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COMPUTER PROGRAMMES FOR ANALYZING THE STRUCTURAL CHARACTERISTICS OF CONCRETE INCORPORATING RICE HUSK ASH (RHAC).

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ABSTRACT

The rising need for concrete is directly tied to urban expansion and population increases. Cement, a crucial component in concrete manufacturing, is a momentous source of global carbon dioxide secretions. To promote more sustainable concrete solutions, the adoption of alternative materials to conventional cement is essential. One such material with great potential is rice husk ash (RHA), which has shown promise in producing environmentally friendly concrete. However, assessing the performance of RHA-based concrete through laboratory testing can be time-consuming and complex. Predictive models provide an efficient approach to estimating the properties of RHA concrete, streamlining the process. Modern engineering increasingly relies on computational tools to save time, reduce resource use, and lower the likelihood of errors in project outcomes. These tools allow for virtual simulations, detailed analyses, and project refinements before actual implementation. This research introduced computer programs based on second-degree techniques from Scheffe and Osadebe to predict the compressive strength, moduli of rupture and elasticity of RHA concrete. Statistical evaluations confirmed the accuracy of these programs, as predicted results closely aligned with experimental data. These findings highlight the feasibility of using RHA concrete in structural applications. The computational programs not only reduce the dependence on extensive physical testing but also enable faster and more precise evaluations. By facilitating broader adoption of RHA as a sustainable building material, this approach supports the transition to greener construction practices. Further advancements in these predictive tools will be crucial for enhancing the practical application of RHA concrete, opening pathways for continued innovation and implementation in sustainable construction.

Keywords: concrete; computer programs; strength properties; Scheffe; Osadebe polynomial; RHA;

1.0 INTRODUCTION

Programming is a technology-driven process that enables people to communicate directly with machines. Through programming, humans create a set of instructions (code) that machines can understand and execute. This skill is essential not only for software development or advanced AI research but also for a wide range of applications. Programming streamlines engineering, optimizes supply chains, and powers the incredible online experiences we enjoy. Similarly, in the latter half of the twentieth century, cement production surged as global demand increased, leading to a marked rise in its production.

The creation of software tailored to analysing the structural characteristics of RHA concrete is a field that remains in its early stages of growth. These programs integrate material properties, such as the modulus of elasticity, compressive and tensile strength, and durability characteristics, into algorithms that can predict performance under different environmental conditions and loading scenarios. A significant challenge in this domain is the accurate modelling of the pozzolanic reaction of RHA and its effect on the microstructure of concrete over time. The development of robust algorithms that capture these effects is crucial for the accurate prediction of structural performance.

The application of computer programs to simulate the behaviour of concrete materials has become more sophisticated over the years. Various software programs, including finite element analysis (FEA) tools, have been developed to predict the structural performance of RHA concrete under different loading conditions. One of the early advancements was the incorporation of RHA into finite element modelling (FEM) frameworks, which allowed researchers to simulate the mechanical properties of RHA concrete at both the micro and macro levels [1].

Researchers have used these programs to predict compressive strength, tensile strength, and modulus of elasticity of RHA concrete with varying RHA percentages. The use of computational programs also allows for the simulation of complex behaviours like creep, shrinkage, and durability, which are critical for the long-term performance of RHA concrete structures [2].

Benefits of Computer Programs in Structural Analysis of RHA Concrete

Computer programs used for RHA concrete modelling offer several advantages. First, they reduce the need for extensive experimental testing, which can be time-consuming and costly. For example, programs like ANSYS and ABAQUS have been employed to simulate the response of RHA concrete beams and slabs under flexural and shear loads, providing valuable insights without the need for full-scale prototypes [3]. These programs enable parametric studies where variables like RHA content, water-cement ratio, and aggregate type can be systematically altered to observe their effects on structural performance.

In addition, modern computer programs integrate artificial intelligence (AI) and machine learning techniques to optimize the mix design of RHA concrete. Neural networks and genetic algorithms have been applied to predict the strength and durability of RHA concrete based on its mix proportions These methods provide a faster, more accurate way of designing high-performance, eco-friendly concrete.

Several researchers have proposed mathematical models and computational algorithms for this purpose. For instance, computational models have been developed that simulate the hydration process and the resulting microstructural changes in concrete with RHA. These models aim to predict how different proportions of RHA affect the concrete's compressive strength, durability, and resistance to cracking. Additionally, the development of optimization algorithms has facilitated the fine-tuning of mix designs, enabling engineers to achieve the desired structural properties while minimizing costs and environmental impact.

According to [4], emphasized that mastering computer programming involves both theoretical understanding and hands-on experience in writing code. To support this, educators often design programming tasks for students to work on in computer labs. To improve the effectiveness of these exercises, it is essential to explore how theoretical knowledge connects with practical application during lab sessions.

According to [5], multidisciplinary skills—of which computational thinking is a fundamental component—are highly valued in current education, signalling the dawn of a new era. The use of IT has influenced education in the twenty-first century. Computational thinking has enabled the establishment of a Do-It-Yourself (DIY) culture and the creation of an all-encompassing social network.

