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Optimization Of Compressive Strength of Concrete Made With Partial Replacement Of Cement With Cassava Peel Ash (CPA) and Rice Husk Ash (RHA)Using Scheffe's Second Degree Model

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ABSTRACT

In a bit to solve the world's rising cost of building materials especially cement, there has been urgent needs to partially replace cement with some locally made binders, such as CPA , RHA or others.The use of these inexpensive binders , especially , CPA and RHA not only reduces the cement requirement or decrease in the overall production cost of concrete., subsequent reduction in cement requirement leads to less environmental pollution by cement factories and also provides economic and environmental benefits of disposing agricultural waste product. Moreover, CPA and RHA provide good compressive strength to the concrete.This research work is aimed at usingScheffe's Second Degree Model for six component mixtures, simply abbreviated asScheffe's (6,2)to optimize the compressive strength of concrete made through partial replacement of 60 percent cement with 30 percent of Cassava Peel Ash (CPA) and 30 percent of Rice Husk Ash (RHA). TheScheffe's second degree model for six component mixtureintroduced and developed by Nwachukwu and others (2022g) was subsequently used in this present work. Through the use of Scheffe'sSimplex optimizationmethod, the compressive strengthsof the present workwere obtained for different mix proportions. Control experiments were also carried out,and the compressive strengths determined. Through the use of the Student's t-test statistics, the adequacy of the modelwas confirmed .The maximum compressive strength was obtained as 39.77MPa.This maximum value is higher than the minimum value specified by the American Concrete Institute (ACI), as 20MPa for good concrete and also the minimum value specified by ASTM C 39 or ASTM C 469, as 30.75 for high performance concrete .Thus, the compressive strength value can sustain construction of light-weight structures and someheavy-weight structures such asBridges, Airports etc at the best possible economic and safety advantages.

Keywords: Concrete, CPA, RHA, Cement, Scheffe's(6,2) Polynomial Model, Compressive Strength, Mixture Design

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1.INTRODUCTION

In life, there are established three basic needs of man. These are Air, Food and Shelter. That is to say that shelter is among the basic necessity of life. However only few percentage of the world populace have access to this basic need due mainly to high cost of building materials especially the cement. From experience and construction point of view, there is general belief that Cement Cost Factor (CCF) constitutes almost 50 percent of the Overall Building Cost Factor (OBCF). This is to to say that any solution geared at providing reduction to the cost of cement will definitely bring down the cost of concrete leading to the reduction of the overall cost of shelter.In general, concrete, being a homogeneous mixture of cement, sand, gravel and water is very strong in carrying compressive forces and hence, it is gaining increasing importance as building materials throughout the world (Syal and Goel, 2007) . According to Oyenuga (2008), concrete is a composite inert material comprising of a binder course (cement), mineral filter or aggregates and water. Concrete, according to Neville (1990), plays an important part in all building structures owing to its numerous advantages which ranges from low built in fire resistance, high compressive strength to low maintenance. Concrete being the most widely used construction material has been undergoing changes both as a material and due to technological advancement a result of dual strength characteristics. According to Shetty (2006), concrete, especially plain type possesses a very low tensile strength, limited ductility and little resistance to cracking. This has resulted to continuous search for upgrading the properties of concrete. Many researches have shown that CPA and RHA are local inexpensive binders that can partially replace cement with utmost positive results in terms of high quality concrete production. The use of these two binders, CPA and RHA, somehow can improve the efficiency of the cement and henceforth the concrete mixture due to the outstanding qualities and inherent properties both possess. For instance, RHA, contains over 85% of amorphous silica by weight. Then, as a pozzolanic reactive material, it can be used to improve surface area of transition zone between the microscopic structure of cement paste and aggregate in the high performance concrete. For the CPA, because it is an agricultural solid waste derivative, its utilization as a supplementarycementitious materials in the production of concrete is vital and necessary because it supports the reuse and recycling of solid wastes in line with environmental sustainability.Thus, for greater efficiency, mixture design of concrete made with cement that is partially replaced with CPA and RHA canbe carried out through optimization. By definition, an optimization problem is one requiring the determination of the optimal (maximum or minimum) value of a given function, called the objective function, subject to a set of stated restrictions, or constraints placed on the variables concerned.Optimization of the concrete mixture design is a process of search for a mixture for which the sum of the costs of the ingredients is lowest, yet satisfying the required performance of concrete, such as workability, strength and durability. The design of concrete mix according to (Shetty, 2006) has not being a simple task on the account of the widely varying properties of the constituent materials, as well as the conditions that prevail at the site of work , the exposure condition, and the conditions that are demanded for a particular work for which the mix is designed. Again, concrete mix design according to Jackson and Dhir (1996)has been defined as the procedure which, for any given set of condition, the proportions of the constituent materials are chosen so as to produce a concrete with all the required properties for the minimum cost. Thus, the cost of any concrete includes, in addition to that of the materials themselves, the cost of the mix design, of batching, mixing and placing the concrete and of the site supervision. In the context of the above guidelines, the methods and procedures proposed by Hughes (1971), ACI- 211(1994) and DOE (1988) are more complexand time consuming as they involve a lot of trial mixes and deep statistical calculations before the desired strength of the concrete can be achieved.According to Shacklock (1974), the objective of mix design has been to determine the most appropriate proportions in which to use the constituent materials to meet the needs of construction work.Thus,optimization of the concrete mixture design remains the fastest method, best option and the most efficient way of selecting concrete mix for better efficiency and performance of concrete when compared withusual empirical methods as listed above. A typical example of optimization model is Scheffe'sModel , which can be in form of Scheffe's Second Degree model or Scheffe's Third Degree model. In thisrecent study, Scheffe's Second Degree Model for six components mixtures (namely Water, Cement, CPA, RHA , Fine Aggregate and Coarse Aggregate) will be presented.

