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Evaluation of Flexural and Split Tensile Strengths of Glass Fibre Reinforced Concrete (GFRC) using Scheffe's Optimization Model

K. C. Nwachukwu[1], D. A. Okodugha [2]

Department of Civil Engineering, Federal University of Technology, Owerri, Imo State, Nigeria[1]

Department of Civil Engineering Technology, Federal Polytechnic, Auchi, Edo State, Nigeria[2]

ABSTRACT: Fibres are usually used in concrete to control cracking due to plastic shrinkage and to drying shrinkage. In general, Fibre Reinforced Concrete (FRC) is a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete as well as uniformly dispersed fibres. Replacing costly conventional reinforcement with inexpensive fibres is one of the techniques that guarantee fast reduction in the cost of concrete production. Glass fibre is a typical example of fibre. This research study is therefore aimed at using Scheffe's Second Degree Model to optimize the Flexural Strength and Split Tensile Strength of Glass Fibre Reinforced Concrete (GFRC). Using Scheffe's Simplex method, the Flexural Strength and Split Tensile Strength of GFRC were determined for different mix proportions. Control experiments were also carried out and the flexural and split tensile strengths evaluated. The test statistics using the Student's t-test validated the results. Maximum design strengths recorded for the flexural test at 14 and 28 days were 6.23MPa and 8.00MPa respectively, while those recorded for the splitting tensile test were 5.56MPa and 4.02MPa respectively. GFRC controllable design strength values are capable of sustaining major construction projects such as bridges and light weight structures still maintaining both economic and safety advantages.

KEYWORDS: GFRC , Optimization, Scheffe's (5,2) Model, Flexural Strength, Split Tensile Strength ,Mixture Design

I. INTRODUCTION

The importance of concrete in the construction industry cannot be over emphasized. According to Oyenuga (2008), concrete is a composite inert material comprising of a binder course (cement), mineral filter or aggregates and water. Again, 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). Concrete, according to Neville (1990), plays an important part in all building structures owing to its numerous advantages that ranges from low built in fire resistance, high compressive strength to low maintenance. Despite the fact that concrete is one of the most widely used construction material, it has got its own limitations. According to Shetty (2006), concrete (especially the plain type) possesses a very low tensile strength, limited ductility, low shear strength and little resistance to cracking. As all stakeholders in the construction industries are focusing on sustainable and environmentally friendly technology that can be safe and economical, efforts have been made to improve the concrete properties with relatively new construction material developed through extensive research and development work. This has led to the reinforcement of the tension zone of the concrete with conventional steel bars. Due to the expensive nature of the conventional reinforcement, further researches have shown that incorporation of fibres into the concrete would act as crack arrester and would substantially improve its static as well as dynamic properties. This also led to a type of research known as Fibre reinforced concrete (FRC) research. FRC is a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete as well as uniformly dispersed fibre. In a nutshell, fibres are usually used in concrete to control cracking due to plastic shrinkage and to drying shrinkage. They can also reduce the permeability of concrete and thus reduce bleeding of water. Incorporation of fibres with concrete can produce a range of materials which possess enhanced tensile strength, compressive strength, elasticity, toughness, and durability etc. Glass Fibre Reinforced Concrete (GFRC) is concrete mixture where the conventionally steel reinforcement in concrete production is partially or wholly replaced with homogenous tiny strands of Alkaline Resistant (AR) glass fibre. Special properties of GFRC under investigation in this present work are the flexural strength and the split tensile strength. Flexural strength is the ability of the material to withstand bending forces applied perpendicular to its longitudinal axis. It is defined as the maximum bending stress that can be applied to the material before it yields. On the other hand, 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

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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).

Investigation of the special mechanical properties of GFRC under consideration requires the optimization of the GFRC mixture. Subsequently, an optimization problem is one requiring the determination of the optimal (maximum or minimum) value of a given function, called the objective function, subject to a set of stated restrictions, or constraints placed on the variables concerned. 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. Thus, 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. When focusing on the widely varying properties of the constituent materials, the conditions that prevail at the site of work, the exposure condition, and the conditions that are demanded for a particular work for which the mix is designed, the design of concrete mix according to (Shetty, 2006) is not a simple task. By definition, concrete mix design according to Jackson and Dhir (1996) remains 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, the cost of any concrete includes, in addition to that of the materials themselves, the cost of the mix design, of batching, mixing and placing the concrete and of the site supervision. In the context of the above guidelines, the empirical mix design methods and procedures proposed by Hughes (1971), ACI-211(1994) and DOE (1988) seems to be a little bit complex and time consuming. This is because, they involve a lot of trial mixes and complex statistical calculations before the desired strength of the concrete can be reached. Thus, when considering the drawbacks associated with the above empirical methods, 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 or proportions for better efficiency and better performance of concrete. Typical examples of optimization model is Scheffe's Model. It could be in the form of Scheffe's Second Degree Model or Scheffe's Third Degree Model. In this present study, Scheffe's Second Degree Model for five components mixtures (namely Water/Cement Ratio, Cement, Fine Aggregate, Coarse Aggregate and Glass Fibre are presented.

