ISSN 2250-3153

Optimization of Compressive Strength of River Sand-Termite Soil Concrete Using Simplex Design

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Abstract- The high demand for concrete in the construction industry has led to a rapid decrease in natural soil deposit such as river sand and granite. The excessive usage of natural soil deposit has resulted into ecological imbalance and environmental problems. There is need to explore an alternate material that could be used as a replacement for the conventional aggregates. This had directed attention to by-product and wastes such as termite soil.

The focus of this research is the development of a function for the optimization of the compressive strength of river sand – termite soil concrete based on simplex design. The response function was used to optimize the compressive strength of concrete made from water, cement, river sand, termite soil and granites. The results of the response function compared favourably with the corresponding experimental results and the predictions from the response function were tested for adequacy using the statistical student's t-test and found to be adequate at 95% confidence level. The optimum compressive strength of concrete at twenty-eight (28) days was found to be 30.15 N/mm^2. This strength corresponds to a mix ratio of 0.575:1:1.75:0.25:3.5 (i.e.water: cement: river sand: termite soil: granites). With the optimization function developed in this work, any desired compressive strength of river sand- termite soil concrete can be predicted from known mix proportions and vice versa.

Index Terms- optimization; compressive strength; river sand; termite soil; concrete; simplex design

I. Introduction

Concrete is the most commonly used building material in the world. It is use in majority of engineering projects like construction of housing units, culverts, rigid pavements, gravity dams, etc. In the last century, the escalation in the need for construction project has led to an increase in the use of concrete. This demand is estimated to double in the next thirty years.

With the global economic recession, coupled with the market inflationary trends, the constituent materials used for these structures had led to a very high cost of construction. Hence, researchers in material science and engineering are committed to having local materials to partially or fully replacing these costly conventional materials (Adewuyi et.al, 2008). Numerous achievements have been made in these regards and the subject is attracting attention due to its functional benefit of waste reusability and sustainable development. Reduction in construction costs and the ability to produce light-weight structures, are added advantages.

The use of river sand as an aggregate, for construction does not overrule the fact that its source is usually at some distance from the final user, thereby necessitating its transportation to where it is needed, hence, it increases the cost of construction. Also the growing concern of resource depletion and global pollution has challenged many researchers and engineers to seek and develop new materials relying on renewable resources (Afolayan and Alhassan, 2010). These include the use of by-products and waste materials such as termite soil in building construction.

Therefore, considering the degree of availability of sand, its cost of transportation which can be meaningfully employed in other areas of construction, preservation of the environment and ecosystem, there is a need to replace a portion of the sand in the concrete mix with another local material that will help overcome the above challenges. In this research work, termite soil is used to replace sand partially in the production of concrete (i.e. river-sand termite soil concrete). The river sand- termite soil concrete produced from various mix ratios were test in compression and the results used to model the compressive strength of the concrete.

II. MATERIALS

The concrete test is a five component composite consisting cement, coarse aggregate, fine aggregate, termite soil and water. The cement used in this work is Ibeto brand of ordinary Portland cement. It conforms to the requirement of BS 12 (1978).

The coarse aggregate consists of crushed granite rock having a maximum size of 20mm. It was obtained from crushed rock industries quarry located in Ishiagu in Ebonyi state, Nigeria. River sand obtained from Otamiri River was the fine aggregate. The river sand was sharp and free from clay, debris and other deleterious materials. The grading of the sand was carried out to BS 812 (BS 812). The sand belongs to grading zone C (Neville, 1996).

The termite soil was obtained from termite mounds above ground termite nest which are located at various places within the premises of Federal University of Technology, Owerri (FUTO). The soil was sun dried for two weeks, and the sieved to sand-sized particles before being used in preparing the concrete. Portable water obtained from a borehole in FUTO was used in producing the concrete.

3.0 METHODS

ISSN 2250-3153

The objective of this work was achieved by employing Scheffe's experimental mixture equation and experimental results obtained after compression test of the concrete cubes of river sand-termite soil concrete. The simple design method was adopted in this work.