According to Ettu (2001), the major aim of engineeringdesign is to ensure that the structure being designed will not reach a Serviceability Limit State (SLS), which is connected with deflection, cracking, vibration etc, and Ultimate Limit State (ULS), which is generally connected with collapse. In all of the above, the concrete's compressive strength is one of the most important properties of concrete that require close investigation because of its important role.Compressive strength of concrete is the Strength of hardened concrete measured by the compression test. It is a measure of the concrete's ability to resist loads which tend to compress it. It is measured by crushing cylindrical concrete specimens in a universal testing machine. Again, the compressive strength of the concrete cube testalso provides an idea about all the characteristics of concrete under examination.

This recent work therefore examines the use of Scheffe's Second Degree Model in optimizing the compressive strength of Concrete made with partial replacement of cement with CPA and RHA. As expected many related works have been done but none has been able to address the subject matter wholly. For example, on CPA and RHA, Raheem and others (2015) carried out investigation on the effect of cassava peel ash (CPA) as alternative binder in concrete. Olatokunbo and others (2018) provided an assessment of strength properties of cassava peel ash-concrete.Mohd-Ashruddin and others (2017) assessed the chemical and morphological studies of cassava peel. Similarly, Ogbonna and others (2020) carried out an investigation into the characteristics and use of cassava peel ash in concrete production. Adetoye and others (2022), in their own contribution, investigated the compressive strength properties of cassava peel ash and wood ash in concrete production. Zareei and others (2017) investigated the role of Rice Husk Ash as a partial replacement of cement in high strength concrete containing micro silica. Again, Obute and others () carried out the effect of the partial replacement of cement with cassava peel ash and rice husk ash on concrete.

Recent works on optimization show that many researchers have used Scheffe's method to carry out one form of optimization work or the other. For example, Nwakonobi and Osadebe (2008) used Scheffe's model to optimize the mix proportion of Clay- Rice Husk Cement Mixture for Animal Building. Ezeh and Ibearugbulem (2009) applied Scheffe's model to optimize the compressive cube strength of River Stone Aggregate Concrete. Scheffe's model was used by Ezeh and others (2010a) to optimize the compressive strength of cement- sawdust Ash Sandcrete Block. Again Ezeh and others (2010b) optimized the aggregate composition of laterite/ sand hollow block using Scheffe's simplex method. The work of Ibearugbulem (2006) and Okere(2006) were also based on the use of Scheffe' mathematical model in the optimization of compressive strength of Perwinkle Shell- Granite Aggregate Concrete and optimization of the Modulus of Rupture of Concrete respectively.Obam (2009) developed a mathematical model for the optimization of strength of concrete using shear modulus of Rice Husk Ash as a case study. The work of Obam (2006) was based on four component mixtures, that is Scheffe's(4,2) and Scheffe's(4,3). Nwachukwu and others (2017) developed and employedScheffe's Second Degree Polynomial model to optimize the compressive strength of Glass Fibre Reinforced Concrete (GFRC). Also,Nwachukwu and others (2022a) developed and usedScheffe's Third Degree Polynomial model,Scheffe's (5,3) to optimize the compressive strength of GFRC where they compared the results with their previous work, Nwachukwu and others (2017). Nwachukwu and others (2022c) used Scheffe's (5,2) optimization model to optimize the compressive strength of Polypropylene Fibre Reinforced Concrete (PFRC). Again,Nwachukwu and others (2022d) applied Scheffe's (5,2) mathematical model to optimize the compressive strength of Nylon Fibre Reinforced Concrete (NFRC).Nwachukwu and others (2022b) applied Scheffe's (5,2) mathematical model to optimize the compressive strength of Steel Fibre Reinforced Concrete (SFRC). Furthermore,Nwachukwu and others (2022e) usedScheffe's Third Degree Regression model,Scheffe's (5,3) to optimize the compressive strength of PFRC.Nwachukwu and others (2022f)applied Modified Scheffe's Third Degree Polynomial model to optimize the compressive strength of NFRC. Nwachukwu and others (2022g) applied Scheffe's Third Degree Model to optimize the compressive strength of SFRC. And finally,Nwachukwu and others (2022h) made use of the Scheffe'sSecond Model to optimize the compressive strength of Hybrid- Polypropylene – Steel Fibre Reinforced Concrete (HPSFRC) .From the above, it can be envisaged that no work has been done on the subject matter. Henceforth,the need for this presentresearch work.

2. SCHEFFE'S (6, 2) MODEL BACKGROUND

A simplex lattice isdescribed as a structural representation of lines joining the atoms of a mixture, whereas these atoms are constituent components of the mixture. For the present concrete mixture, the sixconstituent elements are, Water, Cement, CPA, RHA, FineAggregate, and Coarse Aggregate. Subseqently, a simplex of six-component mixture is a five -dimensional solid.According to Obam (2009), mixture components are usually subject to the constraint that the sum of all the components must be equal to 1. That is:

$X_1 + X_2 + X_3 + \ldots + X_q = 1 \; ; \quad \Rightarrow \sum_{i=1}^{q} X_i = 1$ **(1)**

where $X_i \geq 0$ and $i = 1, 2, 3\ldots$ q, and q = the number of mixtures.

