COMPARATIVE ANALYSIS OF TWO MATHEMATICAL MODELS FOR PREDICTION OF COMPRESSIVE STRENGTH OF SANDCRETE BLOCKS USING ALLUVIAL DEPOSIT

B.O. Mama[a,b], **N.N. Osadebe**[a]

[a]Department of Civil Engineering, University of Nigeria, Nsukka, Nigeria
[b]***Email:*** *mamaunn@yahoo.com*

Abstract

A mathematical modeling for prediction of compressive strength of sandcrete blocks was performed using statistical analysis for the sandcrete block data obtained from experimental work done in this study. The models used are Scheffes and Osadebes optimization theories to predict the compressive strength of sandcrete blocks using alluvial deposit. The results of predictions were comparatively analysed using the statistical package for social sciences (spss) for the students t-test.It was found that the two models are acceptable for the prediction of compressive strength of sandcrete blocks.

Keywords: sandcrete block, compressive strength, laterite, Scheffe's theory, Osadebe's theory

1. Introduction

In engineering field, sandcrete block is considered to be similar to concrete block and is expected to exhibit properties similar to those of concrete except perhaps for its lower strength.

Concrete is a versatile construction material owing to the benefits it provides in term of strength,durability,availability,adoptability and economy. Great efforts have been made to improve the quality of concrete by various means in order to raise and maximize its level of performance.

Prediction of concrete strength has been active area of research and a considerable number of studies have been carried out. A number of improved prediction techniques have been proposed by including empirical or computational modeling and statistical techniques.

1.1. Computational modeling

Many attempts have been made for modeling this process through the use of computational techniques such as finite element analysis but the computational complexity of the models is prohibiting in many cases, requiring non proprietary mathematical tools.

1.2. Statistical techniques

A number of research efforts have concentrated on using multivariable regression models to improve the accuracy of predictions.

Statistical models have the attraction that once fitted they can be used to perform predictions much more quickly than other modeling techniques and are correspondingly simpler to implement in software. Apart from its speed, statistical modeling has the advantage over other techniques that is mathematically rigorous and can be used to define confidence interval for predictions. For these reasons statistical analysis was chosen to be technique for strength prediction of this study.

Modeling the prediction of compressive strength of concrete: The most popular regression equation used in the prediction of compressive strength is:

$$F = b_o + b_1 w/c \tag{1}$$

Where F = compressive strength of concrete, w/c = water/cement ratio and $b_o,\ b_1$ = coefficients.

The earlier equation is the linear regression equation. The origin of the equation is Abram's law [1] which relates compressive strength of concrete to the w/c ratio of the mix and according to this law,increasing w/c ratio will definitely lead to decrease in concrete strength. The original formular for Abram is:

$$F = \frac{A}{B^{w/c}} \tag{2}$$

Where F = Compressive strength of concrete and $A,\ B$ = Empirical constants. Lyse [2] made a formular similar to Abram's but he relates compressive strength to cement/water ratio. According to Lyse strength of concrete increases linearly with increasing c/w ratio the general form of this popular model was:

$$F = A + Bc/w \tag{3}$$

Where F = compressive strength of concrete, c/w = cement/water ratio and $A,\ B$ = Emprirical constants.

The quantities of cement, fine aggregate and coarse aggregate were not included in model and not accounted for the prediction of concrete strength. So, for various concrete mixes were their w/c ratio is constant, the strength will be the same and this is not true. Therefore, effort should be concentrating on models taking into account the influence of mix constituents on the concrete strength in order to have more reliable and accurate results for the prediction of concrete strength. For this reason, Eq. 1 which referred to Abram's Law was extended to include other variables in the form of multiple linear regression equation and used widely to predict the compressive strength of various types of concrete as below;

$$F = b_o + b_1 w/c$$

Eq. 1 linear least square regression (referred to Abram) and Eq. 4 is multiple linear regression;

$$F = b_o + b_1 w/c + b_2 CA + b_3 FA + C \tag{4}$$

Where F = compressive strength of concrete, w/c = water/cement ratio, C = Quantity of cement in the mix, CA = Quantity of coarse aggregate in the mix, FA = Quantity of fine aggregate in the mix.