3.1 SIMPLEX DESIGN

Simplex is a factor space or a polygon. The simplest simplex is a straight line. A straight line is a one dimensional factor space. Other factor spaces could be two dimensional (a plane), three dimensional (a tetrahedron .i.e. solids) or any other imaginary factor space, whose dimension is above three. Scheffe's factor was considered in this work for formulation of the response function. Scheffe's method of optimization is applicable to mixtures in which the desired response depends on the proportion of components present in the mixture, rather than on the quality of the mixture (Scheffe, 1958). River sand-termite soil concrete is a five-component mixture consisting of water, cement, river sand, termite soil and crushed granite rock. This was analyzed using four-dimensional simplex lattice. The four-dimensional simplex lattice factor space is shown in fig 1 below:

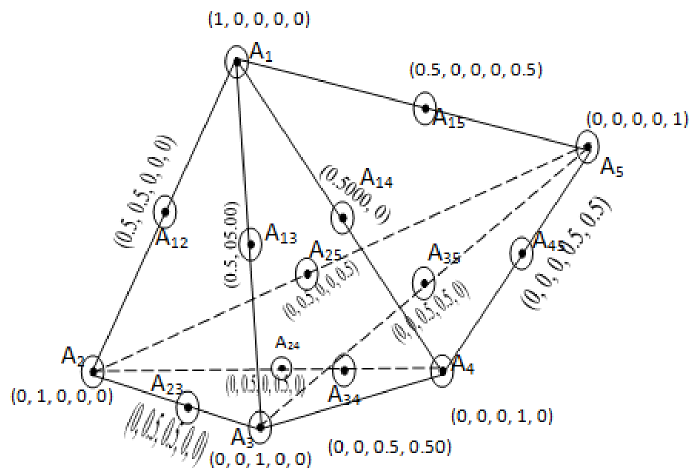

Fig 1: A four-dimensional factor space

According to Scheffe (1958), for a five-component mixture such as like river sand-termite soil concrete, the proportion, X_i of the i^{th} component of the mixture must satisfy the following constraint:

$$X_i \geq 0 \qquad (i = 1, 2, 3, 4, 5) \qquad (1)$$

And the sum of all proportions of the constituents of the five-component of river sand-termite soil concrete must be equal to unity, i.e.

$$\sum_{I=1}^{q} X_i = 1 \qquad (2)$$

For the five- component river sand-termite soil concrete,

$$X_1 + X_2 + X_3 + X_4 + X_5 = 1 \qquad (3)$$

The response sought or the performance criterion of interest (i.e. compressive strength of the river sand-termite soil concrete) is presented using a polynomial function of pseudo components. According to Onwuka et al (2011), the equation of response represented by a polynomial function is given by Eqn(4):

$$Y = b_o + \sum b_i X_i + \sum b_{ij} X_i X_j + \sum b_{ijk} X_i X_j X_k + \cdots + e \qquad (4)$$

where;

b_i, b_{ij}, b_{ijk} are constants; X_i, X_j, X_k are pseudo components and e is the random error term which represents the combined effect of all variables not included in the model.

The number of coefficients, k, of the polynomial, is determined using Eqn(5).

$$k = \frac{(q + m - 1)!}{(q - 1)! * m!} \qquad (5)$$

Where
q is the number of components of the mixture, and, m is the degree of the polynomial.

For the five pseudo component mixture with two degrees of reaction, the number of coefficients is fifteen. The equation of the response, Y, for the five-pseudo component mixture is given as:

$$Y = b_o + \sum b_i X_i + \sum b_{ij} X_i X_j + \ldots + e \qquad (6)$$

where $0 \leq i \leq j \leq 5$

Expanding Eqn(6) by substituting the values of 'I' and ' j' yields Eqn(7)

$$Y = b_0+b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{14}X_1X_4 + b_{15}X_1X_5 + b_{23}X_2X_3 + b_{24}X_2X_4 + b_{25}X_2X_5 + b_{34}X_3X_4 + b_{35}X_3X_5 + b_{45}X_4X_5 + b_{11}X_1^2 + b_{22}X_2^2 + b_{33}X_3^2 + b_{44}X_4^2 + b_{55}X_5^2 \quad (7)$$

Multiplying Eqn(3) by b_o yields Eqn (8)

$$b_0X_1 + b_0X_2 + b_0X_3 + b_0X_4 + b_0X_5 = b_0 \quad (8)$$

Multiplying Eqn(3) successively by $X_1, X_2, X_3, X_4 \, and \, X_5$ and rearranging the products, gives Eqn(9).

