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Application of Osadebe's Regression Model in the Optimization of the Strength Properties of Mound Soil – Rice Husk Ash (MS–RHA) Concrete

G. A. Akeke, D.E Ewa, D. O. Ibiang, J.G Egbe

Abstract — **Cement production is now inextricably linked to increased health risks and negative economic impacts. In order to make concrete that can entirely or partially replace cement in it while maintaining its structural validity and constructional suitability, it will be safer to use readily available, naturally occurring, and ecologically benign components. The primary objective of this study was to evaluate the structural characteristics of a three-binder concrete that used mound soil and rice husk ash as partial replacements for regular Limestone cement (LSC). The concrete cubes underwent a compressive strength test after 28 days of curing. The Osadebe model standards for the real MS-RHA concrete components were the standards used for the laboratory work. The derived second-degree regression polynomial was:** $Y = \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_3 + \beta_4 Z_4 + \beta_5 Z_5 + \beta_6 Z_6 + \beta_{12} Z_1 Z_2 + \beta_{13} Z_1 Z_3 + \beta_{14} Z_1 Z_4 + \beta_{15} Z_1 Z_5 + \beta_{16} Z_1 Z_6 + \beta_{23} Z_2 Z_3 + \beta_{24} Z_2 Z_4 + \beta_{25} Z_2 Z_5 + \beta_{26} Z_2 Z_6 + \beta_{34} Z_3 Z_4 + \beta_{35} Z_3 Z_5 + \beta_{36} Z_3 Z_6 + \beta_{45} Z_4 Z_5 + \beta_{46} Z_4 Z_6$**. In this study, the highest compressive strength was expected to be 39.0 N/mm2 at a water/cement ratio of 0.55 and a mix ratio of 0.55:1:1:2, where 5% of RHA and MS were used in place of the 10% OPC. The lowest value predicted by the model, 15.20N/mm2, had a W/C ratio and a mixture ratio of 0.47. The student's t-test was used to evaluate the model's applicability, and the results showed that it was suitable, with t-calculated = 0.303 and t-table = 2.262. The null hypothesis, which demonstrated both significant and negligible differences between the experimental and projected values, was confirmed, and the alternative hypothesis was rejected. Using concrete enables OPC save some 10%, which brings us to our final point. Also, this research has demonstrated that structural concrete may be produced using a multivariate binder that contains more naturally occurring and environmentally beneficial admixtures while yet keeping the same strength and ensuring environmental sustainability.**

Index terms: **Modelling, Optimization, Optimized, Osadebe, Three-variant.**

I. INTRODUCTION

The demand for cement, which is concrete's basic component, is estimated to have surpassed 10 billion metric tons annually on a global scale. Concrete is currently the most basic and widely used construction material [1,2].

Concrete is a composite construction material that consists of water, a binder, filler, or granules [4]. It is a combination of a number of elements, including water, fine and coarse aggregates, and cement [3]. To give concrete the required properties, some admixtures are however added. Through optimization, the finest concrete strength and properties can be attained. The method of mathematically representing a phenomenon for better understanding can be used in this situation through optimization. [5] An activity or process is said to be optimized if it seeks to produce the best results with the fewest inputs or investments. [6].

With the help of mound soil, regular limestone cement, and rice husk ash as binders, this research seeks to enhance the strength properties of concrete. When rice husks, the outer coverings of rice fields, are burned outside in rice mills, a waste product known as rice husk ash (RHA) is created. It is believed that 700 million tons of rice were produced worldwide, with China and India being the two largest producers. [7] claims that the molecular makeup of rice husk is as follows: 50% cellulose, 10% water, 15%–20% silica, 30%–50% organic carbon, 25%–30% lignin. 20% of the weight of rice is made up of the husk, which has a poor moisture content.

RHA disposal is a challenge for waste managers, but if RHA, a tested pozzolan, in concrete to an extent substitute the costlier cement and is a more natural, local, and affordable material, then the challenge of its disposal will be significantly reduced [8]. At a 25% replacement ratio, replacing OPC with up to 30% RHA increases strength and corrosion resistance characteristics while reducing chloride penetration and permeability [10]. [11] states that a conversion factor of 0.8 is used to convert compressive strength to its equivalent tensile strength.

The majority of people think mound-building termites are harmful, particularly to the agro - industry. They have a track record of destroying crops, trees, and other structures created by humans. Despite what some studies have suggested, not all termite species are detrimental to human social activity [12]. Clay and organic carbon that have been bonded together by termites' excretions, saliva, or other secretions make up a termite mound. The mounds can take on a variety of shapes depending on the type of termite, the temperature, the availability of clay, the extent of the invasion of termites in a specific region, and the overall site conditions [13].

Earthen mounds, which are mostly clay, are the product of termite activity over time and provide shelter for the insects. The termite secretions used to construct the

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mound significantly improve this clay [14]. These secretions increase the mound soil's plasticity, making it more mouldable than the neighbouring soil. According to reports, mound clay outperforms regular clay without termite fluids when building dams [15]. The development of functional and reasonable housing for the teeming population necessitates the use of inexpensive materials. Research is currently being done to identify locally available resources that can be used in place of pricey traditional building materials [16]. To reduce the price of building construction, effective measures are currently being taken to largely replace cement with industrial refuse [17], agricultural waste [18], and recyclable materials [19].

