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Investigation of Compressive Strength Property of PSA-SSA-Cement Concrete (PSCC) Using Scheffe's (6,2) Model

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ABSTRACT

In the move to encourage the incorporation of more innovative environmental friendly less expensive binders in the partial replacement of cement conventional raw materials in cement production, this work takes a look at the use of Periwinkle Shells Ash (PSA) and Snail Shells Ash (SSA). This research work is therefore aimed at applying Scheffe's (6, 2) Model to optimize the Compressive Strength of PSCC. PSCC is a concrete mixture where cement is partially replaced with PSA and SSA in other to reduce the cost of cement production for the general interest of the world populace, in line with safety and economic satisfaction. In this work, only 60 per cent (%) of cement is replaced with the mix proportion of PSA- SSA kept in 50% - 50% ratio. Using Scheffe's (6, 2) simplex model, the Compressive Strength of PSCC were obtained for different twenty- one mix proportions at the initial experimental test points [IETP]. Twenty- one control experiments were also carried out and the compressive strength at the experimental (control) test points [ECTP] determined. By using the Student's t-test statistics, the adequacy of the model was validated .The 28th day optimum (Maximum) compressive strength of PSCC is 31.06 MPa . The maximum value is higher than the minimum value specified by the American Concrete Institute (ACI), as 20 MPa for good concrete as well as the minimum required value specified by ASTM C 469 and ASTM C 39 as 30.75 for high performance concrete. Thus, the PSCC compressive strength value based on Scheffe's Second model can sustain construction of light-weight and some heavy–weight structures still maintaining economic, aesthetic, safety and environmentally friendly advantages.

Keywords: PSCC, PSA, SSA, Scheffe's (6, 2) Optimization Model, Compressive Strength, Mixture Design, Mix Ratio, Polynomial/Mathematical/Regression Model.

1.INTRODUCTION

By simple arithmetic, the Cement Cost Factor (CECF) constitutes almost 50 per cent of the Concrete Cost Factor (CCF), which in turn constitutes almost 50 % of the Overall Building Cost Factor (OBCF). This means that any increase in the cost of bag of cement will definitely affect man's propensity to own a house. In the quest to proffer solution to the increasing cost of cement, researchers across the globe have been on the lookout on how the conventional raw materials of cement can be partially replaced in the cement production. This work is an attempt to investigate the compressive strength property of PSCC mixture so as to be in a better stead to give more information to the cement manufacturing industry. Cement is a very important construction material, which according to Ishaya and others (2016), is described as the widely used construction material globally.

According to Oyenuga (2008), concrete is a composite inert material comprising of a binder course (cement), mineral filter or aggregates and water. It is a homogeneous mixture of cement, sand, gravel and water and is very strong in carrying compressive forces. Thus, according to Syal and Goel (2007), the concrete' capacity to carry compressive forces has made it to gain increasing importance as building materials throughout the world Again, according to Neville (1990), concrete 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. But on the other hand, 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 in the tune of economic realities, especially through consideration of partial replacement of its cement component with inexpensive binders. Recent researches have shown that both PSA and SSA as less expensive and environmentally friendly binders contain very high quantity of calcium carbonate ($CaCO_3$) when calcinated at suitable high temperatures and can partially replace cement with utmost promising results in terms of high quality concrete production. The use of PSA and SSA can improve both the economic and safety criterion of cement and henceforth the PSCC mixture due to the outstanding qualities and inherent properties both possess, especially the compressive strength property. The special property of PSCC to be investigated in this present study is the concrete's compressive strength. By definition, the compressive strength of concrete is the strength of hardened concrete measured by the compression test or the Universal Testing Machine (UTM). It is also a measure of the concrete's ability to resist loads which tend to compress it. It is measured by crushing concrete cubes in a UTM. Further, the compressive strength of the concrete cube test also provides an idea about all the characteristics of concrete under investigation.

For greater efficiency, optimization method is adopted here for the mixture design of concrete made with cement that is partially replaced with PSA and SSA. An optimization problem is one , that is 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. In line with construction works, 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. According to Shacklock (1974), one of the objectives of mix design is to determine the most appropriate proportions in which to use the component materials to meet the needs of construction work. Another definition by Jackson and Dhir (1996) saw concrete mix design 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, placing the concrete and of the site supervision as well as the mix design methods. Thus, the empirical procedures as proposed by Hughes (1971), ACI- 211(1994) and DOE (1988) seems to be more complex and time consuming as they involve a lot of trial mixes and complex statistical calculations before the desired strength of the concrete can be reached. Therefore, optimization of the concrete mixture design still remains the fastest method, best option, most convenient and the most efficient way of selecting concrete mix proportions for better efficiency and better performance of concrete when compared with usual empirical methods as listed above. An example of optimization model is Scheffe's Optimization Model which could be in the form of Scheffe's Second Degree Model or Scheffe's Third Degree Model. Thus, in this present study, Scheffe's Second Degree Model for six components mixtures (namely, water, cement, PSA, SSA, fine aggregate and coarse aggregate) will be in focus.