According to Eq. 4 all the variables related to the compressive strength in a linear fashion, but this is not always true because the variables involved in a concrete mix and affecting its compressive strength are interrelated with each other and additive action is not always true. Here, it appears that there is need for another type of mathematical model that can reliably predict strength of concrete with acceptable high accuracy [3].

This will lead us to mixture designs [4] for an extensive introduction into mixture designs and models. A mixture experiment involves mixing various proportions of two or more components to make different compositions of an end product. Special issues arise when analyzing mixtures of components that must sum to a constant.

To attain certain goals in an optimal manner we must define our objective function , for example cost,profit,chemical concentration, strength etc. Objective functions depend on other variables. At times, problem varies within a domain or region and is not entirely free but must satisfy certain bounds or functional relationship. These are called constraints.

In order to design the best formulation, it is of course possible to use a trial and error approach but (and this has been proved and emphasized by numerous authors) this is not an effective way. Systematic optimization techniques are always preferable. These methods can be divided into sequential methods, simultaneous methods or combinations of both. With sequential methods a small number of initial experiments is planned and carried out: succeeding experiments are based on the results obtained so far in the direction of increase (or decrease) of the response. In this way a maximum (or minimum) is reached.

Simultaneous methods, however, plan the complete set of experiments(the experimental design) beforehand. All the experiments are carried out and the results are used to a mathematical model. A maximum (or minimum) can be found by examining the properties of the fitted model. In this paper emphasis will be laid upon simultaneous methods. Simultaneous methods have the distinct advantage that, assumed that the fitted model is correct over a range of variable settings, response values can be predicted. A wide range of possible choices (factor setting) is therefore available and there is also information available about the stability of the found optimum against errors in the independent variable settings. In this research, we are going to compare Scheffe's and Osadebe's mathematical models for the prediction of compressive strength of sandcrete blocks.

2. Scheffe's Optimization Theory

When investigating multi-component systems, the use of experimental design methodologies [5] reduces the volume of experiments substantially. This reduces the need for a spatial representation of complex surface as the wanted properties can be derived from equations.

To describe such surface adequately Scheffe [6] suggested ways to describe the mixture properties by reduced polynomials given thus

$$\begin{aligned} y = \; & b_0 + \sum b_i x_i + \sum b_{ij} x_i x_j + \sum b_{ijk} x_i x_i x_k + \\ & \ldots + \sum b_{i1,i2,\ldots in} x_{i1} x_{i2} x_{in} \\ & \text{where } (1 \leq i \leq q,\ 1 \leq i \leq j \leq q, \\ & \ 1 \leq i \leq j \leq k \leq q) \end{aligned} \tag{5}$$

where y is the mixture property, b is the polynomial coefficient and x is the mix component ratio in weight.

Henry Scheffe developed a theory for experiments with mixture of which the property studied depends on the proportions of the components present and not on the quantity of the mixture.

Scheffe showed that if q represents the number of constituent components of the mixture, the space of the variables known also as the factor space is a $(q-1)$ dimensional simplex lattice. The composition may be expressed as molar, weight, or volume fraction or percentage.

A simplex lattice is a structural representation of lines or planes joining the assumed coordinates (points) of the constituent materials of the mixture.

According to Scheffe [6], in exploring the whole factor space of a mix design with a uniformly spaced distribution of points over the factor space, we have what we shall call a $[q,\ m]$ simplex lattice. The properties of a $[q,\ m]$ simplex lattice where m is the degree of the polynomial of the multivariate function $f(x_1,\ x_2, \ldots,\ x_q)$ of the response surface are.