Reference [20] conducted research on the effectiveness of termite-mound powder (TMP) as a cement substitute in the manufacture of clay-rich brickwork. The researchers' main areas of concern were the over-reliance on cement, the rise in building costs, and the health risks associated with the hazardous pollutants from the manufacture and use of cement. In accordance to the study's inferences, the compressive strength of the bricks declined even though it increased with curing and reached an ideal level at 10%. as TMP percentage increased. X-ray fluorescence (XRF) technology has been used to examine the geographic variations in the chemical characteristics of rice husk ash in the works of [21], their findings demonstrated that rice husk ash (RHA) has different pozzolanic capabilities depending on where it is located and that, because of its chemical makeup, certain OPC can be replaced by RHA. Termite mound soil is silty-sand with over 80% of the particles being sand and silt, and only 30% being gravel. It has higher specific gravity and maximum dry densities than the soil around it, varying from 2.59 to 2.68 and 1.63 to 1.84g/cm3, respectively [22].

II. MATERIALS AND METHODS

A termite colony in a rural area of Calabar, provided the disturbed sample of mound soil (MS). The hard termite mound was cracked open with a digger, and a nylon sack sealed with airtight tape contained the mound clods to prevent moisture loss. A total of 15kg of the material was gathered and delivered laboratory analyses. The leftover sample was ground up and spread out on a pan to air-dry at room temperature without any moisture. The sample's natural moisture content was calculated using 93g of the entire sample weight. The air-dried, crushed mound dirt was put through the tiniest aperture-sized sieve to obtain the finest particle sizes, and the residue that was gathered in the pan was dried and prepared for the concrete.

The RHA sample was also collected at the Obubra rice factory in Nigeria from a disturbed pile. It was transported to the facility in a sealed container, and in order to determine their natural moisture content, 29g of it were oven-dried. Before being used for the study, the remaining 10.5 kg of it received sieving to remove any unwanted components from the sample. The Lafarge cement production facility in Akamkpa was where the OPC was purchased. The Calabar River and Saturn Quarry, both, Nigeria, provided the fine and coarse aggregates. In this research, smooth sand with particle sizes ranging from 125 to 250 µm was used as the fine aggregate. The average coarse aggregate size was 15 to 22 mm.

With the exception of using three different materials as binders in the same concrete blend, the process for making this three-binder concrete was the same as the one used to produce regular concrete. This three-binder concrete was created by concurrently substituting RHA and MS for OPC in predetermined ratios. Using the 1:2:4 concrete mix ratio as the project's foundation, the binder for the concrete matrix was divided into portions appropriate for OPC, RHA, and MS, with 10, 20, 30, 40, and 50% of the OPC replaced by equal amounts of RHA and MS. These figures were computed using a volumetric measurement technique and a measured container. The production of six (6) different kinds of conventional concrete with 100%OPC served as the standard for comparison.

The concrete underwent a number of experiments to ascertain its flow characteristics, rates of water absorption, and strengths properties. According to BS EN 12350-2:2009, slump experiments on freshly mixed conventional and test concrete were used to determine workability. Freshly mixed concrete was put into 150m3 molds, demoulded, and weighed after settling in order to determine the proportion of water absorption. To obtain an average value, 15 cubes from each concrete batch were cast, 3 cubes for each of the 5 curing ages. The aging times for hardness were 3, 7, 14, and 21 days. In order to evaluate the capillary action of concrete, water absorption tests essentially quantify the difference between the concrete cube dry and moist weights before and immediately after curing. As a result, calculating the potential rate of corrosive fluid infiltration into concrete functions as a test of the material's resilience.

A material's capacity to support loads on its surface without cracking or deflection is known as compressive strength. According to the guidelines of BS EN 12390-3:2019, this process was performed on 150mm x 150mm x 150mm hardened concrete cubes. The process involved cleaning and lubricating the inside of the molds before adding layers of the newly mixed concrete that were roughly 5 cm thick. Before allowing the concrete to solidify, the top surface was always smoothed with a trowel. Using a tamping rod that was 16 mm in diameter, 60 centimetres in length, and bullet-pointed at the bottom end, 35 strokes were used to compact each layer of concrete. The cast concrete cubes were tested using the test sample was loaded across the full surface area of two opposing faces by the Universal Test Machine (UTM)., for 3, 7, 14, 21, and 28 days. The loading flattened the sample and had a tendency to lengthen it perpendicular to the direction of application while shortening it parallel to the direction of application. Each sample was gradually filled until it broke down at a rate of

140 kg/cm2 per minute. The weight at failure was then divided by the area of each cube sample to determine the compressive strength.

$$\sigma = \frac{F}{A} \qquad (30)$$

where A is the cross-sectional area in (mm2) and F is the applied force in (N).

I.S. 456-2000 states that:

flexural strength fs=0.7f ck (31)

where f_{ck} is the compressive strength of a concrete cylinder in MPa (N/mm2).

