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Prediction Of Flexural Strength Of Ternary Blended Snail Shell Ash – Palm Bunch Ash Concrete Beams Using Scheffe's Simplex Method

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ABSTRACT

This study focused on the Development of mathematical model for the prediction of flexural strength of ternary blended Snail Shell Ash – Palm Bunch Ash Concrete beams using Scheffe's simplex method. A total of one hundred and twenty six (126) beams were cast, consisting of three beams per mix ratio and for a total of forty two (42) mix ratio. The first twenty one (21) mixes were used to develop the model, while the other twenty one were used to validate the model. The computer program was written for Scheffe's model, using VISUAL BASIC 6.0. The written program was used to predict the flexural strength for a given mix ratio and vice-versa. The mathematical model results compared favourably with the experimental data. The model predictions was tested for adequacy at 95% confidence level using statistical t – Test and was found adequate. The optimum flexural strength of the blended concrete at twenty eight (28) days was found to be 6.129N/mm2 and the corresponding mix ratio is as follows: Water = 0.565, Cement = 0.865, Snail Shell Ash= 0.075, Palm Bunch Ash = 0.06, Sand = 1.87, Granite = 3.62. The study proved that Snail Shell Ash – Palm Bunch Ash can be used effectively as pozzolanic cementitious materials in concrete.

Keywords:- Blended Cement, Flexural Strength, Concrete, Snail Shell Ash, Palm Bunch Ash, Mathematical Model, Scheffe's Model.

I. INTRODUCTION

Construction works and Civil Engineering practice today depend, to a very large extent, on concrete as major construction material. The basic constituents of concrete are cement, fine aggregate (sand), coarse aggregate and water. The versatility, strength and durability of cement are of utmost priority over other construction materials. The cost of concrete production is relatively high due to the manufacture of its main constituent Ordinary Portland Cement (Waithaka, 2014).

Many researchers in material science and engineering, in recent time, are committed to utilizing agricultural or industrial wastes to either partially or fully replace conventional materials of concrete. The incorporation of agricultural by-product pozzolans has been studied with positive results in the manufacture and application of blended cements (Malhotra and Mehta, 2004).

Recent investigation on the use of palm bunch ash (Ettu *et al*., 2013) and snail shell ash (Zaid and Ghorpade, 2014) have shown that they are good supplementary cementitious materials as they are amorphous in nature and has good pozzolanic properties.

The use of these materials as cement supplements is much more important in developing countries to augment the shortage of construction materials as well as in the development of low-cost construction materials that will be environmental friendly.(Singh *et al*., 2007; Umoh and Olusola, 2012).

Intensified local economic ventures in many Nigerian communities have led to increased agricultural and plant wastes such as snail shell and oil palm bunch. Snail Shell is a waste product which is obtained from the consumption of a small greenish-blue marine snail, which rests in a V shaped spiral shell, found in many coastal regions. These shells are a very strong, hard and brittle material. These snails are found in the lagoons and mudflats of the coastal areas and large deposits have accumulated in many places over the years. Also large quantities of oil palm bunch are generated in local palm oil mills scattered in various communities all over South Eastern Nigeria. Their utilization as pozzolanic material would both reduce the problem of solid waste management (Elinwa and Ejeh, 2004) and add commercial value to the otherwise waste product.

It is with this view that this experimental study seeks to investigate into the suitability of snail shell ash and palm bunch as Partial Replacement for Ordinary Portland Cement in Concrete and also to develop a mathematical model that will ease the prediction of flexural strength from the mix ratio of the blended cement and vice versa.

II. MATERIALS

Cement

The cement used in this research work was Dangote brand of ordinary Portland cement. It conforms to the requirements of BS 12:1978. It was obtained from Dangote cement depot along FUTO – Obinze road, Owerri, Imo State and stored in dry place prior to usage.

Aggregate

The aggregates used in this work were of two sets:

i. **Fine aggregate**

The fine aggregates used in the investigation are of locally available and was obtained from a flowing river (Otamiri River) but was purchased at the aggregate market km 1, Aba road Owerri, Imo State. It was washed and sun dried for seven days in the laboratory and free from organic matter before usage. The river-bed sand passing 4.75mm sieve was used.

Coarse Aggregates

The coarse aggregates used for this research work are of angular shape crushed granite aggregate and are confined to 20 mm size with specific gravity of 2.65. They were obtained from the Abakaliki Quarry Site, but purchased at the aggregate market km1, Aba Road Owerri, Imo State. They were washed and sun dried for seven days in the laboratory to ensure that they were free from excessive dust, and organic matter.

Water

Water used for this research work was obtained from a borehole within the premises of Federal University of Technology Owerri, Imo State.

Snail shell ash

To carry out the experimental study, the Snail Shells were collected from local markets in Owerri district of Imo State, Nigeria. All the shells were washed and sun dried in the laboratory for two weeks and made free from any organic and inorganic matter. The shells were calcined in a furnace and stopped as soon as the temperature reaches 800◦C. Then, the ash was ground to fine powder and sieved with 150µm size. This powder is thus called as Snail Shell Ash (SSA)

Palm bunch ash

Oil palm bunch was obtained from palm-oil milling factories in Owerri district of Imo State, Nigeria, crushed into smaller particles, air-dried, and calcined into ashes in a locally fabricated combustion chamber at temperatures generally below 650ºC. The yield of ash on combustion was found out to be about 30%. The total quantity of palm bunch ash needed for the research was about 40kg. Therefore, 200kg of palm bunch was burnt in the combustion chamber to produce a total of about 60 kg of palm bunch ash and the extra amount was used to account for losses in the course of the experiment.

The temperature of operation of the kiln ranged between 300˚C and 600˚CThe ash was sieved and large particles retained on the 150µm sieve were discarded while those passing the sieve were used for this work. No grinding or any special treatment to improve the ash quality and enhance its pozzolanicity was applied

III. METHODS MODELLING AND OPTIMIZATION

The use of simplex design and the regression in the formulation of concrete design models will be considered in details in this work. In this research, however, the Scheffe's method of optimization will be used in the modeling and optimization.