In this recent work, the use of Scheffe's Second Degree Polynomial Model in the optimization of the Flexural Strength and Split Tensile Strength of GFRC is examined. Despite the fact that there have been little works done on the general glass fibre and optimization applications, none has been able to address the subject matter in full. For example, Rao and others (2011) investigated the effect of size and shape of specimen on compressive strength of GFRC. Kiran.and Teja (2016) assessed the Comparison Of Compressive And Split Tensile Strength Of Glass Fiber Reinforced Concrete With Conventional Concrete. Ibrahim.(2016) investigated the Mechanical Properties of Glass Fibre Reinforced Concrete (GFRC). On optimization, recent works have shown that many researchers have used 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

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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 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. Finally, Nwachukwu and others (2024f) applied the use of Scheffe's Second Degree Model to optimize the flexural strength and split tensile strength of GFRC. From the works reviewed so far, it can be envisaged that no work has been done on the use of Scheffe's Second Degree Model to optimize the flexural strength and split tensile strength of GFRC. Thus, there is urgent need for this present research work.

II. METHODOLOGY

2.1 MATERIALS FOR GFRC MIXTURES

In this present work, the constituent materials for laboratory examinations are cement, water, fine and coarse aggregate and glass fibre. The cement is Dangote cement, which is a brand of Ordinary Portland Cement that conforms to British Standard Institution BS 12 (1978). The water is procured from potable water from the available clean water source and was applied in accordance with ASTM C1602/C1602M-22 (2022). The fine aggregate, with size ranging from 0.05 - 4.5mm was procured from the local river. Crushed granite of 20mm size was obtained from a local stone market and was downgraded to 4.75mm. Both fine and coarse aggregates were procured and prepared in accordance with ASTM C33/C33M-18 (2018). The same size and shape of the glass fibre used is the same as the one used by Nwachukwu and others (2017) and Nwachukwu and others (2022a).

2.2. BASIC INFORMATION ON GFRC SCHEFFE'S (5,2) OPTIMIZATION THEORY

As a simplex lattice is defined as a structural representation of lines joining the atoms of a mixture, it is important to note that these atoms are the constituent components of the same mixture. For instance, when considering this present GFRC concrete mixture, the five constituent elements are Water, Cement, Fine Aggregate, Coarse Aggregate and Glass Fibre. One basic information to know, according to Obam (2009) is that the mixture components are usually subject to the constraint that the sum of all the components must be equal to 1 as stated in Eqn. (1): $X_1 + X_2 + X_3 + \dots + X_q = 1$; $\Rightarrow \sum_{i=1}^{q} X_i = 1$ **(1)**

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

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2.2.1. DETERMINATION OF POSSIBLE DESIGN POINTS FOR GFRC SCHEFFE'S (5,2) MIXTURES

In general, the (q, m) 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 (Aggarwal, 2002). The (q, m) simplex lattice design given by Scheffe, according to Nwakonobi and Osadebe (2008) contains ${}^{q+m-1}C_m$ points where each components proportion takes (m+1) equally spaced values $X_i = 0, \frac{1}{m}, \frac{2}{m}, \frac{3}{m}, \ldots, 1; \quad i = 1, 2, \ldots, q$ ranging between 0 and 1 and all possible mixture with these component proportions are used, and m is scheffe's polynomial degree, which in this present study is 2.

For example a (3, 2) lattice consists of ${}^{3+2-1}C_2$ i.e. ${}^4C_2$ = 6 points. Each X_i can take m+1 = 3 possible values; that is $x = 0, \frac{1}{2}, 1$ with which the possible design points are: $(1,0,0), (0,1,0), (0,0,1), \left(\frac{1}{2}, \frac{1}{2}, 0\right), \left(0, \frac{1}{2}, \frac{1}{2}\right), \left(\frac{1}{2}, 0, \frac{1}{2}\right)$. In order to determine the number of coefficients/terms/ design points required for a given Scheffe's component mixtures, 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 / design points , q = number of components = 5 in this work and m = number of degree of polynomial = 2 in this present work. Using either of Eqn. (2), $k_{(5,2)}$ = 15. Consequently, the possible design points for Scheffe'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 the form of Eqn.(4): $P = b_0 + \sum bi\,xi + \sum bij\,xj + \sum bi\,jxjxk + + \sum bi^{j}{}_2 + \ldots i_n xi_2 xi_n$ **(4)**
where ($1 \le i \le q$, $1 \le i \le j \le k \le q$, $1 \le i_1 \le i_2 \le \ldots \le i_n \le q$ respectively) , b = constant coefficients and 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.

As 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.