This present study examines the application of Scheffe's Second Degree Model for six component mixture, Scheffe's (6, 2) in the optimization of the Compressive Strength of PSCC. Of all the researches related to the subject matter that have been carried out, none has been able to address it sufficiently. For example, in the area of SS and SSA application in the construction industry, Adeala and Olaoye (2019) investigated the Structural Properties Of Snail Shell Ash Concrete (SSAC). Zaid and Ghorpade (2014) carried out an Experimental Investigation of Snail Shell Ash (SSA) as Partial Replacement of Ordinary Portland Cement in Concrete. Alla and Asadi (2022) carried out an Experimental investigation and microstructural behaviour of un-calcined and calcined snail shell powder cement mortar. Alla and Asadi (2021) examined the Mechanical Strength, Durability and Microstructure in an Experimental Investigation of Snail Shell-Based Cement Mortar and Nnochiri and others (2018) investigated the Effects Of Snail Shell Ash On Lime Stabilized Lateritic Soil**.** On Periwinkle Shells (PS), PSA, and other Mollusks Shells works, Agbede and Manasseh (2009) investigated the suitability of periwinkle shell as partial replacement for river gravel in concrete. Bamigboye and others (2021) investigated the prospects and challenges pertaining to the sustainable use of seashells as binder in concrete production. Peceno and others (2019) investigated the substitution of coarse aggregates with mollusc-shells waste in acoustic-absorbing concrete. Adewuyi and others (2015) examined the utilization of mollusc shells for concrete production for sustainable environment. Mohammad and other (2017) carried out a review on seashells ash as partial cement replacement. Gonzalez and others (2015) investigated the effects of seashell aggregates in concrete properties. Oyedepoo (2016) examined the evaluation of the properties of lightweight concrete using periwinkle shells as a partial replacement for coarse aggregate. Gigante and others (2020) investigated the evaluation of mussel shells powder as reinforcement for PLA-based biocomposites. Melo and others (2019) carried out an extensive work on high- density polyethylene/mollusc shell –waste composites, effects of particle size and coupling agent on morphology, mechanical and thermal properties. Elamah and others (2021) accessed the strength characterization of periwinkle polymer concrete. Soneye and others (2016) carried out a research on the study of periwinkle shells as fine and course aggregate in concrete works. Abdullah and Sara (2015) carried out an assessment of periwinkle shells ash as composite materials for particle board production . Offiong and Akpan (2017) carried out an assessment of physico-chemical properties of periwinkle shell ash as partial replacement for cement in concrete. On works done on Flexural Strength (FS) and Split Tensile Strength (STS) as well as on the application of optimization in concrete mixtures, recent works have shown that many works have been done on FS and STS and many researchers have used Scheffe's method to carry out one form of optimization work or the other. For instance, Nwakonobi and Osadebe (2008) applied Scheffe's model to optimize the mix proportion of Clay- Rice Husk Cement Mixture for Animal Building. Egamana and Sule (2017) carried out an optimization work on the compressive strength of periwinkle shell aggregate concrete. Ezeh and Ibearugbulem (2009) made use of 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. Furthermore, Ezeh and others (2010b) optimized the aggregate composition of laterite/ sand hollow block using Scheffe's simplex method. The works of Ibearugbulem (2006) and Okere (2006) were based on the application of Scheffe' 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 and applied mathematical model to optimize the 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) where comparison was made between second degree model and third degree model. Nwachukwu and others (2017) developed and applied Scheffe's Second Degree Polynomial model to optimize the compressive strength of Glass Fibre Reinforced Concrete (GFRC). Again, Nwachukwu and others (2022a) developed and used Scheffe'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). 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) used Scheffe's (5,2) mathematical model to optimize the compressive strength of Steel Fibre Reinforced Concrete (SFRC). Furthermore, Nwachukwu and others (2022e) used Scheffe'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. Again, Nwachukwu and others (2022g) made use of Scheffe's Third Degree Model to optimize the compressive strength of SFRC. In what is termed as introduction of six component mixture and its Scheffe's formulation ,Nwachukwu and others (2022h) developed and use Scheffe's (6,2) Model to optimize the compressive strength of Hybrid- Polypropylene – Steel Fibre Reinforced Concrete (HPSFRC). Nwachukwu and others (2022 i) applied Scheffe's (6,2) model to optimize the Compressive Strength of Concrete Made With Partial Replacement Of Cement With Cassava Peel Ash (CPA) and Rice Husk Ash (RHA). Nwachukwu and others (2022j) applied Scheffe's (6, 2) model in the Optimization of Compressive Strength of Hybrid Polypropylene – Nylon Fibre Reinforced Concrete (HPNFRC) . Nwachukwu and others (2022k) applied Scheffe's Second Degree Polynomial Model to optimize the compressive strength of Mussel Shell Fibre Reinforced Concrete (MSFRC). Nwachukwu and others (2022 l) carried out an optimization Of Compressive Strength of Concrete Made With Partial Replacement Of Cement With Periwinkle Shells Ash (PSA) Using Scheffe's Second Degree Model. Nwachukwu and others (2023a) applied Scheffe's Third Degree Regression Model to optimize the compressive strength of Hybrid- Polypropylene- Steel Fibre Reinforced Concrete (HPSFRC). Nwachukwu and others (2023b) applied Scheffe's (6,3) Model in the Optimization Of Compressive Strength of Concrete Made With Partial Replacement Of Cement With Cassava Peel Ash (CPA) and Rice Husk Ash (RHA)**.** In the work of Nwachukwu and others (2023c), titled Need For Effective Evaluation Of Water Resources Qualities For Sustenance And Attainment Of Construction (Engineering) Development Goals, flexural and split tensile strengths from groundwater sources were determined in other to determine the effectiveness of these water resources in construction works. Nwachukwu and others (2023d) applied the use of Scheffe's Second Degree Model In The Optimization Of Compressive Strength Of Asbestos Fibre Reinforced Concrete (AFRC). Nwachukwu and others (2023e) used optimization techniques in the Flexural Strength And Split Tensile Strength determination of Hybrid Polypropylene - Steel Fibre Reinforced Concrete (HPSFRC). Nwachukwu and others (2023f) applied Scheffe's Optimization model in the evaluation of Flexural Strength And Split Tensile Strength Of Plastic Fibre Reinforced Concrete (PLFRC). Nwachukwu and H.E. Opara (2023) in the their paper presented at the Conference Proceedings of the Nigeria Society of Engineers, demonstrated the use of Snail Shells Ash (SSA) in the partial replacement of cement using Scheffe's (5,2) optimization model. Finally, Nwachukwu and others (2024) applied the use of Scheffe's (6,2) model to evaluate the optimum flexural and split tensile strengths of Periwinkle Shells Ash (PSA)- Mussel Shells Ash (MSA)- Cement Concrete (PMCC). Based on the works reviewed so far, it appears that the subject matter has not been fully addressed as it can be envisaged that no work has been done on the use of Scheffe's (6,2) Model to optimize the Compressive Strength of PSCC. Henceforth, the need for this present research work**.**