IV. SCHEFFE'S OPTIMIZATION MODEL

In this work, Henry Scheffe's optimization method was used to develop models that will predict possible mix proportions of concrete components that will produce a desired compressive strength by the aid of a computer programme. Achieving a desired flexural strength of concrete is dependent to a large extent, on the adequate proportioning of the components of the concrete. In Scheffe's work, the desired property of the various mix ratios, depended on the proportion of the components present, and but not on the quality of mixture.

Therefore, if a mixture has a total of q components/ ingredients of the i^{th} component of the mixture,

$$X_i \geq 0 \; (i = 1, 2, 3, .., q) \qquad (3.1a)$$

Where Xi = … for the ith component of the mixture and assuming the mixture to be a unit quantity, then the sum of all proportions of the component must be unity. That is,

$$X_1 + X_2 + X_3 + \cdots + X_{q-1} + X_q = 1 \qquad (3.1b)$$

This implies that

$$\sum_{i=1}^{q} X_i = 1 \qquad (3.2)$$

Combining Eqn (3.1a) and (3.2), implies that:

$$0 =\leq X_i \leq 1 (3.3)$$

The factor space therefore is a regular (q –1) dimensional simplex.

V. SCHEFFE'S SIMPLEX LATTICE

A factor space is a one-dimensional (a line), a two-dimensional (a plane), a three – dimensional (a tetrahedron) or any other imaginary space where mixture component interact. The boundary within which the mixture components interact is defined by the space.

Scheffe (1958) stated that (q–1) space would be used to define the boundary where q components are interacting in a mixture. In other words, a mixture comprising of q components can be analyzed using a (q –1) space

Interaction of Components in Scheffe's Factor Space

The components of a mixture are always interacting with each other within the factor space. Three regions exist in the factor space. These regions are the vertices, borderlines, inside body space. Pure components of the mixture exist at the vertices of the factor spaces. The border line can be a line for one-dimensional or two – dimensional factor space. It can also be both lines and plane for a three – dimensional, four – dimensional, etc. factor spaces. Two components of a mixture exist at any point on the plane border, which depends on how many vertices that defined the plane border. All the component of a mixture exists right inside the body of the space.

Also, at any point in the factor space, the total quantity of the Pseudo components must be equal to one. A two – dimensional factor space will be used to clarify the interaction components. Fig 3.1: Shows seven points on the two – dimensional factor space.

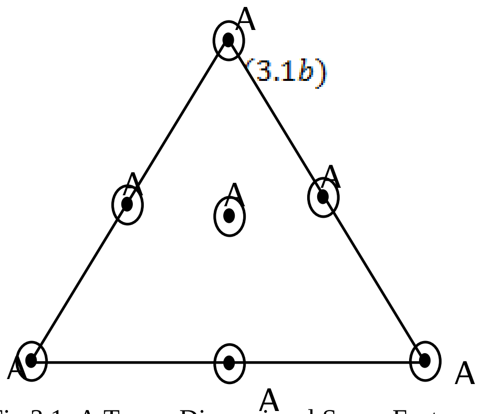

Fig 3.1: A Two – Dimensional Space Factor

The three points, A_1, A_2 and A_3 are on the vertices. Three points A_{12}, A_{13} and A_{23} are on the border of space. One remaining of A_{123} is right inside the body of the space.

A_1, A_2 and A_3 are called principal co-ordinates, only one pure component exists at any of these principal coordinates, and the total quantity of the Pseudo components of these coordinates is equal to one. The other components outside these coordinates are all zero. For instance, at coordinate A_1, only A1 exists and the quantity of its Pseudo component is equal to one. The other components are equal to zero.

A_{12}, A_{13} and A_{23} are point or coordinates where binary mixtures occur at these points only two components exist and the rest do not. For instance, at point A_{12}, components of A_1 and A_2 exists. The total quantity of Pseudo components of A_1 and A_2 at that point, is equal to one, while component A_3 is equal to zero at that point.

If A_{12} is midway, then the component of A_1 is equal to half and that of A_2 is equal to half, while A_3 is equal to zero at that point. At any point inside the space, all the three components A_1, A_2 and A_3 exist. The total quantity of the Pseudo component is still equal to one. Consequently, if a point A_{123} is exactly at the centroid of the space, the Pseudo component of A_1 is equal to those of A_2, and A_2 and is equal to one – third ($^1/_3$).

VII. SIX COMPONENTS FACTOR SPACE

This research work deals with a six component concrete mixture. The components that form the concrete mixture are water/cement (w/c) ratio, cement, sawdust ash, palm bunch ash, river sand and granite. The number of components q is equal to six which is equal to five – dimensional factor space. A five-dimensional factor space is an imaginary dimension space.

The imaginary space used is shown in Fig. 3.2.