2.2.2. PSEUDO AND ACTUAL COMPONENTS IN SCHEFFE'S MIXTURE

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

2.2.3. POLYNOMIAL EQUATION FOR GFRC SCHEFFE'S (5, 2) SIMPLEX LATTICE

The polynomial equation by Scheffe (1958), describing the response is stated 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) and the simplified version is given as follows:

$$P = \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_{12}X_1X_2 + \beta_{13}X_1X_3 + \beta_{14}X_1X_4 + \beta_{15}X_1X_5 + \beta_{23}X_2X_3 + \beta_{24}X_2X_4 + \beta_{25}X_2X_5 + \beta_{34}X_3X_4 + \beta_{35}X_3X_5 + \beta_{45}X_4X_5 \quad (7)$$

2.2.4. COEFFICIENTS DETERMINATION OF THE GFRC SCHEFFE'S (5,2) POLYNOMIAL EQUATION

From the work of Nwachukwu and others (2022h), the simplified equations for the coefficients of the Scheffe'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

2.2.5. SCHEFFE'S (5, 2) MIXTURE DESIGN MODEL FOR GFRC

When we substitute Eqns. (8)-(10) into Eqn. (7), we obtain the mixture design model for the GFRC mixture based on Scheffe's (5, 2) lattice for the flexural and split tensile strengths.

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2.2.6. EVALUATION OF ACTUAL AND PSEUDO MIX RATIOS FOR THE GFRC SCHEFFE'S (5, 2) DESIGN LATTICE

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

As usual, the requirement of simplex lattice design from Eqn.(1) makes it impossible to use the conventional mix ratios such as 1:2:4, 1:1.3:6, as the case may be., at a given water/cement ratio for the actual mix ratio. This necessitates the transformation of the actual components (ingredients) proportions to meet the above criterion. Based on experience and previous knowledge from literature, the following arbitrary prescribed mix proportions were chosen for the five points/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 glass 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 have:

$$\begin{Bmatrix} 0.67 \\ 1 \\ 1.7 \\ 2 \\ 0.5 \end{Bmatrix} = \begin{pmatrix} A_{11} & A_{12} & A_{13} & A_{14} & A_{15} \\ A_{21} & A_{22} & A_{23} & A_{24} & A_{25} \\ A_{31} & A_{32} & A_{33} & A_{34} & A_{35} \\ A_{41} & A_{42} & A_{43} & A_{44} & A_{45} \\ A_{51} & A_{52} & A_{53} & A_{54} & A_{55} \end{pmatrix} \begin{Bmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{Bmatrix} \quad (13)$$

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

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

Thus

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

Considering the mix ratios at the midpoints, we have after substituting these pseudo mix ratios in turn into Eqn. (15). For point A_{12}

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

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

To generate the polynomial 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.

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Table 1: Pseudo (X) and Actual (Z) Mix Ratio For GFRC Based On Scheffe's (5,2) Lattice For IETP (For Flexural Strength And Split Tensile Strength).

S/N	IETP	PSEUDO COMPONENT					RESPONSE SYMBOL	ACTUAL COMPONENT				
		X_1	X_2	X_3	X_4	X_5		Z_1	Z_2	Z_3	Z_4	Z_5
1	E_I	1	0	0	0	0	P_1	0.67	1	1.70	2.00	0.50
2	E_2	0	1	0	0	0	P_2	0.56	1	1.60	1.80	0.80
3	E_3	0	0	1	0	0	P_3	0.50	1	1.20	1.70	1.00
4	E_4	0	0	0	1	0	P_4	0.70	1	1.00	1.80	1.20
5	E_5	0	0	0	0	1	P_5	0.75	1	1.30	1.20	1.50
6	E_{12}	0.50	0.50	0	0	0	P_{12}	0.62	1	1.65	1.90	0.65
7	E_{13}	0.50	0	0.50	0	0	P_{13}	0.59	1	1.45	1.85	0.75
8	E_{I4}	0.50	0	0	0.50	0	P_{14}	0.69	1	1.35	1.90	0.85
9	E_{I5}	0.50	0	0	0	0.50	P_{15}	0.71	1	1.50	1.60	1.00
10	E_{23}	0	0.50	0.50	0	0	P_{23}	0.53	1	1.40	1.75	0.90
11	E_{24}	0	0.50	0	0.50	0	P_{24}	0.63	1	1.30	1.80	1.00
12	E_{25}	0	0.50	0	0	0.50	P_{25}	0.66	1	1.45	1.50	1.15
13	E_{34}	0	0	0.50	0.50	0	P_{34}	0.60	1	1.10	1.75	1.10
14	E_{35}	0	0	0.50	0	0.50	P_{35}	0.63	1	1.25	1.45	1.25
15	E_{45}	0	0	0	0.50	0.50	P_{45}	0.73	1	1.15	1.50	1.50

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

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.(16) , we obtain the values of the actual mixes as follows:

Control 1 C_1

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

The rest are shown in Table 2

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IJARETY

|| Volume 11, Issue 4, July-August 2024 ||

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Table 2: Actual (Z) and Pseudo (X) Component of GFRC Scheffe's (5, 2) Simplex Lattice At ECTP (For Flexural Strength And Split Tensile Strength).

