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PREDICTION OF FLEXURAL STRENGTH OF CHIKOKO POZZOLANA BLENDED CEMENT CONCRETE USING OSADEBE'S REGRESSION FUNCTION

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ABSTRACT
Chikoko mud is abundant in the mangrove swamps of the Niger Delta area of Nigeria. Its utilization in concrete production is traceable to its pozzolanic properties. In this paper, a regression model is developed to predict and optimize the flexural strength of chikoko pozzolana blended cement concrete using Osadebe's regression function. The results obtained from the derived regression model are very close to those obtained from experiment. The model was tested for adequacy using a Fisher test at 5% level of significance and was found to be adequate. A computer program coded in basic language was used to select the mix ratios that would optimize the flexural strength of chikoko pozzolana blended cement concrete. The computer program is user-friendly and can be used to select the mix ratios corresponding to a desired strength value with reasonable accuracy and without waste of time.

Keywords: *Pozzolanic properties, Osadebe's regression function, flexural strength, desired strength, mix ratios*

1. INTRODUCTION
In Nigeria, the provision of decent accommodation at an affordable rate to low income earners has been difficult over the years due to high cost of building materials such as cement [1-3]. Nigeria is blessed with abundance of local building and construction materials such as stones, sand, laterite and timber. However, majority of Nigerians still find it difficult to afford their own shelters due to high cost of cement. Concrete is the most important component of concrete as a structural material in the world [4]. Concrete is a combination of cement, fine and coarse aggregates and water, which are mixed in a particular proportion to achieve a particular strength [5]. The chemical reaction of cement with water forms a paste that binds the aggregates together. The concrete mixture then undergoes a hardening process to form a rock-like material that has high compressive but low tensile strength.

The price of cement is soaring high. Consequently, concrete structures and houses to accommodate the teeming population of Nigerians are difficult to construct [6-9]. There is therefore an immediate need to explore the potentials of locally processed building and construction materials such as chikoko to replace cement partially without negatively affecting the quality and strength properties of concrete [10].These materials are called natural pozzolanas. The use of natural pozzolanas in concrete slows down the hydration process in concrete and results in low rate of heat development in concrete [11-12]. Pozzolanic reaction has been reported to improve concrete impermeability [13]. After a long while, chikoko pozzolana-cement concrete structures may show signs of structural failure due to lack or insufficient knowledge of the predictive models on the structural property such as flexural strength of the end products. The total cost of concrete production depends on the proportions of the component materials. This implies that the addition of chikoko as one of the ingredients would result in increase in the cost per m^3 of concrete. Consequently, the formulation of optimization model becomes a necessity in order to select the best mix ratios that would optimize the concrete property of interest at minimum practicable cost [14].

This paper aims at predicting and optimizing the flexural strength of chikoko pozzolana concrete using Osadebe's regression theory and to develop a computer program for easy, quick and accurate prediction of flexural strength.

2. OSADEBE'SREGRESSION THEORY
The Osadebe's regression theory is based on the principle of absolute volume. Consider the 5-component

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concrete mixture to have a total quantity, S and the proportion of the ith component material as S_i.

Osadebe [9] assumed the response function, $f(Z)$ to be continuous and differentiable with respect to its predictors Z_i The function $f(Z)$ can be expanded in Taylor's series in the neighborhood of a chosen point $Z^{(0)}$.

$$Z^{(0)} = Z_1{}^{(0)},\ Z_2{}^{(0)}, Z_3{}^{(0)}, Z_4{}^{(0)}, Z_5{}^{(0)} \quad (1)$$

Osadebe gave the regression function for predicting and optimizing concrete properties as:

$$f(Z) = f(Z^{(0)}) + \sum_{i=1}^{5} \frac{\partial f(Z^{(0)})}{\partial Z_i} (Z_i - Z_i{}^{(0)}) + \frac{1}{2}! \sum_{i=1}^{4}\sum_{j=1}^{5} \frac{\partial f(Z^{(0)})}{\partial Z_i \partial Z_j} (Z_i - Z_i{}^{(0)})(Z_j - Z_j{}^{(0)}) + \frac{1}{2}! \sum_{i=1}^{5} \frac{\partial^2 f(Z^{(0)})}{\partial Z_i{}^2} (Z_i - Z_i{}^{(0)})^2 + \cdots \quad (2)$$

Let Z_i and S_i represent the volume fraction and actual proportions of the mixture respectively, then:

$$\sum_{i=1}^{5} S_i = S \quad (3)$$

$$\Rightarrow S_i + S_2 + S_3 + S_4 + S_4 = S \quad (4)$$

Dividing both sides of equation (4) by S yields:

$$S_1/S + S_2/S + S_3/S + S_4/S + S_5/S = 1 \quad (5)$$

$$S_i/S = Z_i (i = 1,2,3,4,5) \quad (6)$$

Equation (5) now becomes:

$$Z_1 + Z_2 + Z_3 + Z_4 + Z_5 = 1 \quad (7)$$

Where:

Z_1, Z_2, Z_3, Z_4 and Z_5 is the volume fraction of water, cement, chikoko, sand and coarse aggregate respectively. A vector Z Z_1, Z_2, Z_3, Z_4, Z_5 exists whose elements are subject to the constraint of Equation (7). For each Z_i

$$Z_i > 0 \quad (8)$$

Taking the point $Z^{(0)}$ as the origin means that $Z^{(0)} = 0$.

$$\Rightarrow Z_1{}^{(0)} = 0, Z_2{}^{(0)} = 0, Z_3{}^{(0)} = 0, Z_4{}^{(0)} = 0, Z_5{}^{(0)} = 0. \quad (9)$$

Lets $b_0 = f(0), b_i = \frac{\partial f(0)}{\partial Z_i}, b_{ij} = \frac{\partial^2 f(0)}{\partial Z_i \partial Z_j}, and\ b_{ii} = \frac{\partial^2 f(0)}{\partial Z_i{}^2}$,

Equation (2) now becomes:

$$f(z) = b_0 + \sum_{i=1}^{5} b_i z_i + \sum_{i=1}^{4}\sum_{i=1}^{5} b_{ij} z_i z_j + \sum_{i=j}^{5} b_{ii} z_i^2 + \ldots \quad (10)$$