2. METHODOLOGY

2.1 MATERIALS FOR PSCC MIXTURES

In this present research work, the component materials under investigation in line with Scheffe's (6, 2) model are Water/Cement ratio, Cement, PSA, SSA, Fine and Coarse Aggregates. The water is procured from potable water clean water source and was applied in accordance with ASTM C1602/C1602M-22 (2022). The cement is Dangote cement, a brand of Ordinary Portland Cement obtained from local distributors, which conforms to British Standard Institution BS 12 (1978). Fine aggregate of sizes that range from 0.05 - 4.5mm was purchased from the local river. Crushed granite as a coarse aggregate of 20mm size was purchased from a local stone market and was later downgraded to 4.75mm. As a matter of facts, both fine and coarse aggregates were procured and prepared in accordance with ASTM C33/C33M-18 (2018). The PS and SS used in this work were procured as a waste in an aquaculture industry and were washed and sundried for few days. After sufficient drying, the PS and SS were then calcined in a Gallenkamp Muffle Furnace at about 400^0C. The calcined PS and SS samples were allowed to cool in a deciccator and then grinded into very fine powder ,otherwise described as PSA and SSA respectively using a ceramic mortar and pestle. The resulted PSA and SSA were later sieved through a BS sieve of 75 microns and kept in air tight container for use in the PSCC mixtures.

2.2. BACKGROUND INFORMATION ON PSCC SCHEFFE'S (6,2) OPTIMIZATION THEORY

A simplex lattice is a structural representation of lines joining the atoms of a particular mixture and these atoms are constituent components of that same mixture. For instance, for the present PSCC mixture, the constituent elements are the following six components: water, cement, PSA, SSA, fine aggregate and coarse aggregate. It should be noted that mixture components, according to Obam (2009) are subject to the constraint that the sum of all the components must be equal to 1 as stated in Eqn.(1):

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

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

2.2.1. EVALUATION OF POSSIBLE DESIGN POINTS FOR PSCC SCHEFFE'S (6, 2) MIXTURES

As stated by Aggarwal (2002), the Scheffe's (q, m) simplex lattice design is characterized by the symmetric arrangements of points within the experimental region and a well-chosen regression equation to represent the response surface over the entire simplex region. It can be recalled that 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. All possible mixture with these component proportions are used, and m is Scheffe's polynomial degree, which is 2 in this present study .For example a (3, 2) lattice consists of $^{3+2-1}C_2$ i.e. $^4C_2 = 6$ 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: $(1, 0, 0), (0, 1, 0), (0, 0, 1), \left(\frac{1}{2}, \frac{1}{2}, 0\right), \left(0, \frac{1}{2}, \frac{1}{2}\right), \left(\frac{1}{2}, 0, \frac{1}{2}\right)$. In order to evaluate the number of coefficients or terms or design points required for a given lattice, the following general formula is adopted:

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

Where k = number of coefficients/ terms / design points, q = number of components/mixtures = 6 in this present study and m = number of degree of polynomial = 2 in this present work. Using either of Eqn. (2), $k_{(6,2)} = 21$. Thus, the possible design points for PSCC Scheffe's (6,2) lattice can be stated in Eqn.(3) :

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) stated under:

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

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. For this present work, the property under investigation is the Compressive Strength (N). This research work is based on the Scheffe's (6, 2) simplex, but the actual form of Eqn. (4) for six component mixture , degree two has been developed by Nwachukwu and others (2022h) and thus will be applied subsequently.

2.2.2. PSEUDO AND ACTUAL COMPONENTS IN PSCC SCHEFFE'S (6,2) MIX DESIGN

The relationship between the actual components and the pseudo components in Scheffe's mix design, has been established as :

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

where Z is the actual component; X is the pseudo component and A is the coefficient of the relationship

Re-arranging Eqn. (5) gives: $X = A^{-1} * Z$ **(6)**

2.2.3.FORMULATION OF POLYNOMIAL EQUATION FOR PSCC SCHEFFE'S (6, 2) LATTICE

The polynomial equation by Scheffe (1958), which is also known as response is given in Eqn.(4). But Eqn.(4) has been developed by Nwachukwu and others (2022h) to accommodate six component mixture for Scheffe's second degree model .Hence, the Simplified version of PSCC Scheffe's (6,2) simplex lattice based on Eqn.(4) is shown in Eqn.(7):

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

2.2.4. COEFFICIENTS DETERMINATION OF THE PSCC SCHEFFE'S (6, 2) POLYNOMIAL

From the work of Nwachukwu and others (2022h), the coefficients of the Scheffe's (6, 2) polynomial are expressed as 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)**

$\beta_{36} = 4N_{36} - 2N_3 - 2N_6$; $\beta_{45} = 4N_{45} - 2N_4 - 2N_5$, $\beta_{46} = 4N_{46} - 2N_4 - 2N_6$; $\beta_{56} = 4N_{56} - 2N_{35} - 2N_6$; **12(a-d)**

Where N_i = Response Function (or Compressive Strength in this present work) for the pure component, i

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

By substituting Eqns. (8) - (12) into Eqn. (7), we obtain the mixture design model for the PSCC Scheffe's (6,2) lattice.