S/N	EC TP	PSEUDO COMPONENTS					RESP ONSE SYMB OL	ACTUAL COMPONENTS				
		Wat (X_1)	Cem (X_1)	FA (X_3)	CA (X_4)	GF (X_5)		Water (Z_1)	Cem (Z_2)	FA (Z_3)	CA (Z_4)	GF (Z_5)
1	C_1	0.25	0.25	0.25	0.25	0.00	P_1	0.61	1	1.38	1.83	0.50
2	C_2	0.25	0.25	0.25	0.00	0.25	P_2	0.62	1	1.45	1.68	0.80
3	C_3	0.25	0.25	0.00	0.25	0.25	P_3	0.67	1	1.40	1.70	1.00
4	C_4	0.25	0.00	0.25	0.25	0.25	P_4	0.66	1	1.30	1.68	1.20
5	C_5	0.00	0.25	0.25	0.25	0.25	P_5	0.63	1	1.28	1.63	1.50
6	C_{12}	0.20	0.20	0.20	0.20	0.20	P_{12}	0.64	1	1.36	1.70	0.65
7	C_{13}	0.30	0.30	0.30	0.10	0.00	P_{13}	0.59	1	1.45	1.83	0.75
8	C_{14}	0.30	0.30	0.30	0.00	0.10	P_{14}	0.59	1	1.48	1.77	0.85
9	C_{15}	0.30	0.30	0.00	0.30	0.10	P_{15}	0.65	1	1.42	1.80	1.00
10	C_{23}	0.30	0.00	0.30	0.30	0.10	P_{23}	0.64	1	1.30	1.77	0.90
11	C_{24}	0.00	0.30	0.30	0.30	0.10	P_{24}	0.60	1	1.27	1.71	1.00
12	C_{25}	0.10	0.30	0.30	0.30	0.00	P_{25}	0.60	1	1.31	1.79	1.15
13	C_{34}	0.30	0.10	0.30	0.30	0.00	P_{34}	0.62	1	1.33	1.83	1.10
14	C_{35}	0.30	0.30	0.10	0.30	0.00	P_{35}	0.63	1	1.41	1.85	1.25
15	C_{45}	0.10	0.20	0.30	0.40	0.00	P_{45}	0.61	1	1.25	1.79	0.50

2.2.7. MEASUREMENT OF QUANTITIES OF NFRC MATERIALS

The actual component as transformed from Eqn. (17), Tables (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 Glass Fibre (Z_5) using a weighing balance of 50kg capacity in their respective ratios for the eventual Concrete Beam Cube and Concrete Cylindrical specimen at the laboratory.

Mathematically, Measured Quantity, M^Q of GFRC Mixture is given by Eqn.(19)

$$M^Q = \frac{X}{T} * Y \qquad \textbf{(19)}$$

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 = 5.87 at E_1 in Table 1, for example

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

For the Flexural Strength concrete beam mould of 15cm*15cm*60cm, Average Y from experience = 30kg

For the Split Tensile Strength Concrete cylinder mould of 15cm*30cm, Average Y from experience =12.5kg

Samples of measured quantities can be seen from the works of Nwachukwu and others 2024 (a and b).

2.3. METHOD

2.3.1. METHODS FOR GFRC FLEXURAL STRENGTH TEST

A. GFRC SPECIMEN PREPARATION / BATCHING/ CURING FOR FLEXURAL STRENGTH TEST In this experimental investigation, the standard size of specimen (mould) for the Flexural Strength measures 150mm*150mm*600mm. 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 14 and 28 days of curing respectively, the specimens were taken out of the curing tank for flexural strength determination.

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|| Volume 11, Issue 4, July-August 2024 ||

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B. GFRC FLEXURAL STRENGTH TEST PROCEDURE/CALCULATION

Flexural strength testing was done in accordance with BS 1881 – part 118 (1983) - Method of determination of Flexural Strength, ASTM C78/C78M-22 (2022) 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.(20)

$$MOR = \frac{PL}{bd^2} \quad (20)$$

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.

2.3.2. METHODS FOR GFRC SPLIT TENSILE STRENGTH TEST

A. GFRC SPECIMEN PREPARATION / BATCHING/ CURING FOR 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 14 and 28 days of curing respectively, the specimens were taken out of the curing tank for the Split Tensile Strength determination.

B. GFRC 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-17. Two samples were crushed for each mix proportion and in each case, the Split Tensile Strength of each specimen/sample was then calculated using Eqn. (21)

$$F_t = \frac{2P}{\pi D L} \quad (21)$$

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).