(a) The sum of the components concentration is unity. i.e.

$$\sum_{i=1}^{q} x_i = 1 \tag{6}$$

Additionally for each variable x_i

$$x_i \geq 0 \tag{7}$$

(b) The factor space has uniformly spaced distribution of points

(c) The proportions used for each factor has equally spaced values from 0 to 1 i.e. for each factor (variable) x_i

$$x_i = 0,\ \frac{1}{m},\ \frac{2}{m},\ \cdots,\ \frac{m-1}{m},\ \frac{m}{m} = 1 \tag{8}$$

Scheffe showed that the number of points or coordinates used in the experimental design of a mixture where factor space is $(q,\ m)$ simplex lattice is

$$C^m_{m+q-1} = [q(q+1)(q+2)\dots(q+m-1)]/m! \tag{9}$$

This implies that the number of points associated with (4,2) lattice used in this present work is 4(4+1) / (2*1) = 10

The values of the unknown coefficients of the regression equation are given below

$$b = y_i \quad i = 1,\ 2,\ 3,\ 4 \tag{10}$$

and

$$\beta_{ij} = 4y_{ij} - 2y_j \quad i,j = 1,\ 2,\ 3,\ 4 \tag{11}$$

3. Osadebe's Optimization Theory

The procedure in this present work differs from the earlier ones [7], [8] [9] performed in Scheffe's factor space in which the variable xi are transformed and do not show the actual mix ratios. Again the predictive domain of the response function in Scheffes' simplex lattice (factor space) is restricted within the lattice where boundaries are determined apriori by stipulating the coordinates of the latter [6], [5]. In this present development the factor space is not restricted. The formulation is done from first principle using the so called absolute volume (mass) as a necessary condition. This principle assumes that the volume (mass) of the mixture is equal to the sum of the absolute volume (mass) of all the constituent components [10].

Let us consider an arbitrary amount S measured either by weight or volume of a given mixture. Let the portion of i_{th} component of the constituent materials of the concrete be S_i, $i = 1,\ 2,\ 3,\ 4$. Then in keeping with the principle of absolute volume (mass)

$$S_1 + S_2 + S_3 + S_4 = S \tag{12}$$

or

$$\frac{S_1}{S} + \frac{S_2}{S} + \frac{S_3}{S} + \frac{S_4}{S} = 1 \tag{13}$$

Where S_1/S is the proportion of the i_{th} constituent component of the considered mixture let

$$\frac{S_i}{S} = Z_i \quad i = 1,\ 2,\ 3,\ 4 \tag{14}$$

Substituting eqn (14) into eqn (13) gives

$$Z_1 + Z_2 + Z_3 + Z_4 = 1 \tag{15}$$

4. Osadebe's Concrete Optimization Regression Equation

On the assumption that the response function is continuous and differentiable with respect to its variables, Z_i it can be expanded in Taylor's series in the neighborhood of a chosen point $Z(0) = (Z_1^{(0)},\ Z_2^{(0)},\ Z_3^{(0)},\ Z_4^{(0)})^T$ as follows

$$\begin{aligned} f(Z) &= f(Z^{(0)}) + \textstyle\sum_{i=1}^{4} \frac{\partial f Z^{(0)}}{\partial Z_i}(Z_i - Z^{(0)}) + \\ &\tfrac{1}{2!}\textstyle\sum_{i=1}^{3}\sum_{j=1}^{4} \frac{\partial^2 f Z^{(0)}}{\partial Z_i Z_j}(Z_i - Z_i^{(0)})(Z_j - Z_j^{(0)}) + \\ &\tfrac{1}{2!}\textstyle\sum_{j=1}^{4} \frac{\partial f(Z^{(0)})}{\partial Z_i^2}(Z_i - Z^{(0)}) + \dots \end{aligned} \tag{16}$$

For convenience, the Point $Z^{(0)}$ can be chosen to be the origin without loss of generality of the formulation. Consequently, $Z^{(0)} = 0$, implies that

$$Z_1^{(0)} = 0,\ Z_2^{(0)} = 0,\ Z_3^{(0)}, Z_4^{(0)} = 0.$$

Let $b_0 = f(o), b_i = \frac{\partial f(0)}{\partial z_i},\ b_{ij} = \frac{\partial^2 f(0)}{\partial z_i \partial z_j},\ b_{ii} = \frac{\partial^2 f(0)}{\partial z_i^2}$ eqn 16 can then be written as follows

$$f(z) = b_o + \sum_{i=1}^{6} b_i z_i \sum_{i=1}^{3}\sum_{j=1}^{4} b_{ij} z_i z_j + \sum_{j=1}^{4} b_{ii} z_i^2 \tag{17}$$