Similarly [6] examined the influence of rice husk ash (RHA) on concrete properties through a computational model. The study developed a program that simulates the hydration process of concrete mixed with varying percentages of RHA, highlighting the optimal ratio for strength and durability.

The use of finite element analysis (FEA) to study the mechanical behaviour of RHA concrete. Their study, presented a program that integrates material properties of RHA with stress-strain responses, providing insights into crack propagation under load. [7]

In the works of [8], a software tool was developed to predict the compressive strength of RHA concrete using artificial neural networks (ANN). This work, discussed how the ANN model outperformed traditional methods, yielding a reliable predictive capability based on input variables like water-cement ratio and RHA content.

Again, [9] claim that computational fluid dynamics (CFD) is used to analyse the thermal characteristics of RHA concrete. By simulating heat transfer processes, their program demonstrates the benefits of RHA in improving thermal insulation.

Furthermore, [10] presented a comprehensive computational framework for assessing the long-term durability of RHA concrete. The study incorporated environmental factors into its simulations, addressing issues such as sulphate attack and freeze-thaw cycles.

The introduction of a user-friendly software designed for engineers to evaluate the flexural strength of RHA concrete beams was undertaken in the works of [11]. In their study, they demonstrated how the program facilitates quick design iterations and structural assessments.

Additionally, [12] utilized a hybrid modelling approach to simulate the microstructural properties of RHA concrete. Their findings, emphasized the role of RHA in pore structure refinement and its effect on mechanical performance. Furthermore, [13] developed an optimization tool for the mix design of RHA concrete. The tool employs genetic algorithms to achieve cost-effective and high-performance concrete mixes. Again, [14] explored how different sizes of RHA particles affect concrete's structural characteristics by utilizing a specialized simulation tool. They found that smaller particles improved mechanical strength, primarily due to increased packing efficiency.

The application of machine learning techniques to forecast the physical chattels of RHA concrete was studied in [15]. Their findings, showed that their model could accurately predict properties based on historical data and mix proportions and [16] carryout a study discussing a software tool developed to analyse the workability of RHA concrete mixtures. The tool employs rheological models to predict the flow characteristics of concrete mixes.

Moreover, [17] investigated the seismic performance of RHA concrete structures using nonlinear dynamic analysis software. Their study, provided a framework for assessing structural resilience under seismic loads. Again, [18] developed a program for assessing the life cycle costs of RHA concrete. The program incorporates various sustainability metrics, promoting the use of RHA in eco-friendly construction practices. Additionally, [19] created a software package for simulating the bond behaviour between RHA concrete and steel reinforcement. Their findings, emphasized the improved adhesion properties of RHA concrete.

Furthermore, [20] researched the effects of RHA on the resistance of concrete to chloride ion penetration using a computational model. Their article, highlighted the importance of RHA in enhancing durability against corrosion.

Additionally, [21] created a predictive model to analyse the shrinkage behaviour of RHA concrete, showing its potential to reduce cracking issues caused by drying shrinkage. Separately, [22] investigated the acoustic qualities of RHA concrete through computational simulations, concluding that RHA can effectively limit sound transmission, thus improving building acoustics.

Also, [23] utilized a finite difference approach to analyse the moisture movement in RHA concrete. Their findings, provided insights into how moisture affects the performance and longevity of RHA concrete structures. Again, [24] developed a database-driven program to assist in the selection of optimal RHA content for various structural applications. Their work, facilitated data-driven decision-making in construction practices.

The works of [25] focused on the environmental impacts of RHA concrete through a life cycle assessment (LCA) software. Their study, illustrated the significant reduction in carbon footprint when using RHA as a partial cement replacement.

Challenges and Limitations

While computer modelling has advanced the understanding of RHA concrete, there are still limitations to its application. One challenge is the complexity of accurately modelling the heterogeneous and porous nature of RHA particles within the concrete matrix. Additionally, most computational models rely on simplifications and assumptions that may not fully capture the real-world behaviour of RHA concrete [26]. Further research is needed to improve the accuracy of models, especially in predicting long-term properties such as creep and shrinkage.

Another limitation is the availability of experimental data for validating computer simulations. Since RHA concrete is a relatively new material, there is still a lack of comprehensive experimental datasets that can be used to refine and validate computer models.

Future Prospects

As the application of rice husk ash (RHA) in concrete gains traction, there is an increasing demand for advanced computational tools to simulate and assess the performance of RHA-enhanced concrete structures. Future studies should prioritize improving the accuracy of these tools by integrating data from long-term field observations, thus supplying more reliable inputs for predictive algorithms. Additionally, incorporating artificial intelligence and machine learning techniques could enable these tools to model in a more flexible and responsive manner, making real-time adjustments based on shifts in material behaviour or environmental conditions.

In summary, creating software to analyse the structural characteristics of RHA-modified concrete marks an important step forward in sustainable construction. These programs deepen our understanding of how RHA affects concrete's properties and offer practical solutions for engineers aiming to design longer-lasting, more efficient structures. Continued research and development will be essential to harnessing the full sustainability benefits of RHA in concrete applications.

