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Compressive Strength Investigation of PSA – MSA - Cement Concrete [PMCC] Using Kings - Scheffe's (6, 2) Model

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ABSTRACT: Periwinkle Shells [PS] and Mussel Shells [MS] are important innovative construction materials whose ash forms (PSA and MSA respectively) can be combined and used to partially replace cement in both cement and concrete production for both economic and safety exploitation. This research work is therefore aimed at applying Kings-Scheffe's (6, 2) Model to optimize the Compressive Strength of PMCC so as to ascertain the suitability of these innovative materials when partially used to replace cement conventional raw materials in the cement production. PMCC is a concrete mixture where cement is partially replaced with PSA and MSA.

It is important to note that Kings- Scheffe's model is modified Scheffe's model from six components and above.
In this work, only 60 per cent (%) of cement is replaced with the mix proportion of PSA- MSA kept in 50% - 50% ratio. Using Kings-Scheffe's (6, 2) simplex model, the Compressive Strength of PMCC 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] evaluated. By using the Student's t-test statistics, the adequacy of the model was validated .The 28th day optimum compressive strength of PMCC is **30.18 MPa** . This maximum value is higher than the minimum value specified by the American Concrete Institute (ACI), as 20 MPa for good concrete and the same very close to the minimum required value specified by ASTM C 469 and ASTM C 39 as 30.75 for high performance concrete. Thus, the PMCC compressive strength value based on Kings- Scheffe's Second model can sustain construction of light-weight and some heavy–weight structures at the best economic, aesthetic, safety and environmentally friendly advantages.

KEYWORDS: PMCC, PSA, MSA, Kings-Scheffe's (6, 2) Optimization Model, Compressive Strength, Mixture Design, Mix Ratio, Polynomial Model.

I. INTRODUCTION

Due to ever increasing cost of cement and its impact on the actualization of common man's agenda to own a house, the demand for the use of inexpensive environmentally friendly innovative materials like shells have been on the increase. Ordinarily the PS and MS are capable of constituting a menace to the environment, but when they are harnessed appropriately, they can be ultimately used to partially replace cement during cement and concrete production due their high calcium carbonate content. In a nutshell, cement is a very important construction material, which is described as the widely used construction material globally.

As stated by 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 and construction 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, etc. 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. In other to solve the expensive nature of concrete due to high cost of cement, recent researches have favoured the incorporation of the shells ash as binders when calcinated at suitable high temperatures. The use of PSA and MSA can improve both the economic and safety criteria of cement .The special property of PMCC to be investigated in this present study is the concrete's compressive strength. By definition, the

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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 and better efficiency, optimization method is adopted for the mixture design of concrete made with cement that is partially replaced with PSA and MSA. 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, etc. 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) sees 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. Thus, 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 Model. However, Scheffe's Model could only reflect up to four component mixture, with little expansion to five component mixtures. But through modification of the same Scheffe's model, the works of Nwachukwu and others (2022h, 2022i , 2022j , 2023a, 2023b , 2023c , 2023e, 2024a 2024b, 2024d and 2024i) have expanded the use of this Scheffe's model to six component mixtures and still looking forward to publishing works on seven component mixtures. Thus, the modified Scheffe's model in six or seven or higher component mixtures is better described as Kings- Scheffe's Optimization Model. It could be in the form of Scheffe's Second Degree Model [in binary mixtures- that A_{12}, A_{23}, A_{45}, etc.] or Scheffe's Third Degree Model [in ternary mixtures- that is A_{112}, A_{233}, A_{245}, etc]. Thus, in this present study, Kings-Scheffe's Second Degree Model for six components mixtures (namely, water, cement, PSA, MSA, fine aggregate and coarse aggregate) will be in focus.

This recent work examines the application of Kings-Scheffe's Second Degree Model for six component mixture, in the optimization of the Compressive Strength of PMCC. Of all the researches related to the subject matter that have been carried out, none has been able to address it sufficiently. For example on the application of environmentally friendly techniques to ensure partial replacement of cement for cement,, concrete and overall building optimization and pollution free environment, the works of Ugwuanyi and others (2018), Mmonwuba and others (2023), Mmonwuba and Bonaventure(2025), Ishaya and others (2016), Ogunjiofor and others (2023a), Ogunjiofor and others (2023b) and Ogunjiofor and others (2023c) are all relevant . On Periwinkle Shells (PS), PSA, MS, MSA and other Mollusks Shells works applications 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**.** 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

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(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 the application of optimization in concrete mixtures, recent works have shown that many researchers have used Scheffe's and Kings- Scheffe's method to carry out one form of optimization work or the other. For instance, 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 based on the use 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. Mbadike and Osadebe (2013) applied Scheffe's (4,2) model to optimize the compressive strength of Laterite Concrete. Egamana and Sule (2017) carried out an optimization work on the compressive strength of periwinkle shell aggregate concrete 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) where comparison was made between second degree model and third degree model. Nwachukwu and others (2017) developed and employed Scheffe's Second Degree Polynomial model to optimize the compressive strength of Glass Fibre Reinforced Concrete (GFRC). Also, 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). 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) 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) applied 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 the use of 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 Concete Made With Partial Replacement Of Cement With Cassava Peel Ash (CPA) and Rice Husk Ash (RHA). Nwachukwu and others (2023c) applied Scheffe's (6,2) model to optimize the Flexural Strength And Split Tensile Strength Of Hybrid Polypropylene Steel Fibre Reinforced Concrete (HPSFRC). Finally, Nwachukwu and others (2023d) made 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 Opara (2023) in 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. Nwachukwu and others (2024a) 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). Nwachukwu and others (2024b) applied the use of Scheffe's (6,2) model to evaluate the optimum compressive strength of Periwinkle Shells Ash (PSA)- Snail Shells Ash (SSA)- Cement Concrete (PSCC). Nwachukwu