The number of constant coefficients N of the above polynomial (eqn 17) is given by

$$N = C^m_{q+n} \tag{18}$$

Where m is the degree of the polynomial of the response function and q is the number of variables, here $q = 4$. However, taken advantage of eqn 15, the number of coefficients can be reduced to

$$N = C^m_{q+n-1} \tag{19}$$

But

$$C^m_{q+n-1} = q(q+1)(q+2)\dots(q+m+1)/m! \tag{20}$$

$$Y = \sum \beta_i Z_i + \sum \beta_{ij} Z_i Z_j \quad 1 \leq i \leq j \leq 4 \tag{21}$$

Eqn 21 is the regression equation. The response function is said to be defined if the values of the unknown constant coefficients β_i and $\beta_i j$ are uniquely determined.

5. Osadebe's Model Coefficients of the Regression Equation

Let the K^{th} response be Y^k and the vector of the corresponding set of variables be

$$Z^k = [Z_1^{(x)},\ Z_2^{(k)},\ Z_3^{(x)},\ Z_4^{(k)}]^T$$

Substitution of the above vector in eqn

$$\begin{aligned} Y = \ & \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_3 + \beta_4 Z_4 + \\ & \beta_{12} Z_1 Z_2 + \beta_1 3 Z_1 Z_3 + \beta_1 4 Z_1 Z_4 + \\ & \beta_{23} Z_2 Z_3 + \beta_{24} Z_2 Z_4 + \beta_{34} Z_3 Z_4 \end{aligned} \tag{22}$$

for $K = 1,\ 2,\ 10$, generates the following system of ten linear algebraic equations in the unknown coefficients b_i and b_{ij}

$$\begin{aligned} Y^{(k)} = \ & \sum \beta_i Z_i^{(k)} + \sum \beta_{ij} Z_i^{(k)} Z_j^{(k)} \\ & I \leq i \leq j \leq 4 \text{ and } k = 1,\ 2,\ 3,\ \dots,\ 10 \end{aligned} \tag{23}$$

Let

$$[Y^k] = \begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_1 0 \end{bmatrix}$$

$B = [\beta_1,\ \beta_2,\ \dots,\ \beta_{34}]$ and

$$[Z] = \begin{bmatrix} Z_1^{(1)} & Z_1^{(2)} & \cdots & Z_1^{(10)} \\ Z_2^{(1)} & Z_2^{(2)} & \cdots & Z_2^{(10)} \\ Z_3^{(1)} & Z_3^{(2)} & \cdots & Z_3^{(10)} \\ \vdots & \vdots & \vdots & \vdots \\ Z_1 0^{(1)} & Z_1 0^{(2)} & \cdots & Z_1 0^{(10)} \end{bmatrix}$$

The explicit matrix form of eqn (22) can be written as

$$Y^{(k)} = [B][Z]$$

Since the vector $[Z]$ values are known (easily determined), we can re-arrange this as

$$[Z]^T [B]^T = [Y^{(k)}] \tag{24}$$

The solution of eqn 24 gives the values of the unknown coefficients of the Osadebe's regression equation.

Tables 1 to 3 were used to generate the actual mix ratios for Scheffess and Osodebe's optimization models.

6. Discussion

The specimen exhibited both vertical and peripheral cracks at failure. Failure occurred within one and a half minutes of load application. The maximum load carried by the specimen during the test was recorded and divided by the net area of the specimen. The compressive strength was obtained from the ratio.