The number of constant coefficients of Equation (10) is:

$$N = \frac{q(q+1)(q+2) \ldots . (q+m+1)}{m!} \quad (11)$$

In (11), q is the number of components, and m is the degree of polynomial. Multiplying (7) by b_0 yields:

$$b_0 = b_0 Z_1 + b_0 Z_2 + b_0 Z_3 + b_0 Z_4 + b_0 Z_5 \quad (12)$$

Also, multiplying Equation (7) by z_i yields:

$$Z_1 = Z_1{}^2 + Z_1 Z_2 + Z_1 Z_3 + Z_1 Z_4 + Z_1 Z_5 \quad (13)$$

$$Z_2 = Z_2{}^2 + Z_1 Z_2 + Z_2 Z_3 + Z_2 Z_4 + Z_2 Z_5 \quad (14)$$

$$Z_3 = Z_3{}^2 + Z_1 Z_3 + Z_3 Z_3 + Z_3 Z_4 + Z_3 Z_5 \quad (15)$$

$$Z_4 = Z_4{}^2 + Z_1 Z_4 + Z_2 Z_4 + Z_4 Z_3 + Z_4 Z_5 \quad (16)$$

$$Z_5 = Z_5{}^2 + Z_1 Z_5 + Z_2 Z_5 + Z_3 Z_5 + Z_4 Z_5 \quad (17)$$

Rearranging Equations (13-17), yields:

$$Z_1^2 = Z_1 - Z_1 Z_2 - Z_1 Z_3 - Z_1 Z_4 - Z_1 Z_5 \quad (18)$$

$$Z_2^2 = Z_2 - Z_1 Z_2 - Z_2 Z_3 - Z_2 Z_4 - Z_2 Z_5 \quad (19)$$

$$Z_3^2 = Z_3 - Z_1 Z_3 - Z_2 Z_3 - Z_3 Z_4 - Z_3 Z_5 \quad (20)$$

$$Z_4^2 = Z_4 - Z_1 Z_1 - Z_2 Z_4 - Z_4 Z_3 - Z_4 Z_5 \quad (21)$$

$$Z_5^2 = Z_5 - Z_1 Z_5 - Z_2 Z_5 - Z_3 Z_5 - Z_4 Z_5 \quad (22)$$

Substituting Equations (18) to (22) into Equation (10) and setting f (0) =y yields:

$$y = b_0 Z_1 + b_0 Z_2 + b_0 Z_3 + b_0 Z_4 + b_0 Z_5 + b_1 Z_1 + b_2 Z_2 + b_3 Z_3 + b_4 Z_4 + b_5 Z_5 + b_{12} Z_1 Z_2 + b_{13} Z_1 Z_3 + b_{14} Z_1 Z_4 + b_{15} Z_1 Z_5 + b_{23} Z_2 Z_3 + b_{24} Z_2 Z_4 + b_{25} Z_2 Z_5 + b_{34} Z_3 Z_4 + b_{35} Z_3 Z_5 + b_{45} Z_4 Z_5` + b_{11}(Z_1 - Z_1 Z_2 - Z_1 Z_3 - Z_1 Z_4 - Z_1 Z_5) + b_{22}(Z_2 - Z_1 Z_2 - Z_2 Z_3 - Z_2 Z_4 - Z_2 Z_5) + b_{33}(Z_3 - Z_1 Z_3 - Z_2 Z_3 - Z_3 Z_4 - Z_3 Z_5) + b_{44}(Z_4 - Z_1 Z_4 - Z_2 Z_4 - Z_3 Z_4 - Z_4 Z_5) \quad (23)$$

Factorization of Equation (23) yields:

$$y = (b_0 + b_1 + b_{11}) Z_1 + (b_0 + b_2 + b_{22}) Z_2 + (b_0 + b_3 + b_{33}) Z_3 + (b_0 + b_4 + b_{44}) Z_4 + (b_0 + b_5 + b_{55}) Z_5 + (b_{12} + b_{11} + b_{22}) Z_1 Z_2 + (b_{13} - b_{11} - b_{33}) Z_1 Z_3 + (b_{14} - b_{11} - b_{44}) Z_1 Z_4 + (b_{15} - b_{11} - b_{55}) Z_1 Z_5 + (b_{23} - b_{22} - b_{33}) Z_2 Z_3 + (b_{24} - b_{22} - b_{44}) Z_2 Z_4 + Z_2 Z_5 (b_{25} - b_{22} - b_{55}) + (b_{34} - b_{33} - b_{44}) Z_3 Z_4 + Z_3 Z_5 (b_{35} - b_{33} + b_{55}) + Z_4 Z_5 (b_{45} - b_{44} - b_{55}) \quad (24)$$

Let:

$$\alpha_i = b_0 + b_i + b_{ii} \quad (25)$$

And

$$\alpha_{ij} = b_{ij} + b_{ii} + b_{jj} \quad (26)$$

Substituting Equations (25) and (26) into Equation (24) yields:

$$y = \alpha_1 Z_1 + \alpha_2 Z_2 + \alpha_3 Z_3 + \alpha_4 Z_4 + \alpha_5 Z_5 + \alpha_{12} Z_1 Z_2 + \alpha_{13} Z_1 Z_3 + \alpha_{14} Z_1 Z_4 + \alpha_{15} Z_1 Z_5 + \alpha_{23} Z_2 Z_3 + \alpha_{24} Z_2 Z_4 + \alpha_{25} Z_2 Z_5 + \alpha_{34} Z_3 Z_4 + \alpha_{35} Z_3 Z_5 + \alpha_{45} Z_4 Z_5 \quad (27)$$

Equation (27) is the regression model for predicting the property of a 5-component mixture based on Osadebe's second degree polynomial.

The generalized form of Equation (27) is:

$$y = \sum_{i=1}^{5} \alpha_i Z_i + \sum_{1 \le i \le j}^{5} \alpha_{ij} Z_i Z_j \quad (28)$$

In Equation (28), Y is the flexural strength at any point of observation, $Z_i$andZ_j is the predictor variables and $\alpha_{ij} = \alpha_{ij}$ is the coefficients of the regression model.