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and others (2024c) applied Scheffe's (5,2) model to evaluate the compressive strength of Plastic Fibre Reinforced Concrete [PLFRC]**.** Nwachukwu and others (2024d) applied the use of Scheffe's Third Degree Model to optimize the compressive strength of HPNFRC. Nwachukwu and others (2024e) applied the use of Scheffe's Third Degree Regression Model to optimize the compressive strength of MSFRC. Nwachukwu and Okodugha (2024a) applied the use of Scheffe's Second Degree Model to optimize the flexural strength and split tensile strength of NFRC. Again, Nwachukwu and others (2024f) applied the use of Scheffe's Second Degree Model to optimize the flexural strength and split tensile strength of PFRC. Nwachukwu and Okodugha (2024b) applied the use of Scheffe's Second Degree Model to optimize the flexural strength and split tensile strength of GFRC. Furthermore, Nwachukwu and Okodugha (2024c) made use of Scheffe's (5,2) Model to optimize the flexural strength and split tensile strength of SFRC. Nwachukwu and Okodugha (2024d) applied the use of Scheffe's Second Degree Model to optimize the flexural strength and split tensile strength of AFRC. Nwachukwu and others (2024g) applied the use of Kings -Scheffe's (6,2) Modified Model to optimize the flexural strength and split tensile strength of HNSFRC, Nwachukwu and others (2024h) applied the use of Kings -Scheffe's (6,2) Modified Model to optimize the compressive strength of HNSFRC. Finally, Nwachukwu and others (2024i) applied the use of Kings -Scheffe's (6,2) Model to optimize the flexural strength and split tensile strength of HPNFRC. Based on the works reviewed so far, it can be envisaged that no work has been done on the use of Kings- Scheffe's (6,2) Model to optimize the Compressive Strength of PMCC. Henceforth, the need for this present research work**.**

II. METHODOLOGY

2.1 MATERIALS FOR PMCC- CS MIXTURES

In this present research work, the component materials under investigation in line with Kings- Scheffe's (6, 2) model are Water/Cement ratio, Cement, PSA, MSA, 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. It is worthy to note that both fine and coarse aggregates were procured and prepared in accordance with ASTM C33/C33M-18 (2018). The PS and MS 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 MS were then calcined in a Gallenkamp Muffle Furnace at about 450^{0}C. The calcined PS and MS samples were allowed to cool in a deciccator and then grinded into very fine powder [VFP] ,otherwise described as PSA and MSA respectively using a ceramic mortar and pestle. The resulted PSA and MSA were later sieved through a BS sieve of 75 microns and kept in air tight container for use in the PMCC mixtures for compressive strength determination.

2.2. THEORITICAL BACKGROUND ON PMCC- CS KINGS- SCHEFFE'S (6,2) MODEL

As usual, 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 PMCC mixture, the constituent elements are the following six components: water, cement, PSA, MSA, 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):

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

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

It is important to note that the difference between the Kings- Scheffe's model and the original Scheffe's model is that Kings –Scheffe's model is the upgraded/ modified/ expanded Scheffe's model to accommodate from six component mixtures whether second degree or third degree. Thus, many of the technical terms used in the original Scheffe's model are also used here. Therefore, both models are used here interchangeably for this six component mixture and above.

2.2.1. POSSIBLE DESIGN POINTS FOR PMCC- CS KINGS - SCHEFFE'S (6, 2) MIXTURES

According to 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 $X_i = 0, \frac{1}{m}, \frac{2}{m}, \frac{3}{m}, \dots, 1; \quad i = 1, 2, \dots, q$ ranging between 0 and 1. All possible mixture with these

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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: $(1,0,0), (0,1,0), (0,0,1), \left(\frac{1}{2}, \frac{1}{2}, 0\right), \left(0, \frac{1}{2}, \frac{1}{2}\right), \left(\frac{1}{2}, 0, \frac{1}{2}\right)$. For us to evaluate the number of coefficients or terms or design points required for a given lattice, we use the following general formula:

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

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 PMCC 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)**

Again, 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:

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

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 PMCC- CS KINGS - 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

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

2.2.3. FORMULATION OF POLYNOMIAL EQUATION FOR PMCC- CS KINGS- 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 PMCC- CS Kings- 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)

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2.2.4. COEFFICIENTS DETERMINATION OF THE PMCC- CS KINGS-SCHEFFE'S (6, 2) POLYNOMIAL

From the work of Nwachukwu and others (2022h), the coefficients of the Scheffe's (6, 2)/ Kings- Scheffe's (6, 2) polynomial for compressive strength determination 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. PMCC- CS KINGS- SCHEFFE'S (6, 2) MIXTURE DESIGN MODEL

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

2.2.6. EVALUATION OF THE PSEUDO AND ACTUAL MIX RATIOS FOR THE PMCC- CS KINGS-SCHEFFE'S (6, 2) DESIGN LATTICE AT INITIAL EXPERIMENTAL TEST POINTS[IETP] AND AT EXPERIMENTAL CONTROL TEST POINTS [ECTP].

A. AT THE PMCC 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. Therefore, 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 PMCC- CS Kings- Scheffe's (6,2) mixture, where 60 % of cement is replaced with PSA and MSA and the mix proportion of PSA- MSA 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 (Eqn.14): 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:

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

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).

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

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 depicted in Table 1.

Table 1: Pseudo (X) and Actual (Z) Mix Ratio For PMCC-CS Based On Kings-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_{13}	0.67	0	0.33	0	0	0	N_{13}	0.61	0.40	0.30	0.30	1.54	1.90
9	E_{14}	0.67	0	0	0.33	0	0	N_{14}	0.68	0.40	0.30	0.30	1.47	1.93
10	E_{15}	0.67	0	0	0	0.33	0	N_{15}	0.70	0.40	0.30	0.30	1.57	1.74
11	E_{16}	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 PMCC 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 were also adopted for the ECTP and the results are shown in Table 2.

Table 2:Actual & Pseudo Component Of PMCC- CS Based On Kings- 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 PMCC- CS 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), MSA (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 (2024a), Measured Quantity, M^Q of PMCC Mixture is given by Eqn.(18)

$$M^Q = \frac{X}{T} * Y \tag{18}$$

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 PMCC- CS Materials In The Laboratory At IETP

S/N	IETP	ACTUAL MIX RATIOS						MEASURED QUANTITY OF PMCC 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

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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_{13}	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_{14}	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_{15}	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_{16}	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. PMCC 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 150mm*150mm*150mm. 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 PMCC 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 PMCC 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 PMCC compressive strength test.