Y = (maximum load/cross-sectional area) N/mm^2

The results obtained are shown in table 4

6.1. Result and Analysis

Crushing strength (f_c)

$$f_c = \frac{P}{A}$$

where P = The maximum load on the block (N); A = the cross sectional area of the block (mm^2). After determining coefficients,the mathematical model expressing the crushing strength of block as a multivariate function of proportions of its constituent component is given by

$$\begin{aligned} y = \ & 2.08X_1 + 1.29X_2 + 1.58X_3 + 1.09X_4 - \\ & 0.4X_1X_2 - 1.79X_1X_3 - 1.39X_1X_4 + \\ & 0.59X_2X_3 + 1.77X_2X_4 - 0.4X_3X_4 \end{aligned} \tag{25}$$

$$\begin{aligned} y \ & = 9953Z_1 - 3689Z_2 + 702Z_3 - 325Z_4 + \\ & 14295Z_1Z_2 + 15794Z_1Z_3 + 17Z_1Z_4 + \\ & 521Z_2Z_3 + 1271Z_2Z_4 - 1216Z_3Z_4 \end{aligned} \tag{26}$$

Table 1: Selected mix ratios and components fraction based on Scheffe's second degree polynomial.

S/ NO	PSEUDO COORDINATES					RESPONSE	ACTUAL COORDINATES				
	Coordinate Point	X_1	X_2	X_3	X_4	Y exp	Coordinate points	Z_1	Z_2	Z_3	Z_4
1	A_1	1	0	0	0	Y_1	B_1	0.5	1	4.95	0.55
2	A_2	0	1	0	0	Y_2	B_2	0.55	1	5.10	0.9
3	A_3	0	0	1	0	Y_3	B_13	0.60	1	5.2	1.3
4	A_4	0	0	0	1	Y_4	B_4	0.65	1	6	2
5	A_{12}	1/2	1/2	0	0	Y_{12}	B_{12}	0.525	1	5.025	0.725
6	A_{13}	1/2	0	1/2	0	Y_{13}	B_{13}	0.55	1	5.075	0.925
7	A_{14}	1/2	0	0	1/2	Y_{14}	B_{14}	0.575	1	5.475	1.275
8	A_{23}	0	1/2	1/2	0	Y_{23}	B_{23}	0.575	1	5.15	1.10
9	A_{24}	0	1/2	0	1/2	Y_{24}	B_{24}	0.6	1	5.55	1.45
10	A_{34}	0	0	1/2	1/2	Y_{34}	B_{34}	0.625	1	5.6	1.65

Table 2: Design matrix for control points of a (4, 2) lattice.

S/ NO	PSEUDO COORDINATES					RESPONSE	ACTUAL COORDINATES			
	Coordinate Point	X_1	X_2	X_3	X_4	Y exp	Z_1	Z_2	Z_3	Z_4
1	C_1	1/3	1/3	1/3	0	Y_{C1}	0.55	1	5.08	0.91
2	C_2	1/3	1/3	0	1/3	Y_{C2}	0.57	1	5.35	1.15
3	C_3	1/3	0	1/3	1/3	Y_{C3}	0.59	1	5.38	1.28
4	C_4	0	1/3	1/3	1/3	Y_{C4}	0.60	1	5.43	1.40
5	C_5	1/4	1/4	1/4	1/4	Y_{C5}	0.58	1	5.32	1.20
6	C_6	1/2	1/4	0	1/4	Y_{C6}	0.55	1	5.26	1.01

Table 3: Selected mix ratios and components fraction based on osadebes second degree polynomial.