III. RESULTS PRESENTATION AND DISCUSSION

3.1 GFRC RESPONSES (FLEXURAL STRENGTH) FOR IETP

The results of the Flexural Strength (responses) test at IETP based on Eqn. (20) are shown in Table 3

Table 3: GFRC Flexural Strength (Response) Test Results Based on Eqn.(20) for IETP

S/N	IETP	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	E_I	GFRC/ E_1 A GFRC/ E_1 B	P_1	4.56 4.65	6.05 6.13	9.21	12.18	4.61	6.09
2	E_2	GFRC/ E_2 A GFRC/ E_2 B	P_2	4.98 4.87	5.89 5.68	9.85	11.57	4.93	5.79
3	E_3	GFRC/ E_3 A GFRC/ E_3B	P_3	4.78 4.85	5.44 5.46	9.63	10.90	4.82	5.45

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4	E_4	GFRC/ E_4 A GFRC/ E_4 B	P_4	4.43 4.49	5.98 5.84	8.92	11.82	4.46	5.91
5	E_5	GFRC/ E_5 A GFRC/ E_5 B	P_5	4.34 4.45	6.98 6.87	8.88	13.85	4.44	6.93
6	E_{12}	GFRC/ E_6 A GFRC/ E_6 B	P_{12}	4.90 4.92	7.87 7.85	9.82	15.72	4.91	7.86
7	E_{13}	GFRC/ E_7 A GFRC/ E_7 B	P_{13}	4.17 4.13	5.28 5.24	8.30	10.52	4.15	5.26
8	E_{14}	GFRC/ E_8 A GFRC/ E_8 B	P_{14}	5.76 5.79	5.84 5.76	11.55	11.60	5.78	5.80
9	E_{15}	GFRC/ E_9 A GFRC/ E_9 B	P_{15}	5.45 5.56	6.86 6.85	11.01	13.71	5.51	6.86
10	E_{23}	GFRC/ E_{10} A GFRC/ E_{10} B	P_{23}	5.76 5.78	7.43 7.48	11.54	14.91	5.77	7.46
11	E_{24}	GFRC/ E_{11}A GFRC/ E_{11}B	P_{24}	5.56 5.69	6.21 6.32	11.25	12.53	5.63	6.27
12	E_{25}	GFRC/ E_{12} A GFRC/ E_{12} B	P_{25}	5.43 5.47	5.86 5.83	10.90	11.69	5.45	5.85
13	E_{34}	GFRC/ E_{13} A GFRC/ E_{13} B	P_{34}	6.25 6.21	8.02 7.98	12.46	16.00	6.23	8.00
14	E_{35}	GFRC/ E_{14} A GFRC/ E_{14} B	P_{35}	6.11 6.15	6.50 6.64	12.26	13.14	6.13	6.57
15	E_{45}	GFRC/ E_{15} A GFRC/ E_{15} B	P_{45}	5.33 5.24	7.43 7.49	10.57	14.92	5.29	7.46

3.2 GFRC RESPONSES (SPLIT TENSILE STRENGTH) FOR THE IETP

The results of the Split Tensile Strength (response) test based on Eqn. (21) are shown in Table 4

Table 4: GFRC Split Tensile Strength (Response) Test Results Based on Eqn.(21)

S/N	IETP	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	E_1	GFRC/ E_1 A GFRC/ E_1 B	P_1	3.33 3.45	4.54 4.59	6.78	9.13	3.39	4.57
2	E_2	GFRC/ E_2 A GFRC/ E_2 B	P_2	3.76 3.81	4.76 4.79	7.57	9.55	3.79	4.78
		GFRC/ E_3 A		3.78	4.51	7.53	9.11	3.79	4.56

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IJARETY

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3	E_3	GFRC/ E_3B	P_3	3.75	4.60				
4	E_4	GFRC/ E_4 A GFRC/ E_4 B	P_4	4.00 3.98	4.85 4.89	7.98	9.74	3.99	4.87
5	E_5	GFRC/ E_5 A GFRC/ E_5 B	P_5	3.89 3.79	4.39 4.38	7.68	8.77	3.84	4.39
6	E_{12}	GFRC/ E_6 A GFRC/ E_6 B	P_{12}	3.48 3.52	4.98 5.00	7.00	9.98	3.50	4.99
7	E_{13}	GFRC/ E_7 A GFRC/ E_7 B	P_{13}	3.00 3.00	4.37 4.33	6-00	8.70	3-00	4.35
8	E_{14}	GFRC/ E_8 A GFRC/ E_8 B	P_{14}	3.12 3.21	5.12 5.21	6.33	10.33	3.17	5.17
9	E_{15}	GFRC/ E_9 A GFRC/ E_9 B	P_{15}	3.56 3.67	5.32 5.33	7.23	10.65	3.62	5.33
10	E_{23}	GFRC/ E_{10} A GFRC/ E_{10} B	P_{23}	3.48 3.49	5.45 5.43	6.97	10.88	3.49	5.44
11	E_{24}	GFRC/ E_{11}A GFRC/ E_{11}B	P_{24}	3.21 3.25	5.67 5.63	6.46	11.30	3.23	5.65
12	E_{25}	GFRC/ E_{12} A GFRC/ E_{12} B	P_{25}	3.57 3.61	4.65 4.69	7.18	9.34	3.59	4.67
13	E_{34}	GFRC/ E_{13} A GFRC/ E_{13} B	P_{34}	4.04 4.00	5.58 5.54	8.04	11.12	4.02	5.56
14	E_{35}	GFRC/ E_{14} A GFRC/ E_{14} B	P_{35}	3.88 3.65	5.45 5.47	7.53	10.92	3.77	5.46
15	E_{45}	GFRC/ E_{15} A GFRC/ E_{15} B	P_{45}	3.76 3.81	5.68 5.72	7.57	11.40	3.79	5.70

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3.3. GFRC RESPONSES (FLEXURAL STRENGHT) FOR THE ECTP

The response (Flexural strength) from ECTP is shown in Table 5.