$$\left.\begin{aligned} X_1^2 &= X_1 - X_1X_2 - X_1X_3 - X_1X_4 - X_1X_5 \\ X_2^2 &= X_2 - X_1X_2 - X_2X_3 - X_2X_4 - X_2X_5 \\ X_3^2 &= X_3 - X_1X_3 - X_2X_3 - X_3X_4 - X_3X_5 \\ X_4^2 &= X_4 - X_1X_4 - X_2X_4 - X_3X_4 - X_4X_5 \\ X_5^2 &= X_5 - X_1X_5 - X_2X_5 - X_3X_5 - X_4X_5 \end{aligned}\right\} \quad (9)$$

Substituting Eqns (8) and (9) into Eqn (7) and simplifying the result, gives Eqn (10)

$$Y = \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_{12}X_1X_2 + \beta_{13}X_1X_3 + \beta_{14}X_1X_4 + \beta_{15}X_1X_5 + \beta_{23}X_2X_3 + \beta_{24}X_2X_4 + \beta_{25}X_2X_5 + \beta_{34}X_3X_4 + \beta_{35}X_3X_5 + \beta_{45}X_4X_5 \quad (10)$$

where

β_i and X_i are the coefficient of the response equation and pseudo components of the mix respectively.

The coefficients β_i and β_{ij} are defined as follows:

$$\left.\begin{aligned} \beta_i &= b_0 + b_i + b_{ii} \\ \text{And} \quad \beta_{ij} &= b_{ij} - b_{ii} - b_{jj} \end{aligned}\right\} \quad (11)$$

Eqn(5) can be represented in the form:

$$Y = \sum_{i=1}^{5} \beta_iX_i + \sum_{i \le j \le 5}^{5} \beta_{ij}X_iX_j \quad (12)$$

If the response function is represented by Y, the response function for the pure component, i , and that of binary mixture components , ij, are $Y_i \, and \, Y_{ij}$ respectively.

3.1.1 DETERMINATION OF THE COEFFICIENTS OF THE POLYNOMIAL FUNCTION

If the response function is represented by Y, the response function for the pure component, i, and that of binary mixture components, ij, are $Y_i \, and \, Y_{ij}$ respectively, then,

$$Y_i = \sum_{i=1}^{5} \beta_iX_i \quad (13)$$

And

$$Y_{ij} = \sum_{i=1}^{5} \beta_iX_i + \sum_{i \le j \le 5}^{5} \beta_{ij}X_iX_j \quad (14)$$

The substitution of the values of the pseudo components $X_1, X_2, X_3, X_4 \, and \, X_5$ at the i[th] poion the lattice into Eqn (13), yields Eqn(15)

$$Y_i = \beta_i \quad (15)$$

And the substitution of the pseudo components $X_1, X_2, X_3, X_4 \, and \, X_5$ at the point $ij,$ into Eqn (14), yields Eqn (16)

$$Y_{ij} = \frac{1}{2}\beta_i + \frac{1}{2}\beta_j + \frac{1}{4}\beta_{ij} \quad (16)$$

Rearrangement of Eqns (15) and (16) gives:

$$\beta_i = Y_i \quad (17)$$

$$\beta_{ij} = 4Y_{ij} - 2Y_i - 2Y_j \quad (18)$$

Let $n_i = Y_i$ and $n_{ij} = Y_{ij}$, hence, Eqns (17) and (18) will be:

$$\beta_i = n_i \quad (19)$$

$$\beta_{ij} = 4n_{ij} - 2n_i - 2n_j \quad (20)$$

Substituting Eqns(19) and (20) into Eqn(10) and simplifying further, gives

$$Y = n_1X_1(2X_1 - 1) + n_2X_2(2X_2 - 1) + n_3X_3(2X_3 - 1) + n_4X_4(2X_4 - 1) + n_5X_5(2X_5 - 1) + 4n_{12}X_1X_2 + 4n_{13}X_1X_3 + 4n_{14}X_1X_4 + 4n_{15}X_1X_5 + 4n_{23}X_2X_3 + 4n_{24}X_2X_4 + 4n_{25}X_2X_5 + 4n_{34}X_3X_4 + 4n_{35}X_3X_5 + 4n_{45}X_4X_5 + 4n_{45}X_4X_5 \quad (21)$$

Eqn(21) is the response function for optimization of river sand-termite soil concrete consisting of five components. The terms n_i *and* n_{ij} are the responses (i.e. compressive strengths) at the points i *and* ij. The values of these responses are determined by carrying out laboratory tests.