2.3.2. PMCC 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) as:

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

III. RESULTS PRESENTATION AND DISCUSSION

3.1.PMCC 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 PMCC based on a 28-days strength is presented in Table 4. The IETP responses are calculated from Eqn..(19)

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

S/N	POINTS		REPLICATE		RESPONSES [MPa]		RESPONSE SYMBOL	AVERAGE RESPONSE [MPa]	
	IE TP	EC TP	IETP	ECTP	AT IETP	AT ECTP		AT IETP	AT ECTP
1	E_I	C_1	PMCC/ E_I A/CS	PMCC/ C_IA/CS	**25.55**	**24.43**	N_1	**25.88**	**24.15**
			PMCC/ E_I B/CS	PMCC/ C_IB/CS	**26.21**	**23.87**			
2	E_2	C_2	PMCC/ E_2 A/CS	PMCC/ C_2A/CS	**27.87**	**27.44**	N_2	**27.43**	**27.33**
			PMCC/ E_2 B/CS	PMCC/ C_2B/CS	**26.98**	**27.21**			
3	E_3	C_3	PMCC/ E_3 A/CS	PMCC/C_3 A/CS	**21.11**	**20.23**	N_3	**21.66**	**21.29**
			PMCC/ E_3 B/CS	PMCC/C_3 B/CS	**22.21**	**22.34**			
4	E_4	C_4	PMCC/ E_4 A/CS	PMCC/C_4 A/CS	**16.99**	**18.66**	N_4	**17.16**	**18.21**
			PMCC/ E_4 B/CS	PMCC/C_4 B/CS	**17.32**	**17.76**			
5	E_5	C_5	PMCC/ E_5 A/CS	PMCC/C_5 A/CS	**19.18**	**21.22**	N_5	**19.63**	**21.73**
			PMCC/ E_5 B/CS	PMCC/C_5 B/CS	**20.08**	**22.23**			
6	E_6	C_6	PMCC/ E_6 A/CS	PMCC/ C_6A/CS	**14.27**	**15.32**	N_6	**14.25**	**13.72**
			PMCC/ E_6 B/CS	PMCC/C_6 B/CS	**14.23**	**12.11**			
7	E_{12}	C_{12}	PMCC/ E_{12} A/CS	PMCC/ C_{12}A/CS	**26.77**	**25.33**	N_{12}	**26.99**	**25.27**
			PMCC/ E_{12} B/CS	PMCC/ C_{12}B/CS	**27.21**	**25.21**			
8	E_{13}	C_{13}	PMCC/ E_{13} A/CS	PMCC/ C_{13}A/CS	**24.23**	**23.77**	N_{13}	**25.17**	**23.99**
			PMCC/ E_{13} B/CS	PMCC/ C_{13} B/CS	**26.11**	**24.21**			
9	E_{14}	C_{14}	PMCC/ E_{14} A/CS	PMCC/ C_{14} A/CS	**23.27**	**25.22**	N_{14}	**23.32**	**25.77**
			PMCC/ E_{14} B/CS	PMCC/ C_{14} B/CS	**23.37**	**26.32**			
10	E_{15}	C_{15}	PMCC/ E_{15} A/CS	PMCC/ C_{15} A/CS	**25.34**	**21.89**	N_{15}	**25.39**	**23.33**
			PMCC/ E_{15} B/CS	PMCC/ C_{15} B/CS	**25.43**	**24.77**			
11	E_{16}	C_{16}	PMCC/ E_{16} A/CS	PMCC/ C_{16} A/CS	**28.67**	**24.87**	N_{16}	**28.27**	**24.32**
			PMCC/ E_{16} B/CS	PMCC/ C_{16} B/CS	**27.87**	**23.76**			
12	E_{23}	C_{23}	PMCC/E_{23} A/CS	PMCC/C_{23} A/CS	**19.34**	**20.23**	N_{23}	**19.73**	**20.68**

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			PMCC/ E_{23} B/CS	PMCC/C_{23} B/CS	**20.12**	**21.13**			
13	E_{24}	C_{24}	PMCC/ E_{24}A/CS	PMCC/ C_{24}A/CS	**30.22**	**28.32**	N_{24}	**30.18**	**29.04**
			PMCC/ E_{24} B/CS	PMCC/C_{24} B/CS	**30.14**	**29.76**			
14	E_{25}	C_{25}	PMCC/E_{25} A/CS	PMCC/C_{25} A/CS	**15.37**	**17.43**	N_{25}	**16.07**	**16.89**
			PMCC/ E_{25} B/CS	PMCC/C_{25} B/CS	**16.76**	**16.34**			
15	E_{26}	C_{26}	PMCC/ E_{26}A/CS	PMCC/C_{26}A/CS	**25.43**	**24.38**	N_{26}	**25.43**	**23.81**
			PMCC/ E_{26} B/CS	PMCC/C_{26} B/CS	**23.43**	**23.23**			
16	E_{34}	C_{34}	PMCC/ E_{34}A/CS	PMCC/ C_{34}A/CS	**27.43**	**25.32**	N_{34}	**27.50**	**26.72**
			PMCC/ E_{34} B/CS	PMCC/C_{34} B/CS	**27.56**	**28.12**			
17	E_{35}	C_{35}	PMCC/E_{35} A/CS	PMCC/C_{35} A/CS	**28.21**	**28.33**	N_{35}	**27.77**	**25.77**
			PMCC/ E_{35} B/CS	PMCC/C_{35} B/CS	**27.32**	**23.21**			
18	E_{36}	C_{36}	PMCC/E_{36} A/CS	PMCC/C_{36} A/CS	**25.43**	**25.59**	N_{36}	**25.43**	**25.54**
			PMCC/ E_{36} B/CS	PMCC/C_{36} B/CS	**25.43**	**25.49**			
19	E_{45}	C_{45}	PMCC/E_{45} A/CS	PMCC/C_{45} A/CS	**23.23**	**25.32**	N_{45}	**23.72**	**25.55**
			PMCC/ E_{45} B/CS	PMCC/C_{45} B/CS	**24.21**	**25.78**			
20	E_{46}	C_{46}	PMCC/E_{46} A/CS	PMCC/C_{46} A/CS	**26.32**	**24.32**	N_{46}	**26.33**	**25.88**
			PMCC/E_{46} B/CS	PMCC/C_{46} B/CS	**26.34**	**27.43**			
21	E_{56}	C_{56}	PMCC/E_{56} A/CS	PMCC/C_{56} A/CS	**27.43**	**26.32**	N_{56}	**26.88**	**26.39**
			PMCC/ E_{56} B/CS	PMCC/C_{56} B/CS	**26.32**	**26.45**			