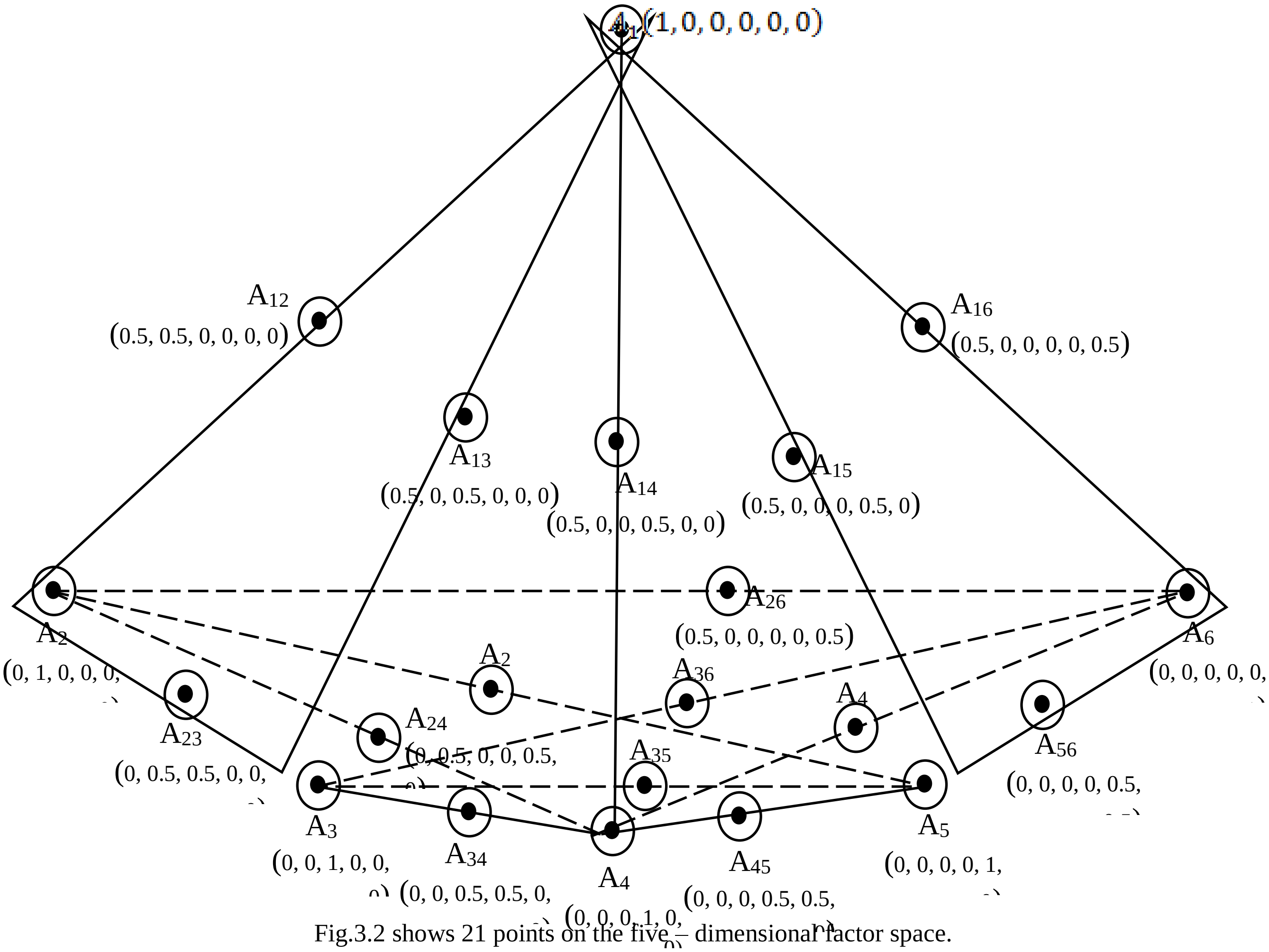

Fig.3.2 shows 21 points on the five – dimensional factor space.

VIII. MIX RATIOS

In Scheffe's mixture design, the Pseudo components have relationship with the actual component. This means that the actual component can be derived from the Pseudo components and vice versa. According to Scheffe, Pseudo components were designated as X and the actual components were designated as S. Hence the relationship between X and S as expressed by Scheffe is given in Eqn (3.4).

$$S = A * X \tag{3.4}$$

where A is the Matrix connecting the relationship and the Eqn (3.4)

The six components are Water, Cement, Snail shell ash, Palm bunch ash, Sand and Granite.

Let $\mathbf{S_1}$ = Water; $\mathbf{S_2}$ = Cement; $\mathbf{S_3}$ = Snail shell ash; $\mathbf{S_4}$ = Palm bunch ash; $\mathbf{S_5}$ = Sand and $\mathbf{S_6}$ = Granite.

The Six mixed ratios (real and pseudo) that defined the vertices of the hexahedron simplex lattice used in this study are shown in Table 3.2.

Table 3.2 First Six Mix Ratios (Actual and Pseudo) Obtained From Scheffe's (6,2) factor space.

N	S_1	S_2	S_3	S_4	S_5	S_6	Response	X_1	X_2	X_3	X_4	X_5	X_6
1	0.50	0.90	0.05	0.05	2.0	4.0	Y_1	1	0	0	0	0	0
2	0.60	0.85	0.10	0.05	1.8	3.6	Y_2	0	1	0	0	0	0
3	0.55	0.80	0.10	0.10	2.2	4.2	Y_3	0	0	1	0	0	0
4	0.45	0.85	0.05	0.10	2.0	3.2	Y_4	0	0	0	1	0	0
5	0.65	0.95	`0.0	0.05	1.5	2.8	Y_5	0	0	0	0	1	0
6	0.55	0.80	0.15	0.50	1.8	4.0	Y_6	0	0	0	0	0	1

Where: **N** = any point on the factor space

Y = response

The six actual and pseudo mix ratios in table 1 correspond to points of observations, located at the six vertices of the hexahedron. For a (6, 2) simplex design, fifteen (15) other observations are needed to add up to the first six to get a total of twenty one (21) observations. This was used to formulate the model. The remaining fifteen (15)points were located at the midpoints of the lines joining the six vertices. On substitution of these pseudo mix ratios one after the other into equation (1.3), the real mix ratios corresponding to the pseudo values were obtained.

