Nigerian Journal of Technology (NIJOTECH)
Vol. 34 No. 3, July 2015, pp. 459 – 466

University of Nigeria, Nsukka, ISSN: 0331-8443
www.nijotech.com
http://dx.doi.org/10.4314/njt.v34i3.5

MATHEMATICAL MODEL FOR PREDICTION OF FLEXURAL STRENGTH OF MOUND SOIL-CEMENT BLENDED CONCRETE

O. U. Orie[1,*] and N. N. Osadebe [2]
[1] DEPARTMENT OF CIVIL ENGINEERING, UNIVERSITY OF BENIN, BENIN CITY, EDO STATE. NIGERIA
[2] DEPARTMENT OF CIVIL ENGINEERING, UNIVERSITY OF NIGERIA NSUKKA, ENUGU STATE. NIGERIA
E-mail addresses: *[1] ogheneale@yahoo.com, [2] mkemamaka@yahoo.com*

ABSTRACT
The paper examined the optimization of flexural strength of a five-component-concrete mix. Mound Soil randomly selected from Iyeke-Ogba in Benin City was used as a case study. The work applied Scheffe's optimization technique for a five by two degree polynomial. This linear optimization technique assumed the proportions of the material components of concrete to be variables in, x and that these proportions sum up to a whole, that is, unity. It obtained a mathematical model of the form $f(x_1, x_2, x_3, x_4, x_5)$. Where, $j = 1, \dots 5$ are proportions of the concrete components namely; cement, fine aggregate, mound soil, coarse aggregates and water/cement ratio. The mound soil-cement blended proportions were mathematically optimized by using scheffe's approach and the optimization model developed. A computer program predicting the mix proportion for the model was written. The optimal proportion by the program was used prepare beam samples measuring 150mm x 150mm x 750mm which were tested for flexural strength at 28 days and their results were compared with those of a standard 1:2:4 concrete mix. The results showed that the standard mix gave a flexural strength of 1.93N/mm^2 at a w/c of 0.5 while the Scheffe's optimized mix of 1.00:1.59:0.46:3.34:0.53 gave a flexural strength of 0.31N/mm^{2}representing 16.06% of the recommended mix. Results obtained by using the model showed reasonable agreement with that of experiment. Therefore, mound soil-cement blended concrete can be used in construction but the mound soil content should not exceed 7% by weight of the cement for optimal flexural strength performance. Some amount of flexural strength is required in horizontal structural elements such as beams. This will provide for the necessary cracking before ultimate failure during service.

Keywords: *strength, concrete, construction, material, optimization.*

1. INTRODUCTION

Generally, concrete finds use in virtually all civil engineering works. In buildings, it finds application from the foundation to the roof. Concrete is good in compression but poor in tension. Hence in reinforced concrete design, it is assumed that the concrete in the tension zone of the member has failed [1].

The ability of a material to bend under stress before yielding is property of its flexural resistance. The flexural strength of concrete was increased by increasing the content of Fe_2O_3 nanoparticles [2]. Temperature has been shown to affect flexural strength [3]. The task of concrete mix optimization implies selecting the most suitable concrete aggregates from the data base [4]. Several methods have been applied. Examples are [5, 6, 7, 8]. An approach which adopts the equilibrium mineral assemblage concept of geochemical thermodynamics as a basis for establishing mix proportions has been proposed [9]. The results of an optimized laterized concrete demonstrated that it can be used in constructing cylindrical storage structures [10]. Optimization has shown that Rice Husk Ash (RHA) concrete generally produce low compressive strength [11]. The cost of the constituents of concrete ultimately determines the cost of the concrete. It has been shown that, using recycled waste concrete in place of natural mineral aggregate produces 15% reduction in cost [12]. Mound Soil, when used as admixture in concrete caused an increase in the compressive strength [13]. The present paper examined the determination of flexural strength of Scheffe's optimized mound soil-cement (MSC) blended Concrete.

