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Optimization of Compressive Strength and Water Absorption of Laterite Concrete incorporating Guinea Corn Husk Ash as Partial Replacement of Cement

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ABSTRACT :
Guinea corn husk (GCH) is an agricultural waste that is common in the northern parts of Nigeria. In this study, GCH was incinerated at a temperature up to 600^{0}C to form Guinea corn husk ash (GCHA). Laterite was used as a partial replacement for fine aggregate. GCHA was to mitigate the environmental nuisance caused by the waste and to reduce carbon dioxide emissions that come with cement production. Laterite soil was considered a possible replacement for the depleted river sand in the Abuja environs. The oxides composition of GCHA from X-RF tests indicated a combined percentage of silicon oxide, aluminum oxide and iron oxide of 86.38% which is above 70% minimum specified for a pozzolana. The X-RD tests results shows an abundance of quartz crystals of 63%, 41%, 48%, and 59% with Kaolinite and Iron oxides. Also the XRF results shows an abundance of aluminium (43.05%), iron (22.67%) and silicon oxide (12.92%) respectively. The presence of quartz shows and indicate that the soil is well weathered and well drained and thus indicate laterite in them. The hydrometer analysis also gave 92.218% sand, 3.672% silt, 0.11% clay and 0% gravel. Scheffe's third-degree polynomial was used for optimisation in obtaining the optimum compressive strength and water absorption with the corresponding mix ratios. The results showed that an optimum strength of 21.3841N/mm^2 was obtained for a mix ratio of 0.55878: 0.5231: 0.3341: 0.1429: 1.0000 and 2.0000 for water, cement, GCHA, fine aggregate, laterite and coarse aggregate respectively. The minimum water absorption value was 10.229% for a mix ratio of 0.5658: 0.5911: 0.1363: 0.2727: 1.000: 2.000 for the six materials earlier listed.

KEYWORDS: *Guinea Corn, Laterite, Pozzolana, Compressive strength, Water Absorption.*

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I. INTRODUCTION

Concrete is a fundamental and basic construction material that is widely used globally as a construction material in the building and construction industry. It has played a pivotal role in the explosive development of modern infrastructure. Its versatility and adaptability have made it the basic and primary choice for various construction uses and application. Concrete is a mixture of cement, aggregates, water and (occasionally) additives (Ndububa *et al.,* 2023). The worldwide consumption of concrete is put at 30 billion metric tons that is approximately three times more consumption in 40 years past (Nature Journal Vol. 597., 2021). The major reason for the high consumption of concrete in the world is the huge source of raw materials, ease of production, and ease of casting into various shapes, good fire resistance, and corrosion resistance. Fine aggregate which is a constituent of Concrete is gradually been over mined in Abuja, Nigeria leading to construction firms and companies sourcing for this material and looking for it elsewhere in very distance location, which is not quite easy (U.C Anya, 2015). Laterite is such material to fill in the gap for fine aggregate to be used as partial replacement for the fine aggregate for concrete production (Ambrose *et al*., 2018). Laterite, an abundant low quality aggregate in tropical countries which are reddish residual soils formed by the weathering of rock with high iron oxide and aluminium hydroxide content, variable amount of clay minerals and low in silica content. Laterite is abundantly available in Abuja, and throughout the tropical regions of Africa, Australia, South east Asia, and South America. It is cheap and has no environmental Hazard. Laterite will be used as partial replacement for sharp sand(fine aggregate) in order to ameliorate the suffering faced due to the high cost of transportation and its unavailability due to over mining. . Cement which is the major binder course in concrete play a vital role in bonding of the constituents materials together during the hydration process. The production of conventional concrete comes with a significant cost due to the excessive use of Portland cement which is energy intensive to produce. Portland Cement production process apart from gradually been expensive due to its high demand and transportation costs have also a high percentage of carbon emission in the atmosphere, depletion of the ozone layer and climate change has lead to researchers having in recent times exploring on other alternative means for a binder course either as a partial replacement of cement in concrete or a complete replacement in other to avert such consequences. One of such material used for partial replacement of cement is Guinea corn Husk Ash (GCHA), which satisfies the properties of a Pozolana (Ndububa, 2015). . GCHA analysis shows that the combination of its various chemical constituents also qualifies it as a pozolana (Ndububa, 2022). These materials heve been used in construction for thousands of years, particularly in ancient Roman and volcanic regions, where they were used as binding agents in concrete and mortar (ASTM C1240-20, 2020). The description of of various kinds of Pozolanas and their specifications are given in ASTM C618 and ASTM C1240 (Faluyi, 2024; ASTM C618–22, 2022). The results of compacting factor tests for workability of GCHA are in accordance with European standard codes (ENV 206, 1992) and the slump test results are in accordance with Brithish standards (BS 1881 Part 102, 1983) .A study carried out by (ASTM C1240-20, 2020) and according to ENV 206 5% replacement of GCHA with cement gave an optimal compressive strength of 26.3KN/M^2. Other classification of laterite and its uses are contained in (Jan *et al*., 2007; Marto, 2014; Maiti *et al*.,2013; Ndububa and ochuluje, 2022).

The aim and purpose of this study is to evaluate and determine the optimisation of the compressive strength and water absorption of laterite concrete incorporating GCHA as partial replacement for cement.