Expanding Eqn (3.4) gives Eqn (3.5).

$$\begin{bmatrix} S_1 \\ S_2 \\ S_3 \\ S_4 \\ S_5 \\ S_6 \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} a_{14} & a_{15} & a_{16} \\ a_{21} & a_{22} & a_{23} a_{24} & a_{25} & a_{26} \\ a_{31} & a_{32} & a_{33} a_{34} & a_{35} & a_{36} \\ a_{41} & a_{42} & a_{43} a_{44} & a_{45} & a_{46} \\ a_{51} & a_{52} & a_{53} a_{54} & a_{55} & a_{56} \\ a_{61} & a_{62} & a_{63} a_{64} & a_{65} & a_{66} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \\ X_6 \end{bmatrix} \tag{3.5}$$

Assembling the coefficients of matrix A, gives:

$$[A\ ] = \begin{bmatrix} 0.50 & 0.60 & 0.550.45 & 0.65 & 0.55 \\ 0.90 & 0.85 & 0.800.85 & 0.95 & 0.80 \\ 0.05 & 0.10 & 0.100.05 & 0.00 & 0.15 \\ 0.05 & 0.05 & 0.100.10 & 0.05 & 0.05 \\ 2.00 & 1.80 & 2.202.00 & 1.50 & 2.00 \\ 4.00 & 3.60 & 4.203.20 & 2.80 & 4.00 \end{bmatrix} \tag{3.6}$$

According to Scheffe's simplex lattice, the mix ratios when shown in an imaginary space will give 21 points on the five – dimensional factor spaces. The actual components of the binary mixture (as represented by points N = 12 to N = 56), are determined by multiplying matrix [A] with values of matrix [X]. That is to say:

[S] = [A] * [X] (3.7)

The pseudo components and their corresponding actual components at different points on the factor space are shown in the table below:

Table 3.3 Actual and Pseudo components of the Actual Mixes

S/N	Values of Actual Components							Values of Pseudo Components					
	S_1	S_2	S_3	S_4	S_5	S_6	Response	X_1	X_2	X_3	X_4	X_5	X_6
1	0.50	0.90	0.05	0.05	2	4	Y_1	1	0	0	0	0	0
2	0.60	0.85	0.10	0.05	1.8	3.6	Y_2	0	1	0	0	0	0
3	0.55	0.80	0.10	0.10	2.2	4.2	Y_3	0	0	1	0	0	0
4	0.45	0.85	0.05	0.10	2.0	3.2	Y_4	0	0	0	1	0	0
5	0.65	0.95	0.00	0.05	1.5	2.8	Y_5	0	0	0	0	1	0
6	0.55	0.80	0.15	0.05	1.8	4.0	Y_6	0	0	0	0	0	1
12	0.55	0.875	0.075	0.05	1.90	3.80	Y_{12}	0.5	0.5	0	0	0	0
13	0.525	0.850	0.075	0.075	2.10	4.10	Y_{13}	0.5	0	0.5	0	0	0
14	0.475	0.875	0.05	0.075	2.00	3.60	Y_{14}	0.5	0	0	0.5	0	0
15	0.575	0.925	0.025	0.05	1.75	3.40	Y_{15}	0.5	0	0	0	0.5	0
16	0.525	0.85	0.10	0.05	1.90	4.00	Y_{16}	0.5	0	0	0	0	0.5
23	0.575	0.825	0.10	0.075	2.00	3.90	Y_{23}	0	0.5	0.5	0	0	0
24	0.525	0.85	0.075	0.075	1.90	3.40	Y_{24}	0	0.5	0	0.5	0	0
25	0.625	0.90	0.05	0.05	1.65	3.20	Y_{25}	0	0.5	0	0	0.5	0
26	0.575	0.850	0.125	0.05	1.80	3.80	Y_{26}	0	0.5	0	0	0	0.5
34	0.50	0.825	0.075	0.100	2.10	3.70	Y_{34}	0	0	0.5	0.5	0	0
35	0.60	0.875	0.05	0.075	1.85	3.50	Y_{35}	0	0	0.5	0	0.5	0
36	0.55	0.800	0.125	0.075	2.00	4.10	Y_{36}	0	0	0.5	0	0	0.5
45	0.55	0.900	0.025	0.075	1.75	3.00	Y_{45}	0	0	0	0.5	0.5	0
46	0.50	0.825	0.100	0.075	1.90	3.60	Y_{46}	0	0	0	0.5	0	0.5
56	0.60	0.875	0.075	0.05	1.65	3.40	Y_{56}	0	0	0	0	0.5	0.5

In order to validate the model, extra 21(twenty one) points (C1, C2, C3, C4, C5, C6, C12, C13, C14, C15, C16, C23, C24, C25, C26, C34, C35, C36, C45, C46 and C56) of observations were used. These observations served as control mix.

Table 3.4: Values of Actual and Pseudo components for control mixes

	Values of Actual Components							Values of Pseudo Components					
Control points	S_1	S_2	S_3	S_4	S_5	S_6		X_1	X_2	X_3	X_4	X_5	X_6
C_1	0.525	0.85	0.075	0.075	2.00	3.75	YC_1	0.25	0.25	0.25	0.25	0.00	0.00
C_2	0.538	0.875	0.05	0.075	1.925	3.55	YC_2	0.25	0.00	0.25	0.25	0.25	0.00
C_3	0.538	0.875	0.063	0.063	1.825	3.5	YC_3	0.25	0.00	0.00	0.25	0.25	0.25
C_4	0.55	0.85	0.083	0.067	2.00	3.933	YC_4	0.333	0.333	0.333	0.001	0.000	0.000
C_5	0.5	0.85	0.067	0.083	2.067	3.8	YC_5	0.333	0.001	0.333	0.333	0.00	0.00
C_6	0.567	0.883	0.067	0.05	1.767	3.601	YC_6	0.333	0.00	0.001	0.00	0.333	0.333
C_{12}	0.55	0.87	0.06	0.07	1.9	3.56	YC_{12}	0.20	0.20	0.20	0.20	0.20	0.00
C_{13}	0.56	0.85	0.08	0.07	1.86	3.56	YC_{13}	0.00	0.20	0.20	0.20	0.20	0.20