Corresponding Author, Tel +234-802-339-5190

2. MATERIALS AND METHODS

Let the objective function be y–the parameter to be optimized, for example compressive strength, y depends on other factors say $x_1, x_2, x_3 \ldots, x_n$–the variables [11]. These variables are also subject to some auxiliary conditions such as limits or boundaries, termed constraints. A major objective in concrete is compressive strength which depends primarily on the proportions of the constituent materials. These include; fine aggregate, coarse aggregate, cement, water and sometimes additives or modifiers here represented as $x_1, x_2, x_3, x_4 and x_5$ respectively. Assuming concrete as a unit mixture,

$$x_1 + x_2 + x_3 + x_4 + x_5 = 1 \quad (1)$$

Hence, optimizing any function y depending on the proportion of n variables,

$$x_1 + x_2 + x_3 +, \ldots x_n = 1 \quad (2)$$

2.1 Simplex Lattice Method

Simplex has been defined as the structural representation of the line or planes joining the assumed positions of the constituents (atoms) of the material [14].

If a mixture has a total of q components and x_1 be the proportions of the *ith* component in the mixture such that,

$$x_i \geq 0 (i = 1,2 \ldots q)$$

Since the mixture is a complete whole, i.e., unity,

$$x_1 + x_2 + x_3 +, \ldots x_q = 1 \quad or$$

$$\sum x_i - 1 = 0 \quad (3)$$

where, $I = 1,2..q$

Thus the factor space is a regular $(q-1)$ dimensional simplex in which, if $q = 2$, we have 2 points of connectivity giving a line lattice. If $q = 3$, a triangular lattice, if $q = 4$a tetrahedron etc. Taking a whole factor space in the design, we have a *(q,m)* simplex lattice.

2.2 Development of the (5, 2) Lattice Model

The properties studied in the assumed polynomial are real-valued functions on the simplex and are termed *responses*.

Mixture properties were described using polynomials assuming that a polynomial function of degree n in the q variables $x_1, x_2, \ldots, x_q$, subject to equation 3 and will be called a *(q,n)* polynomial having a general form

$$y = b_o + \sum b_i x_i + \sum b_{ij} x_i x_j + \sum b_{ijk} x_i x_j x_k + \sum b_{i1,i2} \ldots i_n x_{i1} x_{i2} x_{in} \quad (4)$$

where, $(1 \leq i \leq q, 1 \leq i \leq j \leq q, 1 \leq i \leq j \leq k \leq q)$.respectively and b is a constant coefficient.

The usable form of equation 4 is

$$\hat{Y} = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_4 x_4 + b_5 x_5 + b_{12} x_1 x_2 + b_{13} x_1 x_3 + b_{14} x_1 x_4 + b_{15} x_1 x_5 + b_{23} x_2 x_3 + b_{24} x_2 x_4 + b_{25} x_2 x_5 + b_{34} x_3 x_4 + b_{35} x_3 x_5 + b_{45} x_4 x_5 + b_{11} x_1^2 + b_{22} x_2^2 + b_{33} x_3^2 + b_{44} x_4^2 + b_{55} x_5^2 \quad (5)$$

Hence, the $(5,2)$ polynomial equation is,

$$\acute{y} = \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 + \alpha_4 x_4 + \alpha_5 x_5 + \alpha_{12} x_1 x_2 + \alpha_{13} x_1 x_3 + \alpha_{14} x_1 x_4 + \alpha_{15} x_1 x_5 + \alpha_{23} x_2 x_3 + \alpha_{24} x_2 x_4 + \alpha_{25} x_2 x_5 + \alpha b_{34} x_3 x_4 + \alpha_{35} x_3 x_5 + \alpha_{45} x_4 x_5 \quad (6)$$

In compact form,

$$\hat{Y} = \sum \alpha_i x_i + \sum \alpha_{ij} x_i x_j \quad (6a)$$

where, $1 \leq i \leq q, 1 \leq i \leq j \leq q, 1 \leq i \leq j \leq q$ respectively and α_i are the coefficients of the regression equation.

