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Optimization of Flexural Strength and Split Tensile Strength of Plastic Fibre Reinforced Concrete (PLFRC)

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ABSTRACT
Tensile performance of concrete is an important property of concrete that cannot be overlooked. The determination of the tensile strength of concrete is necessary in order to determine the load at which the concrete members may crack. Again , incorporation of Plastic Fibres (PLF) as partial or total replacement for conventional steel (reinforcement) is one sure way of achieving low cost concrete (LCC) with good mechanical strength output such as reduced structural weight.This research study therefore isaimed at using Scheffe's Second Degree Mathematical Model to optimize the Flexural Strength and Split Tensile Strength ofPlastic Fibre Reinforced Concrete (PLFRC).Using Scheffe's Simplex method, the Flexural Strength and Split Tensile Strength of PLFRC were evaluated for different mix ratios. Control experiments were also carried out and the design strengths determined. The test statistics using the Student's t-test found the model adequate.Maximum design strengths recorded for the flexural test at 14 and 28 days were 6.20MPa and 8.15MPa respectively, while those recorded for the splitting tensile test were 4.50MPa and 6.05MPa respectively. PLFRC controllable design strength values are capable of sustaining light weight and major construction projects such as Suspended floors and roof elements, Large scale industrial floors, Lightweight applications, Architecturally sensitive buildings , Construction of walkways, Pavement slabs,Bridges etc, at the possible economic, aesthetic and safety advantages.

***Keywords**: Optimization,PLFRC, Flexural Strength, Split Tensile Strength, Scheffe's(5,2)Model, Mixture Design*

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I. INTRODUCTION

Recently, there are three common methods for measuring the tensile performance of the concrete. These are the direct tension test, the splitting tensile test, and the flexural test. Each of these testing methods produces different results for the concrete in tension. However for the purpose of this present study, only the the splitting tensile test, and the flexural test shall be discussed. Flexural strength is the ability of the material to withstand bending forces applied perpendicular to its longitudinal axis. The flexural strength of a material is defined as the maximum bending stress that can be applied to that material before it yields. The most common way of obtaining the flexural strength of a material is by employing a transverse bending test using a three-point flexural test technique. Flexural strength is one measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. It is measured by loading 6 x 6-inch (150 x 150-mm) concrete beams with a span length at least three times the depth. Furthermore, splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. It is generally carried out to obtain the tensile strength of concrete, and the stress field in the tests is actually a biaxial stress field with compressive stress three times greater than the tensile stress. The split tensile strength test is an indirect method of testing tensile strength of concrete and is generally greater than direct tensile strength and lower than flexural strength (modulus of rupture).Splitting tensile strength is used in the design of structural lightweight concrete members to evaluate the shear resistance provided by concrete and to determine the development length of reinforcement. The major difference between the flexural strength and the split tensile strength is that the flexural strength is determined by failure due to bending stress considering the compressive and tensile stresses at the failure section while the splitting tensile strength is defined at the point where failure is due to the compression load, inducing pure tensile stress along the diameter of the specimen.

In the construction industry, concrete is the most widely used material. Concrete, according to Oyenuga (2008) is a composite inert material comprising of a binder course (cement), mineral filter or aggregates and water. Concrete, being a homogeneous mixture of cement, sand, gravel and water is very strong in carrying compressive forces and hence is gaining increasing importance as building materials throughout the world (Syal and Goel, 2007). Again, concrete, according to Neville (1990), plays an important part in all building structures owing to its several advantages that ranges from low built in fire resistance, high compressive strength to low maintenance. However, concrete, especially the plain type also has its own disadvantages. According to Shetty (2006), plain concrete possesses a very low tensile strength, limited ductility, and little resistance to cracking to mention but few. That is to say that unreinforced (plain) concrete is brittle in nature, and is characterized by low tensile strength but high compressive strength. As a result of this situation, stakeholders in the construction industries have been in continuous search for the improvement and upgrading of the concrete properties in critical areas. In line with this, attempts have been made in the past to improve the tensile properties of concrete members by way of using conventional reinforced steel bars. Although both these methods provide tensile strength to the concrete members, they however, do not increase the inherent tensile strength of concrete itself. Following further researches and recent developments in concrete technology, it has been established that the addition of fibres to concrete would act as crack arrester and would substantially improve its static as well as dynamic properties. This gave room to a type of concrete known as Fibre reinforced concrete (FRC) which is a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed fibres. The combination of fibres with concrete can produce a range of materials which possess enhanced tensile strength, compressive strength, elasticity, toughness, and durability etc. This is accomplished by limiting or controlling the start, spread, or spread persistence of cracks. Plastic Fibre Reinforced Concrete (PLFRC) is concrete mixture where the conventionally steel reinforcement in concrete production is partially or wholly replaced with Plastic Fibre (PLF). Typical example of plastic fibre is shown in Figure 1.

Incorporation and subsequent utilization of the PLF shown in Figure 1 can be best carried out through optimization. Generally,an optimization problem is one requiring the determination of the optimal value of a given function, known as the objective function, subject to a set of stated constraints placed on the concerned variables. In the specific area of concrete production, 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 strength, workability and durability etc.The objective of mix design, according to Shacklock (1974), is to determine the most appropriate proportions in which to use the constituent materials to meet the needs of construction work By definition, concrete mix design according to Jackson and Dhir (1996) is 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. From the above definition, it can be envisaged that the cost of any concrete includes, in addition to that of the materials themselves, the cost of the mix design, of batching, mixing and placing the concrete and of the site supervision. Consequently, the empirical mix design methods and procedures 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 proves to be the fastest method, best option, most convenient and the most efficient way of selecting concrete mix ratios /proportions for better efficiency and better performance of concrete when compared with usual empirical methods .Typical examples of well-known optimization model is Scheffe's Mathematica Model which can 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 five components mixtures (namely Water/Cement Ratio, Cement, Fine Aggregate, Coarse Aggregate and PlasticFibre will be in focus.

