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Scheffe's Model of the Compressive Strength Characteristics of Concrete Made with Termite Mound Soil from Akwa- Ibom State, Nigeria

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***Abstract*-- This research developed the model for predicting the compressive strengths of concrete made from termite mound soil and granite/chippings using Scheffe's (4, 2) lattice polynomial. The termite mound soil was dug from the hostel site of the Heritage Polytechnic, Ikot Udota, Eket, in Akwa Ibom state, while the chippings were obtained from Akampa, Cross River State, all in South - South zone of Nigeria. Sixty concrete cubes (150mm x 150mm x 150mm) were molded, cured and crushed. The model for the compressive strengths of the concrete developed was $\hat{Y} = 20.66 x_1 + 22 x_2 + 15 x_3 + 9.4x_4 + 1.994 x_1x_2 + 10.426 x x_1 x_3 - 8.296 x_1x_4 + 1.85 x_2x_3 + 4.728 x_2x_4 + 0.282 x_3x_4$. The Fisher test was used to validate the model. The experimental results agreed with the predicted values by the model. and the null hypothesis, H_o was accepted.**

***Keywords* — compressive strength, Fisher's test, null hypothesis, termite mound soil, Scheffe.**

I. INTRODUCTION

A. The Scheffe's (4, 2) Lattice Polynomial

Simplex is the structural representation of the line or planes joining the assumed positions of the constituent materials (atoms) of a mixture [1]. When studying the properties of a *q*-component mixture, which are dependent on the component ratio only, the factor space is a regular,(*q*-1)-simplex, and for the mixture the relationship holds [2],

$$\sum_{i=1}^{q} x_i = 1 \qquad (1)$$

where $x_i \geq 0$ is the component concentration, *q* is the number of components. Scheffe [3] considered experiments with mixtures of which the property studied depended on the proportions of the components present but not on the quantity of the mixture.

Scheffe [3] presented the properties of mixtures in reduced polynomials (equation 2).

$$\hat{Y} = b_0 + \Sigma b_i x_i + \Sigma b_{ij} x_i x_j + \Sigma b_{ijk} x_i x_j x_k + \Sigma b_{i1,i2 \ldots i_n} x_{i1} x_{i2} x_{in} \qquad (2)$$

Multiplying eqn.1 by b_0 and multiplying variously by x_1, x_2, x_3 and x_4 and substituting into equation 2, gives:

$$\hat{Y} = b_0 x_1 + b_0 x_2 + b_0 x_3 + b_0 x_3 + b_0 x_4 + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_4 x_4 + b_{12} x_1 x_2 + b_{13} x_1 x_3 + b_{14} x_1 x_4 + b_{23} x_2 x_3 + b_{24} x_2 x_4 + b_{34} x_3 x_4 + b_{11}(x_1 - x_1x_2 - x_1x_3 - x_1x_4) + b_{22}(x_2 - x_1x_2 - x_2x_3 - x_2x_4) + b_{33}(x_3 - x_1x_3 - x_2x_3 - x_3x_4) + b_{44}(x_4 - x_1x_4 - x_2x_4 - x_3x_4) \qquad (3)$$

By series of re-arrangements, Equation 3 becomes

$$\hat{Y} = \Sigma \propto_i x_i + \Sigma \propto_{ij} x_i x_j \qquad (4)$$

and

$$\propto_i = b_0 + b_i + b_{ii} \text{ and } \propto_{ij} = b_{ij} + b_{ii} + b_{ii} \qquad (5)$$

If y_i represents the response function of x_i and y_{ij}, that of components,i and j, then

$$\Sigma \propto_i x_i = \Sigma y_i x_i \qquad (6)$$

Where (i = 1 to 4)
Evaluating y_i, yields

$$y_i = \propto_i \qquad (7)$$

Also evaluating y_{ij}, yields

$$\propto_{ij} = 4y_{ij} - 2y_i - 2y_j \qquad (8)$$

Then, Scheffe's (4, 2) lattice polynomial, becomes:

$$\hat{Y} = y_1 x_1 + y_2 x_2 + y_3 x_3 + y_4 x_4 + (4y_{12} - 2y_1 - 2y_2) x_1 x_2 + (4y_{13} - 2y_1 - 2y_3) x_1 x_3 + (4y_{14} - 2y_1 - 2y_4) x_1 x_4 + (4y_{23} - 2y_2 - 2y_3) x_2 x_3 + (4y_{24} - 2y_2 - 2y_4) x_2 x_4 + (4y_{34} - 2y_3 - 2y_4) x_3 x_4 \qquad (9)$$

B. Estimate of the Variance

The biased estimate of the unknown variance S^2 is given by [4],

$$S_Y^2 = \frac{\sum \left(y_i - \breve{y} \right)^2}{n - 1} \qquad (10)$$

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and $(1 \leq i \leq j \leq q)$ respectively.

C. The Fisher's Test

The Fishers-test statistic is given by

$$F = S_1^2/S_2^2 \quad (11)$$

The values of $\mathbf{S_1}$(lower value) and $\mathbf{S_2}$ (upper value) are calculated from equation (10).

II. Methodology

A. Materials

The mound soil used for this research work was obtained from the campus of Heritage Polytechnic Eket, Cement used was Dangote cement brand of ordinary Portland cement bought from RCC Road in Eket. Pipe borne water was used, crushed granite (chippings) from Akamkpa, Cross River State were used.