2.2.6 EVALUATION OF THE PSEUDO AND ACTUAL MIX RATIOS FOR THE PSCC SCHEFFE'S (6, 2) DESIGN LATTICE AT INITIAL EXPERIMENTAL TEST POINTS AND CONTROL POINTS.

A. AT THE PSCC INITIAL EXPERIMENTAL TEST POINTS [IETP]

Using the concrete conventional mix ratio, we usually have mix ratios in the form of 1:2:4 or 1:3:6. However this conventional nomenclature is impossible to actualize in the Scheffes optimization mixture because of the requirement of simplex lattice design based on Eqn. (1) criteria 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 Eqn. (1) criterium. Based on experience and knowledge from a typical Scheffe's (4,2) work as well as previous knowledge from literature, the following arbitrary prescribed mix ratios are chosen for the five vertices of Scheffe's (4,2) lattice. They are as follows: A_1 (0.67:1:1.7:2.0); A_2 (0.56:1:1.6:1.8); A_3 (0.5:1:1.2:1.7); A_4 (0.7:1:1:1.8); A_5 (0.75:1:1.3:1.2), and A_6 (0.80:1:1.3:1.2) **(13a)**

From Eqn.(13a), the mix ratios represents water/cement ratio, cement, fine aggregate and coarse aggregate respectively. Now, for the present PSCC Scheffe's (6,2) mixture, where 60 % of cement is replaced with PSA and SSA where the mix proportion of PSA- SSA was in 50% - 50% ratio, the following mix ratio can be formulated from Eqn.(13a) to give Eqn.(13b).

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: 0.4:0.3:0.3:1.0:1.8); A_5 (0.75: 0.4:0.3:0.3:1.3:1.2), and A_6 (0.80: 0.4:0.3:0.3:1.3:1.2) **(13b)**

For the pseudo mix ratio, the following corresponding mix ratios, which conform to Eqn.(1), at the vertices for six component mixtures are always chosen: The rest are listed in Eqn.(3).

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) and A_6(0:0:0:0:0:1) **(14)**

For the transformation of the actual component, Z to pseudo component, X, and vice versa, Eqns. (5) and (6) are applied. By substituting the mix ratios from point A_1 into Eqn. (5), we obtain:

$$\begin{pmatrix} 0.67 \\ 0.40 \\ 0.30 \\ 0.30 \\ 1.70 \\ 2.00 \end{pmatrix} = \begin{pmatrix} A_{11} & A_{12} & A_{13} & A_{14} & A_{15} & A_{16} \\ A_{21} & A_{22} & A_{23} & A_{24} & A_{25} & A_{26} \\ A_{31} & A_{32} & A_{33} & A_{34} & A_{35} & A_{36} \\ A_{41} & A_{42} & A_{43} & A_{44} & A_{45} & A_{46} \\ A_{51} & A_{52} & A_{53} & A_{54} & A_{55} & A_{56} \\ A_{61} & A_{62} & A_{63} & A_{64} & A_{65} & A_{66} \end{pmatrix} \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} \qquad \textbf{(15)}$$

Transforming the R.H.S matrix and solving, we obtain as follows: A_{11}= 0.67; A_{21}= 0.4; A_{31}= 0.3; A_{41}= 0.3; A_{51}= 1.7; A_{61}= 2.0. The same approach is used in obtaining the remaining values as shown in Eqn. (16).

$$\begin{pmatrix} Z_1 \\ Z_2 \\ Z_3 \\ Z_4 \\ Z_5 \\ Z_6 \end{pmatrix} = \begin{pmatrix} 0.67 & 0.56 & 0.50 & 0.70 & 0.75 & 0.80 \\ 0.40 & 0.40 & 0.40 & 0.40 & 0.40 & 0.40 \\ 0.30 & 0.30 & 0.30 & 0.30 & 0.30 & 0.30 \\ 0.30 & 0.30 & 0.30 & 0.30 & 0.30 & 0.30 \\ 1.70 & 1.60 & 1.20 & 1.00 & 1.30 & 1.30 \\ 2.00 & 1.80 & 1.70 & 1.80 & 1.20 & 1.20 \end{pmatrix} \begin{pmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \\ X_6 \end{pmatrix} \qquad \textbf{(16)}$$

Considering mix ratios at the mid points from Eqn.(3) and substituting these pseudo mix ratios in turn into Eqn.(16) yields the corresponding actual mix ratios as follows: At point A_{12} we have: A_{12} (0.67, 0.33, 0, 0, 0, 0). Then substituting Eqn.(16), we have:

$Z_1 = 0.63$; $Z_2 = 0.40$; $Z_3 = 0.30$' $Z_4 = 0.30$; $Z_5 = 1.00$ and $Z_6 = 1.93$. **(17)**

The same approach goes for the remaining mid-point mix ratios. Hence, in order to generate the twenty-one coefficients, twenty-one (21) experimental tests was carried out and the corresponding mix ratios are as displayed in Table 1.