2.1. SIX COMPONENT MIXTURES IN SCHEFFE'S SIMPLEX LATTICE DESIGN

The (q, m) simplex lattice design are characterized by the symmetric arrangements of points within the experimental region and a well-chosenmathematical equation to represent the response surface over the entire simplex region(Aggarwal, 2002). The (q, m) simplex lattice design given by Scheffe, according to Nwakonobi and Osadebe (2008) contains ${}^{q+m-1}C_m$ points where each components proportion takes (m+1) equally spaced values $X_i = 0, \frac{1}{m}, \frac{2}{m}, \frac{3}{m}, \ldots, 1; \quad i = 1, 2, \ldots, q$ ranging between 0 and 1 and all possible mixture with these component proportions are used, and m is scheffe's polynomial degee, which in this present study is 2.

For example a (3, 2) lattice consists of ${}^{3+2-1}C_2$ i.e. ${}^{4}C_2$ = 6 points. Each X_i can take m+1 = 3 possible values; that is $x = 0, \frac{1}{2}, 1$with which the possible design points are: $(1,0,0), (0,1,0), (0,0,1), \left(\frac{1}{2}, \frac{1}{2}, 0\right), \left(0, \frac{1}{2}, \frac{1}{2}\right), \left(\frac{1}{2}, 0, \frac{1}{2}\right)$.The general formula for evaluating the number of coefficients/terms/points required for a given lattice is alwaysgiven by:

$k = \frac{(q+m-1)!}{(q-1)!\,.\,m!}$ Or ${}^{q+m-1}C_m$ **2(a-b)**

Where k = number of coefficients/ terms / points

q = number of components = 6 in this study

m = number of deqree of polynomial = 2 in this present work

Usingeither of Eqn. (2), $k_{(6,2)}$= 21

Thus, the possible design points for Scheffe's (6,2) lattice can be as follows:

A_1 (1,0,0,0,0,0); A_2 (0,1,0,0,0,0); A_3 (0,0,1,0,0,0); A_4 (0,0,0,1,0,0), A_5 (0,0,0,0,1,0);A_6(0, 0,0,0, 0, 1); A_{12}(0.67,0.33, 0, 0, 0, 0); A_{13} (0.67, 0, 0.33,0,0,0); A_{14} (0.67, 0, 0, 0.33,0,0); A_{15} (0.67, 0, 0, 0,0.33, 0); A_{16} (0.67, 0, 0, 0, 0, 0.33); A_{23} (0,0.50,0.50, 0,0,0); A_{24} (0, 0.50, 0, 0.50, 0,0); A_{25}, (0, 0.50, 0, 0,0.50, 0); A_{26} (0, 0.50,0,0, 0.50); A_{34} (0.50, 0.50, 0, 0,0,0); A_{35} (O.50, 0,0.50, 0,0,0); A_{36} (0.50,0, 0,0.50, 0, 0); A_{45} (0.50, 0, 0, 0,0.50, 0); A_{46}(0.50,0,0,0,0,0.50);A_{56}(0,0,0.50,0.50,0,0); **(3)**

According to Obam (2009), a Scheffe's polynomial function of degree, m in the q variable X_1, X_2, X_3,X_4 …X_q is given in the form of Eqn.(4)

$N= b_0 + \sum bi\, xi + \sum bij x j + \sum bi\, jxjxk + + \sum bi^j{}_2 +\ldots i_n x i_2 x i_n$ **(4)**

where ($1 \le i \le q$, $1 \le i \le j \le k \le q$, $1 \le i_1 \le i_2 \le \ldots \le i_n \le q$ respectively) , b = constant coefficients and N is the response which represents the property under investigation, which ,in this case is the compressive strength.

As this research work is based on theScheffe's (6, 2) simplex, the actual form of Eqn. (4) for sixcomponent mixture, degree two (6, 2) has been developedby Nwachukwu and others (2022h)

2.2. ACTUAL AND PSEUDO COMPONENTS.

There exist a relationship between the pseudo components and the actual componentsin theScheffe's mix design, which can be established as Eqn.(5):

$$Z = A * X \qquad \textbf{(5)}$$

where Z is the actual component; X is the pseudo component and A is the coefficient of the relationship
Re-arranging Eqn. (5) yields:

$$X = A^{-1} * Z \qquad \textbf{(6)}$$

2.3. FORMULATION OF POLYNOMIAL EQUATION FOR SCHEFFE'S (6, 2) LATTICE FOR THE PRESENT CONCRETE MIXTURE

The polynomialequation by Scheffe(1958), which is known as response is given in Eqn.(4) . And for the Scheffe's (6,2) simplex lattice, the polynomial equation for six component mixtures has been formulatedbased on Eqn.(4) by the work of Nwachukwu and others (2022g) as under:

