across the country—Adani in Enugu State, Ogoja in the South-Southern area, Abakaliki in Ebonyi State, and Adikpo in Benue State—provided the rice husks. They were burned outside, and the ash was gathered within the building and kept dry. Chemical analysis was used to determine each ash's elemental composition.

Ordinary Limestone cement (LSC), whose composition and qualities meet the established specifications for cement used in concrete production, was obtained from a UNICEM mill.

Coarse Aggregate: Granite with a maximum particle size of 5 - 20 mm was used in this study. It was thoroughly inspected to make sure there were no harmful materials present.

Water: Because it starts the contact between the cement and particles, water is essential for the production of concrete. The mixture is hydrated with its help. In this investigation, pipe-borne water that was contaminant-free was used.

2.1. Compressive Strength Test

In compliance with BSEN 206, 2001 Part 3, the test was conducted. The samples were ready, and three layers of vibrated concrete were added to the mould after the concrete had been thoroughly mixed to obtain a uniform mix. The samples were then crushed or tested immediately after being removed from the curing tank using a constant rate of stress rise of 15 N/mm^2, demolded 24 hours later, and then cured at 20˚C for 7, 14, 21, and 28 days.

Concrete's compressive strength is fundamentally related to the desired level of quality and strength. The most practical application of the equation to determine and evaluate the quality of hardened concrete is compression strength.

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

P stands for the crushing load, and A for the cross-sectional area of the cube. The equation for an object's elastic modulus = f_t (in N/mm^2)

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

where F is the highest breaking force (in N), FL is the test specimen's length in millimeters, and d is the size of its cross-section, the tensile strength is stated to the nearest 0.1 N/mm.

2.2. Osadebe's Method

Concrete is a multivariate unit mass whose strength is influenced by changes in the quantity of its component parts, as Osadebe's research [17] demonstrated. A regression equation was also used by him as an experimental model. When describing the reaction Y, the amounts of the elements Z in the combination were employed, where the sum of all proportions equals one.

$$Z_1 + Z_2 + \cdots + Z_q = \sum_{i=1}^{q} Z_i = 1 \quad (3)$$

q = total number of mixture components;

Z_i = represents their relative fraction.

$$Z^{(k)} = \left[Z_1^{(k)}, Z_2^{(k)}, Z_3^{(k)}, Z_4^{(k)} \right]^{\mathrm{T}} \quad (4)$$

$$\begin{bmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_{10} \end{bmatrix} = \begin{bmatrix} Z_1^{(1)} & Z_1^{(2)} & \cdots & Z_1^{(10)} \\ Z_2^{(1)} & Z_2^{(2)} & \cdots & Z_2^{(10)} \\ Z_3^{(1)} & Z_3^{(2)} & \cdots & Z_3^{(10)} \\ Z_4^{(1)} & Z_4^{(2)} & \cdots & Z_4^{(10)} \end{bmatrix} \begin{bmatrix} y^{(1)} \\ y^{(2)} \\ \vdots \\ y^{(10)} \end{bmatrix} \quad (5)$$

Z_i^k = Variable I's weight in the kth experimental run;

Variable I's overall weight in the kth experimental run.

$$\begin{aligned} Y = {} & \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_3 + \beta_4 Z_4 + \beta_{12} Z_1 Z_2 + \beta_{13} Z_1 Z_3 \\ & + \beta_{14} Z_1 Z_4 + \beta_{23} Z_2 Z_3 + \beta_{24} Z_2 Z_4 + \beta_{34} Z_3 Z_4 \end{aligned} \quad (6)$$

Equation (6) is the mathematical model based on Osadebe's second degree regression method.

3. Presentation and Discussion of Results

Sand (fine aggregate) has a specific gravity of 2.8, whereas coarse aggregate has a specific gravity of 3.35. The specific gravity of RHA varies between 1.76 and 1.98. The cement has a specific gravity of 3.52.

3.1. Compressive Strengths

Concrete cubes were created utilizing limestone cement substitutions of 5%, 10%, 15%, 20%, 25%, and 30% from numerous samples of RHA concrete. Table 1 presents the findings. The results of the compressive strength test and replication using Osadebe's (4, 2) regression algorithms are shown in Table 1 and Table 2.

A transformation of the actual components (normal mix ratios) to meet the conditions necessary for Osadebe's second degree program and design matrix are shown in Table 3 and Table 4 while Table 5 and Table 6 are the transpose and inverse of the Z-matrix as contained in Table 7 which are the mix proportions.

Table 8 is a summary of my findings predicted strength values using Osadebe's second degree polynomials which agree with the laboratory responses as well as satisfying the required standard for structural concrete in Table 9.

Table 1. Compressive strength values for RHA samples Ogoja and Abakaliki.