2.0 OSADEBE SECOND DECREE POLYNOMIAL

Concrete is a composite material with a strength that depends on the volume of each component in the mixture. Its strength is represented by a regression equation, serving as an experimental model. In this model, the variable Y represents the strength, plotted as a function of the proportions of the mixture's components, Z, with the requirement that the total sum of these proportions equals 1. This is written as:

$$Z_1 + Z_2 + \dots + Z_q = \sum_{i=1}^{q} Zi = 1 \qquad (1)$$

Let q denote the entire quantity of ingredients, with Zi representing their respective magnitudes. Starting from his projections, Osadebe utilized a Taylor series expansion to approximate Y near a reference point Z_0, assuming the function is both continuous and differentiable with respect to the predictor variables.

$$Z(0) = (Z_1^{(0)}, Z_2^{(0)}, ..., Z_q^{(0)})^r \quad (2)$$

The formulation retains its ability to generalize when the origin is conveniently chosen as the point Z^0. Consequently,

$$Y = \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_3 + \beta_4 Z_4 + \beta_{12} Z_1 Z_2 + \beta_{13} Z_1 Z_3 + \beta_{14} Z_1 Z_4 + \beta_{23} Z_2 Z_3 + \beta_{24} Z_2 Z_4 + \beta_{34} Z_3 Z_4 \quad (3)$$

Equation (3) outlines the regression framework introduced by Osadebe. To define the model completely, it is essential to determine the unique values of the constant coefficients, βi and βij. Interestingly, this model incorporates an identical quantity of constants, N, as found in Scheffe's {4,2} prototypical. This corresponds to a second-order polynomial with four variables, determined using the formula:

2.1.Osadebe'sRegressionEquationCoefficients

N is the smallest number of independent responses or experimental runs required to calculate Osadebe's regression coefficients. The answer at point k is represented by y^k, while the vector Z^k represents the set of component proportions predictors at point k.

$$Z^{(k)} = \left(Z_1{}^{(k)}, Z_2{}^{(k)}, ... Zq^{(k)}\right) \quad (4)$$

Substituting the vector of Equation (15) into Equation (10) gives:

$$Y^{(k)} = \sum_{i=1}^{q} \beta_i Z_i{}^{(k)} + \sum_{i \le j \le q}^{q} \beta_{ij} Z_i{}^{(k)} Z_j{}^{(k)} \quad (5)$$

Where k=1, 2… N

Substituting the predictor vectors sequentially for each of the NN observation points results in a system of N linear algebraic equations, which can be represented in matrix form as shown below.

$$z\beta = Y \quad (6)$$

Let β represent a vector containing the estimated values of the regression coefficients.

2.2 Scheffe's Method

$$\sum \mathrm{Xi} = 1 \text{ or } \mathrm{X}_1 + \mathrm{X}_2 + \mathrm{X}_3 + \mathrm{X}_4 = 1 \quad (7)$$

Where;

Z_1= Water/Cement Ratio

Z_2 = Binder (80% OPC and 20% RHA)

Z_3 = Fine Aggregates (Sand)

Z_4 = Coarse Aggregates (Granite)

Following Taylor's series,

$$b_oX_1 + b_oX_2 + b_oX_3 + b_oX_4 = b_o \quad (8)$$

Thus, this becomes

$$Y = \propto_i X_1 + \propto_2 X_2 + \propto_3 X_3 + \propto_4 X_4 + \propto_{12} X_1X_2 + \propto_{13} X_1X_3 + \propto_{14} X_1X_4 + \propto_{23} X_2X_3 + \propto_{24} X_2X_4 + \propto_{34} X_3X_4 \quad (9)$$

In compact form, equation can be stated as:

$$Y = \sum \propto_i X_1 + \sum \propto_{ij} X_iX_j \quad (10)$$

Therefore Equation 11 is the mathematical model based on Scheffe's second degree polynomial.

$$\eta_{4,2} = a_1X_1 + a_2X_2 + a_3X_3 + a_4X_4 + a_{12}X_1X_2 + a_{13}X_1X_3 + a_{14}X_1X_4 + a_{23}X_2X_3 + a_{24}X_2X_4 + a_{34}X_3X_4 \quad (11)$$

Also,

$$a_i = \eta_i \quad (12)$$

And for a (4,2) polynomial

$$a_{ij} = 4_{ij} - 2\eta_i - 2\eta_j \quad (13)$$

Equation 13 is the general form of Scheffe's second degree polynomial

3.0 MATERIALS AND METHODS

3.1. Materials

3.1.1. Cement

In this study, Lafarge Cement Company's Portland Limestone Cement (PLC), with a strength grade of 32.5R, was employed, meeting the requirements of ASTM C150. The cement had a specific gravity of 3.15.

3.1.2.RiceHuskAsh(RHA)

RHA was used in the work to partially substitute cement, with 20% being the optimal volumetric replacement level for concrete, as recommended by [6]. The rice husks were sourced from a local rice mill, then incinerated in a muffle furnace at 700°C for approximately three hours. Afterward, the ash was cooled and sieved through a 75-micron BS sieve to obtain an average particle size before being further ground using a ball mill. The specific gravity of the RHA was determined to be 2.09. The chemical composition of the rice husk ash was analysed using X-ray fluorescence (XRF), and the results are shown in Table 1.