N = ß1X1 + ß2X2 + ß3X3 + ß4X4 + ß5X5 +ß6X6 + ß12X1X2 +ß13X1X3 + ß14X1X4 + ß15X1X5 +ß16X1X6 +
ß23X2X3+ ß24X2X4 + ß25X2X5 +ß26X2X6 +ß34X3X4+ ß35X3X5+ ß36X3X6 + ß45X4X5 + ß46X4X6 +ß56X5X6**(7)**

2.4 .COEFFICIENTS OF THESCHEFFE'S (6, 2) POLYNOMIAL

Based on the work ofNwachukwu and others (2022h), the coefficients of theScheffe's (6, 2) polynomialhave been evaluate as stated under. :

$\beta_1= N_1$;$\beta_2=N_2$; $\beta_3=N_3$; $\beta_4= N_4$; $\beta_5= N_5$ and$\beta_6 = N_6$**8(a-f)**

$\beta_{12}= 4N_{12} -2N_1 - 2N_2$; $\beta_{13} = 4N_{13}-2N_1 - 2N_3$;$\beta_{14} = 4N_{14}-2N_1 - 2N_4$; **9(a-c)**

$\beta_{15}= 4N_{15}-2N_1 - 2N_5$; $\beta_{16}= 4N_{16}-2N_1 - 2N_6$;$\beta_{23}=4N_{23}-2N_2 - 2N_3$;$\beta_{24}= 4N_{24}-2N_2 - 2N_4$; **10(a-d)**

$\beta_{25}= 4N_{25}-2N_2 - 2N_5$; $\beta_{26}= 4N_{26}-2N_2 - 2N_6$, $\beta_{34}= 4N_{34}-2N_3 - 2N_4$; $\beta_{35}= 4N_{35}-2N_3 - 2N_5$;**11(a-d)**

$\beta_{36}= 4N_{36}-2N_3 - 2N_6$; $\beta_{45}= 4N_{46}-2N_4 - 2N_6$, $\beta_{46} = 4N_{46}-2N_4 - 2N_6$; $\beta_{56}= 4N_{56}-2N_{35} - 2N_6$; **12(a-d)**

Where N_i = Response Function (Compressive Strength) for the pure component, i

2.5.SCHEFFE'S (6, 2) MIXTURE DESIGN MODEL

When we substitute Eqns. (8)-(12) into Eqn. (7), we obtain the mixture design model for the present concrete mixture based on Scheffe's (6,2) lattice.

2.6. PSEUDO AND ACTUALMIX PROPORTIONS OF SCHEFFE'S (6, 2) DESIGN LATTICE

Based on Eqn. (1), the requirement of simplex lattice design based on Eqn. (1) criteria makes it impossible to use the conventional mix ratios such as 1:2:4 etc., at a given water/cement ratio for the actual mix ratio. Thus,there is need for the transformation of the actual components proportions to meet the above criterion. Based on experience and previous knowledge from literature, the following arbitrary prescribed mix ratios are always chosen for the sixvertices of Scheffe's (6,2) lattice as follows : But note that cement is partially replaced with CPA and RHA in the ratio of C:CPA: RHA = 0.4: 0.3:0.3.

A_1 (0.67:0.4:0.3:0.3:1.7:2:0); A_2 (0.56:0.4:0.3:0.3:1.6:1.8); A_3 (0.5:0.4:0.3:0.3:1.2:1.7);
A_4(0.7:0.4:0.3:0.3:1:1.8);A_5(0.75:0.4:0.3:0.3:1.3:1.2:),andA_6(0.80:0.4:0-3:0.3:1.3:1.2:)**(13)**

Which represent Water/Cement Ratio, Cement, CPA, RHA, Fine Aggregate And Coarse Aggregate.

However , a factor of 0.4 can be used to divide through Eqn.(13), to make the quantity of cement to be unity since the measurement of other components are dependent on cement. Thus Eqn. (13) can be rewritten as:
A_1 (1.7:1.0:0.8:0.8:4.3:5.0); A_2 (1.4:1.0:0.8:0.8:4.0:4.5); A_3 (1.3:1.0:0.8:0.8:3.0:4.3);
A_4(1.8:1.0:0.8:0.8:2.5:6.3);A_5(1.9:1.0:0.8:0.8:3.3:3.0:),andA_6(2.0:1.0:0-8:0.8:3.3:3.0)**(14)**
For the pseudo mix ratio, the following corresponding mix ratios at the vertices for six component mixtures are always chosen:
A_1(1:0:0:0:0:0), A_2(0:1:0:0: 0:0), A_3(0:0:1:0:0:0), A_4(0:0:0:1:0:0), A_5(0:0:0:0:1:0) andA_6(0:0:0:0:0:1) **(16)**
For the transformation of the actual component, Z to pseudo component, X, and vice versa,Eqns. (5) and (6) are used.Substituting the mix ratios from point A_1Eqn.(14) into Eqn. (5) yields:

1.7 A_{11} A_{12} A_{13} A_{14} $A_{15}A_{16}$ 1
1.0 A_{21} A_{22} A_{23} A_{24} $A_{25}A_{26}$ 0
0.8 = A_{31} A_{32} A_{33} A_{34} $A_{35}A_{36}$ 0 **(17)**
0.8 A_{41} A_{42} A_{43} A_{44} $A_{45}A_{46}$ 0
4.3 A_{51} A_{52} A_{53} A_{54} $A_{55}A_{56}$ 0
5.0 A_{61} A_{62} A_{63} A_{64} $A_{65}A_{66}$ 0