Let the response function to the pure components (x_i) be denoted by $(Y_i)$and the response to a 1:1 binary mixture of components i and j be y_{ij}, From Eq. 6,

$$\sum \alpha_i = \sum \alpha_{ij} y_i x_i \quad (7)$$

Where, $I = 1$ to 5

The general equations for evaluating $\alpha_i and\ \alpha_{ij}$ are found to be of the form

$$y_1 = \alpha_i \quad (8)$$

$$\alpha_{ij} = 4_{ij} 2y_i - 2y_j \quad (9)$$

The number of α_{ij} values given as [14],

$q(q+1)/2! = 5(5+1)/2! = 15$

The design matrix as shown in Table 1 or $x_1^{(1)} x_2^{(1)} x_3^{(1)} x_4^{(1)} and\ x_5^{(1)}$ for the *ith* experimental points are referred to as Pseudo-Components. For any actual component Z, the pseudo-component (x) is given by [15],

$$X = AZ \quad (10)$$

where A is the inverse of Z matrix and

$$Z = BX \quad (11)$$

Where B is the inverse of Z matrix and X^T is the transpose of matrix, X.

Table 1. Design Matrix for Scheffe's (5, 2) Lattice (Pseudo and Real components)

Pseudo-Components						Response Comp.	Actual Variables				
No.	X_1	X_2	X_3	X_4	X_5		Z_1	Z_2	Z_3	Z_4	Z_5
1	1	0	0	0	0	Y_1	1	1	0.5	2	0.5
2	0	1	0	0	0	Y_2	1	2	1.5	5	0.55
3	0	0	1	0	0	Y_3	1	1.5	0.25	3	0.325
4	0	0	0	1	0	Y_4	1	3	1	6	0.6
5	0	0	0	0	1	Y_5	1	2.5	2	1.5	0.5
6	$\frac{1}{2}$	$\frac{1}{2}$	0	0	0	Y_{12}	1	1.5	1	3.5	0.525
7	$\frac{1}{2}$	0	$\frac{1}{2}$	0	0	Y_{13}	1	1.25	0.375	2.5	0.5
8	$\frac{1}{2}$	0	0	$\frac{1}{2}$	0	Y_{14}	1	1.25	0.75	4	0.55
9	$\frac{1}{2}$	0	0	0	$\frac{1}{2}$	Y_{15}	1	2.25	1.25	1.75	0.5
10	0	$\frac{1}{2}$	$\frac{1}{2}$	0	0	Y_{23}	1	1.75	0.875	4	0.538
11	0	$\frac{1}{2}$	0	$\frac{1}{2}$	0	Y_{24}	1	2.5	1.25	5.5	0.575
12	0	$\frac{1}{2}$	0	0	$\frac{1}{2}$	Y_{25}	1	2.25	1.75	3.25	0.525
13	0	0	$\frac{1}{2}$	$\frac{1}{2}$	0	Y_{34}	1	2.25	0.625	4.5	0.563
14	0	0	$\frac{1}{2}$	0	$\frac{1}{2}$	Y_{35}	1	2	1.125	2.25	0.513
15	0	0	0	$\frac{1}{2}$	$\frac{1}{2}$	Y_{45}	1	2.75	1.5	3.75	0.55
Control											
1	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$	0	0	C_1	1	1.375	0.688	3	0.514
2	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	0	C_2	1	1.625	0.813	4	0.544
3	0	$\frac{1}{4}$	0	0	$\frac{3}{4}$	C_3	1	2.375	1.875	2.375	0.503
4	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	C_4	1	2.125	1.063	3.5	0.538
5	$\frac{1}{8}$	0	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{4}$	C_5	1	1.875	0.813	2.875	0.525
6	$\frac{1}{4}$	0	$\frac{3}{4}$	0	0	C_6	1	1.375	0.312	2.75	0.644
7	$\frac{1}{4}$	0	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	C_7	1	2	0.938	2.125	0.531
8	$\frac{1}{5}$	$\frac{1}{5}$	$\frac{1}{5}$	$\frac{1}{5}$	$\frac{1}{5}$	C_8	1	2	1.05	2.3	0.535