Fig. 1: Guinea Corn Husk (GCH)

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II. THEORY/CALCULATION/METHODOLOGY

2.1 MATERIALS

All the materials used in this research were collected within the federal capital territory, Abuja. Relevant standards and codes were used in the conducting the experiments. The materials used for this study are fine aggregate (river sand), coarse aggregate (crushed granite), Portland limestone Cement (PLC) , Guinea Corn Husk Ash (GCHA), Laterite and water.

Guinea Corn husk Ash (GCHA) was obtained locally from Madalla Market, Suleja in Niger state. It was gotten as part of the post harvest wastes from guinea corn processing. It was converted from Guinea corn husk (GCH) into GCHA in a furnance at a regulated temperature up to 600^0C, at the chemistry advance research centre of Sheda Science and Technology (SHESTCO) in Abuja and was allowed to cool down before use.

The laterite samples used were obtained from and existing road construction site at Kuje district of the Federal Capital Territory, Abuja.

The fine aggregate (river sand) and coarse aggregate were also obtained from Gwagwalada area council of the federal capital Territory, Abuja.

The ordinary Portland cement (OPC) was obtained from the the Dangote brand of the obajana plant in kogi state from approved retailers in Abuja.

The water was clean potable drinking water. The PH value should be 7. Clean water that is free from impurities improves the strength of concrete.

The fine aggregates and laterite were characterised in accordance with the requirements of BS-EN 1997-2 (2007) and BS 812 – 112 for the laterite , coarse aggregate and cement respectively.

The method of classification use for the soil samples required as are the Particle size distribution for the fine aggregate, GCHA and laterite and the chemical composition of the GCHA were conducted to meet with the requirements of a Pozzolana in in accordance with European standards (BS EN 196-1 2006). The X-Ray diffraction methods were used.

Maximum size of 20 mm for the crushed aggregate was used. The laterite scraps was crushed and sieved through 4.75 mm sieve. The combined sieve analysis for both laterite and the fine aggregate was obtained. As soon as all the materials were collected, the laterite sample was air-dried, broken very well and sieved to obtain a loose material devoid of impurities for the particle size analysis.

2.2 MIX DESIGN

The mix design was carried out in accordance with Concrete Mix Design Manual (COREN, 2017), and the European committee for standardization (BS-EN 206-1:2000 part 1). The proportioning of PLC, fine-aggregate, coarse-aggregate laterite soil, GCHA and water, was carried out by measuring the calculated quantities from the mix design. Using Scheffe's method of mixtures for a simplex lattice configuration of (6,3) a minimum of 56 trial mixes used. The distribution of the mixture points were also determined by the points on the (6,3) simplex tetrahedron, showing where each vertex point corresponds to pseudo components given by X_1,X_2, X_3,X_4,X_5 and X_6 respectively. These components represents , water, cement, Guinea corn husk ash, fine aggregate, laterite soil and the coarse aggregate. These Pseudo components were generated with the consideration the 6 of required mixture components are located at the vertices of the simplex tetrahedron.

In using this approach , six set of initial trial mixture were developed and constituted into a mixture of Matrix A to be determined as; equation below:

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$$A = \begin{bmatrix} 0.55 & 1.00 & 0.00 & 0.00 & 1.00 & 2.00 \\ 0.56 & 0.49 & 0.08 & 0.42 & 1.00 & 2.00 \\ 0.57 & 0.49 & 0.17 & 0.34 & 1.00 & 2.00 \\ 0.58 & 0.48 & 0.36 & 0.26 & 1.00 & 2.00 \\ 0.59 & 0.47 & 0.35 & 0.18 & 1.00 & 2.00 \\ 0.60 & 0.47 & 0.44 & 0.09 & 1.00 & 2.00 \end{bmatrix} \quad (1)$$

The size of the sample space was determined given the 6-components mixture for the work using the equation below

For N (q,m) where $q=6; m=3$

$$N(q,m) = \frac{(q+m-1)!}{m!(q-1)!} \quad (2)$$

$$N(6,3) = \frac{(6+3-1)!}{3!(6-1)!} = 56 \quad trial \quad mixtures$$

The laboratory test results and the laboratory data used are for the compressive and water absorption responses were used herein in developing the required objective function for the use in the optimization computations.

Therefore, the corresponding third- degree polynomial for the dissertation is shown in the equation below. The combination of the linear and quadratic form of the response model is required for which $0 \le i \le j \le k \le 6$ with the general represented below as shown in the equation (2).

The actual relationship between the constant actual component A, the pseudo-component X and the real component Z for a N (6,3) mixture is given by the equation below;

$$Z = X.A \quad (3)$$

After the determination of the scheffe's Mixture space, laboratory mixture quantities were now calculated . The density / bulk density of the materials were determined. The measured quantities of the materials used of water, cement, fine aggregate, laterite, GCHA, and the coarse aggregate and computed in the mix design were mixed thoroughly before the water was added in order to obtain a uniform distribution of consistent material. The wet mix was placed in 150 x 150 x 150 mm concrete mould and compacted and leveled up using a hand trowel. The samples were then demoulded after 24 hours and immediately transferred into a water curing tank that is filled, to be cured for 28 days before testing.

Slump tests were carried out on each of the wet concrete mix proportions in accordance with the relevant British standards. (BS 1881 Part 102, 1991).

2.3 TESTS AND MEASUREMENTS

Two Samples each per trial mix were tested for water absorption and compressive test at 28 days. The average values for both test was be used for analysis and modelling. The compressive test and water absorption tests were carried at the university of Abuja , Civil engineering laboratory. Other tests that was conducted were carried out at the Nigerian Road and Building Research Institutes (NRBRI), SHETCO, and the African university of Science and Technology, Abuja (AUST).

