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Prediction of Compressive Strength of Nano-Silica Blended Ultra High Performance Fiber-Reinforced Concrete

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ABSTRACT
This study carried out an experimental investigation on the compressive strength of Ultra High Performance Fiber Reinforced Concrete (UHPFRC) reinforced with glass fibers at varying percentages (0.5, 1.0, 1.5 %). To increase strength, reduce cost and shrinkages resulting from cement volume, Nanosilica was used as partial replacement of cement. Particle Packing Method of mix design was adopted for the mix design to reduce void volume. Durability of sulphate attack was studied with varying exposure to percentages of MgSO4. The results showed increase in compressive strength of the concrete as the incorporation of nanosilica (5%, 10%, and 15%) and glass fiber (0.5%, 1.0%, and 1.5%) increased. The maximum compressive strength of 152.3 MPa was measured at 15% replacement of cement with nanosilica and 1.5% inclusion of glass fiber. Magnesium sulphate attack also showed loss of compressive strength at 4%, 8% and 12% for 56 and 90 days in the UHPFRC to ascertain durability in an aggressive environment. Regression Models were developed to predict the compressive strength of UHPFRC and the result were compared with the experimental values and found to be close at all experimental points. The models developed were tested for adequacy using F-statistics at 5% level of significance and were found to be adequate.
Keywords: *Ultra High Performance Fiber Reinforced Concrete, Nanosilica, Durability, Compressive strength, Regression Models were*