Table 1: Chemical composition of cement and RHA

Binder	Chemical composition (%)								
	SiO_2	Al_2O_3	ZnO	CaO	Fe_2O_3	K_2O	MnO	MgO	Na_2O
Cement	23.65	5.51	0.14	65.3	3.5	0.42	0.2	1.40	0.3
RHA	85.6	0.23	0.25	0.29	0.10	0.31	0.19	0.05	0.19

3.1.3. Aggregates

In this study, coarse aggregates were obtained from a quarry at the Faith plant in Nsan, Akamkpa, Cross River State, Nigeria. The granite particles, ranging in size from 5 to 20 mm, were graded in accordance with ASTM C33 specifications [27]. Table 2 outlines the coarse aggregates' physical characteristics, including specific gravity, fineness modulus, and water absorption capacity. Fine aggregates were sourced locally from the Calabar River, consisting of river sand with a fineness modulus of 2.67. The sand met the required gradation limits, with sieve analysis and gradation curves confirming compliance with ASTM C33 standards [27]. It was also confirmed to be free of any harmful impurities.

3.2. Experimental Program

Table 3 outlines the composition of the concrete mix utilizing RHA, tailored to meet grade 20 concrete requirements. In this formulation, RHA partially replaced cement in the binder system. The components were measured volumetrically, starting with the dry blending of cement, fine aggregates, and coarse aggregates on a level surface for about 2 minutes. Heated water was then incrementally added, with mixing continuing for 4 to 7 minutes to ensure a consistent blend. The mix design was based on the pentahedron factor space approach, employing a four-component simplex method and adjusted for specific water-to-cement ratios.

Concrete specimens were cast using 150-mm block moulds filled in three layers, each compacted with an automatic vibrator, to evaluate compressive strength. Flexural strength samples were prepared in beam moulds of 500 mm × 100 mm dimensions, with concrete placed in three layers and compacted manually using a 25-mm steel rod with 150 tamps per layer. For split tensile strength testing, cylindrical moulds measuring 100 mm × 200 mm were filled, each layer compacted manually with 35 strokes of a 25-mm steel rod. Molds were removed 24 hours after casting, and the specimens were cured in a water tank under standard conditions. Strength testing was performed at 28 days, with the average values recorded. All procedures conformed to the guidelines of BS 1881-117:1983, BS EN 206:2001, and BS 1881-118:1993.

3.3 Mathematical Optimization Technique

The simplex design required that the sum of components (X1 + X2 + X3 + X4) equal 1, which precluded the use of standard mix ratios like 1:2.4: To meet this requirement, conventional mix ratios were adjusted. Table 2 displays the design matrix for experimental points, denoted as "pseudo-components" (Xi), with the actual components referred to as Zi. [28]

$$X=A*Z \quad (14)$$

If Z represents a matrix, then A is its inverse.

$$Z=A*X^T \quad (15)$$

Matrix A is defined as the reciprocal of Z, whereas X^T signifies the transpose of the matrix X.

Table 2a: Recorded values (Zi) and predicted values (Xi) for Osadebe's {4, 2} simplex lattice.

	Mixture Proportions				**Constituent's Element**			
S/N	Water	Binder	Fine	Coarse	Z_1	Z_2	Z_3	Z_4
1	0.45	1	1.2	2.4	0.09	0.238850	0.300565	0.553122
2	0.40	1	1.5	3.5	0.075	0.18755	0.331566	0.611510
3	0.44	1	2.2	3.4	0.078	0.160040	0.401079	0.556881
4	0.55	1	3.5	6.5	0.050	0.058241	0.314721	0.600430
5	0.42	1	2.4	4.5	0.060	0.14456	0.224190	0.6112381
6	0.50	1	2.7	5.5	0.055	0.122340	0.301729	0.6125300
7	0.52	1	4.5	8	0.045	0.077791	0.450631	0.611300
8	0.35	1	3.0	5.0	0.040	0.205585	0.431551	0.445605
9	0.60	1	2.0	5.45	0.070	0.218850	0.333881	0.601811
10	0.65	1	2.8	6.6	0.060	0.077055	0.234662	0.605124

Table 2b: Osadebe's {4, 2} simplex lattice for control

S/N	Water	Binder	FA	CA	Z_1	Z_2	Z_3	Z_4
11	0.50	1	1	2	0.130	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 3: Z-Matrix of Osadebe's blend proportions

Codes	**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**
C1	0.09	0.34	0.33	0.56	0.018	0.019	0.047	0.054	0.108	0.108
C2	0.084	0.21	0.24	0.53	0.012	0.020	0.057	0.024	0.075	0.138
C3	0.08	0.17	0.41	0.57	0.011	0.023	0.032	0.051	0.081	0.145
C4	0.05	0.08	0.78	0.67	0.005	0.015	0.037	0.029	0.064	0.172
C5	0.06	0.18	0.27	0.66	0.008	0.018	0.041	0.041	0.064	0.155
C6	0.063	0.10	0.29	0.61	0.006	0.050	0.040	0.051	0.071	0.165
C7	0.054	0.10	0.45	0.63	0.004	0.030	0.043	0.040	0.055	0.180
C8	0.06	0.18	0.41	0.64	0.004	0.021	0.059	0.054	0.066	0.162
C9	0.07	0.14	0.33	0.61	0.008	0.045	0.048	0.037	0.070	0.147
C10	0.07	0.09	0.35	0.61	0.006	0.045	0.055	0.035	0.061	0.157

The converse of the 10x10 matrix presented in Table 3 was determined using Microsoft Excel, as performing this calculation manually would be impractical without the aid of advanced computational tools. The outcomes are summarized in Table 4.