Concrete cubes samples placed in a mould of dimensions of 150 x 150 x 150mm was subjected to compressive test on the hydraulic testing machine. The tests was carried out in accordance with requirements of BS 12390-3 (2009) and COREN. The values of the compressive test were then computed and calculated by dividing the failure load F by the cross-sectional area A of the sample recorded.

$$f = {F}/{A} \qquad (4)$$

The water absorption was performed by determining the porosity and permeability of the hardened concrete. The concrete specimen was dried, weighed and immersed in water for a 24 hrs period. When the time of immersion, was over, the specimen was brought out of the water then surface dry and weigh again. The difference recorded in weight before and after immersion was then used to calculate the water absorption percentage. BS 1881-111 .The absorption of water index was computed b the equation below;

$$Iw = \frac{w_2 - w_1}{w_1} X100 \qquad (5)$$

W_1 and W_2 are the actual weights of the required sample before and after immersion in water, while I_W is measured as the actual percentage representing the increase in the weight of the sample due to the absorption of water. Water absorption can vary, but a common standard is that water absorption for quality concrete should be less than 7% on the average. Appendix 1 shows the required mix design.

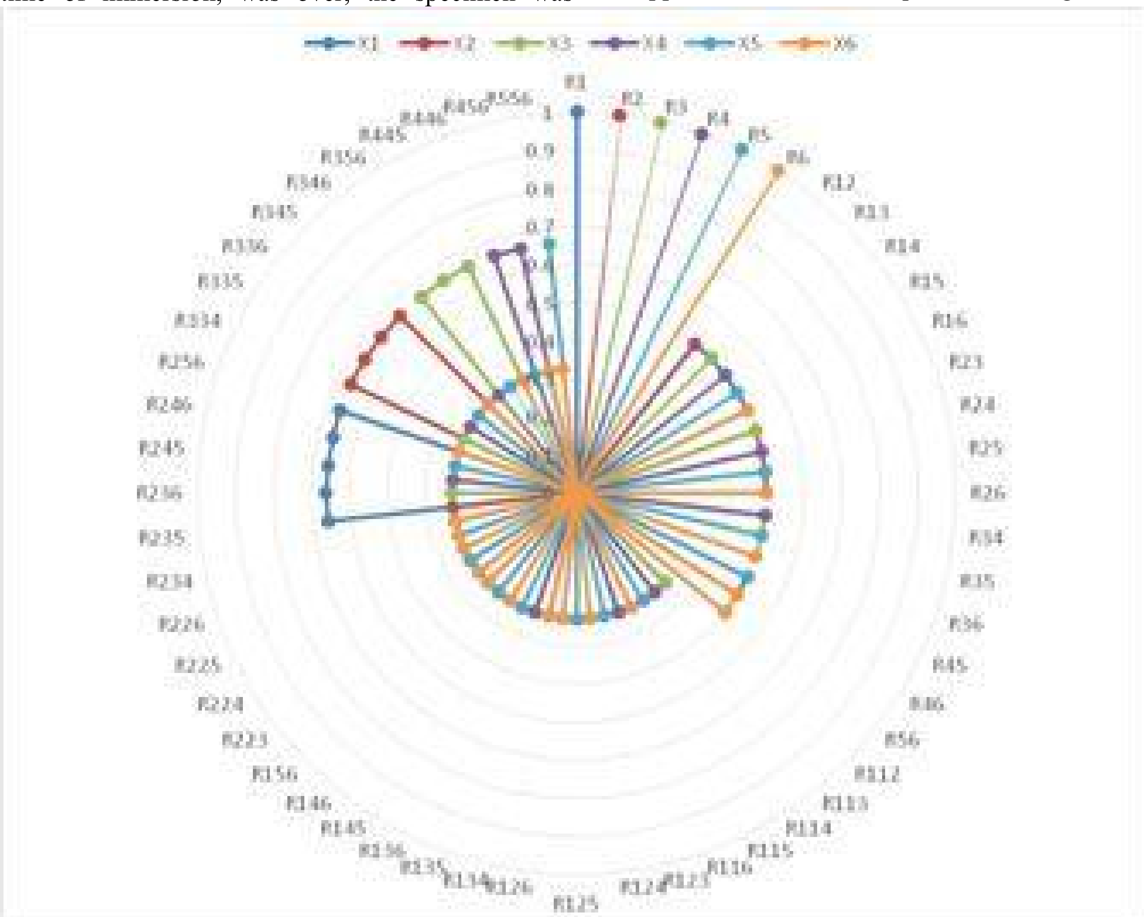

Fig. 2 A Multidimensional Radial Plot of the 6-Pseudo-Components Factor Space

Fig. 3 : Weighing of GCHA sample

III. RESULTS AND DISCUSSIONS

The table below shows the composition of the various compounds found in GCHA. The results of the chemical analysis were done and the various percentage proportion of the oxide content were recorded as shown, the results shows that the total combined content of silica, alumina and ferric oxides were found to be 85.38% which is actually above the specified 70% for pozolanas. Therefore GCHA is thus qualified and suitable for use as a pozolana.