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I. Introduction

Ultra High Performance Fiber Reinforced Concrete is a modern cementations composite containing a large amount of cement, both reactive and non-reactive very fine particles, chemical admixtures and fibers. This type of concrete exhibits compressive strength between 150 MPa and above as recommended by (ACI239R-18). It can also be defined as a special concrete with unique properties when compared to conventional concrete. Buttignol*et al.* (2017). Presently, Engineers are working assiduously to further improve the compressive strength of Ultra High Performance Fiber Reinforced Concrete also known as UHPFRC and to reduce it's associated brittleness by the incorporation of fibers. Ultra High Performance Fiber Reinforced Concrete (UHPFRC) which was developed in the mid 1990's, has attracted much attention from researchers and Engineers for practical applications in architectural and civil structures, because of its excellent strength properties (compressive strength is greater than 150Mpa and a design value of tensile strength of 8MPa), durability, energy absorption capacity, and high fatigue resistance. (AFGC-SETRA (2013); Graybeal and Tanesi 2007; Yoo et al. 2014c). Szuecse*et al.* (2001) found that fibers added to concrete improves its mechanical resistance and ductility, thereby reducing the plastic shrinkage, improving resistance to abrasion, fire and impact. They concluded that with such kind of materials, engineers are able to design structures to resist severe conditions. One of the most important properties of steel fiber reinforced concrete (SFRS) is its superior resistance to cracking and crack propagation. As a result of its ability to resist cracks, fiber composites increased extensibility and tensile strength, both at first crack and at ultimate under flexural loading. The fibers are able to hold the matrix even after the extensive cracking at ultimate under flexural loading. The fibers are able to hold the matrix even after the extensive cracking. The net result of this is post cracking ductility which is unheard in the normal conventional concrete. The transformation from brittle to ductile type of concrete would increase substantially the energy absorption characteristic of the fiber composite and its ability to withstand repeatedly applied shocks or impacts loading (Brühwiler, 2020). Ultra-High Performance Fibre Reinforced Cementitious Composite (UHPFRC) is made of a mix of cement (and other reactive powders), additives, fine aggregate particles (with a maximum grain size of 1 mm), water, admixtures, and a large amount of slender discontinuous steel fibers (Brühwiler, 2016b; Yoo and Yoon, 2016). Academic work has played a significant role in developing the concept of UHPFRC as an enhancement of structural resistance and durability of existing structures (Brühwiler, 2016b). This concept has been referred to as "UHPFRC Technology". UHPFRC mixes have been developed over 30 years of research and applications worldwide. The mechanical properties and structural performance of UHPFRC are summarized in (Brühwiler, 2020). UHPFRC has significant resistance in tension (up to 16 MPa) and compression (up to 180 MPa). Due to its strain-hardening behavior, UHPFRC is a crack-free material and waterproof under service conditions, providing robust protection again environmental actions such as water and chloride ion ingress. Young's modulus in both tension and compression is between 45 and 50 GPa. This value is relatively close to existing RC structures that often present elastic modulus between 30 and 45 GPa, limiting induced stresses due to temperature and shrinkage effects (Kälin, 2020). In this study, an experimental study was carried out on the compressive strength of UHPFRC reinforced with glass fibers at varying percentages (0.5, 1.0, 1.5 %). Mathematical models were also developed to predict the compressive strength of nano-silica blended UHPFRC reinforced with glass fibers at varying percentages at age 7, 14 and 28 days respectively. Patel & Kulkarni, 2012. Experimental work for studying the effect of polypropylene fiber of concrete containing silica fume with different percentages of fiber on workability and durability of concrete was presented in Patel and Kulkarni's study (Patel & Kulkarni, 2012). The results showed that polypropylene fiber added to concrete has a slight effect on workability. Another experiment investigated the properties of concrete with the addition of polypropylene fiber on shear, tensile and compressive strength. The results noted that increasing polypropylene fiber has a little effect on compressive strength by the addition of fiber from 0.35% to 0.50% (Ahmed et al., 2006). The polypropylene fiber with ratios of 0%, 0.1%, 0.2%, 0.3% and 0.5% of cement weight has been used in Mashrei, Sultan and Mahdi's study. (Mashrei et al., 2018). The results show that the addition of polypropylene fiber to concrete influences compressive strength. The maximum compressive strength increased for mixes that contain fibers with a percentage of 0.2% of polypropylene fiber and a decrease in compressive strength when fiber percentage exceeds 0.2%. Gao, Sun, and Morino (1997) found that increasing fiber volume fraction led to increasing splitting tensile strength. It depends on aspect ratio and various fibers volume fractions. To get high splitting tensile strength volume fraction must exceed 1.0%. Song, Hwang, and Sheu (2005) examined polypropylene fiber reinforced concrete with a fiber content of 0,6 kg / m3. The splitting tensile strength improved. Islam and Gupta (2016) used polypropylene fiber with various contents. The results show that the addition of 0.1% of polypropylene fiber gave an increase in tensile strength compared to plain concrete. Hasan, Maroof and Ibrahim (2019) found that the addition of polypropylene fiber with a volume fraction of 0.36% causes an improvement in strength properties Assessment of HPFRC Durability Due to Exposing to Different Environmental Media 97 after 28 days. Fouad et al., (2014), high performance concrete can help in making sustainable construction in larger project making more environment friendly. Even though cement has less impact on environment than steel but still it produces 5% greenhouse gases worldwide. According to Fouad et al., (2014, p. 3) high performance concrete will address sustainability by introducing strategies for reducing Portland cement in concrete, improving concrete's performance by using less material, and making it more durable in order to increase its lifespan with minimum maintenance costs. Therefore, Ultra high performance concrete will help in minimizing the overall cost of the project as well as it will help in making construction sustainable, which is environment friendly producing less greenhouse gas. High performance concrete is a milestone in the process of addressing sustainability in the concrete industry for contractors and subcontractors out in the market (Fouad et al., 2013, p. 9). Fly ash and silica fumes also plays important role for high performance concrete admixtures, these ingredients help in improving the strength and durability of the concrete. Low water cement ratio with fly ash or silica fumes improves the durability and reduces the cost of construction. These ingredients are environment friendly and helps in creating sustainable construction. Kudar et al., (2012), concrete has gained significant importance in the construction industry because it is a versatile, available, and cost effective material. However, Naik, Kumar, Ramme, and Canpolat (2012, p. 463) stated that concrete has not remained a material only composed of cement, commonly Portland cement, aggregate, and ware during the last two decades, and it has changed to a material with various new constituents to satisfy the construction requirements. High performance concrete is a type of regular Portland cement concrete. Excessive water in the concrete admixture can reduce the strength of the concrete and durability. To maintain the water cement ratio and increase the strength, plasticizers are used to increase the bonding between the particles of the Portland cement. Moreover, high performance concrete has a discontinuous pore structure that reduces liquid ingress and permeability, which leads to significantly enhanced durability, longer service life and lower cost for maintenance (Wan et al., 2015). However, in the case of construction in summer time, there are more chances of failure and cracking in the structure. The heat factor plays an important role in the curing of the concrete. At this situation, more water is required for curing of the concrete. Adding more water for curing may increase the water cement ratio in the concrete admixture resulting in less permeability of concrete. According to Guneyisi, Gesoglu, and Ozbay (2010, p. 1878), concrete shrinks due to the tensile stresses produced by the loss of water, which is know as drying shrinkage of concrete. Therefore, temperature in summer construction can create problem of loss of water resulting in shrinkage of the concrete. Dry shrinkage of the concrete leads to cracking and failure of structure at early age. Naik et. Al., 2012). High performance concrete provides high durability, strength, low water-cement ratio and longer life span of the structure. Special ingredients such as plasticizers, optimum aggregate size and fiber steel reinforcement are used to make this type of concrete admixture. This type of concrete type is used in special and complex construction structure such as bridges and tunnels. High performance concrete also helps in reducing the duration of the project, as there is low water cement ratio in making the admixture for the concrete. This type of concrete is useful for fast track construction where owner required the possession of the property as soon as possible. High performance concrete have several advantages over traditional Portland cement concrete.First, high performance concrete provides better strength and durability. Water cement ratio majorly affect the workability of the concrete. According to Naik et al., increase in the water cement ratio, which can be obtained by increasing the water content in the concrete admixture, increases the workability and slump ratio of the concrete.