3.2. KINGS-SCHEFFE'S (6, 2) POLYNOMIAL MODEL FOR THE PMCC 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 Kings- Scheffe's Second degree polynomial for PMCC. Now, substituting the values of these evaluated coefficients into Eqn. (7) yields the mixture design model for the optimization of the Compressive Strength, N, of PMCC (at the 28th day) based on Kings-Scheffe's (6,2) lattice as stated under:

$$N = \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_{12}X_1X_2 + \beta_{13}X_1X_3 + \beta_{14}X_1X_4 + \beta_{15}X_1X_5 + \beta_{16}X_1X_6 + \beta_{23}X_2X_3 + \beta_{24}X_2X_4 + \beta_{25}X_2X_5 + \beta_{26}X_2X_6 + \beta_{34}X_3X_4 + \beta_{35}X_3X_5 + \beta_{36}X_3X_6 + \beta_{45}X_4X_5 + \beta_{46}X_4X_6 + \beta_{56}X_5X_6 \quad (20)$$

3.3. KINGS- SCHEFFE'S (6, 2) MODEL RESPONSES (COMPRESSIVE STRENGHT) FOR PMCC 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 Kings-Scheffe's Second degree model responses (compressive strength) for the ECTP of PMCC.

3.4. TEST OF ADEQUACY / VALIDATION OF PMCC KINGS- 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 relative closeness between the PMCC compressive strengths results (lab responses at IETP) given in Tables 4 and model responses from the control points based on Session 3.3. Through 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 PMCC based on Kings- Scheffe's (6,2) simplex lattice.

3.5. RESULTS DISCUSSION

The maximum compressive strength of PMCC based on Kings-Scheffe's (6,2) lattice is **30.18** MPa for the 28th day result. Similarly the minimum compressive strength of PMCC based on Kings- Scheffe's (6,2) lattice is **14.25**MPa for the 28th day result .The corresponding optimum(maximum) mix ratio is **1.41:0.40:0.30:0.30:1.30:1.80** for Water/Cement Ratio, Cement, PSA, MSA, Fine Aggregate and Coarse Aggregate respectively while the corresponding minimum mix ratios are **0.64:0.40:0.30:0.30:1.36:1.70** for Water/Cement Ratio, Cement, PSA, MSA, Fine Aggregate and Coarse Aggregate respectively. Thus, the Scheffe's model can be used to determine the PMCC compressive strengths of all 21 points (1 - 56) in the simplex based on Kings- Scheffe's Second Degree Model for six component mixtures.

IV. CONCLUSION

In this present research work so far, efforts have been made to showcase the use of Kings- Scheffe's (6,2) to optimize the partial replacement of cement with PSA and MSA. The work not only show that the use of these less expensive innovative materials can help in the low cost cement production, it has also demonstrated that their use can help reduce the menaces and pollution their dumping on site/road can cause to the environment, especially closing of openings of drainage structures. Thus, the compressive strengths investigation of PMCC using Kings-Scheffe's Second Degree Model has been presented. Firstly, the Scheffe's model was used to predict the mix ratio for evaluating the compressive strengths of PMCC. And secondly, through the use of Kings-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 closely related. The maximum and minimum values of the compressive strengths predicted by the model based on Kings-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 close to 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 Kings-Scheffe's (6, 2) model, any desired strength of PMCC, 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 PMCC 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(PS and MS) as partial replacement of cement. Stakeholders in the construction industries as well as environmental engineering sectors are advised to cooperate to this innovation for affordable housing and for effective pollution control.

REFERENCES

[1] Abdullahi, I..and Sara, S.G.(2015): Assessment of periwinkle shell ash as composite materials for particle board production, International conference on African Development Issue

[2] ACI Committee 211. (1994): "Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete (ACI 211.1R-91)"; American Concrete Institute, ACI Manual of Concrete Practice, Detroit, Michigan, USA.

[3] ACI Committee 544. (1982): "State-of-the-Report on Fibre Reinforced Concrete, (ACI 544.1R-82)"; *Concrete International: Design and Construction*. Vol. 4, No. 5: Pp. 9-30, American Concrete Institute, Detroit, Michigan, USA.

[4] ACI Committee 544. (1989): "Measurement of Properties of Fibre Reinforced Concrete, (ACI 544.2R-89)";American Concrete Institute, Detroit, Michigan, USA.

[5] *Adeala, A.J and Olaoye J.O* .(2019): Structural Properties Of Snail Shell Ash Concrete (SSAC); Journal of Emerging Technologies and Innovative Research (JETIR), Vol.6, No. 12.

