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Effect of Guinea Corn Husk Ash on the Mechanical Properties of Lateritic Concrete

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Abstract. Materials in Nigerian building construction are scaling great heights in prices, demanding every stakeholders in the industry to research into alternatives in indigenous materials and agricultural wastes for rural infrastructural development. This research was aimed at investigating the effects of guinea corn ash on mechanical properties of lateritic concrete as partial replacement for Ordinary Portland Cement (OPC). The lateritic concrete was investigated for its workability, porosity, compressive strength and corrosion resistance at varying water-cement ratios with different percentages of Guinea Corn Husk Ash (GCHA). Central composite method was used to obtain an optimal combination that would give the highest compressive strength for the lateritic. The optimal combination was found to be 20% GCHA and 80% OPC at 0.51 water cement ratio. This combination gave a porosity of 14.59%, slump height of 2.75 mm and a compressive strength of 18.78 N/mm². This is higher than the control compressive strength of 17.61 N/mm² by 6.64% obtained at 0.7 water-cement ratio. Therefore, guinea corn husk ash can be used as a replacement for cement in lateritic concrete.

1. Introduction

Concrete is a composition of cement, coarse and fine aggregates with water to facilitate binding, it makes up about 10-15% of the total mass of concrete [1,2]. Concrete being a very strong material in compression requires reinforcement due to its little or no ability to prevent sway effect and poor tensile strength [3–5]. Lateritic concrete are concrete in which laterite fines replace sand or laterite coarse replace crushed stone/coarse aggregate with cement and water [6,7]. Some researchers [8] reported that the average density of lateritic concrete is approximately 2328 kg/m³ or 22.81 kN/m³ which is lower than 24 kN/m³ the average density value for traditional concrete. Lateritic concrete therefore could only be used for low self-weight structural members. Results also show that cubes from lateritic concrete possesses relatively higher compressive strength, which makes it suitable for reinforced concrete elements [9] and concrete under mild conditions of exposure and with effect of harsh weather [10]. Muthusamy *et al.* [11] reported that the use of laterite up to 20% as aggregate replacement in concrete will help to minimize the high dependency on granite and hence preserve the natural resources from going into extinction.

Guinea corn husk is one of the agro-wastes generated after the guinea corn seed has been removed. These husks often become solid wastes in landfills thereby polluting the environment [12–14]. Deriving an alternative use for the waste generated will be a means of reducing the waste going into the environment to avoid potential hazard of pollution posed by disposing this agricultural by-product and provide avenue for cheaper cost of construction. Therefore, this paper is aimed at

investigating the effect of guinea corn ash on mechanical properties of laterized concrete.

The result was enhanced with the use of Design–Expert 10.0, a statistical package from Stat-Ease Inc., It helps in the design and investigation of multi-factor experiments. The software analysed the influence of the factors and their relationship with other factors by varying their values in parallel. The optimization feature makes it possible to deduce the optimum operating parameters for a process.

2. Materials and Methods

Ordinary Portland cement (Dangote cement brands) 42.3R which conform to NIS 444-1:2003 [15] was used for this research. The fine aggregate (natural sand) with 5 mm maximum size and coarse aggregate (lateritic stone) of maximum size of 20 mm were used in this research. Both conform to BS 882:1992 [16]. The Guinea Corn Husk Ash (GCHA) was collected from a farm land at Omugo, Ifelodun Local Government of Kwara State. The husk was burnt to ashes at the temperature of 650°C by Thermolyne furnace at Chemical Engineering Department, Landmark University Omu-Aran.