The materials used in this study are discussed as follows:

- The Portland Limestone Cement grade 42.5R produced by Dangote Group of Company PLC conforming to NIS 444 obtained from Mile 3 Diobu Port-Harcourt.
- Crushed granite stones of maximum size 20mm from quarry in Akamkpa, Cross Rivers State obtained from the Mile 3 Diobu dump were used as the coarse aggregate.
- Fine aggregate (River Sand) conforming to EN 12620 was used and was obtained from the River bed in Choba, Obio/Akpor Local Government Area of Rivers State.
- Water used for this study was obtained from the Civil Engineering Laboratory.
- Nanosilica used for this study was obtained from Lagos State
- Alkali resistant glass fiber in compliance with EN 15422 was used.
- Super plasticizer used was Forsroc Auracast 200 obtained at Aba, Abia State.

The packing density (PD) and void content (CV) are calculated using Eqn (1) and Eqn (2) accordingly to EN1097-3:1998

Packing density $= \frac{BulkDensityxWeightfraction}{SpecificGravity}$ (1)

Void Content $= 1 - \frac{BulkDensityxWeightfraction}{SpecificGravity}$ (2)

Determination of Paste Content

The total packing density (PD) determined by mixing different sized coarse aggregates and fine aggregate is used to determine the void content (VC) of the mixture using Eqn (4)

Void content (VC) $= 1 - PD$ (4)

The void content in percentage volume and packing density are determined from equations (6) and (7).

Void content in percentage volume $= \frac{Specific\ Gravity - Bulk\ Density}{SpecificGravity}$ (6)

Packing Density (max) $= \frac{BulkDensityxWeightFraction}{SpecificGravity}$ (7)

II. Mathematical Model Development

An exponential model was developed to predict compressive strength of concrete cured for 7, 14 and 28 days. Equation (8) shows the form of the model.

$Y = \mu_0 . X_1^{\mu_1} . X_2^{\mu_2} \ldots X_n^{\mu_n}$ (8)

Where Y = Compressive strength or Splitting tensile strength [MPa], X_i= Input variables and μ_i= regression coefficients.

Key parameters assessed in the models include the following the coefficient of determination, R^2, Adjusted R-square, R^2_{adj}, Standard error of estimate, SE, F-statistics and its significance level, Durbin-Watson amongst others.
The coefficient of determination is defined as proportion of the total sum of squares of the dependent variable explained or predicted by the independent variables in the model.

$$R^2 = \frac{SS\ (Regr)}{SS\ (Total)} \quad (9)$$

Adjusted R-square, on the other hand considers the mean square rather than the sum of square. It is a measure of the behaviour of the R-square when more variables are added to the model.

$$R^2_{adj} = 1 - \frac{MS(Regr)}{MS(Total)} = 1 - \frac{(1-R^2)(n-1)}{(n-p')} \quad (10)$$