Transforming the R.H.S matrix and solving, we obtain as follows:
A_{11} (1) + A_{21} (0) + A_{31} (0)+ A_{41}(0) + A_{51} (0) + A_{61} (0) = 1.7.
Thus ,A_{11} = 1.7
Similarly, A_{21}= 1; A_{31}= 0.8; A_{41}= 0.8; A_{51}= 4.3; A_{61}= 5.0
The same approach is used to obtain the remaining values as shown in Eqn. (18)

Z_1 1.7 1.4 1.3 1.8 1.9 2.0 X_1
Z_2 1.0 1.0 1.0 1.0 1.0 1.0 X_2
Z_3 = 0.8 0.8 0.8 0.8 0.8 0.8 = X_3 **(18)**
Z_4 0.8 0.8 0.8 0.8 0.8 0.8 X_4
Z_5 4.3 4.0 3.0 2.5 3.3 3.3 X_5
Z_6 5.0 4.5 4.3 6.3 3.0 3.0 X_6

Considering mix ratios at the mid points from Eqn.(3) and substituting these pseudo mix ratios in turn into Eqn.(18) will yield the corresponding actual mix ratios.
For instance, considering point A_{12}we have:A_{12}(0.67,0.33, 0, 0, 0, 0), and the following equation results:

Z_1 1.7 1.4 1.3 1.8 1.9 2.0 0.67 1.6
Z_2 1.0 1.0 1.0 1.0 1.0 1.0 0.33 1.0
Z_3 = 0.8 0.8 0.8 0.8 0.8 0.8 0 = 0.8 **(19)**
Z_4 0.8 0.8 0.8 0.8 0.8 0.8 0 0.8
Z_5 4.3 4.0 3.0 2.5 3.3 3.3 0 3.9
Z_6 5.0 4.5 4.3 6.3 3.0 3.0 0 4.8

Solving, Z_1 = 1.6; Z_2 = 1.0; Z_3 = 0.8' Z_4 = 0.8; Z_5 = 3.9 and Z_6 = 4.8
The same approach goes for the remaining mid-point mix ratios.
Thus, twenty-one (21) experimental tests will be carried out in other to generate the polynomial coefficients and the corresponding mix ratios are depicted in Table 1.

Table 1: Pseudo (X) and Actual (Z) Mix Ratio For The Present Concrete Mixture Based on Scheffe's (6,2) Lattice

S/N	POINTS	PSEUDO COMPONENT						RESPONSE SYMBOL	ACTUAL COMPONENT					
		X_1	X_2	X_3	X_4	X_5	X_6		Z_1	Z_2	Z_3	Z_4	Z_5	Z_6
1	1	1	0	0	0	0	0	N_1	1.7	1.0	0.8	0.8	0.5	0.5
2	2	0	1	0	0	0	0	N_2	1.4	1.0	0.8	0.8	4.0	4.5
3	3	0	0	1	0	0	0	N_3	1.3	1.0	0.8	0.8	3.0	4.3
4	4	0	0	0	1	0	0	N_4	1.8	1.0	0.8	0.8	2.5	6.3
5	5	0	0	0	0	1	0	N_5	1.9	1.0	0.8	0.8	3.0	3.3
6	6	0	0	0	0	0	1	N_6	2.0	1.0	0.8	0.8	3.0	3.3
7	12	0.67	033	0	0	0	0	N_{12}	1.6	1.0	0.8	0.8	3.9	4.8
8	13	0.67	0	0.33	0	0	0	N_{13}	1.6	1.0	0.8	0.8	3.0	4.2
9	14	0.67	0	0	0.33	0	0	N_{14}	1.8	1.0	0.8	0.8	2.5	3.5
10	15	0.67	0	0	0	0.33	0	N_{15}	1.9	1.0	0.8	0.8	3.3	4.7
11	16	0.67	0	0	0	0	0.33	N_{16}	1.7	1.0	0.8	0.8	3.3	4.5
12	23	0	0.50	0.50	0	0	0	N_{23}	2.0	1.0	0.8	0.8	3.2	4.8
13	24	0	0.50	0	0.50	0	0	N_{24}	1.8	1.0	0.8	0.8	3.4	5.0
14	25	0	0.50	0	0	0.50	0	N_{25}	1.6	1.0	0.8	0.8	3.0	4.5
15	26	0	0.50	0	0	0	0.50	N_{26}	1.8	1.0	0.8	0.8	3.0	4.8
16	34	0.50	0.50	0	0	0	0	N_{34}	1.9	1.0	0.8	0.8	3.4	4.7
17	35	0.50	0	0.50	0	0	0	N_{35}	1.8	1.0	0.8	0.8	2.5	4.8
18	36	0.50	0	0	0.50	0	0	N_{36}	1.6	1.0	0.8	0.8	3.0	4.6
19	45	0.50	0	0	0	0.50	0	N_{45}	1.9	1.0	0.8	0.8	2.5	5.0
20	46	0.50	0	0	0	0	0.50	N_{46}	2.0	1.0	0.8	0.8	2.8	4.8
21	56	0	0	0.50	0.50	0	0	N_{56}	1.8	1.0	0.8	0.8	3.0	4.8

2.7. THE CONTROL POINTS

Twenty- one (21) different controls will be predicted and according to Scheffe's (1958) ,their summation should not be greater than one. The same approach for component transformation adopted for the initial experimental points are also adopted for the control points and the results are shown in Table 2.