Legend: X_1 is the Fraction of ordinary portland cement (OPC), X_2 is the Fraction of fine aggregate (Okhuahe river sand, OKRS), X_3 is the Fraction of mound soil, X_4 is the Fraction of coarse aggregate and X_5 is the Water cement ratio

2.3 Materials

Crushed granite obtained from Ifon, with maximum size of 14mm. Okhuahe River Sand (OKRS). Mound soil was randomly selected from Iyeke-Ogba area in Edo State of Nigeria. Potable water conforming to BS3148 [16] was used. The Design Matrix for Scheffe's (5, 2) Lattice (Pseudo and Real components) was developed. This yielded fifteen mix proportions. An extra eight proportions which served as controls were developed. These mix proportions were used to cast the beam samples which measured 150mm x 150mm x750mm samples [17]. The samples were cured by total immersion in water for 28 days after which they were tested for their flexural strengths with the universal testing machine. The results were statistically tested to 95% accuracy using t-Statistics [18].

3. RESULTS AND DISCUSSION

The results are presented in tables. Table 2 shows the results of the test performed to determine the flexural strength of the experimental number samples.

Table 2.Flexural Strength Test Results and Replication Variance for Experimental Numbers

Expt. No.	Response Symbol	$\sum y_r$	$\hat{Y}$	$\sum Y_r^2$	S_1^2
1	Y_1	0.658	0.219	0.433	0.000
2	Y_2	0.232	0.077	0.054	0.000
3	Y_3	0.667	0.222	0.448	0.001
4	Y_4	0.260	0.087	0.068	0.000
5	Y_5	0.088	0.029	0.008	0.000
6	Y_{12}	0.430	0.143	0.185	0.000
7	Y_{13}	0.774	0.258	0.599	0.000
8	Y_{14}	0.768	0.256	0.590	0.000
9	Y_{15}	0.676	0.225	0.547	0.000
10	Y_{23}	0.570	0.190	0.325	0.000
11	Y_{24}	0.056	0.019	0.003	0.000
12	Y_{25}	0.290	0.097	0.084	0.000
13	Y_{34}	0.620	0.207	0.384	0.000
14	Y_{35}	0.520	0.173	0.270	0.000
15	Y_{45}	0.272	0.091	0.074	0.000

Table 3 shows the results of the test performed to determine the flexural strength of the experimental control samples.

Hence, to obtain the replication variance from Tables 2 and 3,

$$S_y^2 = \frac{0.001}{22} = 0.000045 \; and \; S_y = \sqrt{00000454} = 0.007$$

3.1 The Regression Equation

Based on equations and 9,8

$$\alpha_1 = 0.22, \alpha_2 = 0.08, \alpha_3 = 0.22, \alpha_4 = 0.09, a_5 = 0.03$$

$$\alpha_{12} = 4 \times 0.143 - 2 \times 0.22 - 2 \times 0.08 = -0.03$$

$$a_{13} = 4 \times 0.26 - 2 \times 0.22 - 2 \times 0.22 = 0.16$$

Similarly,

$$\alpha_{14} = 0.40, \alpha_{15} = 0.53, \alpha_{23} = 0.16, \alpha_{24} = -0.26, \alpha_{25} = 0.18, \alpha_{34} = 0.22, \alpha_{35} = 0.18 \; and \alpha_{45} = 0.12$$