The ashes were further grounded to require level of finer particles with a milling machine and allowed to pass through sieve no. (200 to 75 µm). The workability was checked in accordance with BS EN 12350-2 [17] and ASTM C192/C192M [18], porosity in accordance with BS 1881-116 [19] using Equation 1 and the compressive strength in accordance with BS EN 12390-3:2009 [20].

$$\text{Porosity (\%)} = \frac{\text{Total Pore Volume}}{\text{Total Volume}} \times 100 \quad (1)$$

Corrosion resistance test conducted to determine the effect of the GCHA lateritic concrete on the reinforcement. The degree of corrosion of the iron rod was expressed in percentage (%) with using Equation 2.

$$\text{Corrosion resistance (\%)} = \frac{W_1 - W_2}{W_2} \times 100 \quad (2)$$

Where W_1 is the initial weight of reinforcement before inserting into concrete and W_2 is the weight of reinforcement after 56 days of curing.

The experimental setup for optimization was designed using Design Expert (Version 10), where an RSM in a Central Composite Design (CCD) was used to optimize the GCHA, OPC and water-cement ratio. The CCD requires that the combinations would have to be designed before proceeding to the laboratory. Two independent variables [GCHA (0-20%) and water (0.3-0.7)] with 13 experimental runs for compressive strength, slump height, porosity and corrosion resistance were considered in this study.

3. Results

3.1. Chemical Composition

The chemical composition of GCHA was examined using X-ray fluorescence (XRF) techniques and the result is presented in figure 1. Table 1 shows the percentage of the main oxides in the GCHA. The sum of SiO_2 , Al_2O_3 and Fe_2O_3 is higher than the minimum 70% specified by [21] for supplementary cementitious materials. Tables 2-4 shows the data obtained for the days at which the concrete specimen samples were tested.

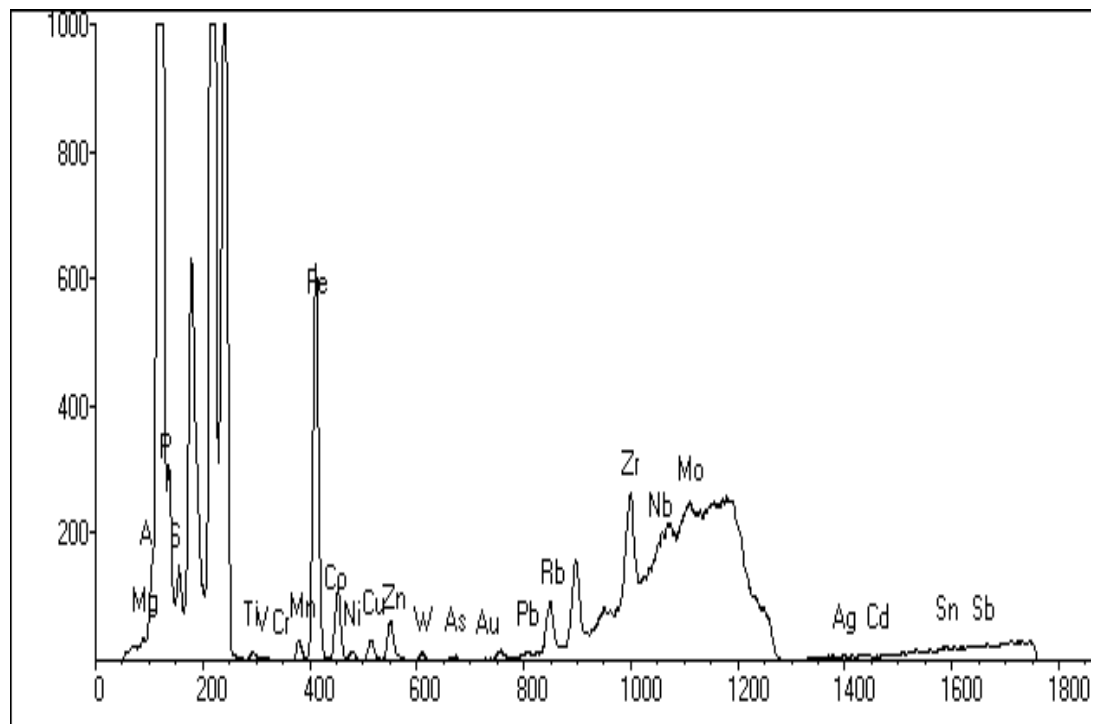


Figure 1. XRF Result of GCHA.