2.1 Coefficients of the Osadebe's Regression Model

Let $y^{(n)}$ represent the n^{th} point of observation. The vector of the corresponding volume fraction is:

$$Z^{(n)} = \left[Z_1{}^{(n)}, Z_2{}^{(n)}, Z_3{}^{(n)}, Z_5{}^{(n)},\right] \quad (29)$$

At n^{th} observation point, the response function, $y^{(n)}$ corresponds with the predictors, $Z_i{}^{(n)}$.

$$\Rightarrow y^{(n)} = \sum_{i=1}^{5} \alpha_i Z_i{}^{(n)} + \sum_{1 \le i \le j}^{5} \alpha_{ij} Z_i{}^{(n)} Z_j{}^{(n)} \quad (30)$$

Where: $1 \le i \le j \le 5 and\ n = 1,2,3 \ldots,15$

Equation (30) can be written in matrix form as:

$$\left[y^{(n)}\right] = \left[y^{(n)}\right][\alpha] \quad (31)$$

Expanding Equation (31), we have:

$$\begin{bmatrix} y^{(1)} \\ y^{(2)} \\ y^{(3)} \\ . \\ . \\ . \\ y^{(15)} \end{bmatrix} = \begin{bmatrix} Z_1^{(1)} & Z_2^{(1)} & Z_3^{(1)} & \ldots & Z_4^{(1)} Z_5^{(1)} \\ Z_1^{(2)} & Z_2^{(2)} & Z_3^{(2)} & \ldots & Z_4^{(2)} Z_5^{(2)} \\ Z_1^{(3)} & Z_2^{(3)} & Z_3^{(3)} & \ldots & Z_4^{(3)} Z_5^{(3)} \\ & & . & & \\ & & . & & \\ & & . & & \\ Z_1^{(15)} & Z_2^{(15)} & Z_3^{(15)} & \ldots & Z_4^{(15)} Z_5^{(15)} \end{bmatrix} \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ . \\ . \\ . \\ \alpha_{45} \end{bmatrix} \quad (32)$$

The constant coefficients α_i in Equation (31) are determined from the values of $y^{(n)}\ and\ Z^{(n)}$. Rearrangement of Equation (32) yields:

$$[\alpha] = \left[Z^{(n)}\right]^{-1} = \left[y^{(n)}\right] \quad (33)$$

Expressing (33) in matrix form yields:

$$\begin{bmatrix} \alpha^{(1)} \\ \alpha^{(2)} \\ \alpha^{(3)} \\ . \\ . \\ . \\ \alpha^{(15)} \end{bmatrix} = \begin{bmatrix} Z_1^{(1)} & Z_2^{(1)} & Z_3^{(1)} & \ldots & Z_4^{(1)} Z_5^{(1)} \\ Z_1^{(2)} & Z_2^{(2)} & Z_3^{(2)} & \ldots & Z_4^{(2)} Z_5^{(2)} \\ Z_1^{(3)} & Z_2^{(3)} & Z_3^{(3)} & \ldots & Z_4^{(3)} Z_5^{(3)} \\ & & . & & \\ & & . & & \\ & & . & & \\ Z_1^{(15)} & Z_2^{(15)} & Z_3^{(15)} & \ldots & Z_4^{(15)} Z_5^{(15)} \end{bmatrix} \begin{bmatrix} y^1 \\ y^2 \\ y^2 \\ . \\ . \\ . \\ y^{15} \end{bmatrix} \quad (34)$$

The actual proportions S_i and the corresponding volume fractions $Z_i{}^{(n)}$ are given in Table 2. The values of the volume fraction $Z_i{}^{(n)}$were used to determine $Z^{(n)}$ matrix (Table 3) and $Z^{(n)}$ matrix inverse (Table 4). The values of $y^{(n)}$matrix were determined from experiments. The values of the constant coefficients $\alpha_i$were determined from known values of the matrices $y^{(n)}$and $Z^{(n)}$using Equation (34).

3. MATERIALS AND METHODS

The cement used for this study was ordinary Portland cement with properties meeting the requirements of [15].The water used in this study was clean, fresh and free from organic matters. The fine aggregate was obtained from Otamiri River in Owerri, Imo State. It was washed and air-dried for a period of two weeks before using it to produce concrete. The grading and properties were determined and met the requirements of [16]. The maximum size of the fine aggregate did not exceed 5mm.The granite aggregate used was obtained from crushed rock industry in Port Harcourt, Rivers State. The granites were properly washed and sundried for two weeks to remove dirt and later surface dried before usage. The maximum size of the granite aggregate was 20mm.The chikoko was obtained in bags from mangrove swamps at Eagle's Island, Port Harcourt, Rivers State. It was sundried for three (3) weeks after which it was ground and sieved with a 212 μm sieve to obtain finer particles and was characterized to determine its suitability for use as a pozzolana (Table 1).The ground and sieved chikoko pozzolana is as shown in Plate 1.The actual mix ratios and their corresponding volume fractions are given in Table 2.

The flexural strength test of the beam was performed using 450mmx150mmx150mm steel moulds. The proportions of the ingredients were weighed and turned over and over with a shovel until a homogenous mix was obtained. Water was then added and the components were mixed until a uniform colour was achieved. The fresh concrete was then compacted into steel moulds with a tamping rod. A total of ninety (90) concrete beams were produced from both the trial and control mixes implying that three test samples were produced per mix ratio. The beam specimens were removed from moulds after 24 hours of casting and were cured in a curing tank for 28 days and tested for flexural strengths on a Universal Testing Machine using a third point loading method. The test results are as shown in Table 4. Concrete beams fractured in the tension zone within the middle third of the beam span. The flexural strength was determined using the formula:

$$\sigma = PL/bd^2 \quad (35)$$

In Equation (35), σ is the flexural strength of the beam specimen, P is the failure load of the beam specimen, L = is the beam span and *b, d is the* width and depth of the beam respectively.