Table 4: Using Microsoft Excel, calculate the Z-matrix inverse as presented in Table 5.

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
60660.40	-12202	41210	-10322	-412610.912	122317.9	-52973.4	29016.3	219307.5	-294470
4613.457	-11729	3794.1	-32991	-62983.0315	89690.91	-5537.67	3076.072	31500.95	-27134.7
214.9767	-241.49	137.58	-452.87	-817.62812	1513.992	-64.768	34.810	701.784	-745.404
193.9706	-464.45	173.81	-1010.6	-1879.62461	3256.507	-209.515	92.85216	921.0915	-1072.99
-79708.7	204886	-64811	550058	912725.9204	-1626042	94593.74	-50854	-384358	463510.8
-58176.2	81143	-37585	255923	412504.3854	-686327	41692	-22867.5	-164951	192854.1
-50214.3	140987	-44454	417590	611568.70	-1291121	59194.36	-44041.9	-361166	391035.0
-10604.0	25091	-7550	64487.4	114108.90	-171120	10204.50	-4291.12	-42166.7	51032.9
-2141.13	5107.2	-1391	14675	20043.077	-36021.3	2034.31	-1202.60	-7907.4	9330.30
-688.60	1853.6	-643.6	3329.60	6311.19	-10811.1	640.40	-274.40	-3355.10	3894.0

Table 5 presents the regression coefficients derived by applying the inverse of the Z-matrix to the laboratory response data processed in Microsoft Excel.

Table 5: The coefficients of regression and the lab. Values

β	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9	β_{10}
CR	-655721	-70825	-1440	-2391	1140104	502150	771040	140120	25190	9021
LV	4.5	3.35	3.14	2.85	3.6	2.7	2.25	3.85	2.32	3.2

CR- coefficients of regression; **LV**- laboratory Values

If the constant constants βi and βij can be determined inimitably, Osadebe's relapse model equation can be formulated. For a polynomial of degree m=2m = 2 with q=4q = 4, the equation takes the following form:

$$Y = \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_3 + \beta_4 Z_4 + \beta_{12} Z_1 Z_2 + \beta_{13} Z_1 Z_3 + \beta_{14} Z_1 Z_4 + \beta_{23} Z_2 Z_3 + \beta_{24} Z_2 Z_4 + \beta_{34} Z_3 Z_4 \quad (16)$$

Consequently, the second-degree regression method developed by Osadebe forms the mathematical foundation for Equation 16.

3.3.1 Scheffe's Method

$$\sum \mathrm{Xi} = 1 \text{ or } \mathrm{X}_1 + \mathrm{X}_2 + \mathrm{X}_3 + \mathrm{X}_4 = 1 \quad (17)$$

Where;

Z_1= Water/Cement Ratio

Z_2 = Binder (80% OPC and 20% RHA)

Z_3 = Fine Aggregates (Sand)

Z_4 = Coarse Aggregates (Granite)

Therefore, the mathematical model based on Scheffe's second degree polynomial.

$$y_{4,2} = a_1 X_1 + a_2 X_2 + a_3 X_3 + a_4 X_4 + a_{12} X_1 X_2 + a_{13} X_1 X_3 + a_{14} X_1 X_4 + a_{23} X_2 X_3 + a_{24} X_2 X_4 + a_{34} X_3 X_4 \quad (18)$$

Also,

$$a_i = y_i \quad (19)$$

And for a (4,2) polynomial

$$a_{ij} = 4_{ij} - 2y_i - 2y_j \quad (20)$$

Equation 20 is the general form of Scheffe's second degree polynomial

4.0 RESULTS AND DISCUSSION

4.1. Osadebe's model for compressive strength.

Using the responses outlined in Table 5, the unknown coefficients of the regression equation can be determined by solving Equation (16) as follows:

$\beta 1 = 3274479$; $\beta_{2} = 33885.5$; $\beta_3 = 3940.6$; $\beta 4 = 12887.8$; $\beta_5 = 5741331$; $\beta_6 = -2198754$; $\beta 7 = -3719964$; $\beta_8 = -6165329$; $\beta 9 = 135781$; $\beta_{10} = -325761.9$.

from equation 16,

$$Os = 3274479Z_1 + 33885.5Z_2 + 3940.6Z_3 + 12887.8Z_4 + 5741331Z_1Z_2 - 2198754Z_1Z_3 - 3719964Z_1Z_4 - 6165329Z_2Z_3 + 135781Z_2Z_4 - 325761.9Z_3Z_4 \quad (21)$$

Equation 21 is the mathematical model for the compressive strength of RHA concrete, based on Osadebe's method.

Table 6: Evaluation of compressive strength test outcomes based on Osadebe's {4,2} polynomial framework and experimental data.