Table 1. Oxides Composition of GCHA.

S/No	Oxide	Percentage (%)
1	Al ₂ O ₃	4.52
2	SiO ₂	65.015
3	Fe ₂ O ₃	4.864
Total		74.399

Table 2. Results of all responses at 7 days of Curing Age.

S/N	% Mix of GCHA	Water Cement Ratio	Results at 7 days of the Experiment			
			Workability (mm)	Compressive strength (N/mm ²)	Porosity (%)	Corrosion Resistance (%)
1	10	0.50	40	9.35	9.93	0.00
2	20	0.30	0	10.78	21.27	0.00
3	5	0.50	30	15.21	3.82	0.00

4	10	0.50	40	9.35	9.93	0.00
5	10	0.50	40	9.35	9.93	0.00
6	0	0.70	210	9.12	6.60	0.00
7	20	0.70	220	4.25	9.21	0.00
8	10	0.40	25	8.28	6.37	0.00
9	10	0.50	40	9.35	9.93	0.00
10	0	0.30	0	11.18	8.44	0.00
11	10	0.50	40	9.35	9.93	0.00
12	15	0.50	30	9.27	17.00	0.00
13	10	0.60	120	9.08	13.00	0.00

Table 3. Results of all responses at 28 days of Curing Age.

S/N	% Mix of GCHA	Water Cement Ratio	Results at 28 days of the Experiment			
			Workability (mm)	Compressive strength (N/mm ²)	Porosity (%)	Corrosion Resistance (%)
1	10	0.50	40	13.41	20.50	0.00
2	20	0.30	0	14.81	12.50	0.00
3	5	0.50	30	16.81	16.32	0.00
4	10	0.50	40	13.41	20.50	0.00
5	10	0.50	40	13.41	20.50	0.00
6	0	0.70	210	10.66	12.05	0.00
7	20	0.70	220	5.91	11.20	0.00
8	10	0.40	25	11.15	15.28	0.00
9	10	0.50	40	13.41	20.50	0.00
10	0	0.30	0	12.16	9.86	0.00
11	10	0.50	40	13.41	20.50	0.00
12	15	0.50	30	13.51	31.11	0.00
13	10	0.60	120	12.23	24.59	0.00

Table 4. Results of all responses at 56 days of Curing Age.

S/N	% Mix of GCHA	Water Cement Ratio	Results at 56 days of the Experiment			
			Workability (mm)	Compressive strength (N/mm ²)	Porosity (%)	Corrosion Resistance (%)
1	10	0.50	40	13.66	17.19	0.00
2	20	0.30	0	14.83	16.95	0.00
3	5	0.50	30	18.83	21.12	0.00
4	10	0.50	40	13.66	17.19	0.00
5	10	0.50	40	13.66	17.19	0.00

6	0	0.70	210	17.61	22.22	0.00
7	20	0.70	220	7.90	18.46	0.00
8	10	0.40	25	13.48	17.42	0.00
9	10	0.50	40	13.66	17.19	0.00
10	0	0.30	0	14.16	19.32	0.00
11	10	0.50	40	13.66	17.19	0.00
12	15	0.50	30	14.86	9.60	0.00
13	10	0.60	120	12.60	12.56	0.00

3.2. Workability

The 3-D relationship of the slump height of the lateritic concrete with water-cement ratio and quantity of GCHA is shown in Figure 2. It was noticed that at 0.3-0.45 water cement ratio the slump height decreased. However, it began to increase from 0.45 to 0.7. Therefore, as the water cement increases, the slump height increases which enhances the workability of the lateritic concrete. At the same time, slump height increases as the percentage of GCHA increased up to 10% but beyond 10% of GCHA, the slump height began to decline up to 20%. It was observed that the best percentage at which best slump can be obtained is at 10% of GCHA of partial replacement for cement.