Table 1: Characterization of chikoko from experiment

S/No	Component	Content (%)
1	CaO	9.85
2	SiO_2	41.21
3	Al_2O_3	10.15
4	Fe_2O_3	2.31
5	MgO	5.02
6	Na_2O	1.97
7	K_2O	8.17
8	SO_3	0.08
9	TiO_2	0.72
10	ZnO	0.09
11	LoI	6.51

Plate 1: Chikoko

Table 2: Values of actual mix ratios and component fractions based on Osadebe's second degree polynomial

S/N	Actual Mix Ratios					Component's Volume Fraction				
	S1	S2	S3	S4	S5	Z1	Z2	Z3	Z4	Z5
1	0.52601	0.947	0.053	2.1	4.2	0.06721305	0.121006745	0.006772289	0.268335972	0.536671944
2	0.566	0.91901	0.081	2.02	4.04	0.074219677	0.120509939	0.010621544	0.264882947	0.529765893
3	0.589	0.823	0.17701	1.91	3.82	0.080475365	0.112446902	0.024184965	0.260964256	0.521928512
4	0.611	0.889	0.111	2.1601	4.32	0.075515072	0.109873812	0.013718777	0.266972352	0.533919986
5	0.596	0.846	0.154	2.15	4.301	0.074064869	0.105132347	0.019137567	0.267180316	0.534484901
6	0.546005	0.933005	0.067	2.06	4.12	0.070671019	0.120761557	0.008672005	0.266631806	0.533263612
7	0.557505	0.885	0.115005	2.005	4.01	0.07362222	0.1168701	0.01518717	0.264773503	0.529547006
8	0.568505	0.918	0.082	2.13005	4.26	0.071433194	0.115347573	0.010303378	0.267642807	0.535273049
9	0.561005	0.8965	0.1035	2.125	4.2505	0.070686656	0.112959042	0.013041005	0.267750099	0.535563198
10	0.5775	0.871005	0.129005	1.965	3.93	0.077283269	0.116561236	0.017263945	0.26296385	0.5259277
11	0.5885	0.904005	0.096	2.09005	4.18	0.074886541	0.115034507	0.012215986	0.265958564	0.531904402
12	0.581	0.882505	0.1175	2.085	4.1705	0.074140194	0.112614616	0.014993929	0.266062486	0.532188775
13	0.6	0.856	0.144005	2.03505	4.07	0.077870956	0.111095897	0.018689678	0.264118816	0.528224653
14	0.5925	0.8345	0.165505	2.03	4.0605	0.077118263	0.108616355	0.021541701	0.264219534	0.528504146
15	0.6035	0.8675	0.1325	2.15505	4.3105	0.074791952	0.107509558	0.016420768	0.26707605	0.534201672
Control Points										
16	0.560336667	0.896336667	0.10367	2.01	4.02	0.073822308	0.118089081	0.013658144	0.264810156	0.529620311
17	0.575336667	0.886333333	0.11367	2.0567	4.113333333	0.074281334	0.114433907	0.014675858	0.265539169	0.531069731
18	0.57767	0.894	0.106	2.1367	4.273666667	0.072316894	0.111917363	0.013269844	0.267487505	0.535008394
19	0.5730025	0.8945025	0.1055025	2.047525	4.095	0.074266099	0.115935290	0.013674040	0.265377017	0.530747554
20	0.5805025	0.87625	0.1237525	2.080025	4.16025	0.074225653	0.112041254	0.015823550	0.265961324	0.531948220
21	0.5692525	0.8837525	0.1162525	2.045	4.09025	0.073885644	0.114705904	0.015088894	0.265429036	0.530890521
22	0.551755	0.9090025	0.0910025	2.0325	4.065	0.072131814	0.118835351	0.011896902	0.265711977	0.531423955
23	0.5767525	0.8655	0.1345025	2.0775	4.1555	0.073850268	0.110822939	0.017222371	0.266013466	0.532090955
24	0.563604	0.905002	0.095002	2.05802	4.116	0.072839377	0.116961167	0.012277923	0.265975568	0.531945966
25	0.577602	0.884802	0.115202	2.06802	4.1362	0.074224482	0.113701077	0.014803980	0.265749967	0.531520494
26	0.573603	0.887601	0.112402	2.07602	4.1522	0.073521635	0.113768367	0.014407140	0.266094117	0.532208742
27	0.586101	0.879002	0.121002	2.07403	4.1482	0.075060944	0.112572271	0.015496518	0.265617446	0.531252822
28	0.5652535	0.8865515	0.1134525	2.053	4.10625	0.073176639	0.114771265	0.014687344	0.265777462	0.531587289
29	0.5744525	0.891002	0.1090015	2.07752	4.1552	0.073580063	0.114126030	0.013961707	0.266103902	0.532228299

S/N	Actual Mix Ratios					Component's Volume Fraction				
	S1	S2	S3	S4	S5	Z1	Z2	Z3	Z4	Z5
30	0.5660045	0.9037005	0.0963	2.12302	4.2463	0.071327198	0.113883237	0.012135609	0.267540397	0.535113559

Table 3: Znmatrix obtained from Table 2

Zn MATRIX														
Z1	Z2	Z3	Z4	Z5	Z1Z2	Z1Z3	Z1Z4	Z1Z5	Z2Z3	Z2Z4	Z2Z5	Z3Z4	Z3Z5	Z4Z5
0.06721305	0.121006745	0.006772289	0.268335972	0.536671944	0.008133232	0.000455186	0.018035679	0.036071358	0.000819493	0.032470463	0.064940925	0.001817249	0.003634497	0.144008388
0.074219677	0.120509939	0.010621544	0.264882947	0.529765893	0.008944209	0.000788328	0.019659527	0.039319054	0.001280002	0.031921028	0.063842055	0.002813466	0.005626932	0.140325951
0.080475365	0.112446902	0.024184965	0.260964256	0.521928512	0.009049205	0.001946294	0.021001194	0.042002387	0.002719524	0.029344622	0.058689244	0.006311411	0.012622823	0.136204686
0.075515072	0.109873812	0.013718777	0.266972352	0.533919986	0.008297129	0.001035974	0.020160436	0.040319006	0.001507334	0.02933327	0.058663824	0.003662534	0.007324729	0.142541875
0.074064869	0.105132347	0.019137567	0.267180316	0.534484901	0.007786614	0.001417421	0.019788675	0.039586554	0.002011977	0.028089294	0.056191652	0.005113181	0.01022874	0.142803845
0.070671019	0.120761557	0.008672005	0.266631806	0.533263612	0.008534342	0.000612859	0.018843141	0.037686283	0.001047245	0.032198872	0.064397744	0.002312232	0.004624465	0.14218504
0.07362222	0.1168701	0.01518717	0.264773503	0.529547006	0.008604236	0.001118113	0.019493213	0.038986426	0.001774926	0.030944106	0.061888212	0.00402116	0.008042321	0.140210016
0.071433194	0.115347573	0.010303378	0.267642807	0.535273049	0.008239645	0.000736003	0.01911858	0.038236263	0.00118847	0.030871948	0.061742447	0.002757625	0.005515121	0.143261981
0.070686656	0.112959042	0.013041005	0.267750099	0.535563198	0.007984697	0.000921825	0.018926359	0.037857172	0.001473099	0.030244795	0.060496706	0.00349173	0.006984282	0.143397099
0.077283269	0.116561236	0.017263945	0.26296385	0.5259277	0.009008233	0.001334214	0.020322706	0.040645412	0.002012307	0.030651391	0.061302783	0.004539793	0.009079587	0.138299973
0.074886541	0.115034507	0.012215986	0.265958564	0.531904402	0.008614536	0.000914813	0.019916717	0.039832481	0.00140526	0.030594412	0.061187361	0.003248946	0.006497737	0.141464531
0.074140194	0.112614616	0.014993929	0.266062486	0.532188775	0.008349269	0.001111653	0.019725924	0.039456579	0.001688536	0.029962525	0.059932234	0.003989322	0.007979601	0.141595469
0.077870956	0.111095897	0.018689678	0.264118816	0.528224653	0.008651144	0.001455383	0.020567185	0.041133359	0.002076347	0.029342517	0.058683592	0.004936296	0.009872349	0.13951407
0.077118263	0.108616355	0.021541701	0.264219534	0.528504146	0.008376305	0.001661259	0.020376151	0.040757322	0.002339781	0.028698563	0.057404194	0.005691738	0.011384879	0.139641119
0.074791952	0.107509558	0.016420768	0.267076050	0.534201672	0.00804085	0.001228141	0.019975139	0.039953986	0.00176539	0.028713228	0.057431786	0.004385594	0.008772002	0.142672472