Table 1 : Chemical Composition Of GCHA

S/no.	Oxide content	Percentage content
1	Sio_2	84.5%
2	Al_2O_3	0.34%
3	Fe_2O_3	0.54%
4	SO_3	0.50%
5	Na_2O	0.88%
6	K_2O	3.98%
7	CaO	2.01%
8	MgO	0.03%
9	TiO_2	0.08%
10	MnO_3	0.99%
11	CuO	0.05%
12	ZnO	0.18%
13	L.O.I	5.92%

The X-Ray fluorescence test also conducted on laterite samples shows that there was a high percentage of Iron oxide which led to the reddish colouring nature amongst other compounds.

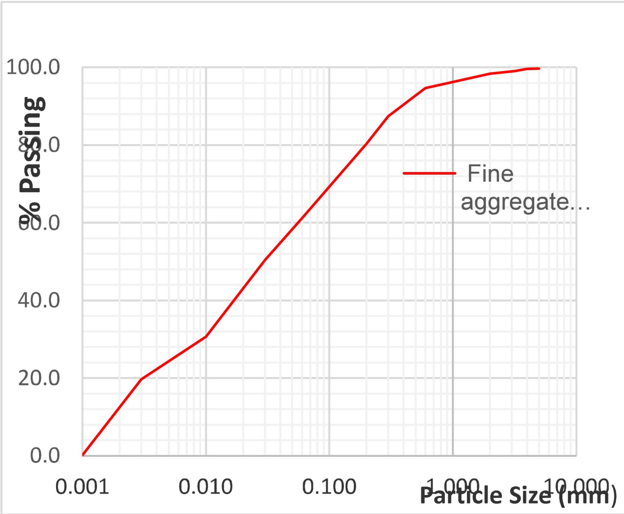

Fig.4: Particle size distribution (Fine aggregate).

The percentage composition of the lateritic material used for the various samples are shown thus;

Table 2: Percentage composition Clay, silt and sand for Laterite

Properties of the lateritic soil	A	B	C	D
Depth of Sampling	2.0m	2.0m	2.0m	2.0m
Moisture content (%)	12.35	10.99	24.36	11.13
Fines (%)	3.78	2.4	5.47	2.21
Silt (%)	3.672	2.13	5.35	2.14
Clay	0.11	0.09	0.13	0.06
Sand (%)	96.2	97.6	97.8	97.6

3.1 Workability

On each mix slump tests were carried out on the proportion of the wet concrete in line with the relevant British standard codes (BS 1881 Part 102, 1991) as required. Some of the results gotten at various mixes were between 11mm and 4mm respectively . The highest slump of 15mm was the controlled sample without GCHA and laterite. Slump decreased with an increase of laterite and GCHA. The densities of the concretes recorded were between 2672kg/m^3 and 3392kg/m^3. This indicates that, the usage of laterite and GCHA does not actually alter the density of the concrete produced. The control sample had a density of 2520 kg/m^3.

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Fig 5: Slump Test

Fig. 6: Compressive Test

3.2 Compressive Strength

The compressive strength obtained from the required experiments indicates the range of response values obtainable from the factor space. The compressive strength model developed below in Eqn. 6 is an objective function for the optimisation computation.

$$\begin{aligned} n(X_{Comp}) = {} & 20.3100X_1 + 20.6063 + 18.4770X_1X_2 - 34.961X_1^2X_2 + 20.5838X_3 + 13.4269X_1X_3 \\ & - 25.7225X_3 - 3.1738X_3 - 45.0248X_2X_3 + 5.2388X_3 \\ & + 21.160436647920793X_4 + 4.0262X_1X_4 - 10.2393X_1^2X_4 - 5.9264X_2X_4 \\ & - 23.4877X_1X_2X_4 + 9.2762X_2^2X_4 + 1.09751X_3X_4 - 22.3581X_1X_3X_4 \\ & + 9.2635X_2X_3X_4 - 2.1185X_4 + 21.6070X_5 - 0.7366X_1X_5 - 1.6626X_5 \\ & - 2.1901X_2X_5 - 21.7023X_1X_2X_5 + 2.5950X_2^2X_5 + 4.5641X_3X_5 - 20.3039X_3X_5 \\ & + 1.4298X_2X_3X_5 - 8.8079X_5 + 12.8323X_4X_5 - 15.8462X_4X_5 - 9.4398X_2X_4X_5 \\ & - 29.7061X_3X_4X_5 - 25.8482X_4^2X_5 + 21.9679X_6 + 0.8819X_1X_6 - 3.76478X_1^2X_6 \\ & + 1.6810X_2X_6 - 28.2840X_1X_2X_6 - 4.5598X_6 + 8.2553X_3X_6 - 25.8535X_1X_3X_6 \\ & - 12.5336X_2X_3X_6 - 15.8324X_3^2X_6 + 15.4053X_4X_6 - 26.8348X_1X_4X_6 \\ & - 21.9441X_2X_4X_6 - 41.8734X_3X_4X_6 - 30.6729X_4^2X_6 + 18.7479X_6 \\ & - 29.5984X_1X_5X_6 - 35.2878X_2X_5X_6 - 55.1617X_5X_6 - 77.2242X_5X_6 \\ & - 37.9023X_5^2X_6 \end{aligned} \qquad (6)$$

The developed model above for the compressive strength has a value of 99.88% indicating its fitness for use as a model for the prediction of compressive strength of the required mixture for the optimisation computations. The optimisation computations using the scheffe's algorithm clearly indicates that the actual recommended mixtures needed for specific compressive strength is indicated below in table 3.