Table 1: Pseudo (X) and Actual (Z) Mix Ratio For PSCC Based On Scheffe's (6,2) Lattice For IETP

S/N	**IETP**	**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	E_I	1	0	0	0	0	0	N_1	0.67	0.40	0.30	0.30	1.70	2.00
2	E_2	0	1	0	0	0	0	N_2	0.56	0.40	0.30	0.30	1.60	1.80
3	E_3	0	0	1	0	0	0	N_3	0.50	0.40	0.30	0.30	1.20	1.70
4	E_4	0	0	0	1	0	0	N_4	0.70	0.40	0.30	0.30	1.00	1.80

5	E_5	0	0	0	0	1	0	N_5	0.75	0.40	0.30	0.30	1.30	1.20
6	E_6	0	0	0	0	0	1	N_6	0.80	0.40	0.30	0.30	1.30	1.20
7	E_{12}	0.67	033	0	0	0	0	N_{12}	0.63	0.40	0.30	0.30	1.00	1.93
8	E_{I3}	0.67	0	0.33	0	0	0	N_{13}	0.61	0.40	0.30	0.30	1.54	1.90
9	E_{I4}	0.67	0	0	0.33	0	0	N_{14}	0.68	0.40	0.30	0.30	1.47	1.93
10	E_{I5}	0.67	0	0	0	0.33	0	N_{15}	0.70	0.40	0.30	0.30	1.57	1.74
11	E_{I6}	0.67	0	0	0	0	0.33	N_{16}	0.71	0.40	0.30	0.30	1.57	1.74
12	E_{23}	0	0.50	0.50	0	0	0	N_{23}	0.53	0.40	0.30	0.30	1.40	1.75
13	E_{24}	0	0.50	0	0.50	0	0	N_{24}	1.41	0.40	0.30	0.30	1.30	1.80
14	E_{25}	0	0.50	0	0	0.50	0	N_{25}	0.66	0.40	0.30	0.30	1.45	1.50
15	E_{26}	0	0.50	0	0	0	0.50	N_{26}	0.68	0.40	0.30	0.30	1.50	1.50
16	E_{34}	0.50	0.50	0	0	0	0	N_{34}	0.62	0.40	0.30	0.30	1.65	1.90
17	E_{35}	0.50	0	0.50	0	0	0	N_{35}	0.59	0.40	0.30	0.30	1.45	1.85
18	E_{36}	0.50	0	0	0.50	0	0	N_{36}	0.69	0.40	0.30	0.30	1.35	1.90
19	E_{45}	0.50	0	0	0	0.50	0	N_{45}	0.71	0.40	0.30	0.30	1.50	1.60
20	E_{46}	0.50	0	0	0	0	0.50	N_{46}	0.74	0.40	0.30	0.30	1.50	1.60
21	E_{56}	0	0	0.50	0.50	0	0	N_{56}	0.60	0.40	0.30	0.30	1.10	1.75

B. AT THE PSCC EXPERIMENTAL (CONTROL) TEST POINTS [ECTP]

Here, twenty- one (21) different control mix ratios were predicted and listed in Table 2, which according to Scheffe's (1958), their summation should not be greater than one. The same approach for component transformation adopted for the IETP are also adopted for the ECTP and the results are shown in Table 2.

Table 2:Actual & Pseudo Component Of PSCC Based On Scheffe 's (6,2) Lattice For ECTP

S/N	**ECTP**	**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	C_1	0.25	0.25	0.25	0.25	0	0	N_1	0.61	0.40	0.30	0.30	1.38	1.83
2	C_2	0.25	0.25	0.25	0	0.25	0	N_2	0.62	0.40	0.30	0.30	1.45	1.68
3	C_3	0.25	0.25	0	0.25	0.25	0	N_3	0.67	0.40	0.30	0.30	1.40	1.70
4	C_4	0.25	0	0.25	0.25	0.25	0	N_4	0.66	0.40	0.30	0.30	1.30	1.68
5	C_5	0	0.25	0.25	0.25	0.25	0	N_5	0.63	0.40	0.30	0.30	1.28	1.63
6	C_6	0.20	0.20	0.20	0.20	0.20	0	N_6	0.64	0.40	0.30	0.30	1.36	1.70
7	C_{12}	0.30	0.30	0.30	0.10	0	0	N_{12}	0.59	0.40	0.30	0.30	1.45	1.83
8	C_{13}	0.30	0.30	0.30	0	0.10	0	N_{13}	0.59	0.40	0.30	0.30	1.48	1.77
9	C_{14}	0.30	0.30	0	0.30	0.10	0	N_{14}	0.65	0.40	0.30	0.30	1.42	1.80
10	C_{15}	0.30	0	0.30	0.30	0.10	0	N_{15}	0.64	0.40	0.30	0.30	1.30	1.77
11	C_{16}	0	0.30	0.30	0.30	0.10	0	N_{16}	0.60	0.40	0.30	0.30	1.27	1.71
12	C_{23}	0.10	0.30	0.30	0.30	0	0	N_{23}	0.60	0.40	0.30	0.30	1.31	1.79

13	C_{24}	0.30	0.10	0.30	0.30	0	0	N_{24}	0.62	0.40	0.30	0.30	1.33	1.83
14	C_{25}	0.30	0.10	0.30	0.30	0	0	N_{25}	0.63	0.40	0.30	0.30	1.41	1.85
15	C_{26}	0.10	0.20	0.30	0.40	0	0	N_{26}	0.61	0.40	0.30	0.30	1.25	1.79
16	C_{34}	0.30	0.20	0.10	0.40	0	0	N_{34}	0.64	0.40	0.30	0.30	1.35	1.85
17	C_{35}	0.20	0.20	0.10	0.10	0.40	0	N_{35}	1.40	0.40	0.30	0.30	1.04	1.59
18	C_{36}	0.30	0.10	0.30	0.20	0.10	0	N_{36}	0.62	0.40	0.30	0.30	1.36	1.77
19	C_{45}	0.25	0.25	0.15	0.15	0.20	0	N_{45}	0.61	0.40	0.30	0.30	1.51	3.16
20	C_{46}	0.30	0.30	0.20	0.10	0.10	0	N_{46}	0.68	0.40	0.30	0.30	1.56	1.96
21	C_{56}	0.10	0.30	0.30	0.30	0	0	N_{56}	1.30	0.40	0.30	0.30	1.31	1.79

2.2.7. MEASUREMENT OF QUANTITIES OF PSCC MATERIALS IN THE LABORATORY

The actual components as obtained from Tables 1 and 2 were used to measure out the quantities of Water/Cement Ratio (Z_1), Cement (Z_2), PSA (Z_3), SSA (Z_4), Fine Aggregate (Z_5) and Course Aggregate (Z_6) using a weighing balance of 50kg capacity in their respective ratios for the Concrete Cube Strengths test at the laboratory.