Table 4: Inverse of Z^n Matrix Based on Osadebe's Second Degree Polynomial

Z_1	Z_2	Z_3	Z_4	Z_5	Z_1Z_2	Z_1Z_3	Z_1Z_4	Z_1Z_5	Z_2Z_3	Z_2Z_4	Z_2Z_5	Z_3Z_4	Z_3Z_5	Z_4Z_5
68861.88734	83391.78	9356.830938	3585.275594	141.8630848	-151583.542	50824.56129	-31433.89793	-6251.99463	-55890.59649	34612.02133	6883.617923	-11613.02714	-2309.333517	1426.276382
1417.537624	2467.210281	2531.776741	15219.10693	711.2766514	4250.284477	4297.382545	-9770.758848	-1943.337219	5557.916002	-12653.17904	-2516.456702	-12802.14894	-2545.795133	5780.184632
24460.8499	55223.9781	31172.00764	8114.437185	400.0677064	-73978.00843	57106.22897	-27791.28067	-5527.501822	-83280.21351	40581.72919	8070.867617	-31347.89137	-6233.74759	3029.477063
204318116	686446898	132899063.7	372509686.6	358016334	-749135171.9	329939076.5	551918114.2	-541027436.3	-604335940.7	-1012238772	992194695.5	446121802.1	-437238796.4	-730387668.7
50731986.81	170433209.4	33248863.52	92726776.03	89582309.62	-186003587.8	82233482.32	137213212.8	-134854827.1	-150618908.4	-251646212.7	247303494.7	111330631.3	-109397106.7	-182283322.8
-90092.69381	-57128.52872	-21635.82023	-33581.93103	-1492.045384	143211.6885	-90801.39295	109338.2428	21746.64636	70789.29429	-85351.42743	-16974.63195	54152.90492	10768.68321	-12948.98849
-175418.9591	-274347.0075	-74689.2729	-22492.63951	-1023.188948	439465.4863	-232898.6329	124106.2024	24683.90237	287653.3305	-153482.7544	-30524.55231	81395.17737	16186.00438	-8613.095675
-211888906.1	-701662180.3	-135138679.8	-370201952.5	-358467202.7	771296593.9	-338815525	-560306802.8	551306658.3	616123628.1	1020220648	-1003761982	-448469497.9	441185117.1	728580084
-47062667.06	-162976678.5	-32142686.42	-93883532.43	-89356989.58	175187973.1	-77875114.03	-132979709.6	129723004.6	144816413.9	247609968.4	-241528862	-110143645.2	107426559	183185965.7
-14083.13954	-81086.79542	-15924.33948	-1107.115161	-43.79980248	67597.15573	-29984.72891	-7899.566103	-1571.169013	71898.48811	18966.46982	3772.033796	-8418.895548	-1674.154381	-440.4441056
-203240	-689055	-131739	-377288	-357002	748506806.7	-327492	-553790	538810194.7	602763130.3	1020599222	-992920	-446845	434678235.3	734017891.5

Z_1	Z_2	Z_3	Z_4	Z_5	Z_1Z_2	Z_1Z_3	Z_1Z_4	Z_1Z_5	Z_2Z_3	Z_2Z_4	Z_2Z_5	Z_3Z_4	Z_3Z_5	Z_4Z_5
288.4	971.3	940.8	229.5	065.1		090	774.7				807.9	312.9		
- 512711 88.03	- 169136 856.3	- 338324 33.28	- 903654 61.89	- 900907 32.69	186310 297.8	- 834610 08.03	- 136266 415.1	135965 529.8	151391 981.8	247498 020.8	- 246934 067.8	- 110946 960.6	110681 745.3	180457 548.1
- 199870 727.7	- 674187 363.6	- 128859 058.8	- 375996 740.6	- 357252 199.3	734223 502.7	- 321194 025	- 548239 088.4	534511 271.4	589668 434.2	100779 9342	- 982494 737.7	- 441174 252.8	430048 691.7	733016 952
- 529847 52.73	- 176624 633.7	- 353163 62.06	- 909991 66.45	- 899651 44.08	193544 722.9	- 866835 96.57	- 139008 672.6	138121 671.5	158062 400.8	253803 262.2	- 252165 936.5	- 113749 553.5	113003 066.9	180962 694.1
- 458671 948.1	- 154096 5914	- 299095 177.5	- 836943 994.3	- 805771 395.7	168170 9131	- 741609 265.6	- 123951 4785	121610 6039	135836 1013	227329 3047	- 223020 3273	- 100317 4771	984049 480.1	164243 1815