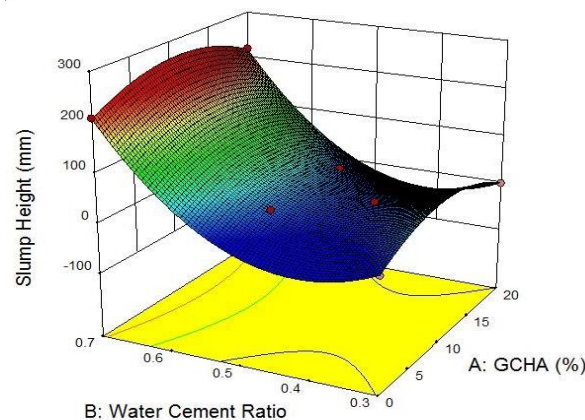


Figure 2. Slump of Lateritic Concrete.

3.3. Porosity

Figures 3, 4 and 5 show the 3-D relationship between the porosity of the lateritic concrete with water-cement ratio and quantity of GCHA. At 7 days of observation (Figure 3), the porosity increased as the GCHA increases. But porosity decreased as the water cement ratio increases. At 28 days of observation (Figure 4), porosity increased as GCHA increased, howbeit at a slower rate when compared with that of the 7 days result. It was also observed that there was an increase in porosity from 0.3 to 0.5 water cement ratio but beyond 0.5 the porosity decreased. At 56 days of observation (Figure 5), the porosity of the concrete decreased as the GCHA increased, but there was an increase in porosity as the water cement ratio increased.

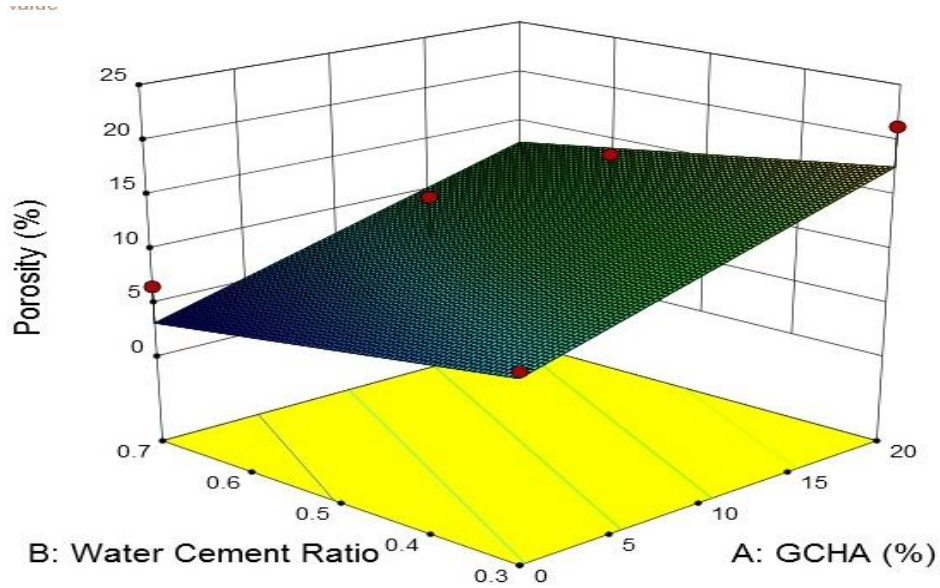


Figure 3. Porosity of Lateritic Concrete at 7 days.