Table 2 :Actual and Pseudo Component Based on Scheffe (6,2) Lattice for Control Points

S/N	POINTS	PSEUDO COMPONENT						CONTROL POINTS	ACTUAL COMPONENT					
		X_1	X_2	X_3	X_4	X_5	X_6		Z_1	Z_2	Z_3	Z_4	Z_5	Z_6
1	1	0.25	0.25	0.25	0.25	0	0	C_1	0.61	1	0.8	0.8	1.38	1.83
2	2	0.25	0.25	0.25	0	0.25	0	C_2	0.62	1	0.8	0.8	1.45	1.68
3	3	0.25	0.25	0	0.25	0.25	0	C_3	0.67	1	0.8	0.8	1.40	1.70
4	4	0.25	0	0.25	0.25	0.25	0	C_4	0.66	1	0.8	0.8	1.30	1.68
5	5	0	0.25	0.25	0.25	0.25	0	C_5	0.63	1	0.8	0.8	1.28	1.63
6	6	0.20	0.20	0.20	0.20	0.20	0	C_6	0.64	1	0.8	0.8	1.36	1.70
7	12	0.30	0.30	0.30	0.10	0	0	C_{12}	0.59	1	0.8	0.8	1.45	1.83
8	13	0.30	0.30	0.30	0	0.10	0	C_{13}	0.59	1	0.8	0.8	1.48	1.77
9	14	0.30	0.30	0	0.30	0.10	0	C_{14}	0.65	1	0.8	0.8	1.42	1.80
10	15	0.30	0	0.30	0.30	0.10	0	C_{15}	0.64	1	0.8	0.8	1.30	1.77
11	16	0	0.30	0.30	0.30	0.10	0	C_{16}	0.60	1	0.8	0.8	1.27	1.71
12	23	0.10	0.30	0.30	0.30	0	0	C_{23}	0.60	1	0.8	0.8	1.31	1.79
13	24	0.30	0.10	0.30	0.30	0	0	C_{24}	0.62	1	0.8	0.8	1.33	1.83
14	25	0.30	0.10	0.30	0.30	0	0	C_{25}	0.63	1	0.8	0.8	1.41	1.85
15	26	0.10	0.20	0.30	0.40	0	0	C_{26}	0.61	1	0.8	0.8	1.25	1.79
16	34	0.30	0.20	0.10	0.40	0	0	C_{34}	0.64	1	0.8	0.8	1.35	1.85
17	35	0.20	0.20	0.10	0.10	0.40	0	C_{35}	1.40	1	0.8	0.8	1.04	1.59
18	36	0.30	0.10	0.30	0.20	0.10	0	C_{36}	0.62	1	0.8	0.8	1.36	1.77
19	45	0.25	0.25	0.15	0.15	0.20	0	C_{45}	0.61	1	0.8	0.8	1.51	3.16
20	46	0.30	0.30	0.20	0.10	0.10	0	C_{46}	0.68	1	0.8	0.8	1.56	1.96
21	56	0.10	0.30	0.30	0.30	0	0	C_{56}	1.30	1	0.8	0.8	1.31	1.79

The actual component as transformed from Eqn. (18) , Table (1) and (2) were used to measure out the quantities of Water/Cement ratio (Z_1), Cement (Z_2), CPA(Z_3), RHA(Z_4) , Fine Aggregate (Z_5) and Coarse Aggregate (Z_6) in their respective ratios for the concrete cube strength test.

3. MATERIALS AND METHODS

3.1 MATERIALS

In this research work, the constituent materials under investigation in line with Scheffe's six component mixture , degree two are Water/Cement ratio, Cement, CPA, RHA, Fine and Coarse Aggregates.The water is obtained from potable water from the clean water source. The cement is Dangotecement, a brand of Ordinary Portland Cement obtained from local distributors, which conforms to British Standard Institution BS 12 (1978).Remember,in this work, only 60% of the cement is being replaced by CPA and RHA. So the quantity of (C:CPA:RHA)by weight is measured out in the ratio of (0.3:0.3:0.4).The CPA was sourced locally in Owerri, Imo state of Nigeria, and thereafter was adequately prepared. The RHA ,of specific gravity of 2.12 sourced from the Afikpo Rice Mill Factory in Ebonyi State, Nigeria. It was thereafter adequately prepared to meet the criterion for the present study. Fine aggregate, whose size ranges from 0.05 - 4.5mm was procured from the local river. Crushed granite(as a coarse aggregate) of 20mm sizewas obtained from a local stone market and was downgraded to 4.75mm.

3.2. METHOD

3.2.1. SPECIMEN PREPARATION / BATCHING/ CURING

The specimen for the compressive strength is concrete cubes. They were cast in steel mould measuring 15cm*15cm*15cm. The mould and its base were damped together during concrete casting to prevent leakage of mortar. Thin engine oil was applied to the inner surface of the moulds to make for easy removal of the cubes. Batching of all the constituent material was done by weight using a weighing balance of 50kg capacity based on the adapted mix ratios and water cement ratios. A total number of 42 mix ratios were to be used to produce 84 prototype concrete cubes. Twenty- one (21) out of the 42 mix ratios were as control mix ratios to produce 42 cubes for the conformation of the adequacy of the mixture design given by Eqn. (7), whose coefficients are given in Eqns. (8) – (12). Curing commenced 24hours after moulding. The specimens were removed from the moulds and were placed in clean water for curing. After 28days of curing the specimens were taken out of the curing tank.