MIX RATIOS					COMPONENT FRACTION			
S/NO	S_1	S_2	S_3	S_4	Z_1	Z_2	Z_3	Z_4
1	0.5	1	4.95	0.55.	0.0714	0.1429	0.7071	0.0786
2	0.55	1	5.10	0.90	0.0728	0.1325	0.6755	0.1192
3	0.60	1	5.20	1.30	0.0740	0.1235	0.6420	0.1605
4	0.65	1	6.00	2.00	0.0674	0.1036	0.6217	0.2073
5	0.525	1	5.025	0.725	0.0722	0.1375	0.6907	0.0996
6	0.55	1	5.075	0.925	0.0728	0.1325	0.6722	0.1225
7	0.575	1	5.475	1.275	0.0691	0.1201	0.6576	0.1532
8	0.575	1	5.15	1.10	0.0735	0.1278	0.6581	0.1404
9	0.60	1	5.55	1.45	0.0698	0.1163	0.6453	0.1686
10	0.625	1	5.60	1.65	0.0704	0.1127	0.6310	0.1859
CONTROL POINTS								
11	0.55	1	5.08	0.91	0.0729	0.1326	0.6737	0.1207
12	0.57	1	5.35	1.15	0.0706	0.1239	0.6630	0.1425
13	0.59	1	5.38	1.28	0.0715	0.1212	0.6521	0.1552
14	0.60	1	5.43	1.40	0.0712	0.1186	0.6441	0.1661
15	0.58	1	5.32	1.20	0.0716	0.1235	0.6568	0.1481
16	0.55	1	5.26	1.01	0.0703	0.1279	0.6726	0.1292

Table 4: Results of crushing strength test.

Exp. No (r)	**Repetition**	**Point**	**wt of Block** (g)	**Response Yr** (N/mm^2)
1	A	y_1	27.1	2.37
	B		26.0	1.78
2	A	y_2	25.6	0.99
	B		25.9	1.58
3	A	y_3	25.2	1.58
	B		26.2	1.58
4	A	y_4	25.0	1.09
	B		25.6	1.09
5	A	y_{12}	25.6	1.09
	B		26.5	1.38
6	A	y_{13}	25.6	1.78
	B		25.0	1.38
7	A	y_{14}	25.8	1.28
	B		25.0	1.19
8	A	y_{23}	25.0	1.78
	B		25.6	1.38
9	A	y_{24}	26.1	1.48
	B		25.6	1.78
10	A	y_{34}	26.0	1.48
	B		24.1	0.99
Control Point				
11	A	C_1	26.0	1.98
	B		27.0	1.68
12	A	C_2	26.4	1.38
	B		26.6	1.19
13	A	C_3	26.5	1.57
	B		25.2	1.09
14	A	C_4	25.2	1.28
	B		26.5	1.48
15	A	C_5	27.0	1.78
	B		25.8	2.07
16	A	C_6	25.8	2.48
	B		26.5	2.07

6.2. Comparison of strength values predicted by the two optimization models

Predicted strength values for compressive strength based on Scheffe's and Osadebe's second degree model equations are shown in Table 5.

6.3. Adequacy test for the models

A statistical adequacy test for the mathematical models is necessary. For this the statistical hypothesis is used as follows:-

i. Null hypothesis, H_0: There is no significant difference between the two models.

ii. Alternative hypothesis, H_1: There is a significant difference between the two models.

The results of predictions were comparatively analysed using the statistical package for social sciences (SPSS) for the student's t-test. The results shows that $t_{cal} = 1.9$ using paired-samples T-test in SPSS. >

At $\alpha = .05$, df 11, $T_{\text{table}} = 2.20$. Since, $T_{\text{table}} > T_{cal}$ It shows that there is no significant different between the two models so the two models are acceptable for the prediction of compressive strength of sandcrete blocks.

7. Conclusion

It has been shown from this work that Scheffe's simplex lattice theory and Osadebe's optimization theory for mixture design have been successfully applied in generating a mathematical models for the compressive strength of sandcrete block as a multivariate function of the proportions of its constituents ingredients: water, cement, sand and laterite fines.

Scheffe's model was established in the form $y = f(x_1,\ x_2,\ x_3,\ x_4)$ where x_1, x_2, x_3, and x_4 are in the pseudo-components ratio and Osadebe's model in the form of $f(z_1,\ z_2,\ z_3,\ z_4)$ where z_1, x_2, z_3, and z_4 are real component ratio assuming absolute mass or volume of the various ingredients of sandcrete block, water-cement ratio, cement, sand and laterite fines. It was also established that the

Table 5: Selected mix ratios and components fraction based on osadebes second degree polynomial.