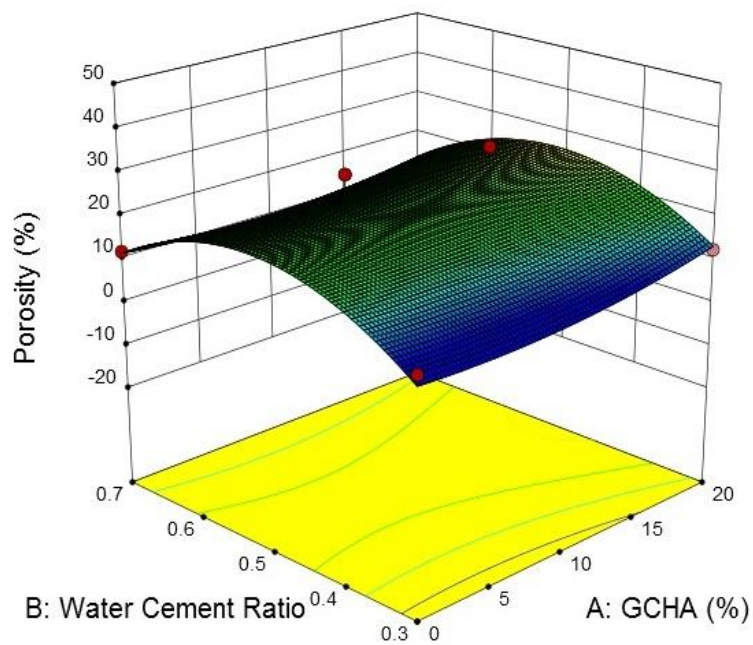


Figure 4. Porosity of Lateritic Concrete at 28 days.

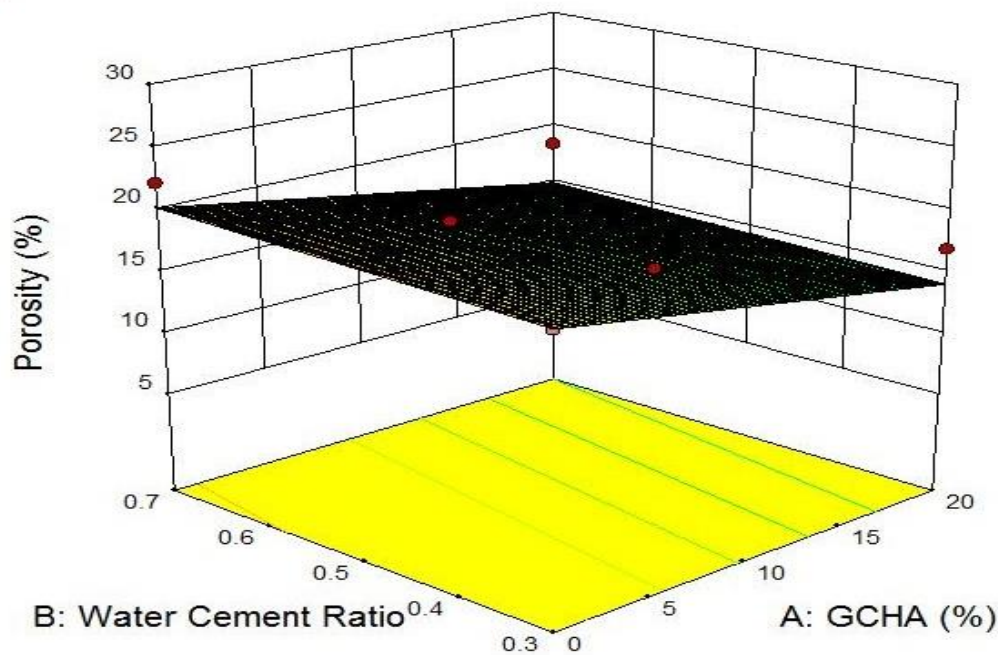


Figure 5. Porosity of Lateritic Concrete at 56 days.

3.4. Compressive Strength

From Figure 6, it was noticed that the compressive strength of the concrete at 7 days of curing decreased as the quantity of GCHA and water-cement ratio increased. Figure 7 revealed that the compressive strength of the concrete at 28 days of curing decreased from 0-10% of GCHA but beyond 10% the strength began to increase. At the same time, the strength of the concrete increased from 0.3 to 0.5 water-cement ratio but began to decline beyond 0.5 water cement ratio. The 56 days result (Figure 8) followed the same trend as that of the 28 days.