Similar calculations can be used to determine tensile strength.

$$F_{ct} = \frac{2P}{\pi L d} \qquad (32)$$

where F_{ct} is the concrete's tensile strength. Maximum weight in N/Sqm = PL stands for the specimen's length (300mm), and D for its diameter (150mm)

III. OSADEBE'S OPTIMIZATION THEORY

Osadebe's mathematical creation acted as a guide for mixing the MS-RHA concrete's component parts (Osabebe 2016). Osadebe used Taylor's series to create an enhanced mixes model. In accordance with the theory, concrete is a multi-variate unit mass whose strength is determined by the volume variance of its component parts.

Table 1: Actual (Z_i) and Faux (X_i) fractions for Osadebe's (4,2) Simplex Lattice

FAUX ELEMENTS					RESPONSE COMPONENT	COMPONENT'S FRACTION			
No.	X_1	X_2	X_3	X_4		Z_1	Z_2	Z_3	Z_4
1	1	0	0	0	R_1	Z_1	Z_2	Z_3	Z_4
2	0	1	0	0	R_2	0.12	0.2	0.2	0.2
3	0	0	1	0	R_3	0.061	0.168	0.25	0.51
4	0	0	0	1	R_4	0.075	0.115	0.22	0.32
5	0.5	0.5	0	0	R_{12}	0.018	0.09	0.21	0.41
6	0.5	0	0.5	0	R_{13}	0.058	0.14	0.26	0.43
7	0.5	0.5	0	0	R_{14}	0.053	0.12	0.2	0.41
8	0	0.5	0.5	0	R_{23}	0.041	0.09	0.21	0.46
9	0	0.5	0	0.5	R_{24}	0.03	0.11	0.22	0.44
10	0	0	0.5	0.5	R_{34}	0.06	0.12	0.15	0.47
CONTROL									
11	0.6	0.2	0.2	0	C_1	0.12	0.22	0.22	0.44
12	0.3	0.3	0.3	0.1	C_2	0.09	0.25	0.25	0.41
13	0.4	0.2	0.2	0.2	C_3	0.06	0.13	0.26	0.55
14	0.25	0.35	0.4	0	C_4	0.05	0.28	0.27	0.4
15	0.55	0	0.25	0.2	C_5	0.03	0.11	0.28	0.58
16	0.2	0.3	0.4	0.1	C_6	0.021	0.2	0.279	0.5
17	0.8	0.1	0.1	0	C_7	0.025	0.085	0.33	0.56
18	0.45	0.25	0.15	0.15	C_8	0.031	0.33	0.33	0.31
19	0	0.35	0.25	0.4	C_9	0.035	0.075	0.34	0.55
20	0.3	0.25	0.2	0.25	C_{10}	0.1	0.3	0.2	0.4

He also employed a regression equation as a component of his testing strategy. He explained the reaction Y in terms of the proportions of the mixture's components Z so that the total aggregate of all the proportions equals one.

$$Z_1 + Z_2 + \ldots + Z_q = \sum_i^q Zi = 1 \qquad (1)$$

where q represents the total number of components in the mixture and Zi represents the component proportion.

According to Osadebe, Taylor's Series can be used to extend the response Y, which is continuous and differentiable from its predictors, in close proximity to a selected point Z_0.

A. Osadebe's Regression Coefficients

The unknown constant coefficients, I and _ij, of Osadebe's regression model equation are specified if they can be determined in only one way. The regression equation is provided as follows if the polynomial's degree is 2 and there are 6 constituents (q).

$$Y = \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_3 + \beta_4 Z_4 + Z_1 Z_2 + \beta_{13} Z_1 Z_3 + \beta_{14} Z_1 Z_4 + \beta_{23} Z_2 Z_3 + \beta_{24} Z_2 Z_4 + +\beta_{34} Z_3 Z_4 \qquad (29)$$

The second-degree regression method proposed by Osadebe centres on Equation (29).

B. Original and Faux Mixtures

Regular concrete mixes cannot be used at any given water-cement ratio due to the simplex requirement as mentioned in Equation (1), necessitating a change in the actual components to meet this criterion. The (Zi) and (Xi) parts of Osadebe's (4,2) Spatial Lattice are shown in Table 1.

Table 2: Mix ratios and Components fractions

MIXTURE PERCENTAGES					**COMPONENT'S FRACTION**			
No.	S_1	S_2	S_3	S_4	Z_1	Z_2	Z_3	Z_4
1	0.2	1	1	3	0.08	0.25	0.23	0.44
2	0.4	1	1.5	4	0.071	0.168	0.25	0.51
3	0.35	1	2	2.5	0.095	0.155	0.32	0.42
4	0.5	1	3	6	0.018	0.09	0.21	0.61
5	0.3	1	2.5	4.5	0.058	0.14	0.26	0.53
6	0.25	1	2	5	0.053	0.12	0.3	0.51
7	0.2	1	1.5	6	0.041	0.09	0.31	0.56
8	0.45	1	3.5	5	0.03	0.11	0.32	0.54
9	0.6	1	1.5	5	0.06	0.12	0.25	0.57
10	0.32	1	2	6	0.06	0.1	0.25	0.59
CONTROL								
11	0.5	1	1	4	0.121	0.21978	0.21978	0.43956
12	0.7	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	0.43	1	2.5	5	0.056	0.277778	0.277778	0.555556
15	0.38	1	3	6	0.038	0.096154	0.288462	0.576923
16	0.4	1	5	7	0.038	0.306212	0.306212	0.568679
17	0.3	1	4	7	0.028	0.080972	0.323887	0.566802
18	0.5	1	2	3.5	0.038	0.333087	0.333087	0.555144
19	0.4	1	3.8	7.5	0.035	0.072046	0.345821	0.54755
20	0.7	1	5.5	9	0.032	0.345543	0.345543	0.552868

The "Pseudo-components" in the design grid in the first table shows the Xi experimentation points., whereas the "Real Experimental Components" are the Ci.