Ogoja			Abakaliki		
Expt. NO. (RHA %)	Response YI (N/MM^2)	Y (N/MM^2)	Expt. NO. (RHA %)	Response YI (N/MM^2)	Y (N/MM^2)
5	34.14 36.96 36.08	35.72	5	41.25 41.0 40.0	40.75
10	31.22 24.01 28.74	27.99	10	33.15 35.0 35.78	34.64
15	23.93 22.41 22.96	23.10	15	17.00 19.00 24.50	20.17
20	17.87 19.61 17.23	18.23	20	18.00 17.20 16.00	17.10

Table 2. Compressive strength values for RHA samples Adani and Adikpo.

Adani			Adikpo		
Expt. NO. (RHA %)	Response YI (N/MM^2)	Y (N/MM^2)	Expt. NO. (RHA %)	Response YI (N/MM^2)	Y (N/MM^2)
5	30.00 30.00 32.00	30.67	5	40.64 34.49 38.03	37.72
10	23.61 25.65 24.64	24.63	10	31.49 31.75 30.42	31.22
15	18.84 20.17 19.10	19.37	15	20.08 20.17 20.52	20.26
20	17.00 17.00 19.00	17.67	20	16.5 15.8 17.0	16.43

Table 3. Actual (Z_i) and pseudo (X_i) components for Osadebe's (4, 2) simplex lattice.

S/N	Mix Ratios				Component's Fraction			
	S_1	S_2	S_3	S_4	Z_1	Z_2	Z_3	Z_4
1	0.35	1	1	2	0.08	0.229885	0.229885	0.45977
2	0.44	1	1.5	3	0.074	0.16835	0.252525	0.505051
3	0.45	1	2	3	0.07	0.155039	0.310078	0.465116
4	0.5	1	3	6	0.048	0.095238	0.285714	0.571429
5	0.43	1	2	4	0.058	0.13459	0.269179	0.538358
6	0.48	1	2.5	5	0.053	0.111359	0.278396	0.556793
7	0.51	1	4	6	0.044	0.086881	0.347524	0.521286
8	0.33	1	3	5	0.035	0.107181	0.321543	0.535906
9	0.55	1	2	5	0.064	0.116959	0.233918	0.584795
10	0.6	1	2.5	6	0.059	0.09901	0.247525	0.594059

Table 4. Control for Osadebe's (4, 2) simplex lattice.

S/N	Mix Ratios				Component's Fraction			
	S_1	S_2	S_3	S_4	Z_1	Z_2	Z_3	Z_4
11	0.55	1	1	2	0.121	0.21978	0.21978	0.43956
12	0.6	1	1.5	3	0.098	0.245902	0.245902	0.491803
13	0.44	1	2	4	0.059	0.134409	0.268817	0.537634
14	0.5	1	2.5	5	0.056	0.277778	0.277778	0.555556
15	0.4	1	3	6	0.038	0.096154	0.288462	0.576923
16	0.43	1	3.5	6.5	0.038	0.306212	0.306212	0.568679
17	0.35	1	4	7	0.028	0.080972	0.323887	0.566802
18	0.51	1	4.5	7.5	0.038	0.333087	0.333087	0.555144
19	0.48	1	4.8	7.6	0.035	0.072046	0.345821	0.54755
20	0.47	1	5	8	0.032	0.345543	0.345543	0.552868

Table 5. Table of Zt matrix.

S/N	Z_1	Z_2	Z_3	Z_4	Z_1Z_2	Z_1Z_3	Z_1Z_4	Z_2Z_3	Z_2Z_4	Z_3Z_4
1	0.09	0.235	0.241	0.46	0.018	0.018496	0.036993	0.052847	0.105694	0.105694
2	0.07	0.168	0.253	0.51	0.012	0.018706	0.037411	0.042513	0.085025	0.127538
3	0.07	0.155	0.31	0.47	0.011	0.021633	0.03245	0.048074	0.072111	0.144222
4	0.05	0.095	0.286	0.57	0.005	0.013605	0.027211	0.027211	0.054422	0.163265
5	0.06	0.135	0.269	0.54	0.008	0.015578	0.031157	0.036229	0.072457	0.144915
6	0.05	0.111	0.278	0.56	0.006	0.014881	0.029762	0.031002	0.062004	0.155009
7	0.04	0.087	0.348	0.52	0.004	0.015399	0.023098	0.030193	0.04529	0.181159
8	0.04	0.107	0.322	0.54	0.004	0.011373	0.018955	0.034463	0.057439	0.172317
9	0.06	0.117	0.234	0.58	0.008	0.015047	0.037618	0.027359	0.068397	0.136794
10	0.06	0.099	0.248	0.59	0.006	0.014704	0.035291	0.024507	0.058818	0.147044

Table 6. The inverse Z-matrix of Table 4.