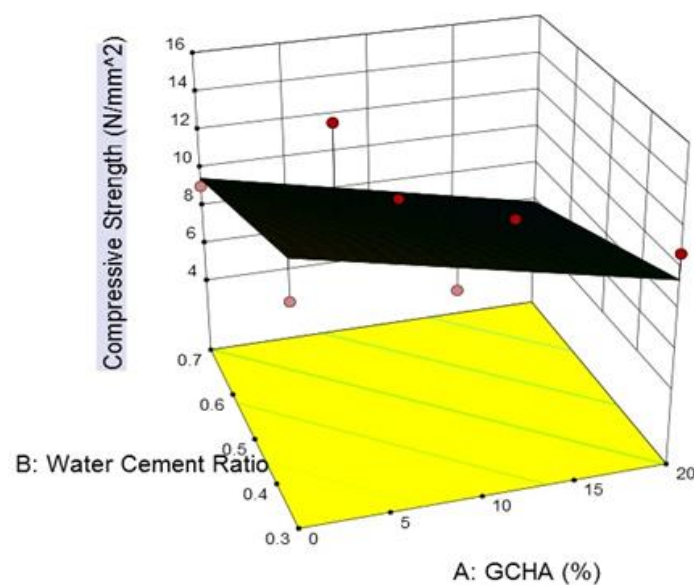


Figure 6. Compressive Strength of Lateritic Concrete at 7 days.

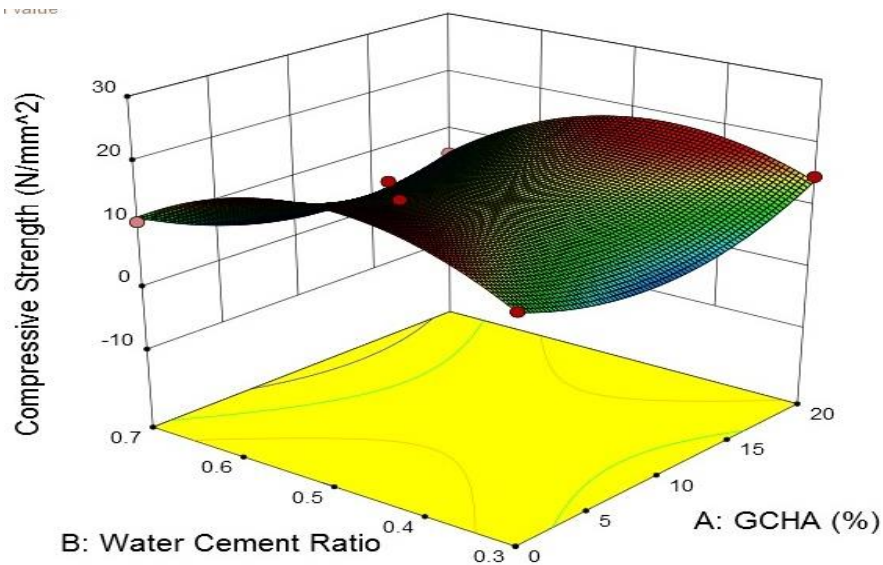


Figure 7. Compressive Strength of Lateritic Concrete at 28 days.

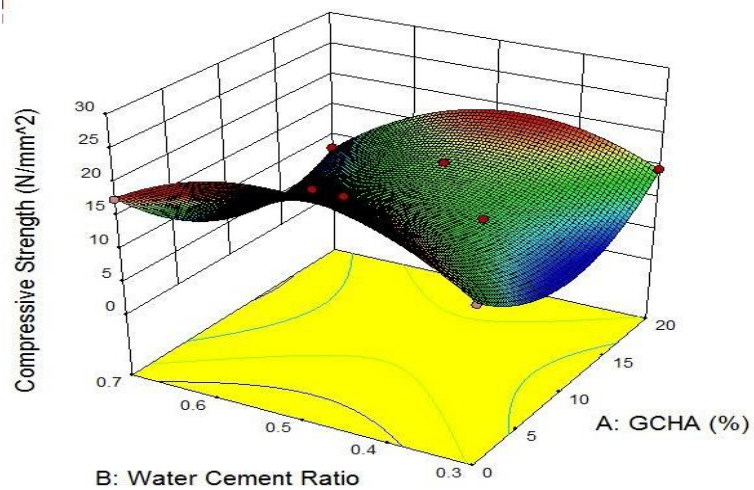


Figure 8. Compressive strength of Lateritic concrete at 56 days.