This present work examines the application of Scheffe's Second Degree Mathematical Model in the optimization of the Flexural Strength and Split Tensile Strength of PLFRC.There are a lot of done researches related to Plastic Fibres, Flexural Strength, Split Tensile Strength andthe general Optimization applications, but none has been able to address the subject matter in detail. For instance, Zhang and others (2013) investigated the mechanical properties of plastic concrete containing bentonite.Sanjaykumar and Daule (2017) examined the use of plastic fibre in the concrete. Adda and Slimane (2019) research investigation focused on the study of concrete reinforced by plastic fibres based on local materials. Yin and others (2015) investigated the use and review of macro plastic fibres in concrete. In Flexural and Split Tensile Strength works, Awodiji and others (2017) carried out an investigation into the Flexural and Split Tensile Strength Properties of Lime Cement Concrete. In a similar development, Uniyal and Aggarwal (2014) examined the Comparison of Flexural strength of concrete made by Two-stage mixing approach (TSMA) using fly ash and nominal concrete made by

Normal mixing approach (NMA).Coming to the use of optimization application in concrete mixtures, recent works show that many researchers have used Scheffe's method to carry out one form of optimization work or the other. For example, Nwakonobi and Osadebe (2008) used Scheffe's model to optimize the mix proportion of Clay- Rice Husk Cement Mixture for Animal Building. Ezeh and Ibearugbulem (2009) applied Scheffe's model to optimize the compressive cube strength of River Stone Aggregate Concrete. Scheffe's model was used by Ezeh and others (2010a) to optimize the compressive strength of cement- sawdust Ash Sandcrete Block. Again Ezeh and others (2010b) optimized the aggregate composition of laterite/ sand hollow block using Scheffe's simplex method. The work of Ibearugbulem (2006) and Okere(2006) were 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.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) Based on the works reviewed so far, it can be envisaged that no work has been done on the use of Scheffe's Second Degree Mathematical Model to optimize the Flexural Strength And Split Tensile Strength of PLFRC. Henceforth,the need for this present research work.

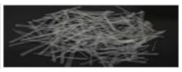

Fig. 1: Typical Example OfPlastic Fibre.

II. SCHEFFE'S OPTIMIZATION MODEL

A simplex lattice according to Aggarwal (2002) perspective can be defined as a structural representation of lines joining the atoms of a mixture. It can be further deduced that these atoms in turn are the constituent components of the mixture. For instance, when we consider the present mixture, PLFRC, the constituent elements are the water, cement, fine aggregate,coarse aggregate and plastic fibre (PLF). According to Obam (2009), mixture components are subject to the constraint that the sum of all the components must be equal to 1. That is:

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

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

2.1. PLFRC SCHEFFE'S (5,2) LATTICE DESIGN

The Scheffe's (q, m) such asScheffe'(5,2) simplex lattice design are characterized by the symmetric arrangements of points within the experimental region and a well-chosen polynomial equation to represent the response surface over the entire simplex region . 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 and all possible mixture with these component proportions are used, and m is scheffe's polynomial degee, which in this present study is

2. For example a (3, 2) lattice consists of ${}^{3+2-1}C_2$ i.e. ${}^{4}C_2$ = 6 points. Each X_i can take m+1 = 3 possible values; that is $x = 0, \frac{1}{2}, 1$ with which the 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 applied: $k = \frac{(q+m-1)!}{(q-1)!\,.\,m!}$ Or ${}^{q+m-1}C_m$ **2(a-b)**Where k = number of coefficients/ terms / points ,q = number of components/mixtures = 5 in this present study, m = number of deqree of polynomial = 2 in this present work .Using either of Eqn. (2), $k_{(5,2)} = 15$

This implies that the possible design points for PLFRCScheffe's (5,2) lattice can be as follows:

A_1 (1,0,0,0,0,); A_2 (0,1,0,0,0,); A_3 (0,0,1,0,0,); A_4 (0,0,0,1,0,), A_5 (0,0,0,0,1), A_{12} (0.5, 0.5, 0, 0, 0); A_{13} (0.5, 0, 0.5, 0, 0); A_{14} (0.5, 0, 0, 0.5, 0); A_{15} (0.5, 0, 0, 0, 0.5); A_{23} (0, 0.5, 0.5, 0,0); A_{24} (0, 0.5, 0, 0.5, 0); A_{25} (0, 0.5, 0, 0, 0.5); A_{34} (0, 0, 0.5, 0.5, 0); A_{35} (0, 0, 0.5, 0, 0.5) and A_{45} (0, 0, 0, 0.5, 0.5) **(3)**

According to Obam (2009), a Scheffe's polynomial function of degree, m in the q variable $X_1, X_2, X_3, X_4 \ldots X_q$ is given in form of: $P = b_0 + \sum bi\, xi + \sum bijxj + \sum bi\,jxjxk + + \sum bi^{j}{}_2 + \ldots i_n xi_2 xi_n$ **(4)**

where ($1 \leq i \leq q$, $1 \leq i \leq j \leq k \leq q$, $1 \leq i_1 \leq i_2 \leq \ldots \leq i_n \leq q$ respectively) , b = constant coefficients and P is the response (the response is a polynomial function of pseudo component of the mix) which represents the property under study, which ,in this case is the Flexural Strength (P^F) or Split Tensile Strength (P^S) as the case may be. This research work is based on the (5, 2) simplex. The actual form of Eqn. (4) has already been developed by Nwachukwu and others (2017) and will be applied subsequently.