3.2.2. COMPRESSIVE STRENGTH TEST

Compressive strength testing was done in accordance with BS 1881 – part 116 (1983) - Method of determination of compressive strength of concrete cube and ACI (1989) guideline. In this present study,two samples were crushed for each mix ratio.In each case, the compressive strength was then calculated using Eqn.(20)

$$\text{Compressive Strength} = \frac{\text{Average failure Load, P (N)}}{\text{Cross- sectional Area, A } (mm^2)} \quad \textbf{(20)}$$

4. RESULTS AND DISCUSSION

4.1. COMPRESSIVE STRENGTHRESULTSFOR THE INITIAL EXPERIMENTAL TESTS.

The results of the compressive strength ($R_{esponse,}$ N_i) based on a 28-days strength is presented in Table 3. These are calculated from Eqn..(20)

Table 3: 28th DayCompressive Strength Test Results Based on Scheffe's (6, 2) Model for the Initial Experimental Tests.

S/N	POINTS	EXPERIMENTAL NUMBER	RESPONSE N_i, MPa	RESPONSE SYMBOL	$\sum N_i$	AVERAGE RESPONSE N, MPa
1	1	1C 1D	**32.65** **33.33**	N_1	**65.98**	**32.99**
2	2	2C 2D	**40.22** **39.32**	N_2	**79.54**	**39.77**
3	3	3C 3D	**29.98** **30.00**	N_3	**59.98**	**29.99**
4	4	4C 4D	**27.23** **28.04**	N_4	**55.27**	**27.64**
5	5	5C 5D	**32.76** **32.54**	N_5	**65.30**	**32.65**
6	6	6C 6D	**28.76** **27.98**	N_6	**56.76**	**28.37**
7	12	7C 7D	**34.33** **34.32**	N_{12}	**68.65**	**34.33**
8	13	8C	**35.43**	N_{13}	**70.75**	**35.38**

		8D	**35.32**			
9	14	9C 9D	**31.86** **31.24**	N_{14}	**63.10**	**31.55**
10	15	10C 10D	**32.76** **32.32**	N_{15}	**65.08**	**32.54**
11	16	11C 11D	**29.32** **29.23**	N_{16}	**58.55**	**29.28**
12	23	12C 12D	**28.54** **29.32**	N_{23}	**57.86**	**28.93**
13	24	13C 13D	**31.24** **32.22**	N_{24}	**63.46**	**31.73**
14	25	14C 14D	**33.64** **33.68**	N_{25}	**67.32**	**33.66**
15	26	15C 15D	**25.76** **24.89**	N_{26}	**50.65**	**25.33**
16	34	16C 16D	**32.76** **32.54**	N_{34}	**65.30**	**32.65**
17	35	17C 17D	**34.75** **35.12**	N_{35}	**69.87**	**34.94**
18	36	18C 18D	**39.22** **38.23**	N_{36}	**77.45**	**38.73**
19	45	19C 19D	**32.34** **32.43**	N_{45}	**64.77**	**32.39**
20	46	20C 20D	**34.54** **35.22**	N_{46}	**69.76**	**34.88**
21	56	21C 21D	**27.98** **28.00**	N_{56}	**55.98**	**27.99**

4.2COMPRESSIVE STRENGTHRESULTS FOR THE EXPERIMENTAL (CONTROL) TEST.

Table 4 shows th**e** 28th day Compressive strength results for the Experimental (Control) Test

Table 4: 28TH Day Compressive Strength Results Based on Scheffe's (6,2) Modelfor the Experimental(Control) Tests.

S/N	CONTROL POINTS	EXPERIMENTAL NUMBER	RESPONSE, MPa	AVERAGE RESPONSE, MPa
1	C_1	1C 1D	**29.65** **30.23**	**29.94**
2	C_2	2C 2D	**26.76** **27.21**	**26.99**
3	C_3	3C 3D	**28.88** **29.32**	**29.10**
4	C_4	4C 4D	**26.44** **26.22**	**26.33**
5	C_5	5C 5D	**30.23** **31.21**	**30.72**
6	C_6	6C 6D	**27.22** **27.00**	**27.11**
7	C_{12}	7C 7D	**30.66** **30.32**	**30.49**
8	C_{13}	8C 8D	**31.23** **32.00**	**31.62**
9	C_{14}	9C 9D	**30.22** **30.33**	**30.28**
10	C_{15}	10C 10D	**29.89** **30.76**	**30.33**
11	C_{16}	11C 11D	**30.23** **30.34**	**30.29**
12	C_{23}	12C 12D	**29.65** **29.34**	**29.50**
13	C_{24}	13C 13D	**30.23** **30.33**	**30.28**
14	C_{25}	14C 14D	**34.56** **35.23**	**34.90**
15	C_{26}	15C 15D	**27.43** **27.42**	**27.43**
16	C_{34}	16C 16D	**32.76** **33.12**	**32.44**
17	C_{35}	17C 17D	**34.78** **35.32**	**35.05**
18	C_{36}	18C	**37.56**	**37.55**