Table 5: GFRC Response (Flexural strength) from ECTP.

S/N	ECTP	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	C_1	GFRC/ C_1 A GFRC/ C_1 B	4.43 4.47	6.21 6.32	0.61	1	1.38	1.83	0.5	4.45	6.27	10.42	
2	C_2	GFRC/ C_2 A GFRC/ C_2 B	4.45 4.53	5.37 5.43	0.62	1	1.45	1.68	0.8	4.49	5.40	9.04	
3	C_3	GFRC/ C_3 A GFRC/ C_3 B	4.32 4.43	5.41 5.42	0.67	1	1.4	1.7	1	4.38	5.42	7.33	
4	C_4	GFRC/ C_4 A GFRC/ C_4 B	4.41 4.42	5.24 5.42	0.66	1	1.3	1.68	1.2	4.42	5.33	7.89	
5	C_5	GFRC/ C_5 A GFRC/ C_5 B	4.54 4.53	6.78 6.68	0.63	1	1.28	1.63	1.5	4.54	6.73	12.81	
6	C_{12}	GFRC/ C_6 A GFRC/ C_6 B	4.23 4.34	7.64 7.61	0.64	1	1.36	1.7	0.65	4.29	7.63	10.77	
7	C_{13}	GFRC/ C_7 A GFRC/ C_7 B	4.21 4.34	5.38 5.43	0.59	1	1.45	1.83	0.75	4.28	5.41	7.6	
8	C_{14}	GFRC/ C_8 A GFRC/ C_8 B	5.75 5.72	5.56 5.75	0.59	1	1.48	1.77	0.85	5.74	5.66	8.1	
9	C_{15}	GFRC/ C_9 A GFRC/ C_9 B	5.23 5.31	6.54 6.67	0.65	1	1.42	1.8	1	5.27	6.61	7.05	
10	C_{23}	GFRC/ C_{10} A GFRC/ C_{10} B	5.43 5.48	7.48 7.49	0.64	1	1.3	1.77	0.9	5.46	7.49	7.25	
11	C_{24}	GFRC/ C_{11} A GFRC/ C_{11} B	5.45 5.64	6.23 6.31	0.6	1	1.27	1.71	1	5.55	6.27	8.04	
12	C_{25}	GFRC/ C_{12} A GFRC/ C_{12} B	5.39 5.41	5.29 5.34	0.6	1	1.31	1.79	1.15	5.40	5.32	7.96	
13	C_{34}	GFRC/ C_{13} A GFRC/ C_{13} B	6.21 6.25	8.09 7.88	0.62	1	1.33	1.83	1.1	6.23	7.99	8.14	
14	C_{35}	GFRC/ C_{14} A GFRC/ C_{14} B	6.23 6.24	6.52 6.62	0.63	1	1.41	1.85	1.25	6.24	6.57	10.54	
15	C_{45}	GFRC/ C_{15} A GFRC/ C_{15} B	5.32 5.43	7.38 7.36	0.61	1	1.25	1.79	1.35	5.38	7.38	11.02	

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3.4. GFRC RESPONSES (SPLIT TENSILE STRENGHT) FOR THE ECTP

The response (Split Tensile Strength) from ECTP is shown in Table 6.

Table 6: GFRC Response (Split Tensile Strength) of ECTP.