Z_1	Z_2	Z_3	Z_4	Z_1Z_2	Z_1Z_3	Z_1Z_4	Z_2Z_3	Z_2Z_4	Z_3Z_4
50760.36	−110,020	36,980	−310,722	−519334.985	922457.9	−53973.4	29016.3	219307.5	−264,470
5413.457	−11,729	3794.1	−32,991	−53983.0315	96690.91	−5537.67	2977.072	22500.95	−27134.7
114.9767	−341.49	127.58	−442.87	−917.628116	1513.992	−64.768	34.81956	701.784	−725.404
193.9706	−464.45	173.81	−1010.6	−1879.62461	3256.507	−209.515	92.85216	921.0915	−1072.99
−89708.7	194,886	−64,811	550,058	912725.9204	−1,626,042	94593.74	−50,854	−384,358	463510.8
−38176.2	82,143	−27,585	235,923	392504.3854	−696,327	40,692	−22667.5	−164,451	197944.7
−60214.3	130,887	−44,134	366,597	615328.7412	−1,092,388	64094.36	−34041.9	−261,166	315037.1
−10594.8	23,168	−7558	63587.4	105968.8725	−189,131	10804.49	−5571.13	−45396.7	54722.7
−2069.13	4397.9	−1388	12,675	19943.07682	−35921.3	2034.306	−1192.57	−7807.35	9328.248
−678.567	1753.6	−653.6	3328.58	6221.183305	−10745.1	639.3391	−284.36	−3465.06	3883.936

Table 7. Z-Matrix of Osadebe's mix proportions.

S/N	Z_1	Z_2	Z_3	Z_4	Z_1Z_2	Z_1Z_3	Z_1Z_4	Z_2Z_3	Z_2Z_4	Z_3Z_4
CI	0.080	0.230	0.230	0.460	0.018	0.018	0.037	0.053	0.106	0.106
C2	0.069	0.168	0.253	0.505	0.012	0.019	0.037	0.043	0.090	0.128
C3	0.070	0.155	0.310	0.465	0.011	0.022	0.032	0.048	0.072	0.144
C4	0.050	0.095	0.286	0.571	0.005	0.014	0.027	0.027	0.054	0.163
C5	0.060	0.135	0.269	0.538	0.008	0.016	0.031	0.036	0.072	0.145
C6	0.055	0.111	0.278	0.557	0.006	0.015	0.030	0.031	0.062	0.155
C7	0.049	0.087	0.348	0.521	0.004	0.015	0.023	0.030	0.045	0.181
C8	0.040	0.107	0.322	0.536	0.004	0.011	0.019	0.034	0.057	0.172
C9	0.070	0.117	0.234	0.585	0.008	0.015	0.038	0.027	0.068	0.137
C10	0.064	0.099	0.248	0.594	0.006	0.015	0.035	0.03	0.065	0.147

Table 8. Summary of predicted strength values using Osadebe's second degree polynomials.

Parameters	Concrete Compression N/mm^2	Flexure N/mm^2	Tension N/mm^2
C1	24.52	3.21	4.2
C2	37.72	3.77	3.71
C3	19.57	3.45	3.25
C4	30.41	3.45	2.7
C5	23.52	2.5	3.9
C6	24.26	3.6	2.8
C7	26.10	4.5	3.5
C8	39.24	5.03	3.2
C9	33.20	5.03	3.33
C10	38.65	4.0	3.0

Table 9. Values of the regression coefficients and the laboratory responses.

β	Regression Coefficients	Laboratory Responses
β_1	3,265,660	40.99
β_2	33765.9	39.99
β_3	3820.453	30.07
β_4	11097.75	19.91
β_5	5,729,225	18.66
β_6	−2,471,994	22.95
β_7	−3,865,974	16.31
β_8	−661,169	17.43
β_9	123,759	17.90
β_{10}	−33934.7	16.54

The regression coefficients and laboratory responses as shown in Table 9 are the product of the inverse of Z-matrix and the laboratory responses.

3.2. The Osadebe's Regression Equation for the Structural Properties of RHA Concrete

Following are the values of the unknown coefficients for determining the compressive strength from the solution of Equation (7) given the responses in Table 8:

$$\beta_1 = 3265660, \beta_2 = 33765.9, \beta_3 = 3820.453, \beta_4 = 11097.75, \beta_5 = 5729225,$$
$$\beta_6 = -2471994, \beta_7 = -3865974, \beta_8 = -661169, \beta_9 = 123759, \beta_{10} = -33934.7$$

The regression equation is given by:

$$\begin{aligned} Ec = {} & 3265660Z_1 + 33765.9Z_2 + 3820.453Z_3 + 11097.75Z_4 \\ & + 5729225Z_1Z_2 - 2471994Z_1Z_3 - 3865974Z_1Z_4 \\ & - 661169Z_2Z_3 + 123759Z_2Z_4 - 33934.7Z_3Z_4 \end{aligned} \tag{7}$$