$X = AC$ (30) and $C = AX^T$, where A is the negative of the C matrix. (31)

No	C_1	C_2	C_3	C_4	C_1C_2	C_1C_3	C_1C_4	C_2C_3	C_2C_4	C_3C_4
1	0.12	0.2	0.2	0.2	0.024	0.024	0.024	0.04	0.04	0.04
2	0.061	0.168	0.25	0.51	0.010248	0.01525	0.03111	0.042	0.08568	0.1275
3	0.075	0.115	0.22	0.32	0.008625	0.0165	0.024	0.0253	0.0368	0.0704
4	0.018	0.09	0.21	0.41	0.00162	0.00378	0.00738	0.0189	0.0369	0.0861
5	0.058	0.14	0.26	0.43	0.00812	0.01508	0.02494	0.0364	0.0602	0.1118
6	0.053	0.12	0.2	0.41	0.00636	0.0106	0.02173	0.024	0.0492	0.082
7	0.041	0.09	0.21	0.46	0.00369	0.00861	0.01886	0.0189	0.0414	0.0966
8	0.03	0.11	0.22	0.44	0.0033	0.0066	0.0132	0.0242	0.0484	0.0968
9	0.06	0.12	0.15	0.47	0.0072	0.009	0.0282	0.018	0.0564	0.0705
10	0.06	0.1	0.15	0.49	0.006	0.009	0.0294	0.015	0.049	0.0735

Table 3: Table of C-values based on the first table

Table 4: A – MATRIX

16.93212654	7481.649975	-610.6215543	4347.704187	-12975.94925	21347.35468	-1359.47389	-8485.25851	-17002.77837	7696.393056
0.673329217	-1283.104315	28.9352308	-810.3781045	2147.4108	-3323.35047	270.8095577	1422.095746	2800.815159	-1327.0333
-2.885443083	1543.724939	-126.2190293	999.8325162	-2635.466913	4395.523741	-269.5845135	-1898.69514	-3443.893754	1536.504015
-0.879843759	-1379.69916	136.978109	-830.5771811	2382.640892	-4008.491155	224.7735035	1651.25813	3123.332856	-1382.538472
65.74659223	9307.193485	-934.9707644	6312.365302	-15631.10179	26004.35478	-1310.065166	-11923.5563	-20389.70797	9067.446301
-100.0541904	-51984.46557	5008.998302	-31559.79409	89639.47605	-149962.2061	9265.73064	61523.42535	118212.1695	-53232.67088
-6.282973659	7406.620387	-953.362686	4765.584048	-12682.43413	22161.41035	-1272.469533	-9508.52183	-17044.94274	7597.028378
16.6037192	-489.8105606	111.9940248	-339.1841914	932.8473049	-1732.25133	-340.8147804	1020.8938	726.1846707	51.19083389
-16.83346143	1121.613469	72.0967027	685.558702	-1863.077063	2618.397192	-193.7676486	-1159.71665	-2160.709446	958.6040452
14.24749386	3681.030869	-423.0965278	2105.233619	-6410.41046	10831.24408	-526.9062057	-4333.50363	-8424.922701	3707.282463

Table 5: X-MATRIX

1	-1.42109E-13	-2.84217E-14	-2.84217E-14	-3.41061E-13	-8.52651E-13	3.90799E-14	2.84217E-13	-1.7053E-13	-2.84217E-14
2.22045E-16	1	0	0	-6.82121E-13	-2.27374E-13	0	-1.1369E-13	2.27374E-13	-2.27374E-13
2.22045E-16	5.68434E-14	1	8.52651E-14	-1.7053E-13	-2.27374E-13	1.42109E-14	1.13687E-13	-1.13687E-13	-5.68434E-14
4.44089E-16	-5.68434E-14	0	1	-3.41061E-13	0	-1.42109E-14	5.68434E-14	3.41061E-13	0
0	-5.68434E-14	0	-5.68434E-14	1	0	7.10543E-15	3.41061E-13	4.54747E-13	-2.27374E-13
2.22045E-16	0	-1.42109E-14	-2.84217E-14	-2.27374E-13	1	-1.42109E-14	1.13687E-13	0	-1.7053E-13
4.44089E-16	-5.68434E-14	-7.10543E-15	-2.84217E-14	-3.41061E-13	-6.82121E-13	1	2.27374E-13	1.13687E-13	-1.7053E-13
4.44089E-16	0	-7.10543E-15	-5.68434E-14	-3.41061E-13	4.54747E-13	-1.42109E-14	1	-2.27374E-13	-5.68434E-14
0	0	-2.13163E-14	-2.84217E-14	-5.68434E-13	1.13687E-13	0	-1.1369E-13	1	0
0	0	-2.4869E-14	2.84217E-14	-2.84217E-13	0	0	2.27374E-13	-4.54747E-13	1