2.2. PSEUDO AND ACTUAL COMPONENTS IN SCHEFFE'S THEORY

In every Scheffe's mixture design, the relationship between the pseudo components and the actual components is given as: $Z = A * X$ **(5)**where Z is the actual component; X is the pseudo component and A is the coefficient of the relationshipRe-arranging Eqn. (5), we have : $X = A^{-1} * Z$ **(6)**

2.3. MATHEMATICAL EQUATION FOR PLFRC SCHEFFE'S (5, 2)LATTICE

The Polynomial/Mathematical equation by Scheffe (1958), describing the response is given in Eqn.(4). But, for Scheffe's (5,2) simplex lattice, the polynomial equation for five component mixtures has been derived from Eqn.(4) by Nwachukwu and others (2017).Eqn.(7) gives the simplified version:

$$P = ß_1X_1 + ß_2X_2 + ß_3X_3 + ß_4X_4 + ß_5X_5 + ß_{12}X_1X_2 + ß_{13}X_1X_3 + ß_{14}X_1X_4 + ß_{15}X_1X_5 + ß_{23}X_2X_3 + ß_{24}X_2X_4 + ß_{25}X_2X_5 + ß_{34}X_3X_4 + ß_{35}X_3X_5 + ß_{45}X_4X_5 \quad \textbf{(7)}$$

2.4. COEFFICIENTS OF THE PLFRCSCHEFFE'S (5, 2) POLYNOMIAL EQUATION

From the work of Nwachukwu and others (2022h), the simplified equations for the coefficients of theScheffe's (5, 2) polynomial are expressed as follows. :

$\beta_1 = P_1$; $\beta_2 = P_2$; $\beta_3 = P_3$; $\beta_4 = P_4$; $\beta_5 = P_5$; $\beta_{12} = 4P_{12} - 2P_1 - 2P_2$; $\beta_{13} = 4P_{13} - 2P_1 - 2P_3$; **8(a-g)**

$\beta_{14} = 4P_{14} - 2P_1 - 2P_4$; $\beta_{15} = 4P_{15} - 2P_1 - 2P_5$; $\beta_{23} = 4P_{23} - 2P_2 - 2P_3$; $\beta_{24} = 4P_{24} - 2P_2 - 2P_4$; **9(a-d)**

$\beta_{25} = 4P_{25} - 2P_2 - 2P_5$; $\beta_{34} = 4P_{34} - 2P_3 - 2P_4$; $\beta_{35} = 4P_{35} - 2P_3 - 2P_5$; $\beta_{45} = 4P_{45} - 2P_4 - 2P_5$ **10(a-d)**

Where P_i = Response Function (Flexural Strength or Split Tensile Strength) for the pure component, i

2.5. SCHEFFE'S (5, 2) MIXTURE DESIGN MODEL FOR PLFRC

If we substitute Eqns. (8)-(10) into Eqn. (7), we obtain the mixture design model for the PLFRC mixture basedon Scheffe's (5,2) lattice.

2.6. ACTUAL AND PSEUDO MIX PROPORTIONS FOR THE PLFRC SCHEFFE'S (5,2) DESIGN LATTICE AT INITIAL EXPERIMENTAL POINT AND CONTROL POINT

2.6.1.AT THE INITIAL EXPERIMENTAL TEST POINTS

The requirement of simplex lattice design from Eqn.(1) makes it impossible to use the conventional mix ratios such as 1:2:4,etc., at a given water/cement ratio for the actual mix ratio. This necessitates the transformation of the actual componentsproportions to meet the above criterion. Based on experience and previous knowledge from literature, the following arbitrary prescribed mix proportions are always chosen for the five vertices.

A_1(0.67:1:1.7:2:0.5);A_2(0.56:1:1.6:1.8:0.8);A_3(0.5:1:1.2:1.7:1);A_4(0.7:1:1:1.8:1.2)andA_5(0.75:1:1.3:1.2:1.5) **(11)**

Which represent water/cement ratio, cement, fine aggregate, coarse aggregate and plastic fibre.For the pseudo mix ratio, we have the following corresponding mix ratios at the vertices:

A_1(1:0:0:0:0), A_2(0:1:0:0: 0), A_3(0:0:1:0:0), A_4(0:0:0:1:0), and A_5(0:0:0:0:1)**(12)**

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

$$\begin{Bmatrix} 0.67 \\ 1 \\ 1.7 \\ 2 \end{Bmatrix} = \begin{pmatrix} A_{11} & A_{12} & A_{13} & A_{14} & A_{15} \\ A_{21} & A_{22} & A_{23} & A_{24} & A_{25}0 \\ A_{31} & A_{32} & A_{33} & A_{34} & A_{35} \\ A_{41} & A_{42} & A_{43} & A_{44} & A_{45} \end{pmatrix} \begin{Bmatrix} 1 \\ \\ 0 \\ 0 \end{Bmatrix} \quad \textbf{(13)}$$

0.5 A_{51} A_{52} A_{53} A_{54} A_{55} 0

Transforming the R.H matrix and solving , we obtain:

$$\begin{Bmatrix} Z_1 \\ Z_2 \\ Z_3 \\ Z_4 \\ Z_5 \end{Bmatrix} = \begin{pmatrix} 0.67 & 0.56 & 0.5 & 0.7 & 0.75 \\ 1 & 1 & 1 & 1 & 1 \\ 1.7 & 1.6 & 1.2 & 1 & 1.3 \\ 2 & 1.8 & 1.7 & 1.8 & 1.2 \\ 0.5 & 0.8 & 1 & 1.2 & 1.5 \end{pmatrix} \begin{Bmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \end{Bmatrix} \quad \textbf{(14)}$$

Then,

$$\begin{Bmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \end{Bmatrix} = \begin{pmatrix} 3.99 & 10.37 & -2.14 & -3.05 & -4.62 \\ -4.88 & -21.46 & 5.40 & 5.95 & 7.31 \\ -1.78 & 17.83 & -3.49 & -4.20 & -4.62 \\ 1.04 & -9.24 & 0.37 & 3.28 & 2.69 \\ 1.63 & 3.49 & -0.13 & -1.98 & -0.77 \end{pmatrix} \begin{Bmatrix} Z_1 \\ Z_2 \\ Z_3. \\ Z_4 \\ Z_5 \end{Bmatrix} \quad \textbf{(15)}$$

Consideringthe pseudo mix ratios at the midpoints of Eqn.(3), and substituting these pseudo mix ratios in turn into Eqn. (15), we obtain the corresponding actual mix ratio.