S/N	ECTP	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	C_1	GFRC/ C_1 A GFRC/ C_1 B	3.30 3.34	4.50 4.51	0.61	1	1.38	1.83	0.5	3.32	4.51	10.42	
2	C_2	GFRC/ C_2 A GFRC/ C_2 B	3.70 3.72	4.71 4.72	0.62	1	1.45	1.68	0.8	3.71	4.72	9.04	
3	C_3	GFRC/ C_3 A GFRC/ C_3 B	3.71 3.72	4.50 4.48	0.67	1	1.4	1.7	1	3.72	4.49	7.33	
4	C_4	GFRC/ C_4 A GFRC/ C_4 B	4.02 3.99	4.80 4.81	0.66	1	1.3	1.68	1.2	4.01	4.81	7.89	
5	C_5	GFRC/ C_5 A GFRC/ C_5 B	3.67 3.72	4.40 4.41	0.63	1	1.28	1.63	1.5	3.70	4.41	12.81	
6	C_{12}	GFRC/ C_6 A GFRC/ C_6 B	3.42 3.47	4.95 5.02	0.64	1	1.36	1.7	0.65	3.45	4.99	10.77	
7	C_{13}	GFRC/ C_7 A GFRC/ C_7 B	3.02 2.94	4.32 4.31	0.59	1	1.45	1.83	0.75	2.98	4.32	7.6	
8	C_{14}	GFRC/ C_8 A GFRC/ C_8 B	3.11 3.12	5.11 5.12	0.59	1	1.48	1.77	0.85	3.12	5.12	8.1	
9	C_{15}	GFRC/ C_9 A GFRC/ C_9 B	3.52 3.53	5.30 5.31	0.65	1	1.42	1.8	1	3.53	5.31	7.05	
10	C_{23}	GFRC/ C_{10} A GFRC/ C_{10} B	3.42 3.43	5.41 5.41	0.64	1	1.3	1.77	0.9	3.43	5.41	7.25	
11	C_{24}	GFRC/ C_{11} A GFRC/ C_{11} B	3.12 3.15	5.62 5.61	0.6	1	1.27	1.71	1	3.14	5.62	8.04	
12	C_{25}	GFRC/ C_{12} A GFRC/ C_{12} B	3.56 3.49	4.61 4.64	0.6	1	1.31	1.79	1.15	3.53	4.63	7.96	
13	C_{34}	GFRC/ C_{13} A GFRC/ C_{13} B	4.01 4.02	5.52 5.51	0.62	1	1.33	1.83	1.1	4.02	5.52	8.14	
14	C_{35}	GFRC/ C_{14} A GFRC/ C_{14} B	3.82 3.74	5.42 5.46	0.63	1	1.41	1.85	1.25	3.78	5.44	10.54	
15	C_{45}	GFRC/ C_{15} A GFRC/ C_{15} B	3.72 3.69	5.45 5.34	0.61	1	1.25	1.79	1.35	3.71	5.40	11.02	

3.5. SCHEFFE' S (5,2) POLYNOMIAL MODEL FOR THE GFRC 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 GFRC. Substituting the values of these coefficients into Eqn. (7) yield the polynomial model for the optimization of the flexural strength of GFRC (at both 14th day or 28th day) based on Scheffe's (5,2) lattice as stated under:

$$P^F = \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_{12}X_1X_2 + \beta_{13}X_1X_3 + \beta_{14}X_1X_4 + \beta_{15}X_1X_5 + \beta_{23}X_2X_3 + \beta_{24}X_2X_4 + \beta_{25}X_2X_5 + \beta_{34}X_3X_4 + \beta_{35}X_3X_5 + \beta_{45}X_4X_5 \quad (22)$$

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 GFRC. Substituting the values of these coefficients into Eqn. (7) yield the polynomial model for the optimization of the split tensile strength of GFRC (at both 14th day or 28th day) based on Scheffe's (5,2) lattice as given under:

$$P^S = \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_{12}X_1X_2 + \beta_{13}X_1X_3 + \beta_{14}X_1X_4 + \beta_{15}X_1X_5 + \beta_{23}X_2X_3 + \beta_{24}X_2X_4 + \beta_{25}X_2X_5 + \beta_{34}X_3X_4 + \beta_{35}X_3X_5 + \beta_{45}X_4X_5 \quad (23)$$

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|| Volume 11, Issue 4, July-August 2024 ||

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3.6. SCHEFFE'S (5,2) MODEL RESPONSES (FLEXURAL STRENGHT AND SPLIT TENSILE STRENGHT) FOR GFRC AT ECTP.

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.(22), we obtain the Scheffe's second degree model responses (flexural strength) for the control points of GFRC.

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.(23), we obtain the second degree model responses (split tensile strength) for the control points of GFRC.

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

The key interest in this session is to perform the test of adequacy so as to determine the percentage correlation between the flexural and split tensile strengths results (lab responses) given in Tables 5 and 6 and model responses from the control points based on Eqns.(22 and 23). 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. The procedures involved in using the Student's – T - test have been explained by Nwachukwu and others (2022 c). Thus, the models are adequate for predicting the flexural and split tensile strengths of GFRC based on Scheffe's (5,2) simplex lattice.

3.8. RESULTS DISCUSSION

The optimum (maximum) flexural strengths of GFRC based on Scheffe's (5,2) lattice are **8.00** MPa and **6.75** MPa respectively for 28th and 14th day results. Similarly the maximum split tensile strengths of GFRC based on Scheffe's (5,2) lattice are **5.56** MPa and **4.02** MPa respectively for 28th and 14th day results .The corresponding optimum mix ratio is **0.60: 1:1.10:1.75: 1.10** for Water/Cement Ratio, Cement, Fine Aggregate, Coarse Aggregate and Glass Fibre respectively. The minimum flexural strength and split tensile strength are **5.26** MPa, **4.75** MPa, **4.35**MPa and **3.00**MPa respectively for the 28th day and 14th day results. The minimum values correspond to the mix ratio of **0.59:1:1.45:1.85: 0.75** for Water/Cement Ratio, Cement, Fine Aggregate, Coarse Aggregate and Glass Fibre respectively. Thus, the Scheffe's model can be used to determine the GFRC flexural and spilt tensile strength of all points (1 - 45) in the simplex based on Scheffe's Second Degree Model**.**