IJARETY | ISSN: 2394-2975 | www.ijarety.in| | Impact Factor: 7.394| A Bi-Monthly, Double-Blind Peer Reviewed & Referred Journal |

|| Volume 12, Issue 1, January-February 2025 ||

DOI:10.15680/IJARETY.2025.1201001

[6] Adewuyi, A.P, Franklin, S.O. and Ibrahim, K. A..(2015):"Utilization of Mollusc Shells for Concrete Production for Sustainable Environment; International Journal of Scientific and Engineering Research, Vol.6. No.9. Pp. 201-208.
[7] Agbede, O.I and Manasseh, J.(2009):" Suitability of Periwinkle Shell as Partial Replacement for River Gravel in Concrete; Leonardo Electronic Journal of Practices and Technologies, Vol. 15. Pp.59- 66..
[8] Aggarwal, M.L. (2002): Mixture Experiments: Design Workshop Lecture Notes", University of Delhi, India.
[9] Alla, S.and Asadi, S.S.(2021):" Experimental Investigation of Snail Shell Based Cement Mortar: Mechanical Strength, Durability and Microstructure, Available at Research gate.
[10] Alla, S and Asadi , S. S.(2022) ;_Experimental investigation and microstructural behavior of un-calcined and calcined snail shell powder cement mortar; Journal of Building Pathology and Rehabilitation, Vol. 7, No. 1.
[11] ASTM C33/C33M-18 (2018); Standard Specification for Concrete Aggregates. ASTM International: West Conshohocken, PA, USA.
[12] ASTM C 39 (1997), Standard Test Method for Compressive Strength of Concrete Cubes , American Society for Testing and Material, West Conshohocken, PA, USA
[13] ASTM C469 (2010), Standard Test Method for Compressive Strength of Concrete Cubes , American Society for Testing and Material, West Conshohocken, PA, USA
[14] ASTM C1602/C1602M-22 (2022); Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete. ASTM International: West Conshohocken, PA, USA.
[15] Bamigboye, G.O, Nwogu, A.I., Odetoyan, A.O, Kareem, M. Enabulele, D.O. and Bassey, D.E.(2021):"Sustainable Use of Seashells as Binder in Concrete Production: Prospects and Challenges" Journal of Building Engineering, Vol. 34
[16] British Standards Institution, BS 12 (1978): Ordinary and Rapid – Hardening Portland cement; London.
[17] British Standards Institution, BS 1881-Part 116 (1983). Methods of Determination of Compressive Strength of Concrete Cube, London.
[18] Department of Environment, DOE(1988): Design of Normal Concrete Mixes , HMSO, London.
[19] Egamana, S and Sule, S.(2017): Optimization of compressive strength of periwinkle shell aggregate concrete, Nigerian Journal of Technology (NIJOTECH), Vol. 36, No. 1, Pp.32- 38.
[20] Elamah, D ., Akhigbe, P, Fadele, S.O.and Ivarah, V.I.(2021):"Strength characterization of periwinkle shell polymer concrete, the International journal of engineering and science (IJES) , Vol. 10, No. 8, Pp.52- 61.
[21] Ezeh, J.C.& Ibearugbulam, O.M. (2009):"Application of Scheffe's Model in Optimization of CompressiveCube Strength of River Stone Aggregate Concrete";*International Journal of Natural and Appllied Sciences;*Vol. 5, No. 4,Pp 303 – 308 .
[22] Ezeh, J.C., Ibearugbulam, O.M.& Anyaogu, L. (2010a):"Optimization of Compressive Strength of Cement-Sawdust Ash Sandcrete Block using Scheffe's Mathematical Model"; *Journal of Applied Engineering Research.* Vol.4, No.4, Pp 487–494.
[23] Ezeh, J.C., Ibearugbulam, O.M.&Anya, U. C (2010b):"Optimization of aggregate composition of laterite/sand hollow Block Using Scheffe's Simplex Method";*International Journal of Engineering,*Vol.4, No.4, Pp. 471 – 478.
[24].Gigante, V., Cinelli, P, Righetti, M.C..,Sandroni,M, Tognotti, L, Seggiani, M and Lazzeri,A.(2020):"Evaluation of Mussel Shell Powder As Reinforcement for PLA-Based Biocomposites,International Journal of Molecular Sciences, Vol.21, Pp. 1-16.
[25] Gonzalez, B., Carro, D., Martinez, C. and Seara-Paz, S.(2015):"Effects of Seashell Aggregates in Concrete Properties, AJCE Special issue, Vol.33, No.2, Pp. 376-382.
[26] Hughes, B.P. (197I): The Economic Utilization of Concrete Materials, Proceedings of the Symposium on Advances in Concrete , Concrete Society, London
[27] Ibearugbulam, O.M. (2006):"Mathematical Model for Optimization of Compressive Strength of Periwinkle Shell-Granite Aggregate Concrete";*M.Eng.. Thesis,* Federal University of Technology, Owerri, Nigeria.
[28].Ishaya, A., Oyemogun, I.M., Arinze, A.and Abah, J.C. (2016): Properties of Concrete Produced With Waste Bottle Caps As Partial Replacement Of Coarse Aggregate and Orange Leaves Powder As Plasticizer, Journal of Civil Engineering and Environmental Research ,Vol.8 , No.7, Pp. 22 – 44.
[29] Jackson,N. and Dhir, R.K. (1996): Civil Engineering Materials, 5th Edition, Palgrave, New York.
[30].Mbadike, E. M. and Osadebe, N.N.(2013): Application Of Scheffe's Model In Optimization Of Compressive Strength Of Laterite Concrete; Journal of Civil Engineering And Construction Technology, Vol. 4, No. 9, Pp. 265- 274.
[31] Melo, P.M.A.,Macedo, O.B, Barbosa, G.P., Ueki, M.M, and Silva, L.B..(2019):"High-Density Polyethylene/Mollusc Shell- Waste Composites: Effects of Particle Size and Coupling Agent on Morphology, Mechanical and Thermal Properties, Journal of Materials Research and Technology, Vol.8,No. 2 Pp. 1915-1925.

| ISSN: 2394-2975 | www.ijarety.in| | Impact Factor: 7.394| A Bi-Monthly, Double-Blind Peer Reviewed & Referred Journal |

|| Volume 12, Issue 1, January-February 2025 ||

DOI:10.15680/IJARETY.2025.1201001

[32].Mmonwuba, N. C., and Bonaventure, C. (2025):Enhancing Concrete Performance in Marine Environments: Insights into Seawater Effects and Cement Optimization. IPS Journal of Physical Sciences, 2(1), 12–19. https://doi.org/10.54117/ijps.v2i1.4

[33].Mmonwuba , N.C, Oreh , David Chekwube and Okoye Stella-Maris Chibuzor(2023): Bioremidation and Phytoremdiation of Petroleum Contaminated Soil ; Journal of Energy Research and Reviews , Vol.15, No.4, Pp.34-44 , DOI: 10.9734/jenrr/2023/v15i4322

[34] Mohammad, W.A.S., Othman, N.H., Ibrahim, M.H.W. Rahim, M.A, Shahidam, S,and Rahman, R.A..(2017):"A Review on Seashells Ash as Partial Cement Replacement; IOP Conference Series : Materials Science and Engineering, Vol.271.