3.1.2 CONCRETE MIX RATIOS

Five mixed ratios (real and pseudo) that defined the vertices of the four-dimensional simplex lattice used in this study are shown in Table 1

Table 1: Five Mix Ratios (Actual and Pseudo) Obtained From Scheffe's (5, 2) Factor Space

points	Real Mix ratios						**Pseudo Mix ratios**				
	Water S_1	Cement S_2	R/sand S_3	T/soil S_4	Granite S_5		Water X_1	Cement X_2	R/sand X_3	T/soil X_4	Granite X_5
N_1	0.500	1.0	1.42	0.08	2.50		1.0	0.0	0.0	0.0	0.0
N_2	0.550	1.0	1.80	0.20	3.00		0.0	1.0	0.0	0.0	0.0
N_3	0.600	1.0	1.70	0.30	4.00		0.0	0.0	1.0	0.0	0.0
N_4	0.450	1.0	1.60	0.40	4.25		0.0	0.0	0.0	1.0	0.0
N_5	0.650	1.0	1.80	0.60	3.50		0.0	0.0	0.0	0.0	1.0

Legend: R/sand= River sand and T/soil = Termite soil

According to Osadebe, et.al (2008) the actual mix ratios relate with pseudo mix ratios in defined by the following equation:

{S} = [A]{X} (22)

where S, A and X represent the real mix ratio, coefficient of relation matrix, and pseudo mix ratio respectively. According to Osadebe et.al(2008), matrix A can be taken to be the transpose of the first five real mix ratios shown in table 1, and this resulted to matrix A:

$$[A] = \begin{bmatrix} 0.50 & 0.55 & 0.60 & 0.45 & 0.65 \\ 1 & 1 & 1 & 1 & 1 \\ 1.42 & 1.8 & 1.7 & 1.6 & 1.8 \\ 0.08 & 0.2 & 0.3 & 0.4 & 0.6 \\ 2.5 & 3.0 & 4.0 & 4.25 & 3.5 \end{bmatrix} \quad (23)$$

The five real and pseudo mix ratios in Table 1 corresponds to points of observations, N_1, N_2, N_3, N_4, N_5 located at the five vertices of the four-dimensional simplex lattice. For a (5, 2) simplex design, ten other point observations are needed to add up to the first five to get a total of fifteen observations needed for the development of the response function. The remaining ten points are located at the mid points of the lines joining the five vertices. On successive substitution of these ten pseudo mix ratios into Eqn(22), the real mix ratios corresponding to the pseudo ones, were obtained. Their values are shown in Table 2.

Table2: Additional Ten Mix Ratios (Real and Pseudo) for formulation of the Optimization Function

points	Real Mix ratios						**Pseudo Mix ratios**				
	Water S_1	Cement S_2	R/sand S_3	T/soil S_4	Granite S_5		Water X_1	Cement X_2	R/sand X_3	T/soil X_4	Granite X_5
N_{12}	0.525	1.0	1.61	0.14	2.75		0.5	0.5	0.0	0.0	0.0
N_{13}	0.550	1.0	1.56	0.19	3.25		0.5	0.0	0.5	0.0	0.0
N_{14}	0.475	1.0	1.51	0.24	3.375		0.5	0.0	0.0	0.5	0.0
N_{15}	0.575	1.0	1.61	0.34	3.00		0.5	0.0	0.0	0.0	0.5
N_{23}	0.575	1.0	1.75	0.25	3.50		0.0	0.5	0.5	0.0	0.0
N_{24}	0.500	1.0	1.70	0.30	3.625		0.0	0.5	0.0	0.5	0.0
N_{25}	0.600	1.0	1.80	0.40	3.25		0.0	0.5	0.0	0.0	0.5
N_{34}	0.525	1.0	1.65	0.35	4.125		0.0	0.0	0.5	0.5	0.0
N_{35}	0.625	1.0	1.75	0.45	3.75		0.0	0.0	0.5	0.0	0.5
N_{45}	0.55	1.0	1.70	0.50	3.875		0.0	0.0	0.0	0.5	0.5

Legend: R/sand= River sand and T/soil = Termite soil

In order to validate the optimization function, extra fifteen points (C_1, C_2, C_3, C_4, C_5, C_6, C_7, C_8, C_9, C_{10}, C_{11}, C_{12}, C_{13}, C_{14}, and C_{15}) of observations were used. These observations provided control mix ratios needed to test the validity of the response function. The mix ratios (actual and pseudo) for the entire work are shown in Table 3.