Substituting into equation 6, we have

$$\hat{Y} = 0.22x_1 + 0.08x_2 + 0.22x_3 + 0.09x_4 + 0.32x_5 - 0.03x_1x_2 + 0.16x_1x_3 + 0.40x_1x_4 + 0.53x_1x_5 + 0.16x_2x_3 - 0.26x_2x_4 + 0.18x_2x_5 + 0.22x_3x_4 + 0.18x_3x_5 + 0.12x_4x_5 \quad (12)$$

Table 3.Flexural Strength Test Results and Replication Variance for Control Points

Expt. No.	Response Symbol	$\sum y_r$	$\hat{Y}$	$\sum Y_r^2$	S_1^2
1	C_1	0.580	0.193	0.336	0.000
2	C_2	0.570	0.190	0.325	0.000
3	C_3	0.280	0.093	0.025	0.000
4	C_4	0.494	0.165	0.244	0.000
5	C_5	0.552	0.184	0.305	0.000
6	C_6	0.456	0.152	0.063	0.000
7	C_7	0.560	0.187	0.314	0.000
8	C_8	0.540	0.180	0.292	0.000
				$\sum$	0.001

Equation (12) is therefore the mathematical model for the optimization of the flexural strength of a 5-component concrete mix using mound soil as the third component. A computer program in Basic language was developed for this model. The desired flexural strength is entered and the program generates the proportion of the components The program is as thus;

```
10 REM A QBasic program that optimizes the proportion of concrete mixes
15 REM Scheffe's Model for flexural strength
20 REM Variable used:
30 REM Z1,Z2,Z3,Z4,Z5,X1,X2,X3,X4,X5,Ymax,Yout,Yin
40 REM begin main program
41 OPEN "ORIEOU.OOU7" FOR APPEND AS #1
50 LET Count = 0
60 CLS
70 GOSUB 100
CLOSE #1
80 END
90 REM End of main program
100 REM Procedure Begin
110 LET Y max = 0
120 PRINT #1,
130 PRINT #1,
140 PRINT #1, "MATHEMATICAL MODELS FOR THE OPTIMIZATION OF THE MECHANICAL PROPERTIES"
```

```
160 PRINT #1, " OF THE CONCRETE MADE FROM RIVER SAND AND MOUND SOIL"
170 PRINT #1,
180 INPUT " ENTER DESIRED STRENGTH"; Yin
185 PRINT #1, "ENTER DESIRED STRENGTH"; Yin
186 PRINT #1,
187 PRINT #1,
190 GOSUB 400
200 FOR X1 = 0 TO 1 STEP .01
210 FOR X2 = 0 TO 1 – X1 STEP .01
220 FOR X3 = 0 TO 1 – X1 – X2 STEP .01
230 FOR X4 = 0 TO 1 – X1 – X2 – X3 STEP .01
235 LET  X5 = 1 – X1 – X2 – X3 – X4
240 LET Yout = .22 * X1 + .08 * X2 + .022 * X3 + .09 * X4 + .03 * X5 - .03 * X1 * X2 +.16 * X1 * X3 + .4 * X1 *
    X4 + .53 * X1 * X5 + .16 * X2 * X3 – .26 * X2 * X4 + .18 * X2 * X5 + .22 * X3 * X4 + .18 * X3 * X5 + .12 * X4 *
    X5
250 GOSUB 500
260 IF (ABS (Yin – Yout) <= .001) THEN 270 ELSE 290
270 LET Count = Count + 1
280 GOSUB 600
285 NEXT X4
290 NEXT X3
291 NEXT X2
292 NEXT X1

295 PRINT #1
300 IF (count > 0) THEN GOTO 310 ELSE GOTO 340
310 PRINT #1, "THE Maximum Value of Strength Predictable By This Model Is"; Ymax; "N / sq.mm."; ""
320 SLEEP (2)
330 GOTO 360
340 PRINT #1, "Sorry! Desired Strength Out Of Range Of Model."
350 SLEEP 2
360 RETURN
400 REM Procedure PrintHeading
410 PRINT #1
420 PRINT #1, TAB (1); "Count"; TAB (7); "X1"; TAB (15); "X2"; TAB (23); "X3"; TAB (31); "X4"; TAB (39);
    "X5"; TAB (47); "Y"; TAB (55); "Z1"; TAB (63); "Z2"; TAB (71); "Z3" TAB (79); "Z4"; TAB(87) ; "Z5"
430 PRINT #1,
440 RETURN
500 REM Procedure CheckMax
510 IF Ymax < Yout THEN Ymax = Yout ELSE Ymax = Ymax
520 RETURN
600 REM Procedure Out Results
610 LET Z1 = XI + X2 + X3 + X4 + X5
620 LET Z2 = X1 + 2 * X2 + 1.5 * X3 + 3 * X4 + 2.5 * X5
630 LET Z3 = .5 * X1 + 1.5 * X2 + .25 * X3 + 6 * X4 + 1.5 * X5
640 LET Z4 = 2 * x1 + 5 * X2 + 3 * X3 + 6 * X4 + 1.5 * X5
645 LET Z5 = .5 * X1 + .55 * X2 + .525 * X3 + .6 * X4 + .5 * X5
650 PRINT #1, TAB (1); Count; USING "####.###"; X1; X2; X3; X4; X5; Yout; Z1; Z2; Z3; Z4; Z5
660 RETURN
```