[34] Neville, A.M. (1990): Properties of Concrete; 3rd edition, Pitman, England.

[35].Nnochiri, E. S., Ogundipe, O. M., & Emeka, H. O. (2018): Effects Of Snail Shell Ash On Lime Stabilized Lateritic Soil. *Malaysian Journal of Civil Engineering*, Vol. *30, No.*2.

[36] Nwachukwu, K.C., Okafor, M. ,Thomas, B., Oputa, A.A., Okodugha,D.A. and Osaigbovo, M.E. (2017): "An Improved Model For The Optimization Of The Compressive Strength Of Glass Fibre Reinforced Concrete (GFRC) Using Scheffe's Second Degree Polynomials"; Researchjournal's Journal of Civil Engineering, Vol. 3, No. 2

[37] Nwachukwu,, K. C., Njoku, ,K.O., Okorie ,P. O, .Akosubo,, I.S. , Uzoukwu , C. S.,Ihemegbulem, E.O.and .Igbojiaku , A.U (2022a):" Comparison Between Scheffe's Second Degree (5,2) And Third Degree (5,3) Polynomial Models In The Optimization Of Compressive Strength Of Glass Fibre Reinforced Concrete (GFRC)"; American Journal of Computing and Engineering (AJCE), Vol. 5, No. 1, Pp 1– 23.

[38] Nwachukwu, K.C.,Okodugha, D.A., Uzoukwu , C. S.,Igbojiaku, A.U. and Okafor, M. (2022b): "Application Of Scheffe's Second Degree Mathematical Model For The Optimization Of Compressive Strength Of Steel Fibre Reinforced Concrete (SFRC)"; International Journal of Advances in Engineering and Management (IJAEM) , Vol. 4, No. 3.

[39] Nwachukwu, K.C., Okorie, P.O.. Ihemegbulem , E.O., Kemebiye Dimaro , Uzoukwu , C. S., and Maduagwu, J.C.. (2022c): "The Use Of Scheffe's Model For The Optimization Of Compressive Strength Of Polypropylene Fibre Reinforced Concrete (PFRC)"; International Journal of Innovative Science and Research Technology (IJISRT), Vol. 7, No. 1

[40] Nwachukwu, K.C.,Ozioko, H.O., Okorie, P.O, and Uzoukwu , C. S. (2022d): "Application Of Scheffe's Mathematical Model For The Optimization Of Compressive Strength Of Nylon Fibre Reinforced Concrete (NFRC)"; International Journal of Advances in Engineering and Management (IJAEM) , Vol. 4, No. 2, Pp 850-862

[41] Nwachukwu, K. C., Okodugha, D.A., Igbojiaku , A.U. , Attah, U.G. And Ihemegbulem, E.O. (2022e): Application Of Scheffe's Third Degree Regression Model For The Optimization Of Compressive Strength Of Polypropylene Fibre Reinforced Concrete (PFRC); International Journal Of Advance Research And Innovative Ideas In Education (IJARIIE) , Vol. 8, No. 2.

[42] Nwachukwu, K. C., Okodugha,, D.A., Edike, O., Okafor, M.. And Attah, U.G. (2022f): Application Of Modified Scheffe's Third Degree Polynomial Model For The Optimization Of Compressive Strength Of Nylon Fibre Reinforced Concrete (NFRC); International Journal of Trend In Scientific Research And Development (IJTSRD) , Vol. 6, No. 3.

[43] Nwachukwu, K.C., Okodugha, D.A, Akosubo, I.S. and Atulomah, F.K (2022g): Optimization of Compressive Strength of Steel Fibre Reinforced Concrete (SFRC) Using Scheffe's Third-Degree Regression Model; Iconic Research And Engineering Journals (IRE), Vol. 5, No. 11.

[44] Nwachukwu, K.C.,Onwuegbuchulem,U.C., Atulomah, ,F.K. and Ihemegbulem, E.O.(2022h): Optimization of Hybrid- Polypropylene- Steel Fibre Reinforced Concrete (HPSFRC) ; Iconic Research And Engineering Journals (IRE), Vol. 5, No. 12

[45] Nwachukwu, K.C.,Thomas , B., Oguaghamba, O. ,Onwuegbuchulem, U.C., Igbojiaku, A.U., Atulomah, F.K and Okafor. M..(2022i): 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; international Journal of Engineering Inventions (IJEI), Vol.11 , No.8,Pp.40-50.

[46] Nwachukwu, K.C , Oguaghamba, O, Akosubo, I.S., Atulomah, F.K. and Igbojiaku, A.U. (2022j): Optimization of Compressive Strength of Hybrid Polypropylene – Nylon Fibre Reinforced Concrete(HPNFRC); International Journal Of Advanced Research And Innovative Ideas In Education (IJARIIE), Vol. 8, No. 5. Pp. 376 -392.

[47] Nwachukwu, K.C.,.Edike, O. Oguaghamba, O., Onwuegbuchulem, U.C and Egbulonu, B.A. (2022k): The Application Of Scheffe's Model For The Optimization Of Mussel Shells Fibre Reinforced Concrete(MSFRC); International Journal of Engineering Inventions (IJEI), Vol. 11, No. 9. Pp. 47- 57

[48].Nwachukwu,K.C., Ozioko,H.O., Akosubo, I.S.,Oguaghamba, O.,Okafor, M.,Onyechere, I.C. and Ikpa, P.N (2022l): Optimization Of Compressive Strength of Concrete Made With Partial Replacement Of Cement With Periwinkle Shells Ash (PSA) Using Scheffe's Second Degree Model; Paper presented at the Proceedings of the 1ST

| ISSN: 2394-2975 | www.ijarety.in| | Impact Factor: 7.394| A Bi-Monthly, Double-Blind Peer Reviewed & Referred Journal |

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International Conference on Advances in cement and concrete research(ICACCR-2022) Organized by Ladoke Akintola University of Technology (LAUTECH), Nigeria. Theme: Cement and Concrete Innovative Materials For Sustainable Development.