Table 3: Mix Ratios for Thirty Points Observations (Actual and Pseudo) Obtained From Scheffe's Factor

Points	Real Mix ratios						**Pseudo Mix ratios**				
	Water S_1	Cement S_2	R/sand S_3	T/soil S_4	Granite S_5		Water X_1	Cement X_2	R/sand X_3	T/soil X_4	Granite X_5
N_1	0.500	1.0	1.42	0.08	2.50		1.0	0.0	0.0	0.0	0.0
N_2	0.550	1.0	1.80	0.20	3.00		0.0	1.0	0.0	0.0	0.0
N_3	0.600	1.0	1.70	0.30	4.00		0.0	0.0	1.0	0.0	0.0
N_4	0.450	1.0	1.60	0.40	4.25		0.0	0.0	0.0	1.0	0.0
N_5	0.650	1.0	1.80	0.60	3.50		0.0	0.0	0.0	0.0	1.0
N_{12}	0.525	1.0	1.61	0.14	2.75		0.5	0.5	0.0	0.0	0.0
N_{13}	0.550	1.0	1.56	0.19	3.25		0.5	0.0	0.5	0.0	0.0
N_{14}	0.475	1.0	1.51	0.24	3.375		0.5	0.0	0.0	0.5	0.0
N_{15}	0.575	1.0	1.61	0.34	3.00		0.5	0.0	0.0	0.0	0.5
N_{23}	0.575	1.0	1.75	0.25	3.50		0.0	0.5	0.5	0.0	0.0
N_{24}	0.500	1.0	1.70	0.30	3.625		0.0	0.5	0.0	0.5	0.0
N_{25}	0.600	1.0	1.80	0.40	3.25		0.0	0.5	0.0	0.0	0.5
N_{34}	0.525	1.0	1.65	0.35	4.125		0.0	0.0	0.5	0.5	0.0
N_{35}	0.625	1.0	1.75	0.45	3.75		0.0	0.0	0.5	0.0	0.5
N_{45}	0.55	1.0	1.70	0.50	3.875		0.0	0.0	0.0	0.5	0.5
CONTROL											
C_1	0.546	0.993	1.828	0.192	3.143		0.333	0.333	0.333	0	0
C_2	0.513	0.993	1.562	0.258	3.556		0.333	0.00	0.333	0.333	0
C_3	0.530	0.993	1.595	0.357	3.391		0.333	0.00	0	0.333	0.333
C_4	0.525	1.0	1.630	0.245	3.438		0.25	0.25	0.25	0.25	0.00
C_5	0.550	1.0	1.630	0.345	3.563		0.25	0.00	0.25	0.25	0.25
C_6	0.575	1.0	1.680	0.295	3.250		0.25	0.25	0.25	0.00	0.25
C_7	0.0538	1.0	1.585	0.165	3.000		0.50	0.25	0.25	0.00	0.00
C_8	0.600	1.0	1.680	0.395	3.375		0.25	0.00	0.25	0.00	0.50
C_9	0.520	1.0	1.588	0.212	3.250		0.40	0.20	0.20	0.20	0.00
C_{10}	0.550	1.0	1.664	0.316	3.450		0.20	0.20	0.20	0.20	0.20
C_{11}	0.545	1.0	1.626	0.304	3.400		0.30	0.10	0.20	0.20	0.20
C_{12}	0.545	1.0	1.682	0.348	3.625		0.10	0.20	0.20	0.30	0.20
C_{13}	0.570	1.0	1.642	0.283	3.200		0.35	0.15	0.25	0.00	0.25
C_{14}	0.545	1.0	1.650	0.305	3.375		0.25	0.20	0.15	0.20	0.20