	Scheff's Variables				**Osadebe's Variables**				**Scheffe's**	**Osadebe's**
S/No	X_1	X_2	X_3	X_4	Z_1	Z_2	Z_3	Z_4	**Value**	**Value**
1	0.7950	0.0500	0.0120	0.1430	0.0708	0.1348	0.6888	0.1056	1.7143	1.1109
2	0.9765	0.0115	0.0120	0.0000	0.0715	0.1425	0.7058	0.0802	2.0395	2.1639
3	0.9865	0.0105	0.0000	0.0030	0.0714	0.1426	0.7064	0.0796	2.0605	2.1912
4	0.5765	0.3100	0.0100	0.1035	0.0714	0.1341	0.6851	0.1095	1.6211	1.0304
5	0.4765	0.3900	0.0200	0.1135	0.0714	0.1327	0.6810	0.1149	1.5650	1.7700
6	0.0765	0.7900	0.1335	0.0000	0.0729	0.1319	0.6729	0.1222	1.4089	1.2333
7	0.0000	0.7900	0.1335	0.0765	0.0725	0.1285	0.6657	0.1333	1.4785	1.0587
8	0.8000	0.0000	0.2000	0.0000	0.0720	0.1385	0.6925	0.0970	1.6936	1.8424
9	0.0000	0.9000	0.0000	0.1000	0.0722	0.1289	0.6688	0.1302	1.4293	1.1828
10	0.000	0.0000	0.7000	0.3000	0.0718	0.1168	0.6351	0.1763	1.3490	0.8467
11	0.0000	0.3500	0.3500	0.3000	0.0714	0.1194	0.6456	0.1636	1.5476	1.8013
12	0.1100	0.3500	0.3500	0.1900	0.0719	0.1237	0.6546	0.1498	1.4904	0.8151

maximum mean strength obtained in Scheffes model is 2.07N/mm^2 which is in agreement with earlier results by Osilli [10]. From this result, it can be concluded that Osadebe's model can also be used as it is easier to apply because it uses actual mix ratio instead of the pseudo-components ratio that needs to be transformed into real component ratio in Scheffe's model. Adequate test shows second degree polynomial can model the response surface with very high degrees of accuracy using the two models.

References

1. Popovics and J. Ujhelyi (2008). Contribution to the concrete strength versus water-cement ratio relationship. *J.mater. civil Eng*, 20. 459-463.

2. Jee, N, Y Sangehun and C Hongbum, (2004). Prediction of compressive strength of in situ concrete based on mixture proportions. *J. Asian Architect. Build. Eng.*, 3 9–16.

3. M.F.M. Zain and S.M. Abd (2009). Multiple regression model for compressive strength prediction of high performance concrete. *J. of Applied Sciences*, 9(1), pp 155–160.

4. J. A. Cornell,(1990). *Experiments with mixtures; designs, models, and the analysis of mixture data*, 2nd ed.,John wiley & Sons, New York-Toronto .

5. Akhanzarova, S. and Kafarove, V,(1982). *Experiment Optimization on Chemisty and Chemical Engr*; Translated from Russian by Matskovsky, Vla Dimir, M. And Repyers, A, Muscow: MIR Publishers. pp 240 248.

6. Scheffe, H .(1958). Experiments with Mixtures. *Journal of the Royal Statistical Society, Ser. R.* 20 (1958) pp. 344 360

7. Akpuokwe, C.V,(1996). *A Computer Model for Optimization in Concrete Mix proportioning*, Project Report (B. Engr). University of Nigeria, Nsukka.

8. Obam, S.O. (2007). *Mathematical models for optimization of the mechanical properties of concrete made from rice husk ash.* PhD thesis, Civil Engineering Department ,university of Nigeria, Nsukka.

9. Nwakonobi, T.U,(1997). *A Computer Optimization Model for Mix Proportioning of Clay - Rice Husk - Cement Mixture for Partition Walls of Animal Building*, Project Report (M. Engr) University of Nigeria, Nsukka .

10. Neville A.M (1981), *Properties of Concrete.* The English Language Book Society and Pitman, 1981, p: 118-201.

11. Osilli,(1962). *Sandcrete Blocks* (Unpublished Report Ministry of Works and Housing, Lagos.