Mathematically, from the works of Nwachukwu and others (2024), Measured Quantity, M^Q of PSCC Mixture is given by Eqn.(18)

$$M^Q = \frac{X}{T} * Y \qquad \textbf{(18)}$$

Where, X = Individual mix ratio at each test point = 0.67 for Z_1 at E_1 in Table 1, for example.

T = Sum of mix ratios at each test point = 5.37 at E_1 in Table 1, for example

And Y = Average weight of Concrete cube/beam/cylinder

For the Compressive Strength concrete cube mould of 15cm*15cm*15cm, Average Y from experience = 8kg

For the mix ratios at IETP of Table 1, the measured quantities are displayed in Table 3.

Table 3: Measured Quantities Of PSCC Materials In The Laboratory At IETP

S/N	**IETP**	**ACTUAL MIX RATIOS**						**MEASURED QUANTITY OF PSCC IN THE LABORATORY [Kg] FOR COMPRESSIVE STRENGHT TEST**					
		Z_1	Z_2	Z_3	Z_4	Z_5	Z_6	Z_1	Z_2	Z_3	Z_4	Z_5	Z_6
1	E_I	0.67	0.40	0.30	0.30	1.70	2.00	1.0	0.6	0.5	0.5	2.5	3.0
2	E_2	0.56	0.40	0.30	0.30	1.60	1.80	0.9	0.6	0.5	0.5	2.6	2.9
3	E_3	0.50	0.40	0.30	0.30	1.20	1.70	0.9	0.7	0.6	0.6	2.2	3.1
4	E_4	0.70	0.40	0.30	0.30	1.00	1.80	1.2	0.7	0.5	0.5	1.8	3.2
5	E_5	0.75	0.40	0.30	0.30	1.30	1.20	1.4	0.8	0.6	0.6	2.4	2.3
6	E_6	0.80	0.40	0.30	0.30	1.30	1.20	1.5	0.7	0.6	0.6	2.4	2.2
7	E_{12}	0.63	0.40	0.30	0.30	1.00	1.93	1.1	0.7	0.5	0.5	1.8	3.4
8	E_{I3}	0.61	0.40	0.30	0.30	1.54	1.90	1.0	0.6	0.5	0.5	2.4	3.0
9	E_{I4}	0.68	0.40	0.30	0.30	1.47	1.93	1.1	0.6	0.5	0.5	2.3	3.0
10	E_{I5}	0.70	0.40	0.30	0.30	1.57	1.74	1.1	0.6	0.5	0.5	2.5	2.8
11	E_{I6}	0.71	0.40	0.30	0.30	1.57	1.74	1.1	0.6	0.5	0.5	2.5	2.8
12	E_{23}	0.53	0.40	0.30	0.30	1.40	1.75	0.9	0.7	0.5	0.5	2.4	3.0
13	E_{24}	1.41	0.40	0.30	0.30	1.30	1.80	2.0	0.6	0.4	0.4	1.9	2.6

14	E_{25}	0.66	0.40	0.30	0.30	1.45	1.50	1.1	0.7	0.5	0.5	2.5	2.6
15	E_{26}	0.68	0.40	0.30	0.30	1.50	1.50	1.2	0.7	0.5	0.5	2.5	2.6
16	E_{34}	0.62	0.40	0.30	0.30	1.65	1.90	1.0	0.6	0.5	0.5	2.6	3.0
17	E_{35}	0.59	0.40	0.30	0.30	1.45	1.85	1.0	0.7	0.5	0.5	2.4	3.0
18	E_{36}	0.69	0.40	0.30	0.30	1.35	1.90	1.1	0.6	0.5	0.5	2.2	3.1
19	E_{45}	0.71	0.40	0.30	0.30	1.50	1.60	1.2	0.7	0.5	0.5	2.5	2.6
20	E_{46}	0.74	0.40	0.30	0.30	1.50	1.60	1.2	0.7	0.5	0.5	2.5	2.6
21	E_{56}	0.60	0.40	0.30	0.30	1.10	1.75	1.1	0.7	0.5	0.5	2.9	2.2

The same approach was used for the measured quantities at the ECTP.

2.3. METHOD

2.3.1. PSCC SPECIMEN PREPARATION / BATCHING/ CURING FOR COMPRESSIVE STRENGHT TEST

The specimen used for the compressive strength is concrete cube. They were cast in steel mould measuring 15cm*15cm*15cm. As usual, 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. The measured actual quantities of PSCC are as shown in Table 3. For the twenty one experimental tests, a total number of 42 mix ratios were to be used to produce 84 PSCC prototype concrete cubes. Twenty one, 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 28 days of curing the specimens were taken out of the curing tank for the PSCC compressive strength test.