C_{14}	0.54	0.86	0.07	0.07	1.9	3.64	YC_{14}	0.20	0.00	0.20	0.20	0.20	0.20
C_{15}	0.575	0.855	0.085	0.06	1.81	3.68	YC_{15}	0.10	0.00	0.20	0.00	0.30	0.40
C_{16}	0.52	0.86	0.07	0.07	2.00	3.8	YC_{16}	0.40	0.20	0.20	0.20	0.00	0.00
C_{23}	0.575	0.88	0.065	0.055	1.84	3.62	YC_{23}	0.30	0.40	0.10	0.00	0.20	0.00
C_{24}	0.52	0.83	0.09	0.08	2.04	3.92	YC_{24}	0.20	0.00	0.40	0.20	0.00	0.20
C_{25}	0.505	0.86	0.07	0.07	1.94	3.6	YC_{25}	0.30	0.20	0.00	0.40	0.00	0.10
C_{26}	0.58	0.9	0.035	0.065	1.79	3.36	YC_{26}	0.20	0.00	0.20	0.10	0.50	0.00
C_{34}	0.52	0.86	0.075	0.065	1.92	3.64	YC_{34}	0.30	0.30	0.00	0.30	0.00	0.10
C_{35}	0.548	0.84	0.093	0.068	1.96	3.95	YC_{35}	0.25	0.00	0.35	0.00	0.10	0.30
C_{36}	0.54	0.828	0.098	0.075	1.95	3.73	YC_{36}	0.00	0.30	0.25	0.25	0.00	0.20
C_{45}	0.52	0.868	0.075	0.058	1.93	3.8	YC_{45}	0.50	0.20	0.00	0.15	0.00	0.15
C_{46}	0.54	0.855	0.075	0.07	2.01	3.96	YC_{46}	0.40	0.00	0.30	0.00	0.10	0.10
C_{56}	0.535	0.875	0.05	0.075	1.85	3.34	YC_{56}	0.10	0.00	0.10	0.40	0.30	0.10

IX. RESULTS

FLEXURAL STRENGTH TEST ON SNAIL SHELL ASH - PALM BUNCH ASH CONCRETE

This test was conducted on concrete beams to determine the flexural strength of each replicate beam after 28days of curing. Having known the load at rupture **P**, the distance between support **L**, the beam breadth **b** and the depth of beam **d**, for all beam specimen, the flexural strength **F**, of each replicate beam was calculated using Enq (4.1) and the mean flexural strength was calculated using equation (4.2).

$$F = \frac{3PL}{2bd^2} \qquad (4.1)$$

$$\textbf{Flexural Strength, F} = \frac{\begin{matrix}\textit{Flexural strength}\\ \textit{of replicate 1}\end{matrix} + \begin{matrix}\textit{Flexural strength}\\ \textit{of replicate 2}\end{matrix} + \begin{matrix}\textit{Flexural strength}\\ \textit{of replicate 3}\end{matrix}}{3} \qquad (4.2)$$

The load at rupture for each beam (150 X 150 X 500) was obtained by the application of pressure from the universal testing machine. The Flexural Strength Test Results of 28th Day of Concrete Beams for Actual and Control are shown in table 4.1.

Table 4.1 Flexural Strength Test Results of 28th Day of Concrete Beams for Actual and Control

S/N	Point of Observation	Flexural strength of Replication 1 (N/mm^2)	Flexural strength of Replication 2 (N/mm^2)	Flexural strength of Replication 3 (N/mm^2)	Mean Flexural Strength (N/mm^2)
1	A_1	4.507	4.760	5.720	4.996
2	A_2	3.947	4.813	4.960	4.573
3	A_3	4.453	4.027	5.133	4.538
4	A_4	6.240	5.893	6.253	6.129
5	A_5	4.187	3.200	4.480	3.956
6	A_6	5.389	5.333	4.533	5.085
7	A_{12}	4.480	5.467	5.120	5.022
8	A_{13}	4.870	4.880	5.227	4.992
9	A_{14}	5.360	3.813	5.907	5.027

10	A_{15}	3.867	3.813	5.040	4.240
11	A_{16}	5.040	5.970	4.427	5.146
12	A_{23}	6.667	6.633	5.053	6.118
13	A_{24}	5.867	5.367	5.413	5.549
14	A_{25}	4.373	4.600	4.213	4.395
15	A_{26}	5.800	6.187	6.027	6.005
16	A_{34}	4.933	5.627	3.427	4.662
17	A_{35}	6.227	4.867	5.613	5.569
18	A_{36}	4.667	5.133	5.067	4.956
19	A_{45}	6.213	6.345	4.160	5.573
20	A_{46}	5.827	6.533	3.427	5.262
21	A_{56}	5.227	8.000	6.440	6.556
22	**C_1**	**6.480**	**6.587**	**6.080**	**6.382**
23	C_2	5.040	5.800	5.533	5.458
24	C_3	6.027	6.080	4.650	5.586
25	C_4	4.293	4.813	6.000	5.035
26	C_5	5.493	6.027	4.080	5.200
27	C_6	4.307	4.467	4.773	4.516
28	C_{12}	4.035	6.000	4.267	4.767
29	C_{13}	5.400	4.867	4.880	5.049
30	C_{14}	6.067	5.093	5.333	5.498
31	C_{15}	7.573	5.840	6.133	6.515
32	C_{16}	6.480	5.867	6.493	6.280
33	C_{23}	6.307	5.467	5.544	5.773
34	C_{24}	5.240	4.893	5.680	5.271
35	C_{25}	6.600	6.634	6.453	6.562
36	C_{26}	4.133	4.747	5.960	4.947
37	C_{34}	5.160	5.440	5.413	5.338
38	C_{35}	4.347	5.133	4.867	4.782
39	C_{36}	4.040	4.667	7.333	5.347
40	C_{45}	6.267	7.467	5.333	6.356
41	C_{46}	6.400	8.467	8.693	7.853
42	C_{56}	5.693	6.307	7.200	6.400

FORMULATION OF THE MODELS FOR OPTIMIZATION OF FLEXURAL STRENGTH OF SNAIL SHELL ASH PALM BUNCH ASH - CONCRETE.