Table 3. **Recommended mix proportions for the Compressive strength values for the Mixture**

S/No.	Item(s)	Symbol	Pseudo X_i	Mix-1	Mix-2	Mix-3	Mix-4	Mix-5	Mix-6
	W/C Ratio	Z1	0.0957	0.5878	0.5638	0.5816	0.5686	0.5686	0.5725
	Cement	Z2	0.1064	0.5231	0.5725	0.4793	0.6013	0.6444	0.4927
	GCHA	Z3	0.0738	0.3341	0.1174	0.2773	0.1971	0.2113	0.2448
	Fine Aggregate	Z4	0.0485	0.1429	0.3101	0.2435	0.1945	0.1346	0.2527
	Laterite	Z5	0.0005	1.0000	1.0000	1.0000	0.9928	0.9900	0.9900
	Coarse Aggregate	Z6	0.6751	2.0000	2.0000	2.0000	1.9855	1.9800	1.9800
	Compressive Strength		1	21.3841	20.7513	21.2077	20.4819	20.3165	20.5000

3.3 Water Absorption

The water content depends largely on the interfacial bonding that exists within the constituent materials that makes up a sample. The equation 7, below indicates the water absorption model developed for the objective function for the optimisation computation.

$$
\begin{aligned}
n(X_{Moisture}) = {} & 2.9280X_1 + 8.5174X_2 + 32.2222X_1X_2 - 54.6932X_1^2X_2 + 12.6048X_3 \\
& + 22.7414X_1X_3 - 37.1271X_1^2X_3 - 57.07261249112113X_2X_3 - 26.8497X_1X_2X_3 \\
& + 119.3550X_2^2X_3 + 13.0467X_4 + 25.50540X_1X_4 - 25.9133X_1^2X_4 - 49.3566X_2X_4 \\
& + 6.3204X_1X_2X_4 + 116.2377X_2^2X_4 - 20.8037X_3X_4 + 11.7588X_1X_3X_4 \\
& + 171.4144X_2X_3X_4 + 55.8059X_3^2X_4 + 8.9865X_5 + 29.2674X_1X_5 - 3.0937X_1^2X_5 \\
& - 8.5412X_2X_5 - 2.5352X_1X_2X_5 + 63.632X_2^2X_5 - 17.9496X_3X_5 \\
& + 49.6306X_1X_3X_5 + 166.5822X_2X_3X_5 + 57.1638X_3^2X_5 + 12.8437X_4X_5 \\
& + 48.7582X_1X_4X_5 + 142.7219X_2X_4X_5 + 103.7933X_3X_4X_5 - 20.5967X_4^2X_5 \\
& + 4.7425X_6 + 40.3904X_1X_6 + 4.4017X_1^2X_6 - 20.6662X_2X_6 + 44.8001X_1X_2X_6 \\
& + 95.6647X_2^2X_6 - 15.9193X_3X_6 + 81.6159X_3X_6 + 222.3855X_3X_6 + 55.6805X_6 \\
& - 61.7473X_4X_6 + 140.9746X_1X_4X_6 + 255.9963X_2X_4X_6 + 202.5897X_3X_4X_6 \\
& + 127.5681X_4^2X_6 - 102.9102X_5X_6 + 178.3876X_1X_5X_6 + 251.5291X_2X_5X_6 \\
& + 241.2276X_3X_5X_6 + 245.4846X_4X_5X_6 + 209.32097X_6
\end{aligned} \tag{7}
$$

Table 4; **Water absorption values for the varying material composition.**

S/No.	Item(s)	Symbol	Pseudo X_i	Mix-1	Mix-2	Mix-3	Mix-4	Mix-5	Mix-6
	W/C Ratio	**Z1**	0.0367	0.5895	0.5658	0.5817	0.5660	0.5687	0.5722
	Cement	**Z2**	0.0763	0.4925	0.5911	0.4793	0.6150	0.6443	0.4832
	GCHA	**Z3**	0.0864	0.3486	0.1363	0.2779	0.1783	0.2119	0.2419

	Fine Aggregate	**Z4**	0.0977	0.1590	0.2727	0.2429	0.1988	0.1340	0.2652
	Laterite	**Z5**	1.08E-01	1.0000	1.0000	1.0000	0.9920	0.9900	0.9900
	Coarse Aggregate	**Z6**	5.95E-01	2.0000	2.0000	2.0000	1.9840	1.9800	1.9800
	Moisture Absorption		1.0000001	11.090	10.229	11.634	12.539	12.854	14.880

3.4 Statistical Validation of the Response Model

The models used for the optimisation computations were obtained by the use of the Wolfram language.

IV. CONCLUSION

The incorporation of Guinea corn husk ash (GCHA) as a partial replacement for cement were seen to have met the requirements of a pozzolanic material and thus can safely be used in the production of concrete . On the other hand laterite can also be used as a partial replacement for fine aggregate.

The Presence of laterites to the mix indicated that the water absorption increases as laterite increases, but affects the compressive strength value of concrete.

In addition, the lower slump value recorded , were due to the presence laterite and thus increase in density, but reduces the compressive strength, therefore, the addition of more laterite to the mix is not advised.

The average compressive strength and water absorption results were seen to be 20.583 Mpa and 12.544 % as recorded in this work.