Table 5: Flexural Strength Test Results

Exp. No	Replicates	Mass(Kg)	Density (Kg/m^3)	Average Density ρ (kg/m^3)	Load at Failure (KN)	Flexural Strength	Average Flexural Strength
	A	27.8	2471.111		39	5.200	
1	B	26.9	2391.111	2432.593	36	4.800	4.933
	C	27.4	2435.556		36	4.800	
	A	28.2	2506.667		30	4.000	
2	B	27	2400.000	2447.407	22	2.933	3.644
	C	27.4	2435.556		30	4.000	
	A	27.1	2408.889		28	3.733	
3	B	27.1	2408.889	2388.148	20	2.667	3.467
	C	26.4	2346.667		30	4.000	
	A	26.8	2382.222		21	2.800	
4	B	27.1	2408.889	2429.630	22	2.933	2.711
	C	28.1	2497.778		18	2.400	
	A	27.8	2471.111		26	3.467	
5	B	28	2488.889	2477.037	21	2.800	3.422
	C	27.8	2471.111		30	4.000	
	A	28.2	2506.667		32	4.267	
6	B	27.9	2480.000	2450.370	40	5.333	4.267
	C	26.6	2364.444		24	3.200	
	A	28.4	2524.444		36	4.800	
7	B	26.2	2328.889	2447.407	30	4.000	4.533
	C	28	2488.889		36	4.800	
	A	28.2	2506.667		36	4.800	
8	B	28	2488.889	2465.185	24	3.200	3.733
	C	27	2400.000		24	3.200	
	A	28.1	2497.778		37	4.933	
9	B	27	2400.000	2432.593	20.5	2.733	4.022
	C	27	2400.000		33	4.400	
	A	27.1	2408.889		35	4.667	
10	B	27.2	2417.778	2420.741	19.5	2.600	3.844
	C	27.4	2435.556		32	4.267	
	A	28.2	2506.667		24	3.200	
11	B	27.2	2417.778	2435.556	18.5	2.467	3.356
	C	26.8	2382.222		33	4.400	
	A	28	2488.889		28	3.733	
12	B	28	2488.889	2459.259	22.7	3.027	3.542
	C	27	2400.000		29	3.867	
	A	27	2400.000		30	4.000	
13	B	26.9	2391.111	2420.741	22.5	3.000	3.311
	C	27.8	2471.111		22	2.933	
	A	27.9	2480.000		34.5	4.600	
14	B	27.4	2435.556	2438.519	25	3.333	3.756
	C	27	2400.000		25	3.333	
	A	28.2	2506.667		29	3.867	
15	B	27	2400.000	2435.556	19	2.533	2.978
	C	27	2400.000		19	2.533	
Control points							
C1	A	27.6	2453.333		28	3.733	
	B	27.2	2417.778	2438.519	40	5.333	4.267

Exp. No	Replicates	Mass(Kg)	Density (Kg/m³)	Average Density ρ (kg/m³)	Load at Failure (KN)	Flexural Strength	Average Flexural Strength
	C	27.5	2444.444		28	3.733	
C2	A	28	2488.889		30	4.000	
	B	27	2400.000	2432.593	26	3.467	3.867
	C	27.1	2408.889		31	4.133	
C3	A	27	2400.000		32	4.267	
	B	26.8	2382.222	2402.963	21	2.800	3.689
	C	27.3	2426.667		30	4.000	
C4	A	28	2488.889		30	4.000	
	B	26.4	2346.667	2411.852	29	3.867	3.867
	C	27	2400.000		28	3.733	
C5	A	27.4	2435.556		32	4.267	
	B	28	2488.889	2447.407	21	2.800	3.689
	C	27.2	2417.778		30	4.000	
C6	A	28.1	2497.778		28	3.733	
	B	26.6	2364.444	2429.630	28	3.733	4.178
	C	27.3	2426.667		38	5.067	
C7	A	26.4	2346.667		33	4.400	
	B	27.5	2444.444	2426.667	32	4.267	4.489
	C	28	2488.889		36	4.800	
C8	A	27.2	2417.778		30	4.000	
	B	28	2488.889	2438.519	34	4.533	4.178
	C	27.1	2408.889		30	4.000	
C9	A	26.3	2337.778		30	4.000	
	B	28	2488.889	2414.815	28	3.733	3.911
	C	27.2	2417.778		30	4.000	
C10	A	27.3	2426.667		30	4.000	
	B	27	2400.000	2420.741	27	3.600	3.822
	C	27.4	2435.556		29	3.867	
C11	A	28	2488.889		29	3.867	
	B	27	2400.000	2417.778	25	3.333	3.911
	C	26.6	2364.444		34	4.533	
C12	A	26.7	2373.333		24	3.200	
	B	27.5	2444.444	2408.889	31	4.133	3.778
	C	27.1	2408.889		26	3.467	
C13	A	27.1	2408.889		25	3.333	
	B	26.9	2391.111	2414.815	34	4.533	4.133
	C	27.5	2444.444		34	4.533	
C14	A	27.8	2471.111		31	4.133	
	B	27.1	2408.889	2426.667	23	3.067	3.911
	C	27	2400.000		34	4.533	
C15	A	26.5	2355.556		28	3.733	
	B	27.2	2417.778	2400.000	30	4.000	3.867
	C	27.3	2426.667		29	3.867	

4.1 The Regression Model

Substituting the values of $y^{(n)}$ from the test results shown in Table 4 into Equation (33) yields Osadebe's coefficients values as follows:

$$\alpha_1 = 10129.60157,\ \alpha_2 - 2969.72244,\ \alpha_3 = 2970.80494,\ \alpha_4 = 157608673.5,\ \alpha_5 = -39230199.22,\ \alpha_6 = -21919.30298,\ \alpha_7 = -19274.41211,\ \alpha_8 = 158913915.9,\ \alpha_9 = 38562608.66,\ \alpha_{10} = 11309.67354,\ \alpha_{11} = 158693269.8,\ \alpha_{12} = 38695844.25,\ \alpha_{13} = 155210497.7,\ \alpha_{14} = 40434855.8,\ \alpha_{15} = 354102810.9$$

Substituting the obtained coefficients into Equation (27) yields:

$$y = 10129.60157Z_1, -2969.72244Z_2\ - 2970.80494Z_3 + 157608673.\,Z_4\ - 39230199.22Z_5, - 21919.30298Z_1Z_2\ - 19274.41211Z_1Z_3 + 158913915.9Z_1Z_4 + 38562608.66Z_1Z_5 + 11309.67354Z_2\,Z_3 + 158693269.8Z\ \ Z_4 + 38695844.25Z\ \ Z_5 + 155210497.7Z\ \ Z_4 + 40434855.8Z\ \ Z_5\ \ 354102810.9Z\ \ Z_5 \quad (36)$$

Equation (36) is the required regression model for the prediction and optimization of flexural strength of chikoko-cement concrete based on Osadebe's second degree polynomial.