The regression equation's undetermined coefficients for the determination modulus of rupture are as following:

$$\beta_1 = -644781.1, \beta_2 = -66894.62, \beta_3 = -1436.54, \beta_4 = -2440.29, \beta_{12} = 1133237,$$
$$\beta_{13} = 485161.5, \beta_{14} = -765461, \beta_{23} = 132727.7, \beta_{24} = -24108.3, \beta_{34} = -8510.76$$

Applying Equation (7), the regression equation is given by:

$$\begin{aligned} Ec = {} & -644781.1Z_1 - 66894.62Z_2 - 1436.54Z_3 - 2440.29Z_4 \\ & + 1133237Z_1Z_2 + 485161.5Z_1Z_3 - 765461Z_1Z_4 \\ & + 132727.7Z_2Z_3 - 24108.3Z_2Z_4 - 8510.76Z_3Z_4 \end{aligned} \tag{8}$$

The unknown coefficients of the regression equation for the determination modulus of elasticity are as following;

$$\beta_1 = 1268384,\ \beta_2 = -131198,\ \beta_3 = -3049.74,$$
$$\beta_4 = -4962.78,\ \beta_{12} = 2227102,\ \beta_{13} = 952640.1,$$
$$\beta_{14} = 1507630,\ \beta_{23} = 261500.1,$$
$$\beta_{24} = -46803.39,\ \beta_{34} = -17491.04$$

$$Y = 1268384Z_1 - 131198Z_2 - 3049.74Z_3 - 4962.78Z_4 + 2227102Z_1Z_2 + 952640.1Z_1Z_3 + 1507630Z_1Z_4 + 261500.1Z_2Z_3 - 46803.39Z_2Z_4 - 17491.04Z_3Z_4 \quad (9)$$

Thus, Equations (7) - (9) are the mathematical models for the optimization of the structural features of RHA concrete based on Osadebe's regression and in agreement with the works of Anya, *et al.* [5].

Table 10. F-Statistics for the controlled points for the compressive strength based on Osadebe's (4, 2) Polynomial.

Response Symbol	Y_K	Y_E	$Y_k - \ddot{y}_k$	$Y_E - \ddot{y}_E$	$(Y_k - \ddot{y}_k)^2$	$(Y_E - \ddot{y}_E)^2$
C1	26.62	26.58	9.729014815	11.00514	94.65373	121.1132
C2	28.52	28.93	11.63057037	13.36378	135.2702	178.5907
C3	28.83	27.23	11.94012593	11.66476	142.5666	136.0665
C4	19.21	18.15	2.322051852	2.584581	5.391925	6.680058
C5	17.99	17.10	1.095385185	1.5254	1.199869	2.326846
C6	14.66	5.74	−2.23054074	−9.83031	4.975312	96.63501
C7	8.75	7.90	−8.13868889	−7.66898	66.23826	58.81329
C8	8.58	9.19	−8.31498519	−6.38025	69.13898	40.70763
C9	8.04	7.18	−8.85276296	−8.39035	78.37141	70.3979
C10	7.71	7.70	−9.18017037	−7.87377	84.27553	61.99626
Σ	168.93	155.6994			682.0818	773.3274
Mean	16.89	15.56994		s_1	75.78686	85.92527
				$s_1/s_2=$	0.882009	

Table 11. F-test two-sample for variances.

	Variable 1	Variable 2
Mean	16.89276296	15.56994091
Variance	75.78686496	85.92526735
Observations	10	10
Df	9	9
F	0.882009068	
P (F ≤ f) one-tail	0.427351147	
F Critical one-tail	0.314574906	

4. Conclusions

The data showed that RHA can be a concrete addition, and structural concrete can use the data to calculate the concrete's compressive strength. The results of the laboratory experiment show that if the replacement percentage is followed, RHA-containing concrete can be utilized for structural purposes. The results showed that the strength values increased as RHA replacements increased by 5% - 15% and decreased when they increased by 25% - 30%. When RHA is utilized to partially replace cement, the strength of the concrete is improved. RHA is a yearly supply of silica that is a naturally occurring pozzolan.

Everywhere RHA is found, there are differences in the strength levels, which primarily attributes to variations in elemental composition and properties. Osadebe's regression model can be used to forecast these reactions using the actual laboratory reactions from Equation (10) of this article.

This work covers the study of the effects of replacement of LSC with RHA sourced from four different locations, the study did not consider other types of cement and consideration was not given to other locations where RHA is found.

As contained in **Table 10** and the Fisher statistical chart shown in **Table 11**, F-critical is less than F-calculated. This is an attestation to the adequacy of the model.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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