Symbol	Water	Binder	F	C	Model (Y_K)	Laboratory(Y_E)
OC1	0.50	1	1.0	2.0	38.65	38.58
OC2	0.55	1	1.5	3.0	35.50	35.95
OC3	0.58	1	2.0	3.0	34.85	34.65
OC4	0.60	1	3.0	6.0	28.24	28.95
OC5	0.46	1	2.0	4.0	31.99	32.65
OC6	0.49	1	2.5	5.0	29.90	29.74
OC7	0.51	1	4.0	6.0	15.50	15.90
OC8	0.54	1	3.4	5.7	18.40	18.20
OC9	0.65	1	2.8	5.8	19.14	19.18
OC10	0.62	1	2.9	6.1	14.80	14.50

Adequacy of the model using statistical methods.

From Table 7, the model is considered suitable since the observed F-value of 1.123 is below the threshold critical F-value of 3.89.

Table 7: Single-tailed F-test for comparing variances in compressive strength of RHA concrete samples.

Varaiable	Mean	Variance	Observations	Df	F	P(F<=f)	F Critical
Model	16.893	75.774	10	9	1.023	0.4867	3.89

Lab.	16.57	74.062	10	9

4.2 The Osadebe Regression Equation for flexural strength of RHA concrete

The regression equation's unknown coefficients are determined as follows:

$\beta_1 = 135160$; $\beta_2 = -1219751$; $\beta_3 = -3110.50$; $\beta_4 = -5120.10$; $\beta_{12} = 2512030$; $\beta_{13} = 899210$; $\beta_{14} = 1610021$; $\beta_{23} = 2710042$; $\beta_{24} = -501520.4$; $\beta_{34} = -18121.5$

from equation 36, the regression equation is given by;

$$Of = 135160Z_1 - 1219751Z_2 - 3110.50Z_3 - 5120.10Z_4 + 2512030Z_1Z_2 + 899210Z_1Z_3 + 1610021Z_1Z_4 + 2710042Z_2Z_3 - 501520.4Z_2Z_4 - 18121.5Z_3Z_4 \quad (22)$$

Equation 22 represents the optimization framework for the flexural strength of RHA concrete, formulated using Osadebe's quadratic polynomial approach.

Table 8: Analysis of flexural strength using Osadebe's {4,2} polynomial model and laboratory testing.

Points	Water	Binder	F	C	Model (Y_K)	Lab Responses(Y_E)
OC1	0.50	1	1.0	2.0	4.5	4.3
OC2	0.55	1	1.5	3.0	4.1	3.9
OC3	0.58	1	2.0	3.0	3.8	3.6
OC4	0.60	1	3.0	6.0	3.0	3.2
OC5	0.46	1	2.0	4.0	3.4	3.5
OC6	0.49	1	2.5	5.0	3.1	2.9
OC7	0.51	1	4.0	6.0	2.5	2.5
OC8	0.54	1	3.4	5.7	2.9	3.0
OC9	0.65	1	2.8	5.8	2.8	2.7
OC10	0.62	1	2.9	6.1	2.4	2.5

Assessment of the model's suitability using statistical analysis

Table 9 presents the ANOVA results for the Fisher test conducted at the flexural strength test checkpoint. With a computed F-value of 0.2312, which is less than the critical F-value of 0.3146, the model equation is deemed appropriate.

Table 9: A one-tailed F-test to compare the variances of two samples in the flexural strength test for RHA concrete.

Variable	Mean Average	Variance	Observation points	Df	F	P(F<=f)	F Critical
Model	3.7	0.2094	10	9	0.2312	0.0200	0.3146
Lab Response	3.345	0.9058	10	9			

4.3 Determination of the tensile strength based on Osadebe technique

The unknown coefficients of the regression equation as follows;

$\beta 1 = -625516$ $\beta_2 = -65521.50$ $\beta_3 = -1512.4$ $\beta 4 = -2551.3$ $\beta_{12} = 1621055$

$\beta_{13} = 451145$ $\beta_{14} = -765515$ $\beta_{23} = 141245$ $\beta_{24} = -25512$ $\beta_{34} = -9651.5$

Applying equation 16, the regression equation is given by;

$$Ot = -625516Z_1 - 65521.5Z_2 - 1512.4\,Z_3 - 2551.3\,Z_4 + 1621055Z_1Z_2 + 485161.5Z_1Z_3 + 451145Z_1Z_4 - 765515Z_2Z_3 + 141245Z_2Z_4 - 9651.5Z_3Z_4 \quad (23)$$

Therefore, equation 23 represents a mathematical formulation designed to optimize the tensile strength of RHA concrete, utilizing Osadebe's quadratic polynomial approach.

Table 10. Experimental outcomes and predicted results for tensile strength testing derived from Osadebe's {4,2} Polynomial model.