4.2 Test of Adequacy of the Model

Equation (36) was tested for adequacy using Fisher test in Table 5 and was found to be adequate.

Table 5: Fisher test for control points

Control points	y_o	y_p	$y_o - \bar{y}_o$	$y_p - \bar{y}_p$	$(y_o - \bar{y}_o)^2$	$(y_p - \bar{y}_p)^2$
C1	4.267	4.276	0.297	0.341	0.088	0.116
C2	3.867	3.901	-0.103	-0.034	0.011	0.001
C3	3.689	3.541	-0.281	-0.394	0.079	0.155
C4	3.867	3.910	-0.103	-0.025	0.011	0.001
C5	3.689	3.754	-0.281	-0.181	0.079	0.033
C6	4.178	4.048	0.208	0.113	0.043	0.013
C7	4.489	4.465	0.519	0.530	0.269	0.281
C8	4.178	3.965	0.208	0.030	0.043	0.001
C9	3.911	4.111	-0.059	0.176	0.004	0.031
C10	3.822	3.783	-0.148	-0.152	0.022	0.023
C11	3.911	3.881	-0.059	-0.054	0.004	0.003
C12	3.778	3.577	-0.192	-0.358	0.037	0.128
C13	4.133	4.165	0.163	0.230	0.026	0.053
C14	3.911	3.810	-0.059	-0.125	0.004	0.016
C15	3.867	3.838	-0.103	-0.097	0.011	0.009
Σ	3.970	3.935		Σ	0.730	0.864

Legend:

$$\bar{y}_o = \frac{\sum y_o}{n};\ \bar{y}_p = \frac{\sum y_p}{n}$$

The F- statistics is the ratio of sample variances and is given by:

$$F = {S_1}^2/{S_2}^2$$

where: ${S_1}^2$ is always the larger value of the sample variances

Let ${S_o}^2, {S_p}^2$ = variance of observed and predicted data respectively

Then,

$${S_o}^2 = \frac{0.730}{14}0.05212, \qquad {S_p}^2 = \frac{0.864}{14} = 0.06169$$

If ${S_o}^2 = {S_p}^2$ it implies that the variances are the equal at all experimental points. ${S_o}^2$ not being equal to ${S_p}^2$ shows that the population variances are not the same at all experimental points. The acceptance of Null hypothesis implies that the difference between the sample variances, ${S_o}^2$ and ${S_p}^2$ at 5% level of significance is not significant by applying the Fisher test.

$$F = \frac{0.06169}{0.05212} = 1.1838$$

From Fisher table, $F_{0.95}(14,14) = 2.48$[17].

The calculated value of F is less than the value from Fisher table. Hence the model is adequate.

5. CONCLUSION

The experimental data are well fitted into the predictive and optimization model showing the effectiveness of Osadebe's model in the prediction and optimization of concrete flexural strength of chikoko pozzolana blended cement concrete. The strength of concrete depends on

the proportions of the component materials: water, cement, chikoko, sand and coarse aggregates. The results of the Fisher test showed that the predictive and optimization model is adequate.
The model can be used to predict and optimize other structural properties of chikoko pozzolana blended cement concrete. With the formulated model, any desired value of flexural strength, given any mix ratios can be easily determined and can also determine the mix ratios when a desired value of flexural strength is given.