3.5. Corrosion Test

In Figure 9, it was noticed that the percentage of GCHA and water cement ratio has no effect on corrosion of reinforcement embedded in the lateritic concrete.

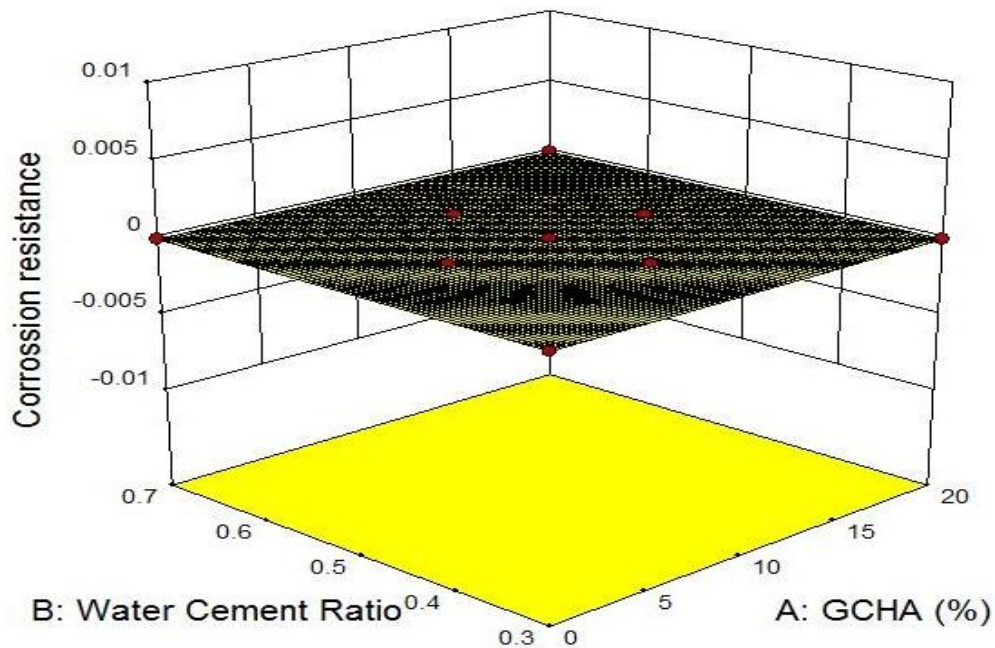


Figure 9. Corrosion resistance of Lateritic concrete at 56 days.

3.6. Optimization of Materials

From the results obtained at 56 days of curing, an optimization of the constituent materials making the lateritic concrete was carried out as shown in Figure 10. It was observed that the optimal combination is 20% of GCHA at 0.51 water-cement ratio. This will result in 2.75 mm slump height, compressive strength of 18.78 N/mm² and 14.59% porosity. This compressive strength with a desirability value of about 78% is higher than the control strength of 17.61 N/mm² by 6.64% obtained at 0.7 water cement ratio.