[49].Nwachukwu, K.C and Opara, H.E. (2023): Maximizing And Exploring The Benefits Of Using Latest Innovative Materials (LIM) And Low Cost Automation (LCA) For The Rapid Economic Growth Of The Cement Manufacturing Industry; Paper presented at the Conference Proceedings of the Nigeria Society of Engineers (Abuja 2023), Nov. 27 – Dec.1, 2023.

[50] Nwachukwu, K.C., Ozioko, H. O., Mama, B.O., Oguaghamba, O., and Atulomah, F.K. (2023a): The Application of Scheffe's Third Degree Regression Model In The Optimization Of Compressive Strength of Hybrid-Polypropylene- Steel Fibre Reinforced Concrete (HPSFRC); International Journal of Research and Analytical Reviews (IJRAR), Vol. , No.. Pp.

[51].Nwachukwu, K.C., Oguaghamba, O., Ozioko, H. O. and Mama, B.O. (2023b): 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 (6,3) Model; International Journal of Trend In Scientific Research and Development (IJTSRD), Vol.7 , No.2, Pp. 737-754

[52] Nwachukwu, K. C., Mathew, C.C., Mama , B.O. , Oguaghamba, O. And Uzoukwu, C.S. (2023c): Optimization Of Flexural Strength And Split Tensile Strength Of Hybrid Polypropylene Steel Fibre Reinforced Concrete (HPSFRC) : International Journal Of Advance Research And Innovative Ideas In Education (IJARIIE) , Vol. , No.

[53] Nwachukwu, K. C., Oguaghamba, O, Akosubo, I.S., Egbulonu, B.A., Okafor, M. and Mathew, C.C.(2023d): The Use Of Scheffe's Second Degree Model In The Optimization Of Compressive Strength Of Asbestos Fibre Reinforced Concrete (AFRC); Research Inventy: International Journal of Engineering and Science (IJES) , Vol. , No. .

[54].Nwachukwu, K.C., Nnegha, A.R., Senator, W.U., Okere, C.P. , Nmecha, T.M., Obi, C.G., Etukudoh, E.E. and Ezeike, U.C.(2024a): Determination Of Optimized Flexural And Split Tensile Strengths Of PSA-MSA- Cement Concrete (PMCC) Using Scheffe's (6, 2) Model; International Journal of Research Publication and Reviews [IJRPR], Vol. 5, No. 5, Pp.

[55].Nwachukwu, K. C., Anyachi, C.M., Njoku, I.C., Olinya, I.A., Nkama, J., Egbara, T.E., Anike, V.A., Nwabueze, C.S and Ejiofor, H.C.(2024b): Investigation Of Compressive Strength Property Of PSA - SSA-Cement Concrete (PSCC) Using Scheffe's (6, 2) Model; International Journal of Research Publication and Reviews [IJRPR], Vol. 5, No. 6, Pp.

[56].Nwachukwu, K. C., Edike, O., Mathew, C.C., Mama, B.O. and Oguaghamba, O..(2024c): Evaluation Of Compressive Strength Property Of Plastic Fibre Reinforced Concrete (PLFRC) Based On Scheffe's Model; International Journal of Research Publication and Reviews [IJRPR], Vol. 5, No. 6, Pp.

[57].Nwachukwu, K. C., Edike, O., Mathew, C.C., Oguaghamba, O. and Mama, B.O.(2024d): Investigation of Compressive Strength Property of Hybrid Polypropylene - Nylon Fibre Reinforced Concrete (HPNFRC) Based on Scheffe's (6,3) Model; International Journal of Research Publication and Reviews [IJRPR], Vol. 5, No. 6, Pp. 4020-4039

[58].Nwachukwu, K. C., Nwachukwu, A.N., Njoku, C.F. , Uzoukwu, C.S., Ozioko, H.O. and Mathew, C.C.,(2024e): Application Of Scheffe's (5,3) Model In The Compressive Strength Determination Of Mussel Shells Fibre Reinforced Concrete (MSFRC); Goya Journal, Vol. 17, No. 6.

[59].Nwachukwu, K. C. and Okodugha, D.A.(2024a): Application Of Scheffe's (5,2) Optimization Model In The Flexural And Split Tensile Strengths Determination Of Nylon Fibre Reinforced Concrete [NFRC]; International Journal of Progressive Research In Engineering Management And Science [IJPREMS], Vol. 4, No. 8, Pp. 628- 642

[60].Nwachukwu, K. C., Okodugha, D.A. and Atulomah, F.K.(2024f): Investigation of Flexural and Split Tensile Strengths Properties of Polypropylene Fibre Reinforced Concrete [PFRC] Based on Scheffe's Optimization Model International Journal of Research Publication and Reviews [IJRPR], Vol. 5, No. 8, Pp. 2606- 2620

[61].Nwachukwu, K. C., Okodugha, D.A., Njoku, C.F. and Nwachukwu, A.N. (2024g): Flexural And Split Tensile Strengths Evaluation Of Hybrid Nylon- Steel Fibre Reinforced Concrete [HNSFRC] Based On Kings - Scheffe's (6,2) Optimization Model.;International Journal of Advanced Research in Education and Technology[IJARETY], Vol. 11, No. 5, Pp. 2304-2322.

[62].Nwachukwu, K. C., Okodugha, D.A and Njoku, C.F.(2024h): Optimized Compressive Strength Determination of Hybrid Nylon –Steel Fibre Reinforced Concrete [HNSFRC] Using Kings - Scheffe's Binary Mixture; International Journal of Advanced Research in Education and Technology[IJARETY], Vol. 11, No. 5, Pp. 2323-2338..