The Mix design using Scheffe's third degree polynomial generated for these materials should be adopted. However the incoporation of laterite did not improve the compressive strength due to the water absorption results it may likely improve other properties of concrete but not shown in this report. We can optimise for water absorption and compressive strength by maintaining the recommended optimisation results and material composition as stated in this study and thus can be used for the production of concrete.

This study on the use laterite and Guinea corn husk ash in the production of concrete can be seen to focus on these key areas as contribution to knowledge;

The statistical parameters shows and validates the suitability of the models.

(i) Alternative material Innovation: This research contributes to knowledge by exploring sustainable, cost-effective alternatives to traditional concrete materials. Its major Significance is that it supports environmentally friendly construction practices.

(ii) Mechanical & Durability Performance

It Provides data for engineers and builders to consider these materials as viable options in real-world construction.

(iii) Environmental Impact Reduction

It helps to quantify how using laterite and GCHA can reduce CO_2 emissions associated with cement production, promoting the use of agricultural waste (GCH), supports local material sourcing and reducing transportation energy costs. It therefore encourages the adoption of greener building materials in line with sustainable development goals (SDGs).

(iv) Economic Viability

It includes cost analysis, thus it can show a Reduction in overall concrete production costs. And viability for low-income housing projects or rural construction. It thus makes a case for practical application in affordable construction markets.

(v) Optimized Mix Designs

This Offers a ready-to-use formula for field engineers and construction companies.

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APPENDICES

Appendix 1

Matrix table for scheffe's N (6,3) mixture points for – water, cement, GCHA, laterite, fine aggregate and granite- Lattice Polynomial

S/No.	Response	Psuedo Componets						Real Components					
		X1	X2	X3	X4	X5	X6	Z1	Z2	Z3	Z4	Z5	Z6
1	R1	1	0	0	0	0	0	0.55	1.00	0.00	0.00	1.00	2.00
2	R2	0	1	0	0	0	0	0.56	0.49	0.08	0.42	1.00	2.00
3	R3	0	0	1	0	0	0	0.57	0.49	0.17	0.34	1.00	2.00
4	R4	0	0	0	1	0	0	0.58	0.48	0.26	0.26	1.00	2.00
5	R5	0	0	0	0	1	0	0.59	0.47	0.35	0.18	1.00	2.00
6	R6	0	0	0	0	0	1	0.60	0.47	0.44	0.09	1.00	2.00
7	R12	0.5	0.5	0	0	0	0	0.56	0.75	0.04	0.21	1.00	2.00
8	R13	0.5	0	0.5	0	0	0	0.56	0.74	0.09	0.17	1.00	2.00
9	R14	0.5	0	0	0.5	0	0	0.57	0.74	0.13	0.13	1.00	2.00
10	R15	0.5	0	0	0	0.5	0	0.57	0.74	0.18	0.09	1.00	2.00
11	R16	0.5	0	0	0	0	0.5	0.58	0.73	0.22	0.04	1.00	2.00
12	R23	0	0.5	0.5	0	0	0	0.57	0.49	0.13	0.38	1.00	2.00
13	R24	0	0.5	0	0.5	0	0	0.57	0.49	0.17	0.34	1.00	2.00
14	R25	0	0.5	0	0	0.5	0	0.58	0.48	0.22	0.30	1.00	2.00
15	R26	0	0.5	0	0	0	0.5	0.58	0.48	0.26	0.26	1.00	2.00
16	R34	0	0	0.5	0.5	0	0	0.58	0.48	0.22	0.30	1.00	2.00
17	R35	0	0	0.5	0	0.5	0	0.58	0.48	0.26	0.26	1.00	2.00
18	R36	0	0	0.5	0	0	0.5	0.59	0.48	0.31	0.22	1.00	2.00
19	R45	0	0	0	0.5	0.5	0	0.59	0.48	0.31	0.22	1.00	2.00
20	R46	0	0	0	0.5	0	0.5	0.59	0.47	0.35	0.17	1.00	2.00
21	R56	0	0	0	0	0.5	0.5	0.60	0.47	0.40	0.13	1.00	2.00
22	R112	0.33	0.33	0.33	0	0	0	0.55	0.65	0.08	0.25	0.99	1.98

23	R113	0.33	0.33	0	0.33	0	0	0.56	0.65	0.11	0.23	0.99	1.98
24	R114	0.33	0.33	0	0	0.33	0	0.56	0.65	0.14	0.20	0.99	1.98
25	R115	0.33	0.33	0	0	0	0.33	0.56	0.65	0.17	0.17	0.99	1.98
26	R116	0.33	0	0.33	0.33	0	0	0.56	0.65	0.14	0.20	0.99	1.98
27	R123	0.33	0	0.33	0	0.33	0	0.56	0.65	0.17	0.17	0.99	1.98
28	R124	0.33	0	0.33	0	0	0.33	0.57	0.64	0.20	0.14	0.99	1.98
29	R125	0.33	0	0	0.33	0.33	0	0.57	0.65	0.20	0.14	0.99	1.98
30	R126	0.33	0	0	0.33	0	0.33	0.57	0.64	0.23	0.12	0.99	1.98
31	R134	0.33	0	0	0	0.33	0.33	0.57	0.64	0.26	0.09	0.99	1.98
32	R135	0	0.33	0.33	0.33	0	0	0.56	0.48	0.17	0.34	0.99	1.98
33	R136	0	0.33	0.33	0	0.33	0	0.57	0.48	0.20	0.31	0.99	1.98
34	R145	0	0.33	0.33	0	0	0.33	0.57	0.48	0.23	0.28	0.99	1.98
35	R146	0	0.33	0	0.33	0.33	0	0.57	0.48	0.23	0.28	0.99	1.98
36	R156	0	0.33	0	0.33	0	0.33	0.57	0.48	0.26	0.25	0.99	1.98
37	R223	0	0.33	0	0	0.33	0.33	0.58	0.47	0.29	0.23	0.99	1.98
38	R224	0	0	0.33	0.33	0.33	0	0.57	0.48	0.26	0.26	0.99	1.98
39	R225	0	0	0.33	0.33	0	0.33	0.58	0.47	0.29	0.23	0.99	1.98
40	R226	0	0	0.33	0	0.33	0.33	0.58	0.47	0.32	0.20	0.99	1.98
41	R234	0	0	0	0.33	0.33	0.33	0.58	0.47	0.35	0.17	0.99	1.98
42	R235	0.66	0.33	0	0	0	0	0.55	0.82	0.03	0.14	0.99	1.98