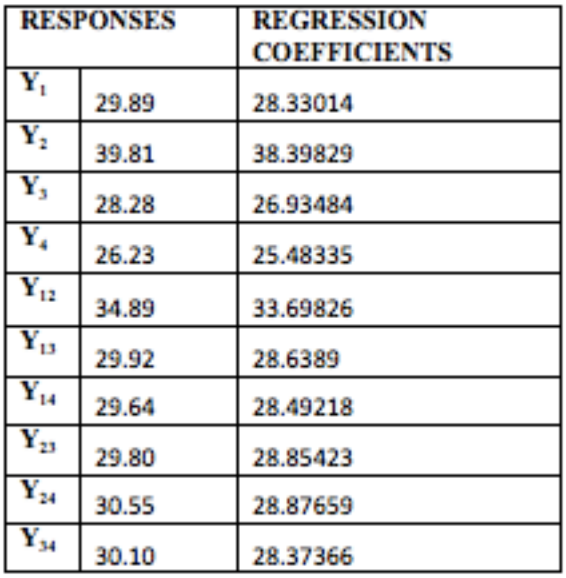
Table 6: Matrix of X – Transpose

1	2.22045E-16	2.22045E-16	4.44089E-16	0	2.22045E-16	4.44089E-16	4.44089E-16	0	0
-1.42109E-13	1	5.68434E-14	-5.68434E-14	-5.68434E-14	0	-5.68434E-14	0	0	0
-2.84217E-14	0	1	0	0	-1.42109E-14	-7.10543E-15	-7.1054E-15	-2.13163E-14	-2.4869E-14
-2.84217E-14	0	8.52651E-14	1	-5.68434E-14	-2.84217E-14	-2.84217E-14	-5.6843E-14	-2.84217E-14	2.84217E-14
-3.41061E-13	-6.82121E-13	-1.7053E-13	-3.41061E-13	1	-2.27374E-13	-3.41061E-13	-3.4106E-13	-5.68434E-13	-2.84217E-13
-8.52651E-13	-2.27374E-13	-2.27374E-13	0	0	1	-6.82121E-13	4.54747E-13	1.13687E-13	0
3.90799E-14	0	1.42109E-14	-1.42109E-14	7.10543E-15	-1.42109E-14	1	-1.4211E-14	0	0
2.84217E-13	-1.13687E-13	1.13687E-13	5.68434E-14	3.41061E-13	1.13687E-13	2.27374E-13	1	-1.13687E-13	2.27374E-13
-1.7053E-13	2.27374E-13	-1.13687E-13	3.41061E-13	4.54747E-13	0	1.13687E-13	-2.2737E-13	1	-4.54747E-13
-2.84217E-14	-2.27374E-13	-5.68434E-14	0	-2.27374E-13	-1.7053E-13	-1.7053E-13	-5.6843E-14	0	1

Table 7: Z - MATRIX

16.93212654	7481.649975	-610.6215543	4347.704187	-12975.94925	21347.35468	-1359.47389	-8485.25851	-17002.77837	7696.393056
0.673329217	-1283.104315	28.9352308	-810.3781045	2147.4108	-3323.35047	270.8095577	1422.095746	2800.815159	-1327.0333
-2.885443083	1543.724939	-126.2190293	999.8325162	-2635.466913	4395.523741	-269.5845135	-1898.69514	-3443.893754	1536.504015
-0.879843759	-1379.69916	136.978109	-830.5771811	2382.640892	-4008.491155	224.7735035	1651.25813	3123.332856	-1382.538472

65.74659223	9307.193485	-934.9707644	6312.365302	-15631.10179	26004.35478	-1310.065166	-11923.5563	-20389.70797	9067.446301
-100.0541904	-51984.46557	5008.998302	-31559.79409	89639.47605	-149962.2061	9265.73064	61523.42535	118212.1695	-53232.67088
-6.282973659	7406.620387	-953.362686	4765.584048	-12682.43413	22161.41035	-1272.469533	-9508.52183	-17044.94274	7597.028378
16.6037192	-489.8105606	111.9940248	-339.1841914	932.8473049	-1732.25133	-340.8147804	1020.8938	726.1846707	51.19083389
-16.83346143	1121.613469	72.0967027	685.558702	-1863.077063	2618.397192	-193.7676486	-1159.71665	-2160.709446	958.6040452
14.24749386	3681.030869	-423.0965278	2105.233619	-6410.41046	10831.24408	-526.9062057	-4333.50363	-8424.922701	3707.282463



RESPONSES		REGRESSION COEFFICIENTS
Y_1	29.89	28.33014
Y_2	39.81	38.39829
Y_3	28.28	26.93484
Y_4	26.23	25.48335
Y_{12}	34.89	33.69826
Y_{13}	29.92	28.6389
Y_{14}	29.64	28.49218
Y_{23}	29.80	28.85423
Y_{24}	30.55	28.87659
Y_{34}	30.10	28.37366

Table 8: Model Responses

RESPONSE SYMBOLS	MODEL RESPONSES
Y_{m1}	40.1
Y_{m2}	31.0
Y_{m3}	38.9
Y_{m4}	25.5
Y_{m5}	20.9
Y_{m6}	15.2
Y_{m7}	43.4
Y_{m8}	35.5
Y_{m9}	32.5
Y_{m10}	25.1

CONCLUSION

The chart below shows the test results for each of the 20 design elements for compressive strength. Ten of the twenty sites are control points, and at each of the control points, two replicate experimental observations were taken. The average values calculated from the sample strength values are also shown in Table 8.