		18D	**37.54**	
19	C_{45}	19C 19D	**30.43** **31.32**	**30.88**
20	C_{46}	20C 20D	**33.76** **33.54**	**33.65**
21	C_{56}	21C 21D	**28.23** **28.11**	**28.17**

4.3 SCHEFFE'S (6,2) REGRESSION MODEL FOR COMPRESSIVE STRENGTH OF THE PRESENT CONCRETE MIXTURE

Substituting the values of the compressive strengths (responses) from Table 3 into Eqns.(8) through (12),we obtain the coefficients (in MPa) of the Scheffe'sSecond Degree Polynomial for the CPA-RHA/ Cement concrete Mixture as follows:

β_1 = 32.09;β_2 =39.77; β_3 = 29.99; β_4 = 27.64; β_5 = 32.65; β_6= 28.37; β_{12}= -6.40;β_{13}= 17.36;β_{14}= 6.73;β_{15}= 0.68; β_{16}= -12.36; β_{23}= -23.8;β_{24}= -7.90.; β_{25}= -10.24; β_{26}= -34.96;β_{34}= 15.34;β_{35}= 14.48;β_{36}= 38.20;β_{45}=-8.98;β_{46}= 27.7; β_{56}= -10.08.**(21)**

Substituting the values of these coefficients in Eqn.(21) into Eqn. (7), we obtain the polynomial model for the optimization of the compressive strength based on Scheffe's (6,2) lattice as given in Eqn.(22)

N = 32.09X1 + 39.77X2 + 29.99X3 + 27.64X4 + 32.65X5 +28.37X6 - 6.40X1X2 + 17.36X1X3 + 6.73X1X4 + 0.68X1X5 – 12.36X1X6 – 23.80X2X3– 7.90X2X4 – 10.24X2X5 – 34.96 X2X6 + 15.34X3X4 +14.48X3X5 +38.20X3X6 – 8.98 X4X5 - 27.70X4X6 - 10..08X5X6 **(22)**

4.4.SCHEFFE'S (6,2) MODEL RESPONSES FOR THE CONCRETE MIXTUREAT CONTROL POINTS

By substituting the pseudo mix ratio of points c_1, c_2, c_3, c_4, c_5, ……..c_{56} of Table 2 into Eqn.(22) , we obtain the second degree model responses for the control points .

4.5VALIDATION AND TEST OF ADEQUACY OF THE SCHEFFE'S (6,2) MODEL

In this session, the test of adequacy isperformed to check if there is any significant difference between the compressive strength results (lab responses) given in Table 4 and model responses from the control points based on Eqn.(22). Here, the Student's – T - test is adopted as the means of validating the Scheffe's Model. The procedures for using the Student's – T - test have been explained by Nwachukwu and others (2022 c). The result of the test shows that there is no significant difference between the experimental results and model responses.Therefore, the model isvery adequate for predicting the compressive strength of the present CPA-RSA Concrete Mixture based on Scheffe's(6,2) lattice.

4.6. DISCUSSION OF RESULTS

The Optimum attainable compressive strength of the CPA-RHA Concrete Mixture based on Scheffe's (6,2) lattice is 39.77MPa . This corresponds to mix ratio of 1.4:1.0:0.8:0.8:4.0:4.5 for Water/Cement Ratio, Cement, CPA, RSA, FineAggregate and Coarse Aggregate respectively.Similarly, the lowestcompressive strength was found to be 25.33MPa which also correspond to the mix ratio of 1.8:1.0:0.8:0.8:3.4.8 for Water/Cement Ratio, Cement, CPA, RSA, FineAggregate and coarse Aggregate respectively. The maximum value from the model wasfound to be greater than the minimum value specified by the American Concrete Institute for the compressive strength of good concrete and also minimum standard (of 4500psi or 30.75MPa) specified by the American Society of Testing and Machine, ASTM C 39 and ASTM C 469.Subsequently, using the model, all compressive strength of all points (1 - 56)in the simplex can be evaluated based on Scheffe'sSecond Degree Model**.**

5.CONCLUSION

So far, Scheffe's Second Degree Optimization Model, for six component mixtures, Scheffe's (6,2) has been presented . The Scheffe's Method was used to predict the mix proportionsas well as a model for predicting the compressive strength of the CPA-RHA Concrete mixture. By using Scheffe's (6,2) simplex model, the values of the compressive strength were obtained at all 21 points.The result of thestudent's t-test confirmedthat thereis a good correlation between the strengths predicted by the models and the corresponding experimentally observed results. The optimumattainable compressive strengthpredicted by the Scheffe's (6,2) model based onScheffe's (6,2) model was 39.77MPa. As expected, the maximum value meet the minimum standard requirement (of 20MPa and 30.75MPa) stipulated by American Concrete Institute (ACI) andAmerican Society of Testing and Machine, ASTM C 39 and ASTM C 469 respectively, for the compressive strength of good concrete.Thus, with the Scheffe's (6,2) model, any desired strength, given any mix proportions can be easily predicted and evaluated and vice versa.By the utilization of thisScheffe's optimization model,the problem of having to gothrough vigorous, time-consuming and laborious mixture design procedures to obtain the desired strength has been reduced to the barest minimum. Finally, it can be deduced that the RHA and CPA compositions that should have posed as a menace to the environment is now being utilized as a substantial cement part replacements with capacities of increasing the concrete's compressive strength.

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