2.3.2. PSCC COMPRESSIVE STRENGTH TEST PROCEDURE/CALCULATION

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. Two samples were crushed for each mix ratio and in each case, the compressive strength was calculated using Eqn.(19)

$$\text{Compressive Strength (MPa)} = \frac{\text{Average failure Load,P}}{\text{Cross- sectional Area, A}} \qquad \textbf{(19)}$$

3. RESULTS PRESENTATION AND DISCUSSION

3.1.PSCC RESPONSES FOR THE INITIAL EXPERIMENTAL TESTS POINTS [IETP] AND EXPERIMENTAL (CONTROL) TEST POINTS [ECTP].

The results of the compressive strength ($R_{esponse,}$ N_i) of PSCC based on a 28-days strength is presented in Table 4. The initial experimental test responses are calculated from Eqn..(19)

Table 4: 28th Day Compressive Strength (Responses) Test Results for PSCC Based on Scheffe's (6, 2) Model for the IETP and ECTP.

S/N	**POINTS**		**EXPT. NO.**		**RESPONSES [MPa]**		**RESPONSE SYMBOL**	**AVERAGE RESPONSE [MPa]**	
	IETP	**ECTP**	**IETP**	**ECTP**	**AT IETP**	**AT ECTP**		**AT IETP**	**AT ECTP**
1	E_I	C_1	PSCC/ E_I A	PSCC/ C_I A	**28.32**	**31.02**	N_1	**28.99**	**30.24**
			PSCC/ E_I B	PSCC/ C_I B	**29.65**	**29.45**			

2	E_2	C_2	PSCC/ E_2 A	PSCC/ C_2 A	**30.00**	**29.34**	N_2	**30.06**	**28.62**
			PSCC/ E_2 B	PSCC/ C_2 B	**30.12**	**27.89**			
3	E_3	C_3	PSCC/ E_3 A	PSCC/ C_3 A	**26.13**	**28.89**	N_3	**26.48**	**28.56**
			PSCC/ E_3 B	PSCC/ C_3 B	**26.82**	**28.23**			
4	E_4	C_4	PSCC/ E_4 A	PSCC/ C_4 A	**31.08**	**28.56**	N_4	**31.06**	**28.51**
			PSCC/ E_4 B	PSCC/ C_4 B	**31.04**	**28.45**			
5	E_5	C_5	PSCC/ E_5 A	PSCC/ C_5 A	**19.89**	**28.23**	N_5	**20.53**	**28.23**
			PSCC/ E_5 B	PSCC/ C_5 B	**21.17**	**28.23**			
6	E_6	C_6	PSCC/ E_6 A	PSCC/ C_6 A	**23.45**	**27.21**	N_6	**23.84**	**26.79**
			PSCC/ E_6 B	PSCC/ C_6 B	**24.22**	**26.37**			
7	E_{12}	C_{12}	PSCC/ E_{12} A	PSCC/ C_{12} A	**30.09**	**26.45**	N_{12}	**29.60**	**27.37**
			PSCC/ E_{12} B	PSCC/ C_{12} B	**29.11**	**28.28**			
8	E_{13}	C_{13}	PSCC/ E_{13} A	PSCC/ C_{13} A	**19.77**	**21.23**	N_{13}	**21.00**	**22.29**
			PSCC/ E_{13} B	PSCC/ C_{13} B	**22.23**	**23.34**			
9	E_{14}	C_{14}	PSCC/ E_{14} A	PSCC/ C_{14} A	**29.06**	**25.23**	N_{14}	**28.30**	**25.78**
			PSCC/ E_{14} B	PSCC/ C_{14} B	**27.54**	**26.33**			
10	E_{15}	C_{15}	PSCC/ E_{15} A	PSCC/ C_{15} A	**25.34**	**29.23**	N_{15}	**26.28**	**29.83**
			PSCC/ E_{15} B	PSCC/ C_{15} B	**27.21**	**30.43**			
11	E_{16}	C_{16}	PSCC/ E_{16} A	PSCC/ C_{16} A	**28.32**	**31.34**	N_{16}	**27.89**	**30.34**
			PSCC/ E_{16} B	PSCC/ C_{16} B	**27.45**	**29.34**			
12	E_{23}	C_{23}	PSCC/ E_{23} A	PSCC/ C_{23}A	**17.15**	**19.65**	N_{23}	**17.25**	**19.94**
			PSCC/ E_{23} B	PSCC/C_{23} B	**17.35**	**20.23**			
13	E_{24}	C_{24}	PSCC/ E_{24} A	PSCC/C_{24} A	**18.98**	**25.45**	N_{24}	**19.61**	**26.33**
			PSCC/ E_{24} B	PSCC/C_{24} B	**20.23**	**27.21**			
14	E_{25}	C_{25}	PSCC/ E_{25} A	PSCC/C_{25} A	**29.32**	**27.23**	N_{25}	**29.44**	**27.72**
			PSCC/ E_{25} B	PSCC/C_{25} B	**29.56**	**28.21**			
15	E_{26}	C_{26}	PSCC/ E_{26} A	PSCC/C_{26} A	**24.44**	**24.32**	N_{26}	**25.78**	**25.27**
			PSCC/ E_{26} B	PSCC/C_{26} B	**27.11**	**26.21**			