Using the regression formula in equation 29,

$$Y = \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_3 + \beta_4 Z_4 + \beta_5 Z_5 + \beta_6 Z_6 + \beta_{12} Z_1 Z_2 + \beta_{13} Z_1 Z_3 + \beta_{14} Z_1 Z_4 + \beta_{15} Z_1 Z_5 + \beta_{16} Z_1 Z_6 + \beta_{23} Z_2 Z_3 + \beta_{24} Z_2 Z_4 + \beta_{25} Z_2 Z_5 + \beta_{26} Z_2 Z_6 + \beta_{34} Z_3 Z_4 + \beta_{35} Z_3 Z_5 + \beta_{36} Z_3 Z_6 + \beta_{45} Z_4 Z_5 + \beta_{46} Z_4 Z_6$$

Table 8 lists the validity of the findings based on the mode.

Table 9: Student t-test for the optimization model

Controls	Y_E	Y_M	$D_i = Y_E - Y_M$	$D_A - D_i$	$(D_A - D_i)^2$
C1	41.7	42.1	-0.4	-0.04	0.00016
C2	35.5	35	0.5	0.05	0.0025
C3	31.8	32	-0.2	-0.06	0.0036
C4	25.51	25.5	0.01	-0.05	0.0025
C_5	20.95	20.90	0.05	-0.11	0.0121
C_6	15.17	15.20	-0.03	-0.03	0.0009
C_7	43.37	43.40	-0.03	-0.03	0.0009
C_8	35.52	35.50	0.02	-0.08	0.0064
C_9	33.38	33.40	-0.02	-0.04	0.0016
C_{10}	24.88	24.90	-0.02	-0.04	0.0016
		$\sum D_i$	**-0.12**	$\sum (D_A - D_i)^2$	0.03226

Evaluating the Model Suitability.

The tool used to determine whether the model was sufficient was the t-test. At a 95% confidence level, there is no appreciable difference between the experimental and predicted compressive strength readings of the MS-RHA concrete. (h_0). (2). The alternative theory considerably differs from the experimental and predicted values of the compressive strength of MR-RHA concrete with a 95% accuracy. (hi).

Di is equals to YE - YM, where YE stands for experimental responses, YM for model responses, and N for sample count.

DA (mean of difference between YE and YM) equals (D i)/N (32)

$$S^2 \text{ (Variance of difference of } D_\text{i} \text{ and } D_\text{A}) = \frac{\sum(D_A - D_i)^2}{N-1} \quad (33)$$

$$t_{calculated} = \frac{D_A \times N^{0.5}}{S} \quad (34)$$

$$D_\text{A} = \frac{\sum D_i}{N} = \frac{-0.12}{10} = --0.012$$

Total variance permitted in the t-test: Degree of Freedom = N - 1 = 95% two-tailed test significance = 2.5% = 0.025 100% - 2.5% = 97.5% = 0.975

Allowable total variance in t-test = t (0.975, N1) = t (0.975, 9) = 2.262, according to the t-table. We support the null hypothesis and reject the alternate hypothesis because $t_\text{calculated} < t_\text{table}$.

V. CONCLUSION

The research's findings could lead to the following conclusions:

1. OPC in concrete can be concurrently replaced by RHA and MS.
2. The compressive strength of RHA-MS concrete can be predicted using the Osadebe's mathematical formula.
3. The highest compressive strength identified in this research is 35.0N/mm2, which translates to a water to cement ratio of 0.55 in a mix ratio of 0.55:1:1:2 with a 10% substitution of OPC with 5% of each RHA and MS. The RHA-MS concrete's predicted compressive strength varied from 35.0N/mm2 to 15.2N/mm2, demonstrating that it can be used as both structural and mass concrete.
4. Using concrete enables OPC save some 10%, which brings us to our final point. Also, this research has demonstrated that structural concrete may be produced using a multivariate binder that contains more naturally occurring and environmentally beneficial admixtures while yet keeping the same strength and ensuring environmental sustainability.
5. It has also been shown in this work that more ecologically friendly and naturally occurring admixtures can be used to create structural concrete from a variety of binder types while keeping the same strength.