Points	Water	Binder	F	C	Model (Y_K)	Lab Responses(Y_E)
OC1	0.50	1	1.0	2.0	5.5	5.2
OC2	0.55	1	1.5	3.0	4.5	4.2
OC3	0.58	1	2.0	3.0	3.8	3.5
OC4	0.60	1	3.0	6.0	2.45	2.6
OC5	0.46	1	2.0	4.0	3.34	3.1
OC6	0.49	1	2.5	5.0	2.82	2.7
OC7	0.51	1	4.0	6.0	2.2	2.3

OC8	0.54	1	3.4	5.7	2.3	2.5
OC9	0.65	1	2.8	5.8	2.2	2.4
OC10	0.62	1	2.9	6.1	2.4	2.6

Statistical Test for Model Tolerability

Table 11: A one-tailed F-test to compare the variances of two samples in the moduli of elasticity of RHA concrete

Variable	Mean Average	Variance	Observations points	Df	F	P(F<=f)	F Critical
Model	3.15	0.2757	10	9	0.3140	0.1597	0.5155
Laboratory	3.11	0.549	10	9			

4.4 Compressive Strength Test Result Based on Scheffe's (4, 2) Simplex Lattices

The results of the compressive strength test based on Sheaffe's (4, 2) simplex lattices are shown in computations using the following regression equations

α_1 = 35.72, α_2 = 27.99, α_3 = 23.1, α_4 =18.23

From equation 20

$\propto_{12} = 4\,(40.75) - 2(35.72) - 2(27.99) = 35.58$

$\propto_{13} = 4(34.6) - 2(35.72) - 2(23.1) = 20.76$

$\propto_{14} = 4(17.35) - 2(35) - 2(24) =- 48.6$

$\propto_{23} = 4(30.6) - 2(27.99) - 2(23.1) = 20.22$

$\propto_{24} = 4(7.42) - 2(27.99) - 2(18.23) = -62.76$

$\propto_{34} = 4(24.63) - 2(23.1) - 2(18.23) = 15.86$

Thus, from Equation 18, we have;

$$\sigma_C = 35.7X_1 + 27.99X_2 + 23.1X_3 + 18.23X_4 + 35.42X_1X_2 + 20.56X_1X_3 - 47.60X_1X_4 + 20.22X_2X_3 - 62.76X_2X_4 + 15.86X_3X_4 \quad (24)$$

Therefore, equation 24 represents the mathematical formulation used to optimize the compressive strength of RHA concrete, derived from Scheffe's (4,2) polynomial model.

4.5 Tensile Strength Test results, based on Scheffe's (4,2) Simplex Lattice

The Tensile Strength Test results, based on Scheffe's (4,2) Simplex Lattice and the Regression Equation of Modulus of Elasticity, Based on Scheffe's (4,2) Polynomial

Based on equation 20

α_1= 3.72, α_2= 2.2, α_3 = 2.9, α_4 = 2.2

From Eqn. 18

$\propto_{\mathbf{12}} = 4x(3.25) - 2x(3.7) - 2x(2.71) = 0.18$

$\propto_{\mathbf{13}} = 4x(1.75) - 2x(4.37) - 2x(2.9) - 7.15$

$\propto_{\mathbf{14}} = 4x(1.82) - 2x(3.7) - 2x(2.2 =- 4.5$

$\propto_{\mathbf{23}} = 4x(3.28) - 2x(2.71) - 2x(2.9) = 1.9$

$\propto_{24} = 4x(1.95) - 2x(2.71) - 2x(2.2) =- 2.02$

$\propto_{34} = 4x(2.74) - 2x(2.9) - 2x(2.2) =- 0.7$

$\sigma_f = 3.7X_1 + 2.1X_2 + 2.2X_3 + 2.2X_4 +0.8X_1X_2 -7.5X_1X_3 - 4.5X_1X_4 + 1.9X_2X_3 - 2.02X_2X_4 + 0.7X_3X_4$ (25)

Therefore, equation 25 represents the mathematical framework used to optimize the tensile strength of RHA concrete, utilizing Scheffe's (4,2) polynomial as the basis for the model.

4.6 Regression Equation for the flexural strength properties based on Scheffe's simplex Latice

α_1 = 4.2, α_2 = 3.71, α_3 = 3.25, α_4 = 2.68

From Eqn. 20,

$\propto_{12} = 4x(4.94) - 2x(4.2) - 2x(3.71) = 3.94$

$\propto_{13} = 4x(4.3) - 2x(4.2) - 2x(3.25) = 2.3$

$\propto_{14} = 4x(3.8) - 2x(4.2) - 2x(2.28) = 2.24$

$\propto_{23} = 4x(3.8) - 2x(4.2) - 2x(2.28) = 2.48$

$\propto_{24} = 4x(0.9) - 2x(3.71) - 2x(2.68) = -9.18$

$\propto_{34} = 4x(3.49) - 2x(3.25) - 2x(2.68) = 2.1$

Thus, from equation 18, we have;

$$\sigma_t = 4.2X_1 + 3.71X_2 + 2.25X_3 + 2.08X_4 + 3.9X_1X_2 + 2.3X_1X_3 - 2.26X_1X_4 + 2.48X_2X_3 - 9.18X_2X_4 + 2.1X_3X_4 \quad (26)$$

Therefore, equation 26 represents the mathematical framework used to optimize the flexural strength of RHA concrete, utilizing Scheffe's (4,2) polynomial model.