Using point A_{12}as case study, we have:

$$\begin{Bmatrix} Z_1 \\ Z_2 \\ Z_3 \\ Z_4 \\ Z_5 \end{Bmatrix} = \begin{pmatrix} 0.67 & 0.56 & 0.5 & 0.7 & 0.75 \\ 1 & 1 & 1 & 1 & 1 \\ 1.7 & 1.6 & 1.2 & 1 & 1.3 \\ 2 & 1.8 & 1.7 & 1.8 & 1.2 \\ 0.5 & 0.8 & 1 & 1.2 & 1.5 \end{pmatrix} \begin{pmatrix} 0.5 \\ 0.5 \\ 0 \\ 0 \\ 0 \end{pmatrix} = \begin{Bmatrix} 0.62 \\ 1 \\ 1.65 \\ 1.90 \\ 0.65 \end{Bmatrix} \quad \textbf{(16)}$$

Hence comparing, $Z_1 = 0.62$, $Z_2 = 1$, $Z_3 = 1.65$, $Z_4 = 1.9$, $Z_5 = 0.65$. The rest are shown in Table 1.
In order to generate the requiredpolynomial coefficients, fifteen experimental tests(each for Flexural Strength and Split Tensile Strength) will be carried out and the corresponding mix ratio is as depicted in Table 1.

Table 1: Actual Mix Ratios For ThePLFRCScheffe's (5, 2) Simplex Lattice At The Initial Experimental Test Points(For Flexural Strength And Split Tensile Strength).

S/N	Points	Water/Cement Ratio (Z_1)	Cement (Z_2)	Fine Aggregate(Z_3)	Coarse Aggregate(Z_4)	Plastic Fibre (Z_5)	Response P
1	1	0.67	1	1.70	2.00	0.50	P_1
2	2	0.56	1	1.60	1.80	0.80	P_2
3	3	0.50	1	1.20	1.70	1.00	P_3
4	4	0.70	1	1-00	1.80	1.20	P_4
5	5	0.75	1	1.30	1.20	1.50	P_5
6	12	0.62	1	1.65	1.90	0.65	P_{12}
7	13	0.59	1	1.45	1.85	0.75	P_{13}
8	14	0.69	1	1.35	1.90	0.85	P_{14}
9	15	0.71	1	1.50	1.60	1.00	P_{15}
10	23	0.53	1	1.40	1.75	0.90	P_{23}
11	24	0.63	1	1.30	1.80	1.00	P_{24}
12	25	0.66	1	1.45	1.50	1.15	P_{25}
13	34	0.60	1	1.10	1.75	1.10	P_{34}
14	35	0.63	1	1.25	1.45	1.25	P_{35}
15	45	0.73	1	1.15	1.50	1.50	P_{45}

2.6.2. AT THE EXPERIMENTAL (.CONTROL) POINT

For the purpose of this research, fifteen different controls test (each for Flexural Strength and Split Tensile Strength) were predicted which according to Scheffes, their summation should not be more than one. Thus, the following pseudo mix proportions are applicable at the control points:
C_1(0.25, 0.25, 0.25, 0.25, 0), C_2 (0.25, 0.25, 0.25, 0, 0.25), C_3 (0.25, 0.25, 0, 0.25, 0.25), C_4 (0.25, 0, 0.25, 0.25, 0.25), C_5(0, 0.25, 0.25, 0.25, 0.25), C_{12} (0.20, 0.20, 0.20, 0.20, 0.20), C_{13} (0.30, 0.30, 0.30, 0.10, 0), C_{14} (0.30, 0.30, 0.30, 0, 0.10), C_{15}(0.30, 0.30, 0, 0.30, 0.1), C_{23} (0.30, 0, 0.30, 0.30, 0.1), C_{24}(0, 0.30, 0.30, 0.30, 0.10), C_{25} (0.10, 0.30, 0.30, 0.30, 0), C_{34}(0.30, 0.10, 0.30, 0.30, 0), C_{35} (0.30, 0.30, 0.10, 0.30, 0), C_{45} (0.10, 0.20, 0.30, 0.40, 0), **(17)**

Substituting into Eqn.(17) into Eqn.(16), we obtain the values of the actual mixes as follows using Control C_1as case study**:**

$$\begin{Bmatrix} Z_1 \\ Z_2 \\ Z_3 \\ Z_4 \\ Z_5 \end{Bmatrix} = \begin{pmatrix} 0.67 & 0.56 & 0.5 & 0.7 & 0.75 \\ 1 & 1 & 1 & 1 & 1 \\ 1.7 & 1.6 & 1.2 & 1 & 1.3 \\ 2 & 1.8 & 1.7 & 1.8 & 1.2 \\ 0.5 & 0.8 & 1 & 1.2 & 1.5 \end{pmatrix} \begin{pmatrix} 0.25 \\ 0.25 \\ 0.25 \\ 0.25 \\ 0 \end{pmatrix} = \begin{Bmatrix} 0.61 \\ 1 \\ 1.38 \\ 1.8 \\ 0.5 \end{Bmatrix} \qquad \textbf{(18)}$$

Following the same procedure as above, the rest results are depicted in Table 2

Table 2: Actual (Z_i) and Pseudo (X_i) Componentof PLFRC Scheffe's (5, 2) Simplex LatticeAt Control Point (For Flexural Strength And Split Tensile Strength).