B. Methods

B.1 Mound Soil

The mound soil was broken and dug up with a spade and carried to the soil mechanic laboratory of the building technology department, it was further broken into smaller particles with a wooden rammer. The particles were air dried and sieved with a 5mm sieve. The crushed aggregates are crushed granite chippings from Akamkpa in Cross River State.

B.2 Making, Curing and Crushing the Concrete Cube Samples

The aggregates were sampled in accordance with BS 812: Part 1:1975 [5]. The particle size distribution satisfied BS 882:1992 [6] and BS 410:1986 [7]. The physical properties of the coarse aggregates were determined according to BS 812: Part 2: 1975 [8]. The mechanical properties test (Los Angeles Abrasion test) was carried out in accordance with ASTM. Standard C131: 1976 [9]. The water used for mixing and curing purposes was portable drinking water obtained from the tab water from Heritage Polytechnic, Eket and satisfied the conditions prescribed in BS 3148:1980 [10]. The molding, curing and crushing of the concrete specimens were in accordance with BS 1881: 108:1983 [11], BS 1881: Part 111: 1983 [12] and BS 1881: Part 116:1983 [13].These specimens were cured for 28 days and the crushing was done using universal testing machine.

B.3 Fit of the Second-degree Polynomials

The second-degree polynomial was validated by comparing it to the experimental results. The null hypothesis, H_0, was when the two results agreed with only very little variation and the alternative hypothesis, H_1, is when there was a great variation between the values from the model and the experimental results.

III. Results And Discussion

A. Physical Components of the Termite Mound soil

The sedimentation test result is shown in Table III.A

Table III.A
Sedimentation test on termite mound soil

Constituents	Depths (mm)	% Content
Sand Layer	0	0
Silt Layer	70	60.87
Clay Layer	45	39.13

B. The Regression Equation for the Compressive Strength

Applying the responses of Table III.B to eqns. (7) and (8), gives α_1=20.66, α_2=22, α_3=15, α_4 = 9.481. Similarly, α_{12}=1.99, α_{13}=10.426, α_{14}=-8.296, α_{23}=-1.85, α_{24}=4.728, α_{34}=0.282. Thus, from eqn.9: $\hat{Y} = 20.66\,x_1 + 22\,x_2 + 15\,x_3 + 9.481x_4 + 1.994\,x_1x_2 + 10.426\,x_1\,x_3 - 8.296\,x_1x_4 + 1.85\,x_2x_3 + 4.728\,x_2x_4 + 0.282\,x_3x_4.$ This is the mathematical model for the the compressive strength of concretes made with mound soil and chippings from Akamkpa in Cross River state based on Scheffe's (4, 2) polynomial

Table III.B
Compressive strength test results of termite mound soil concrete, based on Scheffe's (4, 2) Simplex Lattice.

S/N	Replica tion	Responses y_1 (N/mm^2)	Average response $\hat{Y}$
1	A	21.20	
	B	20.60	
	C	20.20	20.66
2	A	22.40	
	B	22.80	
	C	21.80	22.27
3	A	15.70	
	B	15.00	
	C	14.70	15.13
4	A	9.800	
	B	9.400	

	C	9.200	9.47
	A	24.10	
5	B	24.80	
	C	24.00	24.3
	A	20.90	
6	B	20.00	
	C	20.40	20.4
	A	13.30	
7	B	12.90	
	C	13.10	13.1
	A	20.00	
8	B	19.10	
	C	18,70	19.3
	A	16.90	
9	B	17.10	
	C	16.90	17.0
	A	12.80	
10	B	11,70	
	C	12.40	12.3
	A	20.00	
11	B	19.56	
	C	19.11	0.23
	A	17.11	
12	B	17.33	
	C	16.89	0.15
	A	18.44	
13	B	18.44	
	C	18.22	0.03
	A	18.53	
14	B	18.44	
	C	18.22	0.025
	A	21.56	
15	B	20.89	
	C	21.33	0.115
	A	19.56	
16	B	19.33	
	C	19.11	0.05
	A	19.11	
17	B	18.89	
	C	18.89	0.015
	A	20.36	
18	B	20.22	
	C	20.22	0.01
	A	19.47	
19	B	19.51	
	C	19.33	0.01
	A	12.44	
20	B	12.58	
	C	12.49	0.01

Legend: Z_1= water/cement ratio; Z_2=Cement; Z_3=Fine aggregate; Z_4=Coarse aggregate; $Y_=$ responses

B. The Model Equation

The model developed was $\hat{Y} = 20.66 x_1 + 22 x_2 + 15 x_3 + 9.481x_4 + 1.994 x_1x_2 + 10.426 x_1 x_3 - 8.296 x_1x_4 + 1.85 x_2x_3 + 4.728 x_2x_4 + 0.282 x_3x_4$, was tested and agreed with the actual experimental results. Therefore, the null hypothesis, H_0 was accepted.

C. F-Statistic Analysis

Based on eqn.(10), we had that $S_K^2 = 40.0201/9 = 4.447$, $S_E^2 = 47.445/9 = 5.716$ & **F** = 5.716 /4.447= 1.3. This value was below $F_{0.95(9,9)} = 3.3$, hence the model was adequate.

IV. CONCLUSION

The strengths (responses) of the termite soil concrete were dependent on the proportions of water, cement, termite mound soil and coarse aggregates. Since the predicted strengths by the model were in agreement with the corresponding experimental values, this meant that the model equation was valid.

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