Some examples of executed program include;

```
ENTER DESIRED STRENGTH .22
Count X1    X2    X3    X4    X5    Y     Z1    Z2    Z3    Z4    Z5
 1  0.000 0.000 0.950 0.000 0.050 0.219 1.000 1.550 0.338 2.925 0.524
 2  0.000 0.000 0.950 0.010 0.040 0.220 1.000 1.555 0.328 2.970 0.525
 3  0.000 0.000 0.960 0.000 0.040 0.219 1.000 1.540 0.320 2.940 0.524
 4  0.000 0.000 0.960 0.010 0.030 0.220 1.000 1.545 0.310 2.985 0.525
 5  0.000 0.000 0.970 0.000 0.030 0.220 1.000 1.530 0.303 2.955 0.524
 6  0.000 0.000 0.970 0.010 0.020 0.221 1.000 1.535 0.293 3.000 0.525
The Maximum Value of Strength Predictable by this Model Is .274528 N / sq.mm
```

```
ENTER DESIRED STRENGTH .23
Count X1    X2    X3    X4    X5    Y     Z1    Z2    Z3    Z4    Z5
 1  0.060 0.000 0.930 0.000 0.010 0.229 1.000 1.480 0.283 2.925 0.523
 2  0.060 0.000 0.930 0.010 0.000 0.230 1.000 1.485 0.273 2.970 0.524
 3  0.060 0.000 0.940 0.000 0.000 0.229 1.000 1.470 0.265 2.940 0.523
The Maximum Value of Strength Predictable by this Model Is .274528 N / sq.mm
```

A similar program for the prediction of the optimal proportion of other mechanical property as compressive strength has been developed and published separately [18].

Table 4 show the statistical check performed on the control points to ascertain their level of significance and hence adequacy using the student *t*-test.

Table 4.t-Statistics for the Control Points

N	Response symbol	i	j	α_i	α_{ij}	α_i^2	α_{ij}^2	ε	y_0	y_t	Δ_y	t
		1	2	0	0.625	0	0.391					
		1	3	0	0.625	0	0.391					
		1	4	0	0	0	0					
		1	5	0	0	0	0					
		2	3	-0.125	0.313	0.016	0.100	0.961	0.193	0.211	0.018	2.22
1	C1	2	4	-0.125	0	0.016	0					
		2	5	-0.125	0	0.016	0					
		3	4	-0.125	0	0.016	0					
		3	5	-0.125	0	0.016	0					
		4	5	0	0	0	0					
		5	-	0	-	0	-					
					$\sum$	0.079	0.882					
Similarly												
2		-	-	-	-	-	-	0.744	0.190	0.193	0.003	0.04
3		-	-	-	-	-	-	1.067	0.093	0.076	0.017	2.04
4		-	-	-	-	-	-	0.568	0.165	0.170	0.005	0.70
5		-	-	-	-	-	-	0.701	0.184	0.206	0.022	2.93
6		-	-	-	-	-	-	1.223	0.152	0.160	0.008	0.93
7		-	-	-	-	-	-	0.613	0.187	0.200	0.013	1.77
8		-	-	-	-	-	-	0.558	0.180	0.202	0.022	3.17