S/N	PTS	PSEUDO COMPONENTS					CONTROL PTS	ACTUAL COMPONENTS				
		Wa (X_1)	Cem(X_1)	FA (X_3)	CA (X_4)	PLF (X_5)		Water(Z_1)	Cem(Z_2)	FA (Z_3)	CA (Z_4)	PLF (Z_5)
1	**1**	0.25	0.25	0.25	0.25	0.00	C_1	0.61	1	1.38	1.83	0.50
2	**2**	0.25	0.25	0.25	0.00	0.25	C_2	0.62	1	1.45	1.68	0.80
3	**3**	0.25	0.25	0.00	0.25	0.25	C_3	0.67	1	1.40	1.70	1.00
4	**4**	0.25	0.00	0.25	0.25	0.25	C_4	0.66	1	1.30	1.68	1.20
5	**5**	0.00	0.25	0.25	0.25	0.25	C_5	0.63	1	1.28	1.63	1.50
6	**12**	0.20	0.20	0.20	0.20	0.20	C_{12}	0.64	1	1.36	1.70	0.65
7	**13**	0.30	0.30	0.30	0.10	0.00	C_{13}	0.59	1	1.45	1.83	0.75
8	**14**	0.30	0.30	0.30	0.00	0.10	C_{14}	0.59	1	1.48	1.77	0.85
9	**15**	0.30	0.30	0.00	0.30	0.10	C_{15}	0.65	1	1.42	1.80	1.00
10	**23**	0.30	0.00	0.30	0.30	0.10	C_{23}	0.64	1	1.30	1.77	0.90
11	**24**	0.00	0.30	0.30	0.30	0.10	C_{24}	0.60	1	1.27	1.71	1.00
12	**25**	0.10	0.30	0.30	0.30	0.00	C_{25}	0.60	1	1.31	1.79	1.15
13	**34**	0.30	0.10	0.30	0.30	0.00	C_{34}	0.62	1	1.33	1.83	1.10
14	**35**	0.30	0.30	0.10	0.30	0.00	C_{35}	0.63	1	1.41	1.85	1.25
15	**45**	0.10	0.20	0.30	0.40	0.00	C_{45}	0.61	1	1.25	1.79	0.50

The actual component as transformed from Eqn. (17) , Table (1) and (2) were used to measure out the quantities of Water/Cement Ratio (Z_1), Cement (Z_2), Fine Aggregate (Z_3), Coarse Aggregate (Z_4), and PlasticFibre (Z_5) in their respective ratios for the eventual concrete cube strength test.

III. MATERIALS AND METHODS

3.1 MATERIALS

In this wok, the component materials under investigation are Water/Cement ratio, Cement, Fine Aggregates, Coarse Aggregates and PLF. Potable water is obtained from the clean water source. The cement is Dangote cement, which is a brand of Ordinary Portland Cement obtained from local distributors, which conforms to British Standard Institution BS 12 (1978). The fine aggregate (sizesfrom 0.05 - 4.5mm)was procured from the local river. Crushed granite (as a coarse aggregate) of 20mm size was obtained from a local stone market and was downgraded to 4.75mm. Plastic Fibres (PLF) as shown in Figure 1with diameter: 2mm; and Length: 50mm were procured from the local market.

3.2. METHOD

3.2.1. SPECIMEN PREPARATION / BATCHING/ CURING FOR FLEXURAL STRENGTH TEST

The standard size of specimen (mould) for the Flexural Strength measures 15cm*15cm*60cm. The mould is of steel metal with sufficient thickness to prevent spreading or warping. The mould is constructed with the longer dimension horizontal and in such a manner as to facilitate the removal of the moulded specimen without damage. Batching of all the constituent material was done by weight using a weighing balance of 50kg capacity based on the adapted mix ratios and water cement ratios. A total number of 30 mix ratios were to be used to produce 60 prototype concrete cubes. Fifteen (15) out of the 30 mix ratios were as control mix ratios to produce 30 cubes for the conformation of the adequacy of the mixture design given by Eqn. (7), whose coefficients are given in Eqns. (8) – (10). Twenty-four (24) hours after moulding, curing commenced. Test specimens are stored in water at a temperature of 24^0 to 30^0 for 48 hours before testing. They are tested immediately on removal from the water whilst they are still in a wet condition. After 28 days of curing the specimens were taken out of the curing tank for flexural strength determination.

3.2.2. FLEXURAL STRENGTHTEST PROCEDURE/CALCULATION

Flexural strength testing was done in accordance with BS 1881 – part 118 (1983) - Method of determination of TensileStrength and Modulus of Rupture respectively and ACI (1989) guideline. In this present study, two samples were crushed for each mix ratio. In each case, the Flexural Strength of each specimen/sample which is expressed as the Modulus of Rupture (MOR)was then calculated to the nearest 0.05 MPa using Eqn.(19)

$$MOR = \frac{PL}{bd^2} \quad \mathbf{(19)}$$

where b = measured width in cm of the specimen, d = measured depth in cm of the specimen at the point of failure, where L = Length in cm of the span on which the specimen was supported and P = maximum load in kg applied to the specimen.