The flexural strength (i.e. the responses) developed at the 28th day (concrete age of 28 days) at each observation point is affected by mix proportion at that point. This response obtained from the experimental investigation was used to formulate Scheffe's Simplex Model. This Model was used to develop a computer program for optimization of flexural Strength of Snail Shell Ash Palm Bunch Ash Concrete.

$$\begin{aligned} Y = {} & X_1(2X_1-1)y_1 + X_2(2X_2-1)y_2 + X_3(2X_3-1)y_3 + X_4(2X_4-1)y_4 + X_5(2X_5-1)y_5 \\ & + X_6(2X_6-1)y_6 + 4y_{12}X_1X_2 + 4y_{13}X_1X_3 + 4y_{14}X_1X_4 + 4y_{15}X_1X_5 \\ & + 4y_{16}X_1X_6 + 4y_{23}X_2X_3 + 4y_{24}X_2X_4 + 4y_{25}X_2X_5 + 4y_{26}X_2X_6 \\ & + 4y_{34}X_3X_4 + 4y_{35}X_3X_5 + 4y_{36}X_3X_6 + 4y_{45}X_4X_5 + 4y_{46}X_4X_6 + 4y_{56}X_5X_6 \\ & + e \qquad (4.3) \end{aligned}$$

Eqn (3.8) is the mixture design model for the optimization of a concrete mixture consisting of six components. The term, y_i and y_{ij} represent compressive strength at the point *i* and *ij*. These responses are determined by carrying out laboratory tests.

FORMULATION OF SCHEFFE'S RESPONSE FUNCTION AND DETERMINATION OF FLEXURAL STRENGTHS FROM THE SCHEFFE'S SIMPLEX MODEL

The Scheffe's response function for optimization of flexural Strength of Snail Shell Ash Palm Bunch Ash concrete was formulated by substituting the values of the flexural strength results y_i, from Table 4.1 into Scheffe's model given equation (4.3).

Substituting these values gives Eqn (4.4)

$$\begin{aligned} Y = {} & 4.996X_1(2X_1-1) + 4.573X_2(2X_2-1) + 4.538X_3(2X_3-1) + 6.129X_4(2X_4-1) \\ & + 3.956X_5(2X_5-1) + 5.085X_6(2X_6-1) + 20.088\,X_1\,X_2 + 19.968\,X_1\,X_3 \\ & + 20.108\,X_1\,X_4 + 16.96X_1\,X_5 + 20.584\,X_1\,X_6 + 24.472\,X_2\,X_3 + 22.196\,X_2\,X_4 \\ & + 17.58X_2\,X_5 + 24.02X_2\,X_6 + 18.648X_3\,X_4 + 22.276X_3\,X_5 + 19.824X_3\,X_6 \\ & + 22.292X_4\,X_5 + 21.048X_4\,X_6 + 26.224X_5\,X_6 \end{aligned} \tag{4.4}$$

Equation (4.4) is the Scheffe's response function for optimization of flexural Strength of Snail Shell Ash - Palm Bunch Ash - concrete. The flexural strengths from the Scheffe's response function were calculated using equation (4.4).

The experimental result values and that obtained from Scheffe's response function are as shown in Table 4.2.

Table 4.2: Results of Flexural Strength Test of that obtained from Scheffe's Response Function

Response Function			
S/No	Point of observation	Flexural strength test result (N/mm^2)	Scheffe's model flexural strength results (N/mm^2)
1	1	4.996	4.996
2	2	4.573	4.573
3	3	4.538	4.538
4	4	6.129	6.129
5	5	3.956	3.956
6	6	5.085	5.085
7	12	5.022	5.022
8	13	4.992	4.992
9	14	5.027	5.027
10	15	4.240	4.240
11	16	5.146	5.146
12	23	6.118	6.118
13	24	5.549	5.549
14	25	4.395	4.395
15	26	6.005	6.005

16	34	4.662	4.662
17	35	5.569	5.569
18	36	4.956	4.956
19	45	5.573	5.573
20	46	5.262	5.262
21	56	6.556	6.556
22	C_1	6.382	5.313
23	C_2	5.458	5.063
24	C_3	5.586	5.430
25	C_4	5.035	5.595
26	C_5	5.200	4.787
27	C_6	4.516	5.526
28	C_{12}	4.767	5.280
29	C_{13}	5.049	5.829
30	C_{14}	5.498	5.353
31	C_{15}	6.515	5.975
32	C_{16}	6.28	5.197
33	C_{23}	5.773	5.055
34	C_{24}	5.271	4.837
35	C_{25}	6.562	5.288
36	C_{26}	4.947	4.978
37	C_{34}	5.338	5.294
38	C_{35}	4.782	5.335
39	C_{36}	5.347	5.658
40	C_{45}	6.356	5.195
41	C_{46}	7.853	5.157
42	$\mathbf{C_{56}}$	6.400	5.500

4.3 COMPARISON OF FLEXURAL STRENGTH OF THE BEAMS OBTAINED FROM EXPERIMENT AND THAT PREDICTED FROM THE MODEL

Table 4.3 Comparison of the Experimental and Predicted Flexural Strength Results.

Observation point	Experimental Flexural Strength YE	Predicted Flexural Strength YM	Difference YE-YM	% Difference $\frac{YE-YM}{YE} * 100$
C1	6.382	5.313	1.069	16.75024
C2	5.458	5.063	0.395	7.237083
C3	5.586	5.43	0.156	2.792696
C4	5.035	5.595	-0.56	-11.1221
C5	5.2	4.787	0.413	7.942308
C6	4.516	5.526	-1.01	-22.3649
C7	4.767	5.28	-0.513	-10.7615
C8	5.049	5.829	-0.78	-15.4486

C9	5.498	5.353	0.145	2.637323
C10	6.515	5.975	0.54	8.288565
C11	6.28	5.197	1.083	17.24522
C12	5.773	5.055	0.718	12.43721
C13	5.271	4.837	0.434	8.233732
C15	6.562	5.288	1.274	19.41481
C16	4.947	4.978	-0.031	-0.62664
C17	5.338	5.294	0.044	0.824279
C18	4.782	5.335	-0.553	-11.5642
C20	5.347	5.658	-0.311	-5.81635
C21	6.356	5.195	1.161	18.26621

The result in table 4.3 shows that the maximum percentage difference of the experimental result and that of the model are very close.