IV. CONCLUSION

In this work so far, Scheffe's Second Degree Polynomial has been presented and used to formulate a model for predicting the flexural and split tensile strengths of GFRC. Firstly, the Scheffe's model was used to predict the mix ratio for predicting both flexural and split tensile strengths of AFRC. And through the use of Scheffe's (5,2) simplex model, the values of both strengths were determined at all 15 points (1- 45). The results of the student's t-test validated the strengths (responses) predicted by the models and the corresponding experimentally observed results. The maximum attainable strengths predicted by the model based on Scheffe's (5,2) model are as stated in the results discussion session, as well as the minimum values. Furthermore, with the Scheffe's (5,2) model, any desired strength, given any mix ratio can be easily predicted and evaluated and vice versa. Thus, the application of this Scheffe's optimization model has helped to solve the problem of having to go through vigorous, time-consuming and laborious empirical mixture design procedures in order to obtain the desired strengths.

REFERENCES

[1] 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.
[2] ACI Committee 544. (1989): "Measurement of Properties of Fibre Reinforced Concrete, (ACI 544.2R-89)";American Concrete Institute, Detroit, Michigan, USA.
[3] Aggarwal, M.L. (2002): "Mixture Experiments: Design Workshop Lecture Notes", University of Delhi, India.
[4]ASTM C33/C33M-18(2018); Standard Specification for Concrete Aggregates. ASTM International: West Conshohocken, PA, USA.
[5]ASTM C78/C78M-22(2022); Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading). ASTM International: West Conshohocken, PA, USA.
[6]ASTM C496/C496M-17 (2017); Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens. ASTM International: West Conshohocken, PA, USA.

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

|| Volume 11, Issue 4, July-August 2024 ||

DOI:10.15680/IJARETY.2024.1104001

[7]ASTM C1602/C1602M-22(2022); Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete. ASTM International: West Conshohocken, PA, USA.

[8]British/European code (BS EN 12390-6) (2009).Testing concrete - Split tensile strength of test specimens. BSI - London.

[9] British Standards Institution, BS 12 (1978): Ordinary and Rapid – Hardening Portland cement; London.

[10]British Standards Institution, BS 1881-Part 118 (1983). Methods of Determination of Flexural Strength of concrete, London

[11] Department of Environment, DOE(1988): Design of Normal Concrete Mixes , HMSO, London.

[12] 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.

[13] Ezeh, J.C.& Ibearugbulam, O.M. (2009):"Application of Scheffe's Model in Optimization of Compressive Cube Strength of River Stone Aggregate Concrete";International Journal of Natural and Appllied Sciences;Vol. 5, No. 4,Pp 303 – 308 .

[14] 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.

[15] 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.

[16] Hughes, B.P. (197I): The Economic Utilization of Concrete Materials, Proceedings of the Symposium on Advances in Concrete , Concrete Society, London

[17] 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.

[18] Ibrahim, K.I.M.(2016): Mechanical Properties of Glass Fibre Reinforced Concrete(GFRC) ; IOSR Journal Of Mechanical and Civil Engineering (IOSR-JMCE), Vol.13, No. 4. Pp. 47-50

[19] Jackson,N. and Dhir, R.K. (1996): Civil Engineering Materials, 5th Edition, Palgrave, New York.

[20]Kiran, T.S.and Teja, C. S. (2016): Comparison Of Compressive And Split Tensile Strength Of Glass Fiber Reinforced Concrete With Conventional Concrete; International Research Journal of Engineering and Technology (IRJET) , Vol.3, No. 3

[21].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.

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

[23] 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

[24] 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.

[25] 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.

[26] 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

[27] 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

[28] 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.

[29] 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.

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IJARETY

|| Volume 11, Issue 4, July-August 2024 ||

DOI:10.15680/IJARETY.2024.1104001

[30] 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.

[31] 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

[32] 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.

[33] 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.

[34] 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

[35].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 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.

[36].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.

[37] 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.

[38].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

[39] 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.

[40] 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. .

[41].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.

[42].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.

[43].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.

[44].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

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

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[45].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.

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

[47] 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

[48] 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.

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

[50] 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..

[51] 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.

[52] 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.

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

[54] Samir, B, Nordine, L. and Pierre, M (2014):"Use of Asbestos-Free Fibre- Cement Waste as a partial substitute of Portland cement in mortar; Materials and Structure, Vol. 48, No. 6, Pp 1679 – 1687 .

[55] Rao,M.V.K., Kumar, P.R, and Srinivas, R: (2011):"Effect of Size and Shape of Specimen on Compressive Strength of Glass Fibre Reinforced Concrete (GFRC)"; FACTA UNIVERSTATIS series: Architecture and Civil Engineering, vol.9, No. 1,Pp 1-9

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

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

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

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

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