3.2.3. SPECIMEN PREPARATION / BATCHING/ CURINGFOR SPLIT TENSILE STRENGTH TEST

The specimen for the Split Tensile Strength is Concrete Cylindrical specimen measuring diameter 150 mm and length 300 mm. They were cast with plastic fibres and the specimen was loaded for ultimate compressive load under Universal Testing Machine (UTM) for each mix. A total number of 30 mix ratios were to be used to produce 60 prototype concrete cubes. Fifteen (15) out of the 30 mix ratios were as control mix ratios to produce 30 cubes for the conformation of the adequacy of the mixture design given by Eqn. (7), whose coefficients are given in Eqns. (8) – (10).. After 28 days of curing the specimens were taken out of the curing tank for the Split Tensile Strength determination.

3.2.4. SPLIT STRENGTH TEST PROCEDURE/CALCULATION

The cylindrical split tensile test was done using the universal testing machine in accordance with BS EN 12390-6:2009 and ASTM C 496/ C 496 M-11.Two samples were crushed for each mix ratio and each case, the Split Tensile Strength of each specimen/sample was then calculatedusing Eqn. (20)

$$F_t = \frac{2P}{\pi D L} \quad \mathbf{(20)}$$

Where, F_t= Split Tensile Strength, MPa ,P = maximum applied load (that is Load at failure, N); D = diameter of the cylindrical specimen (Dia. Of cylinder, mm); and L = Length of the specimen (Length of cylinder, mm),

IV. RESULTSPRESENTATION AND DISCUSSION

4.1 PLFRC RESPONSES (FLEXURAL STRENGTH) FOR THE INITIAL EXPERIMENTAL TEST

The results of the Flexural Strength (responses) test based on Eqn. (19) are shown in Table 3

Table 3:PLFRC Flexural Strength (Response) Test Results Based on Eqn.(19)

S/N	POINTS	REPLICATE	RESPONSE SYMBOL	RESPONSE P_i, MPa		$\sum P_i$		AVERAGE RESPONSE P, MPa	
				14th day Results	28th day Results	14th day Results	28th day Results	14th day Results	28th day Results
1	1	1A 1B	P_1	4.34 4.43	5.06 5.11	8.77	10.17	4.39	5.09
2	2	2A 2B	P_2	6.00 5.96	6.68 6.74	11.96	13.42	5.98	6.71
3	3	3A 3B	P_3	4.68 4.74	5.87 5.76	9.42	11.63	4.71	5.82
4	4	4A 4B	P_4	5.44 5.46	5.00 5.12	10.90	10.12	5.45	5.06
5	5	5A 5B	P_5	4.54 4.57	6.45 6.47	9.11	12.92	4.56	6.46
6	12	6A 6B	P_{12}	6.22 6.18	8.17 8.13	12.40	16.30	6.20	8.15
7	13	7A 7B	P_{13}	6.11 6.12	8.11 8.09	12.23	16.20	6.12	8.10
8	14	8A 8B	P_{14}	4.45 4.48	6.75 6.86	8.93	13.61	4.47	6.81
9	15	9A 9B	P_{15}	4.98 4.95	6.54 6.57	9.93	13.11	4.97	6.56
10	23	10A 10B	P_{23}	5.43 5.47	6.89 6.92	10.90	13.81	5.45	6.91

11	24	11A 11B	P_{24}	4.88 4.96	5.78 5.86	9.84	11.64	4.92	5.82
12	25	12A 12B	P_{25}	5.86 5.84	5.98 5.93	11.70	11.91	5.85	5.96
13	34	13A 13B	P_{34}	4.00 4.00	4.88 4.92	8.00	9.80	4.00	4.90
14	35	14A 14B	P_{35}	4.50 4.56	7.88 7.86	9.06	15.74	4.53	7.87
15	45	15A 15B	P_{45}	5.56 5.65	6.95 6.84	11.21	13.79	5.61	6.90

4.2 PLFRC RESPONSES (SPLIT TENSILE STRENGTH) FOR THE INITIAL EXPERIMENTAL TEST

The results of the Split Tensile Strength (response) test based on Eqn. (20) are shown in Table 4

Table 4: PLFRC Split TensileStrength (Response) Test Results Based on Eqn.(20)

S/N	POINTS	REPLICATE	RESPONSE SYMBOL	RESPONSE P_i, MPa		$\sum P_i$		AVERAGE RESPONSE P, MPa	
				14th day Results	28th day Results	14th day Results	28th day Results	14th day Results	28th day Results
1	1	1A 1B	P_1	3.46 3.49	4.08 4.10	6.95	8.18	3.48	4.09
2	2	2A 2B	P_2	4.08 4.28	4.58 4.78	8.36	9.36	4.18	4.68
3	3	3A 3B	P_3	4.32 4.38	5.76 5.89	8.70	11.65	4.35	5.83
4	4	4A 4B	P_4	4.12 4.21	6.00 5.98	8.33	11.98	4.17	5.99
5	5	5A 5B	P_5	3.87 3.89	4.56 4.59	7.76	9.15	3.88	4.58
6	12	6A 6B	P_{12}	4.52 4.48	6.07 6.03	9.00	12.10	4.50	6.05
7	13	7A 7B	P_{13}	3.65 3.75	5.34 5.38	7.43	10.72	3.72	5.36
8	14	8A 8B	P_{14}	3.69 3.78	4.86 4.84	7.47	9.70	3.74	4.85
9	15	9A 9B	P_{15}	4.00 4.03	4.38 4.38	8.03	8.76	4.02	4.38
10	23	10A 10B	P_{23}	3.89 3.92	5.86 5.78	7.81	11.64	3.91	5.82
11	24	11A 11B	P_{24}	3.98 3.86	5.23 5.34	7.84	10.57	3.92	5.29
12	25	12A 12B	P_{25}	4.08 4.03	4.56 4.49	8.11	9.05	4.06	4.53
13	34	13A 13B	P_{34}	3.37 3.33	4.02 3.98	6.70	8.00	3.35	4.00
14	35	14A 14B	P_{35}	3.99 3.68	4.98 5.00	7.67	9.98	3.84	4.99
15	45	15A 15B	P_{45}	4.04 4.00	5.78 5.86	8.04	11.64	4.02	5.82

4.3. PLFRC RESPONSES (FLEXURAL STRENGHT) FOR THE EXPERIMENTAL (CONTROL) TEST POINTS

The response (Flexural strength) from experimental (control) tests is shown in Table 5.