43	R236	0.66	0	0.33	0	0	0	0.55	0.82	0.06	0.11	0.99	1.98
44	R245	0.66	0	0	0.33	0	0	0.55	0.82	0.09	0.09	0.99	1.98
45	R246	0.66	0	0	0	0.33	0	0.56	0.82	0.12	0.06	0.99	1.98
46	R256	0.66	0	0	0	0	0.33	0.56	0.81	0.15	0.03	0.99	1.98
47	R334	0	0.66	0.33	0	0	0	0.56	0.49	0.11	0.39	0.99	1.98
48	R335	0	0.66	0	0.33	0	0	0.56	0.48	0.14	0.36	0.99	1.98
49	R336	0	0.66	0	0	0.33	0	0.56	0.48	0.17	0.34	0.99	1.98
50	R345	0	0.66	0	0	0	0.33	0.57	0.48	0.20	0.31	0.99	1.98
51	R346	0	0	0.66	0.33	0	0	0.57	0.48	0.20	0.31	0.99	1.98
52	R356	0	0	0.66	0	0.33	0	0.57	0.48	0.23	0.28	0.99	1.98
53	R445	0	0	0.66	0	0	0.33	0.57	0.48	0.26	0.26	0.99	1.98
54	R446	0	0	0	0.66	0.33	0	0.58	0.47	0.29	0.23	0.99	1.98
55	R456	0	0	0	0.66	0	0.33	0.58	0.47	0.32	0.20	0.99	1.98
56	R556	0	0	0	0	0.66	0.33	0.59	0.47	0.38	0.14	0.99	1.98

Appendix 2

Compressive strength / Water absorption laboratory results of Sample concrete

	Compressive Strength (Mpa)				**Moisture Absorption**			
Response	**Sample -1**	**Sample -2**	**Stan. Dev.**	**Mean**	**Sample -1**	**Sample -2**	**Stan. Dev.**	**Mean**
R1	18.515	21.993	2.388	20.30	2.978	3.070	0.07	3.02
R2	20.658	20.546	0.079	20.60	9.494	7.682	1.28	8.59
R3	20.651	20.510	0.100	20.58	13.727	11.598	1.51	12.66
R4	21.154	21.160	0.004	21.16	13.724	12.489	0.87	13.11
R5	21.420	21.786	0.259	21.60	9.261	8.848	0.29	9.05
R6	21.704	22.223	0.367	21.96	4.725	4.910	0.13	4.82
R12	20.742	20.700	0.030	20.72	7.448	5.983	1.04	6.72
R13	20.658	20.546	0.079	20.60	9.494	7.682	1.28	8.59
R14	20.526	20.425	0.072	20.48	12.024	9.780	1.59	10.90

R15	20.651	20.510	0.100	20.58	13.727	11.598	1.51	12.66
R16	21.007	20.799	0.147	20.90	15.099	13.416	1.19	14.26
R23	20.526	20.425	0.072	20.48	12.024	9.780	1.59	10.90
R24	20.651	20.510	0.100	20.58	13.727	11.598	1.51	12.66
R25	21.007	20.799	0.147	20.90	15.099	13.416	1.19	14.26
R26	21.154	21.160	0.004	21.16	13.724	12.489	0.87	13.11
R34	21.007	20.799	0.147	20.90	15.099	13.416	1.19	14.26
R35	21.154	21.160	0.004	21.16	13.724	12.489	0.87	13.11
R36	21.272	21.492	0.156	21.38	11.715	10.895	0.58	11.31
R45	21.272	21.492	0.156	21.38	11.715	10.895	0.58	11.31
R46	21.420	21.786	0.259	21.60	9.261	8.848	0.29	9.05
R56	21.531	21.983	0.320	21.76	7.074	6.867	0.15	6.97
R112	19.028	20.563	1.086	19.80	7.841	8.193	0.25	8.02
R113	19.565	20.711	0.810	20.14	10.191	11.384	0.84	10.79
R114	19.907	20.707	0.566	20.31	12.340	13.457	0.79	12.90
R115	20.239	20.672	0.306	20.46	13.887	15.100	0.86	14.49
R116	19.907	20.707	0.566	20.31	12.340	13.457	0.79	12.90
R123	20.239	20.672	0.306	20.46	13.887	15.100	0.86	14.49
R124	20.580	20.674	0.066	20.63	15.145	16.598	1.03	15.87
R125	20.580	20.674	0.066	20.63	15.145	16.598	1.03	15.87
R126	20.659	20.460	0.141	20.56	15.586	17.308	1.22	16.45
R134	20.686	20.319	0.259	20.50	15.201	17.044	1.30	16.12
R135	20.239	20.672	0.306	20.46	13.887	15.100	0.86	14.49
R136	20.580	20.674	0.066	20.63	15.145	16.598	1.03	15.87
R145	20.659	20.460	0.141	20.56	15.586	17.308	1.22	16.45
R146	20.659	20.460	0.141	20.56	15.586	17.308	1.22	16.45
R156	20.686	20.319	0.259	20.50	15.201	17.044	1.30	16.12
R223	20.718	20.166	0.390	20.44	14.854	16.369	1.07	15.61
R224	20.686	20.319	0.259	20.50	15.201	17.044	1.30	16.12
R225	20.718	20.166	0.390	20.44	14.854	16.369	1.07	15.61
R226	20.708	20.002	0.499	20.35	13.745	15.162	1.00	14.45