From the t-value table, significant level,$\alpha = 0.05\ and t_{\alpha/l}(V_c) = t_{0.05/8}(7) = 3.5$

This is greater than any of the t-values obtained by calculation as shown in Table 4. Hence we accept the Null Hypothesis. In other words, the regression equation is adequate.

Table5 show a second statistical check performed on the control points to ascertain their level of significance and hence adequacy using Fisher-test.

Table 5. F-Statistics for the Controlled Points

Response Symbol	Y_K	Y_E	$(Y_K - \hat{Y}_K)$	$(Y_E - \hat{Y}_E)$	$(Y_K - \hat{Y}_K)^2$	$(Y_E - \hat{Y}_E)^2$
C_1	0.193	0.196	0.025	0.021	0.0006	0.0004
C_2	0.190	0.193	0.022	0.018	0.0048	0.0003
C_3	0.093	0.076	-0.075	-0.099	0.0056	0.0098
C_4	0.165	0.170	-0.003	-0.005	0.0009	0.0000
C_5	0.184	0.206	0.016	0.031	0.0003	0.0010
C_6	0.152	0.160	-0.016	-0.015	0.0003	0.0002
C_7	0.187	0.200	0.019	0.025	0.0004	0.0006
C_8	0.180	0.202	0.012	0.027	0.0001	0.0007
$\sum/8$	0.168	0.175			0.00016	0.0019

Where, $\boldsymbol{Y_K}$ is the Experimental values (responses), $\boldsymbol{Y_E}$ is the Expected or theoretically calculated values (responses)

$$S_K^2 = \frac{(Y_K - \hat{Y}_K)^2}{8} = 0.0016,\ S_E^2 = (Y_E - \hat{Y}_E)^2/8 = 0.0019$$

Hence, $F =$ higher of the two values divided by the lower and F = 0.0019/0.0016 = 1.19.

Table 6, Mass and Strength of Standard and Optimized Mixes

Item	Cement (kg)	Fine Agg. (kg)	Mound Soil (kg)	Coarse Agg. (kg)	Water(kg)	Flexural Strength(N/mm^2)
Standard Mix	1	2.00	0.00	4.00	0.55	1.93
Optimized Mix	1	1.59	0.46	3.34	0.53	0.31
Saving	0	0.41		0.66	0.02	

From Fisher table, F_{095} (7, 7) = 3.9 which was higher than the calculated value, hence the regression equation is adequate.

Table 6 is the masses of the proportions of the materials in Scheffe's optimized mound soil-cement blended concrete and that for a standard concrete mix has been presented with their flexural strengths and savings evaluation.

The proposed regression models for flexural strength were tested for adequacy using the student's t-test and F-test. These are shown in Tables 4 and 5. The tables showed that the regression models are adequate. Table 6 presents the results obtained from test carried out to experimentally check the outcome of the regression model. The experimental results agreed favourably with the predicted. MSC has been shown to have relatively lower flexural strength than their standard plain concrete counterparts but however will be adequate with 56.36% of the 0.55N/mm^2 requirement [1]. Table 6 also showed that the optimized mound soil-cement blended concrete had 6.6% mound soil content. The optimized mound soil-cement blend concrete will be more economical considering the savings of0.41kg in fine aggregate and 0.66kg in coarse aggregates per unit volume of concrete.