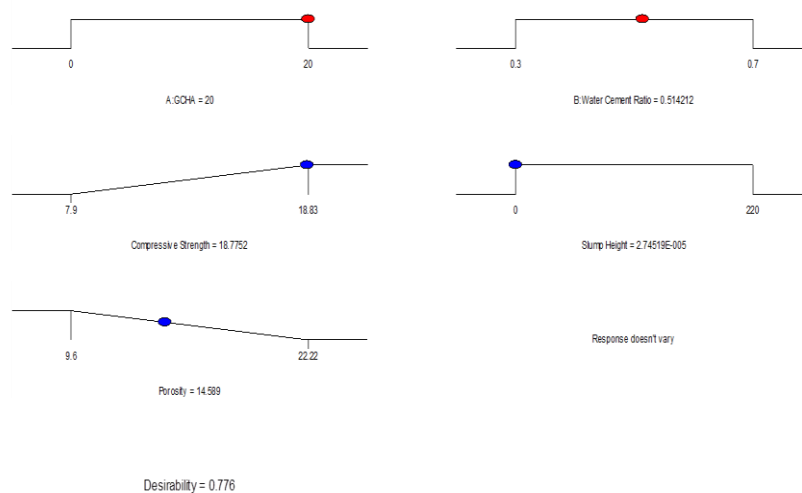


Figure 10. Optimization results from Design Expert 10.0.

3.7. Validation of Model

The relationship between the experimental and predicted values for the compressive strength is shown in Figure 11. The adequate precision value greater than 4.0 in the experiments signify a reasonable signal to noise level, denoting that their models can be relied upon to navigate the design space. This validates the results obtained.

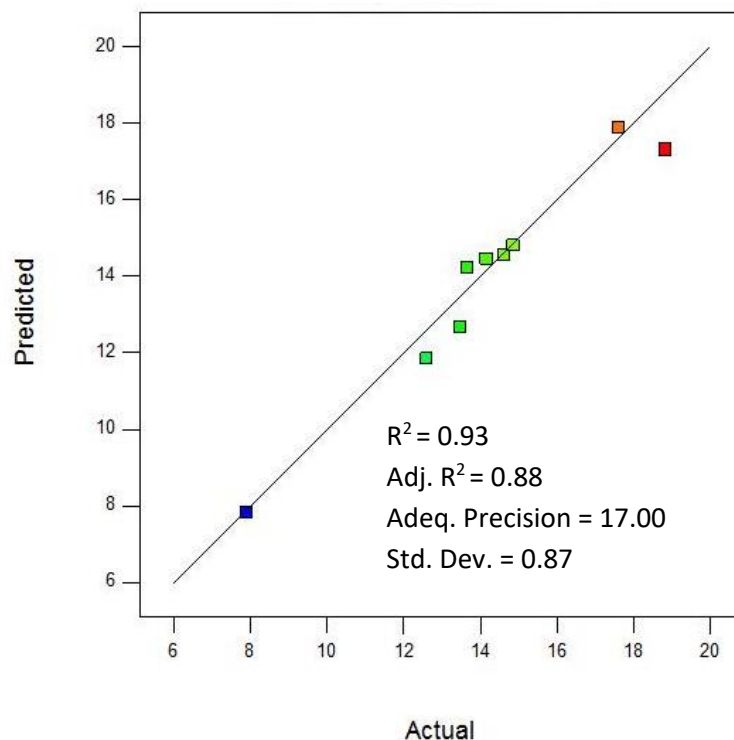


Figure 11. Predicted Compressive Strength versus Actual Compressive Strength.

4. Conclusion

The conclusions drawn are:

- GCHA is a suitable pozzolana because the summation of aluminum, silicon and ferric oxides was 74.40% which is more than 70% specified by BS EN 197-1:2000 and ASTM C-618 (2005) standards.
- The workability of lateritic concrete containing GCHA increased from 0% up to 10% of GCHA after which it decreased with higher percentage of GCHA.
- The increment in GCHA reduces the porosity of the lateritic concrete. However, porosity of the concrete increased with the increase in water cement ratio.
- Lateritic concrete containing GCHA of 5% at 0.5 water cement ratio produced the highest compressive strengths for 7, 28 and 56 days greater than their respective controls.
- GCHA and water cement ratio has no effect on the corrosion of reinforcement in the lateritic concrete
- Optimization of the materials at the end of 56 days gave a combination of 20% of GCHA at 0.51 water cement ratio which produced lateritic concrete with a slump height of 2.75 mm, compressive strength of 18.78 N/mm² and 14.59% porosity.

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