Table 5: PLFRC Response (Flexural strength)of Control Points from Experimental (control) Tests (5, 2) Simplex Lattice

S/N	POINTS	REPLICATE	RESPONSE MPa		Z_1	Z_2	Z_3	Z_4	Z_5	AVERAGE RESPONSE,MPa			
			14thday Results	28th day Results						14th day Results	28th day Results		
1	C1	1A 1B	4.21 4.32	5.11 5.21	0.61	1	1.38	1.83	0.5	4.27	5.16	10.42	
2	C2	2A 2B	5.55 5.45	6.88 6.78	0.62	1	1.45	1.68	0.8	5.50	6.83	9.04	
3	C3	3A 3B	4.78 4.80	5.43 5.42	0.67	1	1.4	1.7	1	4.79	5.43	7.33	
4	C4	4A 4B	5.22 5.53	5.22 5.34	0.66	1	1.3	1.68	1.2	5.38	5.28	7.89	
5	C5	5A 5B	4.32 4.36	6.46 6.48	0.63	1	1.28	1.63	1.5	4.34	6.47	12.81	
6	C12	6A 6B	6.43 6.46	8.08 8.06	0.64	1	1.36	1.7	0.65	6.45	8.07	10.77	
7	C13	7A 7B	6.32 6.43	8.16 8.13	0.59	1	1.45	1.83	0.75	6.38	8.15	7.6	
8	C14	8A 8B	4.32 4.43	6.86 6.78	0.59	1	1.48	1.77	0.85	4.38	6.82	8.1	
9	C15	9A 9B	4.38 4.76	6.34 6.45	0.65	1	1.42	1.8	1	4.57	6.40	7.05	
10	C23	10A 10B	5.33 5.38	6.58 6.76	0.64	1	1.3	1.77	0.9	5.36	6.67	7.25	
11	C24	11A 11B	4.54 4.59	5.54 5.67	0.6	1	1.27	1.71	1	4.57	5.65	8.04	
12	C25	12A 12B	5.48 5.54	5.87 5.89	0.6	1	1.31	1.79	1.15	5.51	5.88	7.96	
13	C34	13A 13B	4.00 3.96	4.90 4.85	0.62	1	1.33	1.83	1.1	3.98	4.88	8.14	
14	C35	14A 14B	4.48 4.65	7.90 7.86	0.63	1	1.41	1.85	1.25	4.57	7.88	10.54	
15	C45	15A 15B	5.32 5.43	7.00 7.06	0.61	1	1.25	1.79	1.35	5.38	7.03	11.02	

4.4. PLFRC RESPONSES (SPLIT TENSILE STRENGHT) FOR THE EXPERIMENTAL (CONTROL) TEST POINTS

The response (Split Tensile Strength) from experimental (control) tests is shown in Table 6.

Table 6: PLFRC Response (Split Tensile Strength)of Control Points from Experimental (control) Tests (5, 2) Simplex Lattice

S/N	POINTS	REPLICATE	RESPONSE MPa		Z_1	Z_2	Z_3	Z_4	Z_5	AVERAGE RESPONSE MPa			
			14th day Results	28th day Results						14th day Results	28th day Results		
1	C1	1A	3.34	4.10								10.42	
		1B	3.40	3.98	0.61	1	1.38	1.83	0.5	3.37	4.04		
2	C2	2A	4.00	4.44								9.04	
		2B	4.11	4.45	0.62	1	1.45	1.68	0.8	4.06	4.45		
3	C3	3A	4.31	5.76								7.33	
		3B	4.36	5.78	0.67	1	1.4	1.7	1	4.34	5.77		
4	C4	4A	4.09	6.05								7.89	
		4B	4.08	6.00	0.66	1	1.3	1.68	1.2	4.09	6.03		
5	C5	5A	3.67	4.74								12.81	
		5B	3.76	4.76	0.63	1	1.28	1.63	1.5	3.72	4.75		
6	C12	6A	4.42	6.12								10.77	
		6B	4.43	6.23	0.64	1	1.36	1.7	0.65	4.43	6.18		
7	C13	7A	3.43	5.38								7.6	
		7B	3.46	5.40	0.59	1	1.45	1.83	0.75	3.45	5.39		
8	C14	8A	3.48	4.96								8.1	
		8B	3.65	5.00	0.59	1	1.48	1.77	0.85	3.57	4.98		
9	C15	9A	4.13	4.54								7.05	
		9B	4.23	4.59	0.65	1	1.42	1.8	1	4.18	4.57		
10	C23	10A	3.42	5.86								7.25	
		10B	3.39	5.84	0.64	1	1.3	1.77	0.9	3.41	5.85		
11	C24	11A	3.38	5.27								8.04	
		11B	3.45	5.47	0.6	1	1.27	1.71	1	3.42	5.37		
12	C25	12A	4.03	4.67								7.96	
		12B	4.12	4.65	0.6	1	1.31	1.79	1.15	4.08	4.66		
13	C34	13A	3.42	4.86								8.14	
		13B	3.32	4.98	0.62	1	1.33	1.83	1.1	3.37	4.92		
14	C35	14A	3.56	4.28								10.54	
		14B	3.59	4.64	0.63	1	1.41	1.85	1.25	3.58	4.46		
15	C45	15A	4.12	5.45								11.02	
		15B	4.22	5.56	0.61	1	1.25	1.79	1.35	4.17	5.51		