4. CONCLUSION

The mathematical model for the optimization of the flexural strength of mound soil-cement (MSC) blended concrete has been developed and tested for adequacy. MSC has been shown to have relatively lower flexural strength than plain concrete but however will be adequate in structural members as it has been shown to have 56.36% of 0.55N/mm^2 requirement. The work also showed that the optimized mound soil-cement blend will be more economical as it showed a saving of 0.41kgof fine aggregate and 0.66kg of coarse aggregate per unit volume of concrete. Scheffe's optimized mound soil concrete can be applied in construction woks such as; columns, beams, slabs, silos and rigid pavements.

5. REFERENCES

[1] British Standards Institution, BS 8110: Part 5. *Structural Use of Concrete*, British Standards House, London, 1985.

[2] Nazari, A., Riahi, S., Shamekhi, S. F. and Khadeenmo, A. "The Effects of Incorporation Fe_2O_3 Nanoparticle on Tensile and Flexural Strength of Concrete", ,*Journal of American Science*, Vol. 6, 2010, No. 4, pp 90-93.

[3] Husem, H. "The Effects of High Temperatures on Compressive and Flexural Strengths of Ordinary and High Performance Concrete*", Fire Safety Journal*, Vol. 41, 2006, Number 2, pp155-163.

[4] Genedij, S. and Juris, B."Concrete Mix Design and Optimization",*2nd Int. Symposium in Civil Engineering*, Budapest,1998.

[5] Mohan, D.,Muthukumar, M. and Rajendran, M."Optimization of Mix Proportions of Mineral Aggregates Using Box Jenken Design of Experiments",*Elsevier Applied Science*, Vol. 25, 2002,Number 7, p.751-759.

[6] Simon, M. "Concrete Mix Optimization Using Statistical Methods",*Federal Highway Administration Report*, Maclean V. A., 2003.

[7] Lech, C., Andrzej, G., Pawel, L. and James, R. C. "Optimization of Polymer Concrete Composites", *United States Department. of Commerce Technology and. Administration*, National Institute of Standards and Technology, 1999.

[8] Czarnecki, L., Garbacz, A., Piela, P. and Lukowski, P. "Material Optimization System: Users

Guide", *Warsaw University of Technology Internal Report*, 1994.

[9] Nordstrom, D. K. and Munoz, J. L. "*Geochemical*", Thermodynamics, Blackwell Science Publications, Boston, 1994.

[10] Nwakonobi, T. U. *Static Analysis and Design of Laterized Concrete Cylindrical Shells for Farm Storage*, PhD Thesis, University of Nigeria, Nsukka, 2007.

[11] Obam, S. O. "*Mathematical Models for Optimization of Some Mechanical Properties of Concrete Made from Rice Husk Ash*", PhD Thesis, University of Nigeria, Nsukka, 2007.

[12] Orie, O. U. "Recycled Waste Concrete: An alternative to Natural Mineral Aggregate", *Journal of Science and Technology Research,* Vol. 3, 2008, Number 3, pp 57-61.

[13] Felix, F. U., Alu, O. C. and Suleiman, J. "Mound soil as a Construction Material", *Journal of Materials in Civil Engineering*, Vol. 12, 2000, Number 3, pp 205-211.

[14] Jackson, N. *Civil Engineering Materials*, RDC Artser Ltd., Hong Kong, 1983.

[15] Scheffe, H. "Experiments with Mixtures", ,*Journal of the Royal Statistics Society*, Series B, Vol. 20, 1958, pp 344-360.

[16] British Standards Institution, BS 3148. *Test of Water for Making Concrete*, British Standards House, 1980.

[17] British Standards Institution, BS 1881: 109. *Specifications for Concrete Moulds*, British Standards House, 1983.

[18] Orie, O. U. and Osadebe, N. N. "Optimization of the Compressive Strength of Five-component-concrete Mix Using Scheffe's Theory – A case Study of Mound Soil Concrete", ,*Journal of the Nigerian Association of Mathematical Physics*, Vol. 14, 2009, pp 81-86.