DETERMINATION OF ERROR OF REPLICATES

Table 4.4a Results of Error of Replicates for Actual

Observation Points	Replicate Values Y_i	$\bar{Y}$	Y_i^2	ΣY_i	ΣY_i^2	$(\Sigma Y_i)^2$	S_i^2
A1	4.507 4.760 5.720	4.996	20.313 22.658 32.718	14.987	75.689	224.610	0.409
A 2	3.947 4.813 4.960	4.573	15.579 23.165 24.602	13.720	63.345	188.238	0.300
A 3	4.453 4.027 5.133	4.538	19.829 16.217 26.348	13.613	62.394	185.314	0.311
A 4	6.240 5.893 6.253	6.129	38.938 34.727 39.100	18.386	112.765	338.045	0.042
A 5	4.187 3.200 4.480	3.956	17.531 10.240 20.070	11.867	47.841	140.826	0.450
A 6	5.389 5.333 4.533	5.085	29.041 28.441 20.548	15.255	78.030	232.715	0.229
A 12	4.480 5.467 5.120	5.022	20.070 29.888 26.214	15.067	76.173	227.014	0.251

A 13	4.870 4.880 5.227	4.992	23.717 23.814 27.322	14.977	74.853	224.311	0.041
A 14	5.360 3.813 5.907	5.027	28.730 14.539 34.893	15.080	78.161	227.406	1.180
A 15	3.867 3.813 5.040	4.240	14.954 14.539 25.402	12.720	54.894	161.798	0.481
A 16	5.040 5.970 4.427	5.146	25.402 35.641 19.598	15.437	80.641	238.301	0.604
A 23	6.667 6.633 5.053	6.118	44.449 43.997 25.533	18.353	113.978	336.833	0.850
A 24	5.867 5.367 5.413	5.549	34.422 28.805 29.301	16.647	92.527	277.123	0.076
A 25	4.373 4.600 4.213	4.395	19.123 21.160 17.749	13.186	58.032	173.871	0.038
A 26	5.800 6.187 6.027	6.005	33.640 38.279 36.325	18.014	108.244	324.504	0.038
A 34	4.933 5.627 3.427	4.662	24.334 31.663 11.744	13.987	67.742	195.636	1.265
A 35	6.227 4.867 5.613	5.569	38.776 23.688 31.506	16.707	93.969	279.124	0.464
A 36	4.667 5.133 5.067	4.956	21.781 26.348 25.674	14.867	73.803	221.028	0.064
A 45	6.213 6.345 4.160	5.573	38.601 40.259 17.306	16.718	96.166	279.492	1.501
A 46	5.827 6.533 3.427	5.262	33.954 42.680 11.744	15.787	88.378	249.229	2.651
A 56	5.227 8.000 6.440	6.556	27.322 64.000 41.474	19.667	132.795	386.791	1.932
					$\sum S^2_i=$		
					Sy^2	13.177	13.177
					Sy	3.63	3.63

Table 4.4b: Results of Error of Replicates for Control

Observation Points	Replicate Values Y_i	$\bar{Y}$	Y_i^2	ΣY_i	ΣY_i^2	$(\Sigma Y_i)^2$	S_i^2
C1	6.480		41.990				
	6.587		43.389				
	6.080	6.382	36.966	19.147	122.345	366.608	0.071
C 2	5.040		25.402				
	5.800		33.640				
	5.533	5.458	30.614	16.373	89.656	268.075	0.149
C 3	6.027		36.325				
	6.080		36.966				
	4.650	5.586	21.623	16.757	94.914	280.797	0.657
C 4	4.293		18.430				
	4.813		23.165				
	6.000	5.035	36.000	15.106	77.595	228.191	0.766
C 5	5.493		30.173				
	6.027		36.325				
	4.080	5.200	16.646	15.600	83.144	243.360	1.012
C 6	4.307		18.550				
	4.467		19.954				
	4.773	4.516	22.782	13.547	61.286	183.521	0.056
C 12	4.035		16.281				
	6.000		36.000				
	4.267	4.767	18.207	14.302	70.489	204.547	1.153
C 13	5.400		29.160				
	4.867		23.688				
	4.880	5.049	23.814	15.147	76.662	229.432	0.092
C 14	6.067		36.808				
	5.093		25.939				
	5.333	5.498	28.441	16.493	91.188	272.019	0.258
C 15	7.573		57.350				
	5.840		34.106				
	6.133	6.515	37.614	19.546	129.070	382.046	0.860
C 16	6.480		41.990				
	5.867		34.422				
	6.493	6.280	42.159	18.840	118.571	354.946	0.128
C 23	6.307		39.778				
	5.467		29.888				
	5.544	5.773	30.736	17.318	100.402	299.913	0.216
C 24	5.240		27.458				
	4.893		23.941				
	5.680	5.271	32.262	15.813	83.661	250.051	0.156
C 25	6.600		43.560				
	6.634		44.010				
	6.453	6.562	41.641	19.687	129.211	387.578	0.009
C 26	4.133	4.947	17.082	14.840	75.137	220.226	0.864

	4.747 5.960		22.534 35.522				
C 34	5.160 5.440 5.413	5.338	26.626 29.594 29.301	16.013	85.520	256.416	0.024
C 35	4.347 5.133 4.867	4.782	18.896 26.348 23.688	14.347	68.932	205.836	0.160
C 36	4.040 4.667 7.333	5.347	16.322 21.781 53.773	16.040	91.875	257.282	3.057
C 45	6.267 7.467 5.333	6.356	39.275 55.756 28.441	19.067	123.472	363.550	1.144
C 46	6.400 8.467 8.693	7.853	40.960 71.690 75.568	23.560	188.218	555.074	1.597
C 56	5.693 6.307 7.200	6.400	32.410 39.778 51.840	19.200	124.028	368.640	0.574
						$\sum S^2_i$=	
						Sy^2	13.003
						Sy	3.606

X. TEST FOR ADEQUACY FOR SCHEFFE'S RESPONSE MODEL

The test for adequacy for Scheffe's Response Model was done using statistics student's t- test at 95% accurate level

Null Hypothesis: This states that there is no significant difference between the experimental and theoretical (model) results.