[63].Nwachukwu, K. C. and Okodugha, D.A.(2024b): Evaluation of Flexural and Split Tensile Strengths of Glass Fibre Reinforced Concrete [GFRC] using Scheffe's Optimization Model; International Journal of Advanced Research in Education and Technology[IJARETY], Vol. 11, No. 4, Pp. 1301-1316.

[64].Nwachukwu, K. C. and Okodugha, D.A.(2024c): Flexural And Split Tensile Strengths Investigation Of Steel Fibre Reinforced Concrete [SFRC] Using Scheffe' S (5,2) Optimization Model; International Journal of Progressive Research In Engineering Management And Science [IJPREMS], Vol. 4, No. 9, Pp. 1116- 1131

[65].Nwachukwu, K. C. and Okodugha, D.A.(2024d): Flexural and Split Tensile Strengths Evaluation of Asbestos Fibre Reinforced Concrete [AFRC] Based on Scheffe's (5,2) Model; International Journal of Research Publication and Reviews [IJRPR], Vol. 5, No. 10, Pp. 160- 175.

[66].Nwachukwu, K.C, Okodugha, D.A, Edike, O, Njoku , C.F , Uzoukwu. C.S. (2024i): Flexural and Split Tensile Strengths Evaluation of Hybrid Polypropylene -Nylon Fibre Reinforced Concrete [HPNFRC] Using Kings Scheffe's Six Components – Binary Mixture, International Journal of All Research Education and Scientific Methods (IJARESM), Vol. 12, No.10.

[67] Nwakonobi, T.U and Osadebe, N.N (2008):"Optimization Model for Mix Proportioning of Clay- Ricehusk-Cement Mixture for Animal Buildings"; *Agricultural Engineering International:the CIGR Ejournal,Manuscript BC 08 007*, Vol x

[68] Obam, S.O. (2006). The Accuracy of Scheffe's Third Degree over Second Degree Optimization Regression Polynomials, Nigerian Journal of Technology, Vol. 2, No.25, Pp 1 – 10.

[69] Obam, S.O.(2009):"A Mathematical model for Optimization of Strength of concrete : A case study forshear modulus of Rice Husk Ash Concrete." *Journal of Industrial Engineering International l;* Vol.5, No.9,Pp 76 – 84.

[70] Offiong , U and Akpan, G.E.(2017):Assessment of physico- chemical properties of periwinkle shell ash as partial replacement for cement in concrete , International journal of scientific engineering and science, Vol. 1, No. 7, Pp.33-36.

[71].Ogunjiofor, E.I., Agbataekwe E. and Ohizu E. (2023): "Assessment of the Mechanical properties of steel fiber reinforced concrete for Low-Cost Construction "; American Journal of Innovation in Science and Engineering (AJISE), Vol. 2, Issue 1, pp. 51 – 56.

[72].Ogunjiofor, E.I., Amete D. C. and Nwabunwanne J.C. (2023): "Structural Behaviour of Concrete Produced Using Palm Kernel Shell (PKS) as a Partial Substitute for Coarse Aggregate"; American Journal of Innovation in Science and Engineering (AJISE), Vol. 2, No.1, Pp. 1 – 7.

[73].Ogunjiofor, E.I., Onuh R. and Ojukwu K.C. (2023): "Compressive Strength Development of Concrete Produced with Partial Replacement of Fine Aggregate with Crushed Glass" World Wide Journal of Multidisciplinary Research and Development (WWJMRD), Vol. 9, No.1, Pp. 91 – 96.

[74] Okere, C.E., (2006):"Mathematical Models for Optimization of the Modulus of rupture of concrete"; M.Eng. Thesis, Civil Engineering Department, Federal University of Technology, Owerri.

[75] Onwuka,D.O, Okere, C.E.,Arimanwa, J.I. and Onwuka, S.U.(2011):"Prediction of Concrete Mix ratios using Modified Regression Theory, *Computer Methods in Civil Engineering*, Vol. 2. No.1 Pp.95- 107.

[76] Oyedepoo, O.J.(2016):"Evaluation of the Properties of Lightweight Concrete Using Periwinkle Shells as Partial Replacement for Course Aggregate; Journal of Applied Science and Management, Vol.20, No. 3. Pp. 498-505.

[77] Oyenuga, V.O. (2008): Simplified Reinforced Concrete Design, 2nd Edition, Asros Ltd, Lagos, Nigeria.

[78] Peceno, B., Arenas, C., Alonso-Farinas, B and Leiva, C.(2019):" Substitution of Coarse Aggregates with Mollusc-Shells Waste in Acoustic-Absorbing Concrete; Journal of Materials in Civil Engineering, ASCE,Vol. 31. No.6.

[79] Scheffe, H. (1958):Experiment with Mixtures"; *International Journal of Royal Statistics Society*, Series B, Vol.20, Pp. 344-360.

[80] Shacklock, B.W. (1974): Concrete Constituents And Mix Proportions, The Cement and Concrete Association, London.

[81] Shetty, M.S. (2006): Concrete Technology (Theory and Practice), S. Chand and Company Ltd, India.

[82] Soneye, T., Ede, A.N..,Bamigboye, G.O. and Olukanni, D.O.(2016):The study of periwinkle shell as fine and course aggregate in concrete works; 3rd International conference on African Development

[83] Syal, I.C. and Goel, A.K. (2007): Reinforced Concrete Structures, S.Chand , India.

[84].Ugwuanyi ,S.E, Mmonwuba, N. C. and Adibe ,T.N (2018): "Partial Replacement of Cement with Burnt rice Husk Ash for Low Strength Concrete Production" International Journal of Innovation Engineering, Technology and Science. IJIETS, Vol. 2, No.2.

[85] Zaid, S.T. and Ghorpade, V.G.(2014): Experimental Investigation of Snail Shell Ash (SSA) as Partial Repalacement of Ordinary Portland Cement in Concrete; : IJERT, Vol..3, No.

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