C_{15}	0.538	1.0	1.589	0.306	3.175		0.45	0.05	0.00	0.20	0.30

3.2 COMPRESSIVE STRENGTH TEST

Compressive strength tests were carried out in order to determine the responses needed to formulate and validate the optimization function. The river sand- termite soil concrete specimen, were concrete cubes measuring 150 x 150x 150 mm in size. A total of ninety cubes were produced from the thirty mix ratios given in T able 3, three cubes from each mix. The first set of 45 cubes made from first set of fifteen mix ratios, were used in formulating the final optimization functions, while the second set of 45 cubes from the second set of fifteen mix ratios, were used as control test for validating the optimization functions .The concrete cubes were cured in water for 28 days, and tested in compression thereafter. The compression load at failure were recorded and used in Eqn(24) to determine the compressive strength of the river sand-termite soil concrete and presented in Table 4:

$$\text{Compressive strength} = \frac{compressive\ load\ of\ cube\ at\ failure\ (N)}{cross\ sectional\ area\ of\ mould\ (mm^2)} \qquad (24)$$

III. RESULTS AND ANALYSIS

The results of compressive strength obtained from both in experiment and the optimization function's are given in Table 4

Table 4: Compressive strength (N/mm^2) of the 28 day old concrete cubes

Points	**Compressive Strength (N/mm^2)**			**Mean Experiment compressive strength (N/mm^2)**	**Predicted Compressive Strength of Concrete cubes (N/mm^2)**
	Replicate 1	**Replicate 2**	**Replicate 3**		
N_1	25.77	26.22	20.44	24.14	24.14
N_2	24.44	21.33	27.11	24.29	24.29
N_3	24.89	26.67	27.78	26.45	26.45
N_4	24.22	23.33	23.11	23.55	23.55
N_5	25.11	22.22	23.56	23.63	23.63
N_{12}	24.89	25.33	23.56	24.59	24.59
N_{13}	22.67	24.89	23.56	23.71	23.71
N_{14}	22.22	23.56	25.33	23.70	23.70
N_{15}	24.00	24.00	22.67	23.56	23.56
N_{23}	29.11	30.22	31.11	30.15	30.15
N_{24}	21.78	19.11	19.11	20.00	20.00
N_{25}	20.89	18.22	18.67	18.96	18.96
N_{34}	16.89	17.33	17.33	17.19	17.19
N_{35}	16.89	17.11	16.89	16.96	16.96
N_{45}	11.56	11.11	11.11	11.26	11.26
C_1	25.40	25.20	25.30	25.30	26.55
C_2	19.78	19.56	19.64	19.66	20.47
C_3	18.98	19.00	19.08	19.02	18.09
C_4	21.83	22.12	22.20	22.05	22.53
C_5	21.78	20.00	20.89	20.89	16.87
C_6	22.91	22.53	22.78	22.74	22.17
C_7	23.78	25.11	24.22	24.37	25.35
C_8	20.44	20.02	20.44	20.30	19.86
C_9	22.54	22.33	22.69	22.52	22.97
C_{10}	18.24	18.25	18.59	18.36	18.97
C_{11}	19.98	20.07	20.07	20.04	19.10
C_{12}	17.33	18.67	17.33	17.78	17.11
C_{13}	22.35	22.35	22.20	22.30	21.97
C_{14}	18.63	18.67	18.62	18.64	19.31

C_{15}	21.00	21.04	21.20	21.08	20.27

4.1 OPTIMIZATION FUNCTION FOR PREDICTING THE COMPRESSIVE STRENGTH OF THE CONCRETE

The final optimization function is obtained by substituting compressive strength of concrete cubes from the first fifteen points of observations (N_1, N_2, N_3, N_4, N_5, N_6, N_7, N_8, N_9, N_{10}, N_{11}, N_{12}, N_{13}, N_{14}, and N_{15}) into Eqn (21) to obtain:

$$Y = 24.14(2X_1 - 1)X_1 + 24.29(2X_2 - 1)X_2 + 26.45(2X_3 - 1)X_3 + 23.55(2X_4 - 1)X_4 + 23.63(2X_5 - 1)X_5 + 98.36X_1 X_2 + 94.84X_1 X_3 + 94.80X_1 X_4 + 94.24X_1 X_5 + 120.60X_2 X_3 + 80.00X_2 X_4 + 75.84X_2 X_5 + 68.76X_3 X_4 + 67.84X_3 X_5 + 45.04X_4 X_5$$

The Eqn (25) is the final function for the optimization of compressive strength of river sand-termite soil concrete.