Basic Computer Program Based on Osadebe's Flexural Strength Model

```
Private Sub STARTMNU_Click ()
   Cls
   Text1.Text = ""
    Print "     THE PROGRAM WAS WRITTEN BY"
   Print: Print
   Print "   Sule"
   Print:
      WWWWW = InputBox ("CLICK OK. TO CONTINUE"): Cls
   Print: Print "      THIS PROJECT IS IN PARTIAL FULFILMENT OF THE AWARD"
   Print "     OF PhD IN CIVIL ENGINEERING"
   WWWWW = InputBox ("CLICK OK. TO CONTINUE"): Cls
   Print "     I ACKNOWLEDGE MY SUPERVISOR, Dr. D. O.  ONWUKA"
   Print "     FOR INITIATING AND SUPERVISING THIS PROJECT"
   WWWWW = InputBox ("CLICK OK. TO CONTINUE"): Cls

'   CIVIL ENGINEERING DEPARTMENT, FUTO
   CT = 0: YMAX = 0: KK = 0

   ReDim X (15), A (5, 5), Z(5), N(15), B(5, 5)
  Rem       ***     COEFFICIENTS OF REGRESSION     ***
  A1 = 10129.60157: A2 = -2969.72244: A3 = -2970.80494: A4 = -157608673.5: A5 = -39230199.22
  A6 = -21919.30298: A7 = -19274.41211: A8 = 158913915.9: A9 = 38562608.66: A10 = 11309.67354
  A11 = 158693269.8: A12 = 38695844.25: A13 = 155210497.7: A14 = 40434855.8: A15 = 354102810.9

   Rem ***   DECISION FOR CALCULATING MIX RATIOS GIVEN DESIRED STRENGTH OR OTHER WISE ***
10 QQ = Input Box ("WHAT DO YOU WANT TO DO? TO CALCULATE MIX RATIOS GIVEN DESIRED FLEXURAL
STRENGTH OR CALCULATING FLEXURAL STRENGTH GIVEN MIX RATIO?", "IF FLEXURAL STRENGHT IS KNOWN
TYPE 1 ", "Type 1 or 0 and CLICK OK.")
   If QQ <> 1 and QQ <> 0 Then EE = Input Box ("No Way! You must ENTER 1 or 0",, "CLICK OK  and do so"): GoTo
10
   If QQ = 0 Then GoTo 100

   Rem PUT IN THE VALUE OF STRENGTH DESIRED HERE
   YY = Input Box ("WHAT IS THE DESIRED FLEXURAL STRENGHT?"): YY = 1 * YY
Rem    *** Here is where the Actual Strength is calculated    ***
   For Z1 = 0.066 To 0.081 Step 0.0001
   For Z2 = 0.1 To 0.1211 Step 0.001
   For Z3 = 0.0067 To 0.0242 Step 0.001
   For Z4 = 0.26 To 0.269 Step 0.0001

   Z5 = 1 - Z1 - Z2 - Z3 - Z4

   Rem    ***    The Binary Predictors will be calculated here    ***
   Z6 = Z1 * Z2: Z7 = Z1 * Z3: Z8 = Z1 * Z4: Z9 = Z1 * Z5: Z10 = Z2 * Z3
   Z11 = Z2 * Z4:    Z12 = Z2 * Z5: Z13 = Z3 * Z4: Z14 = Z3 * Z5: Z15 = Z4 * Z5
```

```
  Z23 = Z2 + Z3
  Rem CACCULATING ACTUAL STRENGTH
  YACT = A1 * Z1 + A2 * Z2 + A3 * Z3 + A4 * Z4 + A5 * Z5
  YACT = YACT + A6 * Z6 + A7 * Z7 + A8 * Z8 + A9 * Z9 + A10 * Z10
  YACT = YACT + A11 * Z11 + A12 * Z12 + A13 * Z13 + A14 * Z14 + A15 * Z15
  Y = YACT
  If Z1 / Z23 < 0.52 Then GoTo 30
  If Z1 + Z2 + Z3 + Z4 + Z5 <> 1 Then GoTo 30 'or Z1 + Z2 + Z3 + Z4 + Z5 < 1

  If Y > YY - 0.05 and Y < YY + 0.05 Then GoTo 20 Else GoTo 30

20    Text1.Text = Text1.Text + CStr ("flexural Strength" & vbTab & Format (YACT, "0.00#") & ",") & vbTab
    Text1.Text = Text1.Text + CStr ("     WATER   =" & vbTab & Format (Z1 / Z23, "0.00#") & ",") & vbTab
    Text1.Text = Text1.Text + CStr ("     CEMENT =" & vbTab & Format (Z2 / Z23, "0.00#") & ",") & vbTab
    Text1.Text = Text1.Text + CStr ("     ASH =" & vbTab & Format (Z3 / Z23, "0.00#") & ",") & vbTab
    Text1.Text = Text1.Text + CStr ("     SAND =" & vbTab & Format (Z4 / Z23, "0.00#") & ",") & vbTab
    Text1.Text = Text1.Text + CStr ("     COARSE AGG =" & vbTab &Format (Z5 / Z23, "0.00#")) & vbCrLf

30
  Next Z4
  Next Z3
  Next Z2
  Next Z1

70 'Print "Sorry! Desired strength is outside the range of the model"
111 GoTo 222

100 Rem *** Here is where the INPUT of the Principal Predictors will be made   ***
  Cls
  Z1 = InputBox ("What is Water/Cement ratio"): Z1 = Z1 * 1
  Z2 = InputBox ("What is Cement value"): Z2 = Z2 * 1
  Z3 = InputBox ("What is Ash value"): Z3 = Z3 * 1
  Z4 = InputBox ("What is Sand value"): Z4 = Z4 * 1
  Z5 = InputBox ("What is Coarse Agg value"): Z5 = Z5 * 1

  Z23 = Z2 + Z3
  TZT = Z1 + Z2 + Z3 + Z4 + Z5
  Z1 = Z1 / TZT: Z2 = Z2 / TZT: Z3 = Z3 / TZT
  Z4 = Z4 / TZT: Z5 = Z5 / TZT
  Rem    ***    The Binary Predictors will be calculated here   ***
  Z6 = Z1 * Z2: Z7 = Z1 * Z3: Z8 = Z1 * Z4: Z9 = Z1 * Z5: Z10 = Z2 * Z3
  Z11 = Z2 * Z4:    Z12 = Z2 * Z5: Z13 = Z3 * Z4: Z14 = Z3 * Z5: Z15 = Z4 * Z5

  Rem CACCULATING ACTUAL STRENGTH
  YACT = A1 * Z1 + A2 * Z2 + A3 * Z3 + A4 * Z4 + A5 * Z5
  YACT = YACT + A6 * Z6 + A7 * Z7 + A8 * Z8 + A9 * Z9 + A10 * Z10
  YACT = YACT + A11 * Z11 + A12 * Z12 + A13 * Z13 + A14 * Z14 + A15 * Z15

  Text1.Text = Text1.Text + CStr ("FLEXURAL Strength" & vbTab & Format (YACT, "0.00#") & ",") & vbTab
    Text1.Text = Text1.Text + CStr ("     WATER   =" & vbTab & Format (Z1 / Z23, "0.00#") & ",") & vbTab
    Text1.Text = Text1.Text + CStr ("     CEMENT  =" & vbTab & Format(Z2 / Z23, "0.00#") & ",") & vbTab
    Text1.Text = Text1.Text + CStr ("     ASH  =" & vbTab & Format(Z3 / Z23, "0.00#") & ",") & vbTab
    Text1.Text = Text1.Text + CStr("     Sand  =" & vbTab & Format(Z4 / Z23, "0.00#") & ",") & vbCrLf
```

```
    Text1.Text = Text1.Text + CStr("     COARSE AGG  =" & vbTab & Format(Z5 / Z23, "0.00#") & ",") & vbCrLf
222

End Sub

Private Sub STOPMNU_Click ()
End
End Sub
```

WHAT IS THE DESIRED FLEXURAL STRENGHT? 4.255/mm^2

Flexural Strength 4.255, WATER = 0.521, CEMENT = 0.884, ASH = 0.116, SAND = 2.123, COARSE AGG = 4.249
Flexural Strength 4.277, WATER = 0.522, CEMENT = 0.939, ASH = 0.061, SAND = 2.123, COARSE AGG = 4.247
Flexural Strength 4.232, WATER = 0.524, CEMENT = 0.908, ASH = 0.092, SAND = 2.122, COARSE AGG = 4.246
Flexural Strength 4.263, WATER = 0.522, CEMENT = 0.908, ASH = 0.092, SAND = 2.103, COARSE AGG = 4.207
Flexural Strength 4.254, WATER = 0.526, CEMENT = 0.829, ASH = 0.171, SAND = 2.121, COARSE AGG = 4.245
Flexural Strength 4.234, WATER = 0.526, CEMENT = 0.868, ASH = 0.132, SAND = 2.122, COARSE AGG = 4.244
Flexural Strength 4.211, WATER = 0.527, CEMENT = 0.852, ASH = 0.148, SAND = 2.121, COARSE AGG = 4.245

Flexural strength result (for a given mix ratio)

Y = 4.589, WATER = 0.53, CEMENT = 0.94, ASH = 0.06, SAND = 2.00, COARSE AGG. = 4.00

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