4.7 Basic Computer Programmes

Computer programmes were developed using the basic computer language for the determination of the strength properties of RHA concrete as shown in flow charts 1 and 2

Flowchart 1: Computer Program for Calculating Concrete Strength of RHA Using Scheffe's Models

100 REM A PHP program that executes values for Concrete strength, Flexibility and quality for effective concrete mix

101 REM: Akeke's model developed based on Scheffe's

102 Count = 0

103 Go to 100

104 End

105 REM Start Process

106 Set YMAX = 0

106 PRINT

107 PRINT "AKEKE COMPUTATION FOR CONCRETE STRENGTH BASED ON SCHEFFE'S METHOD"

108 PRINT

109 DEFINE X_1, X_2, X_3, ……., X_{Ni}

110 FOR X_1 = 0 TO 1> 10.0, GO TO 109

111 FOR X_2 = 0 T0 1 > 10.0, GO TO 109

112 FOR X_3, ……., X_{Ni} = 0 T0 1.00 >10, GO TO 109

113 LET $\mathbf{B_1}$, B_2, B_3, B_4, …. B_N = INT , SUCH THAT INT>0

114 RECALL THAT Y = X_1 B_1 + X_2 B_2 + , X_3 B_3 + …. + X_{Ni} B_N

115 FOR X_1 = 0 T0 1>10 && $\mathbf{B_1}$ = INT, SUCH THAT INT > 0, THEN

116 GO TO 114,

117 RPT 116, UNTIL X_{Ni} = 0 T0 1.0> 10 && B_N = INT, INT>0

118 GO TO 106

```
119 GO TO 107
120 GO TO 108
121 PRINT Y.
 122 RPT 117 UP TO 121
 123 END 121, IF Y = 0.
123, RPT 109 TO 121, FOR Y = FLEXIBILITY, Y= COMPATIBILTY
124 END Y
125 INT "THE VALUES OF Y, AS RUN BY THE PROGRAM. UNIT Y =
    N/Sq.mm"
  126 PRINT OUTPUT 1 FOR SCHEFFE'S
 127 PRINT SCHEFFE'S- AKEKE OUTPUT 2
128 PRINT SCHEFFE'S- AKEKE OUTPUT 3
129 END SCHEFFE'S-AKEKE OUTPUT
 END ALL
 STOP.
```

Flow chart 2. Flowchart 1: Computer Program for Calculating Concrete Strength of RHA Using Osadebe's Models

A. PROGRAM FOR OSADEBE'S/AKEKE MODEL

```
100 REM A PHP MODEL ALGORITHM PROGAM TO COMPUTE THE PROPORTIONS OF MIX CONCRETE BREED FOR EFFECTIVE CONSTRUCTION
110 REM OSADEBE'S MODEL
120 COUNT = 0
130 GO TO 100
140 END
150 START SUB ROUTINE
160 PRINT " A MODEL FOR COMPUTATION OF MIX CONCRETE PROPPORTIONS "
170 PRINT
```

180 ENTER “DESIRED STRENGTH” ; YINT

190 GO TO 130

200 DEFINE THE VALUES Z_1, Z_2, Z_3, … Z_N

210 DEFNE THE VALUES OF B_1, B_2 B_3, …. B_N, SUCH THAT BN=INT >0

220 DEFINE Z_1B_1,

225 DEFINE Z_2 B_2, ……..,

229 DEFINE Z_N B_N

230 FOR EACH Z_N B_N, WHERE $N \neq 0$, N = INT > 0, Z_N IS KNOWN AND B = >0

240 BUILD Z_N B_N, FOR ALL CASES

250 LET ALL THE CASES, BE SUCH THAT Z_N B_N ARE DEFINED. N>0

260 GO TO 220

270 RPT 240, UNTIL Z_N = 0, ELESE

280 GO TO 200

290 RETURN TO 270, UNTIL B_N IS EXHUSTED

300 END 280

310 GO TO 110

320 FOR EACH Z_N B_N, DEFINE OSADEBE’S/AKEKE

330 PRINT Y/OUTPUT = Z_1 B_1 + Z_2 B_2 + Z_3 B_3 + ….. + Z_N B_N

340 GO TO 320

350 GO TO 330

410 PRINT OSADEBE’S /AKEKE OUTPUT 1

420 PRINT OSADEBE’S /AKEKE OUTPUT 2

430 PRINT OSADEBES’/AKEKE OUT PUT 3

440 END OSADEBE’S/AKEKE

END ALL

STOP.

5.0 CONCLUSION

Conclusively, the creation of software tools for assessing the structural characteristics of Rice Rusk Ash (RHA) concrete marks a major progress in the fields of sustainable construction and material science. Through precise modelling and computational analysis, these programs provide a reliable, efficient, and accessible way to assess the potential of RHA as a partial cement replacement, helping reduce the environmental impact of traditional concrete production.

The software tools developed offer insights into critical structural properties such as compressive strength, flexural strength, and durability, helping engineers and researchers optimize RHA concrete mixtures for various applications. By integrating these programs into the material design process, the construction industry can advance towards greener practices without sacrificing performance standards.

Furthermore, these programs facilitate faster and more accurate testing, minimizing reliance on extensive physical experimentation. This not only saves time and resources but also enhances the precision of data analysis, supporting wider adoption of RHA as a viable, eco-friendly building material. Continued development and refinement of these tools will be essential for advancing RHA concrete as a sustainable alternative in modern construction, paving the way for future research and practical implementations in the field.

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