4.5. SCHEFFE' S (5,2) POLYNOMIAL MODEL FOR THE PLFRC RESPONSES (FLEXURAL STRENGHT AND SPLIT TENSILE STRENGHT).

A. FLEXURAL STRENGHT

By substituting the values of the flexural strengths (responses) from Table 3 into Eqns.(8) through (10), we obtain the coefficients(β_1 ,β_2 …β_{34} ,β_{35}…. β_{45})of the Scheffe's second degree polynomial for PLFRC.Substituting the values of these coefficients into Eqn. (7) yieldthe polynomial model for the optimization of the flexural strength of PLFRC (at both 14th dayor 28th day) based on Scheffe's (5,2) lattice as given under:

$$P^F = ß_1X_1 + ß_2X_2 + ß_3X_3 + ß_4X_4 + ß_5X_5 + ß_{12}X_1X_2 + ß_{13}X_1X_3 + ß_{14}X_1X_4 + ß_{15}X_1X_5 + ß_{23}X_2X_3 + ß_{24}X_2X_4 + ß_{25}X_2X_5 + ß_{34}X_3X_4 + ß_{35}X_3X_5 + ß_{45}X_4X_5 \quad \textbf{(21)}$$

B. SPLIT TENSILE STRENGHT

By substituting the values of the split tensile strengths (responses) from Table 4 into Eqns.(8) through (10), we obtain the coefficients (β_1 ,β_2 …β_{34} ,β_{35}…. β_{45}) of the Scheffe's second degree polynomial for PLFRC. Substituting the values of these coefficients into Eqn. (7) yield the polynomial model for the optimization of the split tensile strength of PLFRC (at both 14th day or 28th day) based on Scheffe's (5,2) lattice as given under:

$$P^S = ß_1X_1 + ß_2X_2 + ß_3X_3 + ß_4X_4 + ß_5X_5 + ß_{12}X_1X_2 + ß_{13}X_1X_3 + ß_{14}X_1X_4 + ß_{15}X_1X_5 + ß_{23}X_2X_3 + ß_{24}X_2X_4 + ß_{25}X_2X_5 + ß_{34}X_3X_4 + ß_{35}X_3X_5 + ß_{45}X_4X_5 \quad \textbf{(22)}$$

4.6. SCHEFFE'S (5,2) MODEL RESPONSES(FLEXURAL STRENGHT AND SPLIT TENSILE STRENGHT) FOR PLFRCAT CONTROL POINTS.

A. FLEXURAL STRENGHT

By substituting the pseudo mix ratio of points C_1, C_2, C_3, C_4, C_5, … C_{45} of Table 5 into Eqn.(21), we obtain the Scheffe's second degree model responses (flexural strength) for the control points of PLFRC.

B. SPLIT TENSILE STRENGHT

By substituting the pseudo mix ratio of points C_1, C_2, C_3, C_4, C_5, … C_{45} of Table 6 into Eqn.(22), we obtain the second degree model responses (split tensile strength) for the control points of PLFRC.

4.7.VALIDATION OF PLFRC MODEL RESULTS (FOR FLEXURAL STRENGHT AND SPLIT TENSILE STRENGHT) USING STUDENT'S – T -TEST

Here, our major aim is to perform the test of adequacy so as to determine the percentage correlation between the compressive strength results (lab responses) given in Tables 5 and 6 and model responses from the control points based on Eqns.(21 and 22). By using the Student's – T – test as the means of validation, the result shows that there are no significant differences between the experimental results and model responses as the procedures/steps involved in using the Student's – T - test have been explained by Nwachukwu and others (2022 c). Therefore, the models areadequate for predicting the flexural and split tensile strengths of PLFRC based on Scheffe's (5,2) simplex lattice.

4.8. RESULTS DISCUSSION

The maximum flexural strengths of PLFRC based on Scheffe's (5,2) lattice are **8.15**MPaand **6.20**MPa respectively for 28th and 14th day results. Similarly the maximum split tensile strengths of PLFRC based on Scheffe's (5,2) lattice are **6.05**MPa and **4.50**MPa respectively for 28th and 14th day results .The corresponding optimum mix ratio is **0.62:1:1.65:1.90:0.65** for Water/Cement Ratio, Cement, Fine Aggregate, Coarse Aggregate and Plastic Fibre respectively.The minimum flexural strength and split tensile strength are **4.50** MPa, **4.00** MPa, **4.00**MPa and **3.35**MPa respectively for the 28th day and 14th day results. The minimum values correspond to the mix ratio of **0.60 : 1: 1.10:1.75:1.10**for Water/Cement Ratio, Cement, Fine Aggregate, Coarse Aggregate and Plastic Fibre respectively. Thus, the Scheffe's model can be used to determine the PLFRC flexural and spilt tensile strength of all points (1 - 45) in the simplex based on Scheffe's Second Degree Model**.**

V. CONCLUSION

In this study so far, Scheffe's Second Degree Polynomial (5,2) was used to formulate a model for predicting the flexural and split tensile strengths of PLFRC. In the first instance, the Scheffe's model was used to predict the mix ratio for predicting both strengthsof PLFRC. By using Scheffe's (5,2) simplex model, the values of the strengths were determined at all 15 points (1- 45). The results of the student's t-test validated the strengths predicted by the models and the corresponding experimentally observed results. The optimum (maximum) attainable strengths predicted by the model based on Scheffe's (5,2) model are as stated in the results discussion session, likewise the minimum values. Furthermore, with the Scheffe's (5,2) model, any desired strength, given any mix proportions can be easily predicted and evaluated and vice versa.Once again, the utilization of this Scheffe's optimization model has solved the problem of having to go through vigorous, time-consuming and laborious empirical mixture design procedures in other to obtain the desired strengths.

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