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$$S^2 = \frac{\sum(D_A - D_i)^2}{N-1} = \frac{0.03226}{10-1} = 0.00393 \;\therefore s = 0.003584$$

$$t_{calculated} = \frac{D_A \times N^{0.5}}{S} = \frac{-0.012 \times 10^{0.5}}{0.003584} = --10.5867$$

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cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	**0.50**	**0.25**	**0.20**	**0.15**	**0.10**	**0.05**	**0.025**	**0.01**	**0.005**	**0.001**	**0.0005**
two-tails	**1.00**	**0.50**	**0.40**	**0.30**	**0.20**	**0.10**	**0.05**	**0.02**	**0.01**	**0.002**	**0.001**
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.000	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.327	31.599
3	0.000	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.215	12.924
4	0.000	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	0.000	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.000	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.000	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.000	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	0.000	0.697	0.876	1.088	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	0.000	0.695	0.873	1.083	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	0.000	0.694	0.870	1.079	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	0.000	0.692	0.868	1.076	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	0.000	0.691	0.866	1.074	1.341	1.753	2.131	2.602	2.947	3.733	4.073
16	0.000	0.690	0.865	1.071	1.337	1.746	2.120	2.583	2.921	3.686	4.015
17	0.000	0.689	0.863	1.069	1.333	1.740	2.110	2.567	2.898	3.646	3.965
18	0.000	0.688	0.862	1.067	1.330	1.734	2.101	2.552	2.878	3.610	3.922
19	0.000	0.688	0.861	1.066	1.328	1.729	2.093	2.539	2.861	3.579	3.883
20	0.000	0.687	0.860	1.064	1.325	1.725	2.086	2.528	2.845	3.552	3.850
21	0.000	0.686	0.859	1.063	1.323	1.721	2.080	2.518	2.831	3.527	3.819
22	0.000	0.686	0.858	1.061	1.321	1.717	2.074	2.508	2.819	3.505	3.792
23	0.000	0.685	0.858	1.060	1.319	1.714	2.069	2.500	2.807	3.485	3.768
24	0.000	0.685	0.857	1.059	1.318	1.711	2.064	2.492	2.797	3.467	3.745
25	0.000	0.684	0.856	1.058	1.316	1.708	2.060	2.485	2.787	3.450	3.725
26	0.000	0.684	0.856	1.058	1.315	1.706	2.056	2.479	2.779	3.435	3.707
27	0.000	0.684	0.855	1.057	1.314	1.703	2.052	2.473	2.771	3.421	3.690
28	0.000	0.683	0.855	1.056	1.313	1.701	2.048	2.467	2.763	3.408	3.674
29	0.000	0.683	0.854	1.055	1.311	1.699	2.045	2.462	2.756	3.396	3.659
30	0.000	0.683	0.854	1.055	1.310	1.697	2.042	2.457	2.750	3.385	3.646
40	0.000	0.681	0.851	1.050	1.303	1.684	2.021	2.423	2.704	3.307	3.551
60	0.000	0.679	0.848	1.045	1.296	1.671	2.000	2.390	2.660	3.232	3.460
80	0.000	0.678	0.846	1.043	1.292	1.664	1.990	2.374	2.639	3.195	3.416
100	0.000	0.677	0.845	1.042	1.290	1.660	1.984	2.364	2.626	3.174	3.390
1000	0.000	0.675	0.842	1.037	1.282	1.646	1.962	2.330	2.581	3.098	3.300
z	0.000	0.674	0.842	1.036	1.282	1.645	1.960	2.326	2.576	3.090	3.291
	0%	50%	60%	70%	80%	90%	95%	98%	99%	99.8%	99.9%
	Confidence Level										

PROFILE OF ENGR. DR. GODWIN ADIE AKEKE. PhD,fnse, fnice, JP

Dr. Akeke started his academic career with a Primary Education at the Primary School Kutiang, Government Secondary School Ipong, Obudu. He then proceeded to the then prestigious Polytechnic, Calabar where he obtained his Higher National Diploma. After his National Youth Service Corp at Igabi LGA of Kaduna State, he proceeded to the Rivers State University of Science and Technology, Port Harcourt where he obtained a Post Graduate Diploma in Civil Engineering and a Masters Degree in Civil Engineering (Structural Engineering) respectively. He later went back to the Cross River University of Technology where he Studied and obtained a Bachelors of Engineering in Civil Engineering. Dr. Akeke proceeded to the famous University of Nigeria, Nsukka where he obtained a PhD in Structural Engineering from the Department of Civil Engineering. He also obtained a

Doctorate degree in Business Administration, specializing in **Project Management,** awarded by the Common Wealth University, London and a Masters Certificate in e-learning and digital marketing from the London Graduate School. He is currently pursuing another Post Graduate program in Geotechnical Engineering.

Engr. Dr. Akeke, has acquired a lot of work experience at various levels. Such as; A Technologist at the Cross River University of Technology, Calabar and rose to the rank of Senior Lecturer. Within the period he was appointed the acting Head of Department of Wood Product Engineering and served in several committees of the University and now a visiting Senior Lecturer in the Department of Civil Engineering, University of Cross River.

He is a member of the Council for the Regulation of Engineering in Nigeria, a Fellow of the Nigerian Society of Engineers, a Fellow of the Nigerian Institution of Civil Engineers, a Member of the American Society of Civil Engineers, a Deacon and an Ambassador of Peace.

Dr. Akeke, has attended several conferences locally and internationally and has published academic and technical papers in learned journals both locally and internationally.