Alternative Hypothesis: States that there is a significant difference between the experimental and theoretical (model) results.

The null hypothesis test was carried out using both student t-test at 95% confidence level. The results are as shown in the tables below:

Table 4.5 :Statistical t-test computations for Scheffe's Response Model

Control ponits	YE	YM	Di = YE - YM	DA – Di	$(DA - Di)^2$
C1	6.382	5.313	1.069	2.605	6.7860
C2	5.458	5.063	0.395	-0.2113	0.0447
C3	5.586	5.43	0.156	-0.156	0.0243
C4	5.035	5.595	-0.560	0.56	0.3136
C5	5.200	4.787	0.413	-0.413	0.1706
C6	4.516	5.526	-1.010	1.01	1.0201
C7	4.767	5.28	-0.513	0.513	0.2632
C8	5.049	5.829	-0.780	0.78	0.6084

C9	5.498	5.353	0.145	-0.145	0.0210
C10	6.515	5.975	0.540	-0.54	0.2916
C11	6.28	5.197	1.083	-1.083	1.1729
C12	5.773	5.055	0.718	-0.718	0.5155
C13	5.271	4.837	0.434	-0.434	0.18836
C15	6.562	5.288	1.274	-1.274	1.6231
C16	4.947	4.978	-0.031	0.031	0.0010
C17	5.338	5.294	0.044	-0.044	0.0019
C18	4.782	5.335	-0.553	0.553	0.3058
C20	5.347	5.658	-0.311	0.311	0.0967
C21	6.356	5.195	1.161	-1.161	1.3479
		ΣDi	3.674	$\Sigma(DA\text{-}Di)^2$	14.7967
		$DA = \frac{\Sigma Di}{N-1}$	0.1837	$S^2 = \frac{\Sigma(DA - Di)^2}{N-1}$	0.7398
				$S = \sqrt{S^2}$	0.8601
				$t = \frac{DA \times \sqrt{(N-1)}}{S}$	0.9551

Legend:

$Y_E =$ Responses(flexural strength) from the experiment

$Y_M =$ Responses (flexural strength) from the Second degree polynomial equation

N = Number of observations

Di= Difference of Y_E and Y_M

$DA = \frac{\sum Di}{N}$ =Mean of difference of Y_E and Y_M

$S^2 = \frac{\sum (DA - Di)^2}{N-1}$ = Variance of difference of Di and DA

$t = \frac{DA * N^{0.5}}{S}$ = Calculated value of t

OP = Observation Points

EXECUTED COMPUTER PROGRAM AND DETERMINATION OF THE OPTIMUM FLEXURAL STRENGTH

A computer program for the prediction of SSA- PBA concrete beams was developed using VISUAL BASIC 6.0.

The sample of the executed program is as follows:

PROGRAM

Click start

Click ok to continue

What do you want to do?? To calculate mix ratio given desired flexural strength or calculate flexural strength given desired mix ratio? Type 1 0r 0 and click ok

Type 1 and click ok

What is the desired flexural strength??

Enter value and click ok

OUTPUT

Y = 4.573, WATER = 0.60, CEMENT = 0.85, SHELL ASH = 0.10, P. BUNCH ASH = 0.05, SAND = 1.80, GRANITE = 3.60,

Y = 4.538, WATER = 0.55, CEMENT = 0.80, SHELL ASH = 0.10, P. BUNCH ASH = 0.10, SAND = 2.20, GRANITE = 4.20

Y = 4.558, WATER = 0.605, CEMENT = 0.86, SHELL ASH = 0.09, P. BUNCH ASH = 0.05, SAND = 1.77, GRANITE = 3.52,

Y = 4.451, WATER = 0.62, CEMENT = 0.89, SHELL ASH = 0.06, P. BUNCH ASH = 0.05, SAND = 1.68, GRANITE = 3.28,

Y = 4.455, WATER = 0.54, CEMENT = 0.805, SHELL ASH = 0.095, P. BUNCH ASH = 0.10, SAND = 2.18, GRANITE = 4.10,

Y = 4.451, WATER = 0.52, CEMENT = 0.815, SHELL ASH = 0.085, P. BUNCH ASH = 0.10, SAND = 2.14, GRANITE = 3.90,

Y = 4.49, WATER = 0.64, CEMENT = 0.935, SHELL ASH = 0.01, P. BUNCH ASH = 0.055, SAND = 1.57, GRANITE = 2.94,

Y = 4.454, WATER = 0.61, CEMENT = 0.925, SHELL ASH = 0.02, P. BUNCH ASH = 0.055, SAND = 1.63, GRANITE = 3.04,

OPTIMUM FLEXURAL STRENGTH PREDICTABLE BY THIS MODEL IS 6.129

THE CORRESPONDING MIXTURE RATIO IS AS FOLLOWS:

WATER = 0.565 CEMENT = 0.865 SSA = 0.075 PBA = 0.06 SAND = 1.87 GRANITE = 3.62

XI. CONCLUSION

A mathematical model was developed using Scheffe's Simplex Theory. The mathematical model was used to predict flexural strength of snail shell ash – palm bunch ash cement concrete beams given any mix ratio and vice versa. There was no significant difference between the experimental results and those predicted from the model. The model developed was tested using statistical student's t – Test at 95.00% confidence level and was found to be adequate. The computer program developed using Visual Basic 6.0 can predict all possible combinations of mix proportion of Snail Shell Ash – Palm Bunch Ash – cement concrete given any flexural strength and can predict the flexural strength given a mix ratio.

The optimum flexural strength of Snail Shell Ash – Palm Bunch Ash – cement concrete predicted by this Model is 6.129N/mm^2. The corresponding mix ratio for the optimum flexural strength are: Water = 0.565, Cement = 0.865, Snail Shell Ash = 0.075, Palm Bunch Ash =0.06, Sand =1.87, and Granite =3.62.

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