TEST OF ADEQUACY OF THE MODEL

The test for adequacy of the optimization function, obtained from the (5,2) simplex design, was done using statistical student's t-test at 95% accuracy level. The compressive strength at the control points

(i.e. C_1, C_2, C_3, C_4, C_5, C_6, C_7, C_8, C_9, C_{10}, C_{11}, C_{12}, C_{13}, C_{14}, C_{15}). Two hypotheses were considered in the test namely:

a) **Null Hypothesis**: At 95% accuracy level, that there is no significant difference between the laboratory concrete cube strength and the cube strength results obtained from the optimization function.
b) **Alternative Hypothesis:** At 95% accuracy level, there is a significant difference between the laboratory concrete cube strength and concrete cube strength obtained from the optimization model.

The test is carried out as shown in Table 6

Table 6: Statistical Student's t-test for (5,2) simplex design

		TWO-TAILED t-TEST			
Point	**Y_E**	**Y_M**	**$D_i = Y_E - Y_M$**	**$D_A - D_i$**	**$(D_A - D_i)^2$**
C_1	25.30	26.55	-1.25	1.4627	2.1395
C_2	19.66	20.47	-0.81	1.0227	1.0459
C_3	19.02	18.09	0.93	-0.7173	0.5145
C_4	22.05	22.53	-0.48	0.6927	0.4798
C_5	20.89	16.87	4.02	-3.8073	14.4955
C_6	24.74	22.17	0.30	-0.0873	0.0076
C_7	24.37	25.35	-0.98	1.1927	1.4225
C_8	20.30	19.86	0.44	-0.2273	0.0517
C_9	22.52	22.97	-0.45	0.6627	0.4392
C_{10}	18.36	18.97	-0.61	0.8227	0.6768
C_{11}	20.04	19.10	0.94	-0.7273	0.5290
C_{12}	17.78	17.11	0.67	-0.4573	0.2091
C_{13}	22.30	21.97	0.33	-0.1173	0.0138
C_{14}	18.64	19.31	-0.67	0.8827	0.7792
C_{15}	21.08	20.27	0.81	-0.5973	0.568
		$\sum D_i =$	3.19	$\sum(D_A - D_i)^2 =$	23.1567

Legend: Y_E is the experiment compressive strength and Y_M is the Model compressive strength

Let:

$D_i =$ The difference of Compressive strength obtained from Experiment, Y_E and the one optimization function, Y_M

$D_A =$ The mean of $D_i = \frac{\sum D_i}{N}$

The variance of the square of difference of D_A and D_i, $S^2 = \frac{\sum(D_A - D_i)^2}{N-1} =$

$N =$ Number of observation points

The standard deviation of the difference of D_A and D_i, $S = \sqrt{S} =$

Therefore,

$$D_i = \frac{\sum D_i}{N} = \frac{3.19}{15} = 0.2127$$

$$S^2 = \frac{\sum(D_A - D_i)^2}{N-1} = \frac{23.1567}{14} = 1.65405$$

$$S = \sqrt{S} = \sqrt{1.65405} = 1.2861$$

Actual value of total variation in t-test

For the two-tailed test, the actual value of t is:

$$t_{calculated} = \frac{D_A N^{0.5}}{S} = \frac{0.2127(15)^{0.5}}{1.2861} = 0.6405$$

Allowable value of total variation in t-test:

Degree of freedom = N-1 = 15-1 = 14

At 5 % significance level, for the two-tailed Test = 2.5 %

100 - 2.5% = 97.5% = 0.975

Allowable total variation in t-test, i.e. $t_{table} = t_{(0.975,14)}$ = 2.14 (Obtained from standard statistical table).

From table 5, the calculated t = 0.6405 which is less than t-value of 2.14 from standard statistical table.

Thus, $t_{table} > t_{calculated}$

This implied that difference between the two set of cubes compressive strength is insignificant. Hence the null hypothesis is accepted and alternative hypothesis rejected. Therefore, the optimization function for prediction of compressive strength of river sand-termite soil concrete is adequate.

IV. CONCLUSION

Using simplex design polynomial equation, mix design function for a five component river sand- termite soil concrete cube, was developed. This optimizing function could predict the compressive strength of concrete cube when the mix ratios are known and vice versa. The predictions from this model were tested at 95% accuracy level using statistical student's t-test and found to be adequate. The maximum strength predicted by this model is 30.15 N/mm^2. This strength is from a mix ratio 0.575:1:1.75:0.25:3.5 (corresponding to the water: cement: river sand: termite soil: granite).

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