ENGR. DR. DESMOND ENYIA EWA MNSE

Engr. Dr. Desmond E. Ewa began his Engineering career with the then Polytechnic Calabar where he bagged a Higher National Diploma in Civil Engineering (Highway and Transportation option) with Distinction in 1999. In the year 2007, he earned his bachelor’s in Civil Engineering from the Federal University of Technology Owerri. In the years 2011 and 2016 he added an M. Eng and a Ph. D respectively in Civil Engineering (Materials & Construction) from the University of Nigeria Nsukka, (UNN), Enugu State. He has over 45 academic and professional publications/presentations with research interest in sustainable construction materials and mangement. He is a registered engineer with the Council for Regulation of Engineering in Nigerian (COREN). He is a member of the following professional bodies:

- Fellow, The Nigerian Society of Engineers (NSE)
- Fellow, The Nigerian Institution of Civil Engineers (NICE)
- Corporate Member, Nigerian Institute of Safety Engineers (NISafetyE)
- Corporate Member, Nigerian Institute of Highway & Transport Engineers (NIHTE)
- Associate Member, Nigerian Institute of Chartered Arbitrators (NICArb.).

He is a Visiting Senior Lecturer and former Head, Department of Civil Engineering in the Cross River University of Technology, Calabar and, Director, Directorate of Entrepreneurship, CRUTECH. He was a visiting Senior Lecturer in the Department of Civil and Environmental Engineering, University of Calabar, and External Examiner, Department of Civil Engineering, University of Nigeria Nsukka, (UNN). He is currently, Director, Civil, Cross River State Ministry of Works and Branch Chairman of NSE Calabar.

He has worked with STATUS ASSOCIATES, EKPE ARA & Partners and Struct- Design Consulting Engineering Firms. Where he was involved in a number of Federal and State Governments as well as World Bank Projects. He was also Site Agent for, SERMATECH NIGERIA LIMITED. He was a Director of Kairos Infrastructures Ltd (Consulting Engineers), and Associate Consultant – RABIONA ENGINEERING LTD.

He has served the Nigerian Society of Engineers in a number of capacities at the national, divisional, and branch levels, and has always upheld the Society's beliefs and ideals. Some of these positions include: Treasurer, General Secretary, Vice Chairman and currently, Chairman of NSE Calabar.

He was Technical Secretary of Nigerian Institution of Civil Engineers, Calabar branch and chairman, Technical Subcommittee for the 2018 National Conference of NICE, held in Calabar.

Engr. Dr. Jerome Godwin Egbe is a senior lecturer with the Department of Civil Engineering, with 15 years of teaching experience. He holds a B.ENG in Civil Engineering from Cross River University of Technology, Calabar, an MSc in Petroleum Refining Systems Engineering from the University of Surrey, United Kingdom, and a Ph.D. in Water Resources and Environmental Engineering, from the University of Nigeria, Nsukka- Enugu State.

He has worked with Cross River Road Maintenance Agency as a site supervisor, Engineer, and consultant to many construction firms, where his work traversed across different civil engineering disciplines and including, economic and technical feasibility studies, facilities planning, design, geotechnical investigations, contract administration, and construction and maintenance supervision. His research interest areas are in hydraulics, open channel flows, sediment transport, flood routing, and computational analysis in water treatment. Converting inert wastes into bio-amendments / bio-fertilizers – pilot projects at legacy waste dumping sites, Hydrothermal carbonization of crude oil sludge for recovery of solid fuel, Encapsulation and solidification of salt-based evaporation residues, Use of textile and tannery sludge as fine aggregates in concrete mix

Engr. Dr. Jerome Egbe has served as Vice-Chairman Nigerian Institution of Civil Engineers Cross River State, Chapter, and Past Chairman of the Nigerian Institution of Civil Engineers Calabar Chapter.

He is a prolific writer who has published over 40 research papers in several local and international journals and conferences of international repute. He is a member of the Geotechnical Association of Nigeria, a member of the Nigerian Society of Engineers, a registered member of the Council of Regulation of Engineering Profession in Nigeria, a Member Nigerian Institution of Civil Engineers, and a member of the Nigerian Institution of Water Engineers.

Engr. Dr. Jerome is currently Deputy, Student Affairs of UNICROSS, Coordinator of the Postgraduate Programme of

Civil Engineering, and Faculty of Engineering representative of the Postgraduate School of UNICROSS.

PROFILE OF DODEYE OKOI

Mr. Dodeye Okoi is an enterprising young man who is taking roots in the field of Engineering. He has a first degree in Structural Engineering with the University of Cross River State (UNICROSS), Cross River State of Nigeria.

Mr. Dodeye has been involved with several Engineering researches and publications and has had about eight years of experience. He has worked with Lafarge Company, Nigeria on industrial attachment within the period which he very significantly partook in the geotechnical investigations for the construction of the Company's cement production phase II facilities. He has also worked with a construction company – Na Mai Bingida Construction Company – which was to construct a three-storey faculty of allied medical science building for the University of Calabar, Calabar, Nigeria. Mr. Dodeye currently works with the Civil Engineering Department of the Cross River State Ministry of Works, Nigeria which is saddled with the responsibility of, amongst others, overseeing projects going on within the state.

Mr. Dodeye Okoi is now at the verge of obtaining a second degree in Structural Engineering with the University of Cross River State, (UNICROSS), Nigeria, after which he intends to still achieve more grounds in this unique field of study.