R234	20.729	19.842	0.627	20.29	12.275	13.534	0.89	12.90
R235	18.024	20.387	1.671	19.21	4.418	3.318	0.78	3.87
R236	18.449	20.406	1.384	19.43	5.937	5.377	0.40	5.66
R245	19.028	20.563	1.086	19.80	7.841	8.193	0.25	8.02
R246	19.565	20.711	0.810	20.14	10.191	11.384	0.84	10.79
R256	19.907	20.707	0.566	20.31	12.340	13.457	0.79	12.90
R334	20.239	20.672	0.306	20.46	13.887	15.100	0.86	14.49
R335	20.580	20.674	0.066	20.63	15.145	16.598	1.03	15.87
R336	20.580	20.674	0.066	20.63	15.145	16.598	1.03	15.87
R345	20.659	20.460	0.141	20.56	15.586	17.308	1.22	16.45
R346	20.686	20.319	0.259	20.50	15.201	17.044	1.30	16.12
R356	20.718	20.166	0.390	20.44	14.854	16.369	1.07	15.61
R445	20.708	20.002	0.499	20.35	13.745	15.162	1.00	14.45
R446	20.683	19.665	0.720	20.17	10.839	12.026	0.84	11.43
R456	20.149	20.170	0.015	20.16	14.038	16.157	1.50	15.10
R556	20.136	20.151	0.011	20.14	14.099	16.285	1.55	15.19

REFERENCES

[1] E.E Ndububa, et al.“Sheffe’s Polynomial Optimisation of Laterite Concrete incorporating Periwinkle Shells and Coir”pp. 2, 2023.

[2] Nature Journal, “Concrete needs to lose its colossal footprint” vol.597, pp. 593-594, 2021. DOI:10.1038/ d41586-021-02612-5.

[3] U.C Anya “Models for predicting the structural characteristics of Sand-quarry dust block” Phd thesis Department of Civil engineering, University of Nigeria Nsukka, 2015.

[4] E.E Ambrose, D.U Ekpo, I.M Umoren, U.S Ekwere. “Compressive Strength and Workability of Laterized Quarry Sand Concrete”.Nigerian Journal of Technology Vol. 37, No. 3 pp 605-610, July 2018

[5] E.E Ndububa and N. Yakubu. “Effect of Guinea Corn Husk Ash as Partial Replacement for Cement in Concrete”, (IOSR-JMCE), Volume 12, Issue 2 Ver. I pp 40-45, (Mar - Apr. 2015),

[6] E.E Ndububa. “ Concrete from Alternative waste materials” DOI:http://dx.doi.org/10.5992/intechopen. Dec. 2022.

[7] A. S. A. T. Measurements, ASTM C1240-20 Standard Specification for Silica Fume used in Cementitious Mixtures. West Conshohocken, PA: ASTM International; 2020.

[8] F. Faluyi, C. Arum, O. Adetayo. “Effects of Partial replacement of sand with laterite on

compressive strength of OPC-activated Rice husk Ash (ARHA) Concrete”(2024)

[9] A. S. A. T. Measurements, ASTM C618–22 Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete. West Conshohocken, PA: ASTM International; 2022.

[10] British Standards, BS 1881 Part 102, "*Method of Determination of Workability*"

(London: British Standard Institution, 1983).

[11] European Standards ENV 206: 1992." *Concrete: Performance, Production, Placing, and Compliance Criteria"* (Brussels: European

Standards ENV, 1992)

[12] Y.L. Jan, S.C. Tsai, Y.Y. Wei, N.C. Tung, C.C. Wei, C.N. Hsu. "Coupled mechanics, hydraulics and absorption properties of mixtures to evaluate buffer/backfill materials". Phys. Chem. Earth, 32 98-14), (2007).

[13] A. Marto, N. Latifi, A. Eisazadeh. "Effect of non-traditional additives on engineering

and microstructural characteristics of laterite soil", Arab J. Sci. Eng., 39 (10), pp 6949-6958, (2014)

[14] A. Maiti, B.K. Thakur, J.K. Basu, S. De". Comparison of treated laterite as arsenic

adsorbent from different locations and performance of best filter under field conditions". J Hazard. Mater., 262. Pp 1176-1186, (2013).

[15] E.E Ndububa, S.O Ochuluje,. "A computational assessment of the deflection and shear improvement of concrete beam with laterite". An Asian journal of civil engineering, ;23:173-186-2022.