16	E_{34}	C_{34}	PSCC/ E_{34} A	PSCC/C_{34} A	**25.23**	**23.32**	N_{34}	**25.05**	**23.82**
			PSCC/ E_{34} B	PSCC/C_{34} B	**24.87**	**24.32**			
17	E_{35}	C_{35}	PSCC/ E_{35} A	PSCC/C_{35} A	**27.77**	**28.43**	N_{35}	**27.95**	**27.65**
			PSCC/ E_{35} B	PSCC/C_{35} B	**28.13**	**26.87**			
18	E_{36}	C_{36}	PSCC/ E_{36} A	PSCC/C_{36} A	**28.98**	**27.23**	N_{36}	**28.93**	**27.55**
			PSCC/ E_{36} B	PSCC/C_{36} B	**28.88**	**27.86**			
19	E_{45}	C_{45}	PSCC/ E_{45} A	PSCC/C_{45} A	**21.13**	**28.94**	N_{45}	**21.18**	**27.64**
			PSCC/ E_{45} B	PSCC/C_{45} B	**21.23**	**26.34**			
20	E_{46}	C_{46}	PSCC/ E_{46} A	PSCC/C_{46} A	**23.43**	**27.21**	N_{46}	**23.89**	**27.71**
			PSCC/ E_{46} B	PSCC/C_{46} B	**24.34**	**28.21**			
21	E_{56}	C_{56}	PSCC/ E_{56} A	PSCC/C_{56} A	**27.34**	**29.34**	N_{56}	**27.84**	**29.73**
			PSCC/ E_{56} B	PSCC/C_{56} B	**28.34**	**30.12**			

3.2. SCHEFFE' S (6, 2) POLYNOMIAL MODEL FOR THE PSCC RESPONSES (COMPRESSIVE STRENGHT).

By substituting the values of the responses (compressive strengths) from Table 4 into Eqns.(8) through (12), we obtain the coefficients (β_1, β_2 … …. B_{56}) of the Scheffe's Second degree polynomial for PSCC. Now, substituting the values of these obtained coefficients into Eqn. (7) yields the mixture design model for the optimization of the Compressive Strength, N, of PSCC (at the 28th day) based on Scheffe's (6,2) lattice as stated under:

N = ß1X1 + ß2X2 + ß3X3 + ß4X4 + ß5X5 + ß6X6 + ß12X1X2 +ß13X1X3 + ß14X1X4 + ß15X1X5 + ß16X1X6 +
ß23X2X3 + ß24X2X4 + ß25X2X5 + ß26X2X6 +ß34X3X4+ ß35X3X5+ ß36X3X6 + ß45X4X5 + ß46X4X6
+ß56X5X6 **(20)**

3.3. SCHEFFE'S (6, 2) MODEL RESPONSES (COMPRESSIVE STRENGHT) FOR PSCC AT ECTP.

By substituting the pseudo mix ratio of points C_1, C_2, C_3, C_4, C_5, … C_{56} of Table 2 into the revised Eqn.(20), we obtain the Scheffe's Second degree model responses (compressive strength) for the ECTP of PSCC.

3.4. VALIDATION OF PSCC SCHEFFE'S (6, 2) MODEL RESULTS (FOR COMPRESSIVE STRENGHT) USING STUDENT'S – T - TEST

Here, the test of adequacy is performed in order to determine the degree of closeness between the PSCC compressive strengths results (lab responses at IETP) given in Tables 4 and model responses from the control points based on Session 3.3. By employing the use of the Student's – T – test, the result shows that there are no significant differences between the experimental results and model responses. Therefore, the model results are validated. The procedures involved in using the Student's – T - test have been described by Nwachukwu and others (2022 c). Thus, the models are adequate for determining the compressive strengths of PSCC based on Scheffe's (6,2) simplex lattice.

3.5. RESULTS DISCUSSION

The maximum compressive strength of PSCC based on Scheffe's (6,2) lattice is **31.06** MPa for the 28th day result. Similarly the minimum compressive strength of PSCC based on Scheffe's (6,2) lattice are **17.25** MPa for the 28th day result .The corresponding optimum(maximum) mix ratio is **0.70:0.40:0.30:0.30:1.00:1.80** for Water/Cement Ratio, Cement, PSA, SSA, Fine Aggregate and Coarse Aggregate respectively while the corresponding minimum mix ratios are **0.53:0.40:0.30:0.30:1.40:1.75** for Water/Cement Ratio, Cement, PSA, SSA, Fine Aggregate and Coarse Aggregate respectively.

Thus, the Scheffe's model can be used to determine the PSCC compressive strengths of all 21 points (1 - 56) in the simplex based on Scheffe's Second Degree Model for six component mixtures.

4. CONCLUSION

In this present work, so far the compressive strengths investigation of PSCC using Scheffe's Second Degree Model; Scheffe's (6, 2) has been presented. Firstly, the Scheffe's model was used to predict the mix ratio for evaluating the compressive strengths of PSCC. And secondly, through the use of Scheffe's (6, 2) simplex model, the values of the compressive strengths were determined at all 21 points (1- 56). The result of the student's t-test shows that the strengths predicted by the models and the corresponding experimentally observed results are very close to each other. The maximum and minimum values of the compressive strengths predicted by the model based on Scheffe's (6, 2) model are as stated in the results discussion session. But the maximum value from the model is found to be greater than the minimum value specified by the American Concrete Institute [ACI] 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 for high performance concrete . Thus, with the Scheffe's (6, 2) model, any desired strength of PSCC, given any mix ratio can be easily predicted and evaluated and vice versa. Subsequently, the application of this Scheffe's optimization model has reduced the problem of having to go through vigorous, time-consuming and laborious empirical mixture design procedures in order to obtain the desired design strengths of PSCC mixture based on Scheffe's (6,2) simplex lattice. Again, the use of Scheffe's optimization techniques has not only helped us to reduce the cost of production of cement , but also has helped us to reduce pollution in the environment by allowing provision to the incorporation of these environmentally friendly shells as partial replacement of cement. Stakeholders in the construction industries are therefore advised to cooperate maximally to this innovation, so that housing can be affordable to all and sundry through affordable bags of cements.

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