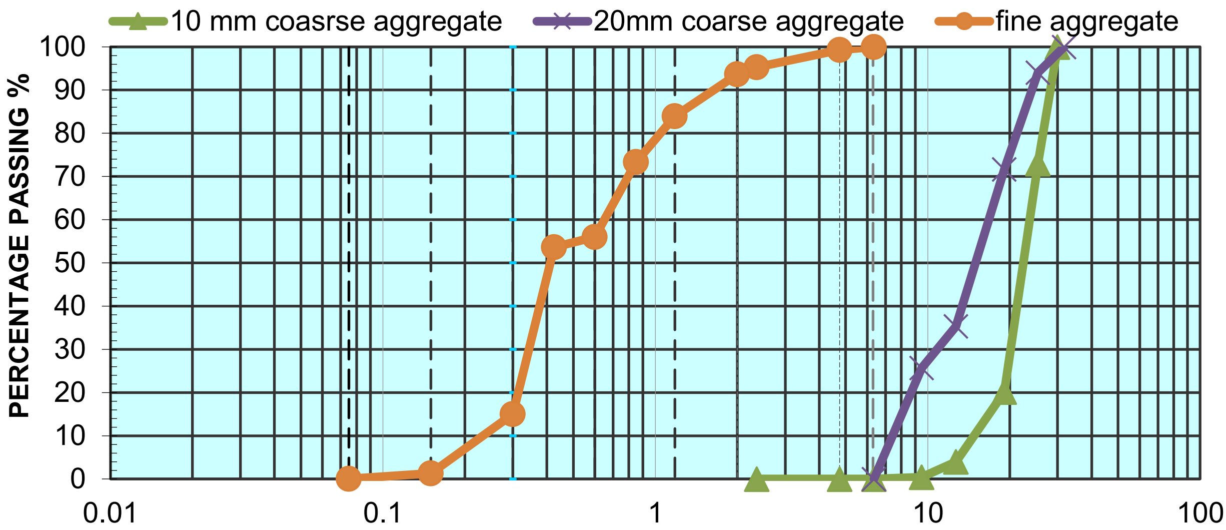
Where n = number of observation and p'= number input variables
Standard error of estimate shows the deviation of the observations from the regression line. The more reduced it is, the better the regression.

$$SE = \left(\sqrt{1 - R^2_{adj}}\right).\sigma \quad (11)$$

Where SE = Standard error of estimate and σ = standard deviation of observations from mean value.
Results obtained for compressive strength (7, 14 and 28 days) were regressed as the dependent variables. The weight densities of constituent materials (cement, 20mm coarse aggregate, 10mm coarse aggregate, fine aggregate, glass fibre and nanosilica) were used as independent variables.

III. Results and Discussion

The results of the sieve analysis test carried out on the aggregates are presented in Figure 1.



CLAY	SILT			SAND			GRAVEL		
	FINE	MED	COARSE	FINE	MED	COARSE	FINE	MED	COARSE

Figure 1. Particle Size Distribution

- **Compressive Strength**

The concrete prepared for the experiment at 0.20 water/cement ratio were subjected to compressive test after curing it for 7, 14 and 28 days. The results obtained are presented in Table 1.

Table 1: Compressive Strength Results of Control and Nanosilica blended UHPFRC at various ages

– % Replacement With Nanosilica	% Inclusion of Glass Fiber	Compressive Strength (MPa) 7Days	14Days	28Days
	1.0	83.11	103.73	117.72
	1.5	86.34	107.00	122.35
5	0.0	78.67	99.12	109.14
	0.5	83.00	105.91	122.27
	1.0	85.71	106.25	125.37
	1.5	88.30	110.56	130.70
10	0.0	83.21	102.17	118.79
	0.5	89.72	107.41	131.21
	1.0	90.43	110.39	137.23
	1.5	92.70	115.23	142.73
15	0.0	90.13	110.17	124.82
	0.5	96.00	116.92	137.84
	1.0	98.36	119.36	145.04
	1.5	101.30	125.70	152.30

From Table 1, the maximum compressive strength value of 152.3 MPa was achieved for a mix with 15% replacement of ordinary cement with Nanosilica and 1.5% by volumeincorporation of fiber from the table above, it was observed that the strength of the concrete at different amount of Nanosilica increases steadily with the inclusion of glass fiber from 0.5 to 1.5%. Partial replacement of cement with Nanosilica significantly affected the compressive strength of the concrete mix. Increasing the amount of Nanosilica in the concretes increased the compressive strength of the concrete. In essence, the increase in compressive strength is as a result of reduction of voids in the concrete through the introduction of finer particles of Nanosilica (NS). Thus, for all curing ages, the maximum strength values were observed for concretes with 15% replacement of cement with Nanosilica and 1.5% by volume inclusion of glass fiber. Therefore, the compressive strength of UHPFRC was obtained at 15% Nanosilica content and 1.5% glass fiber content.

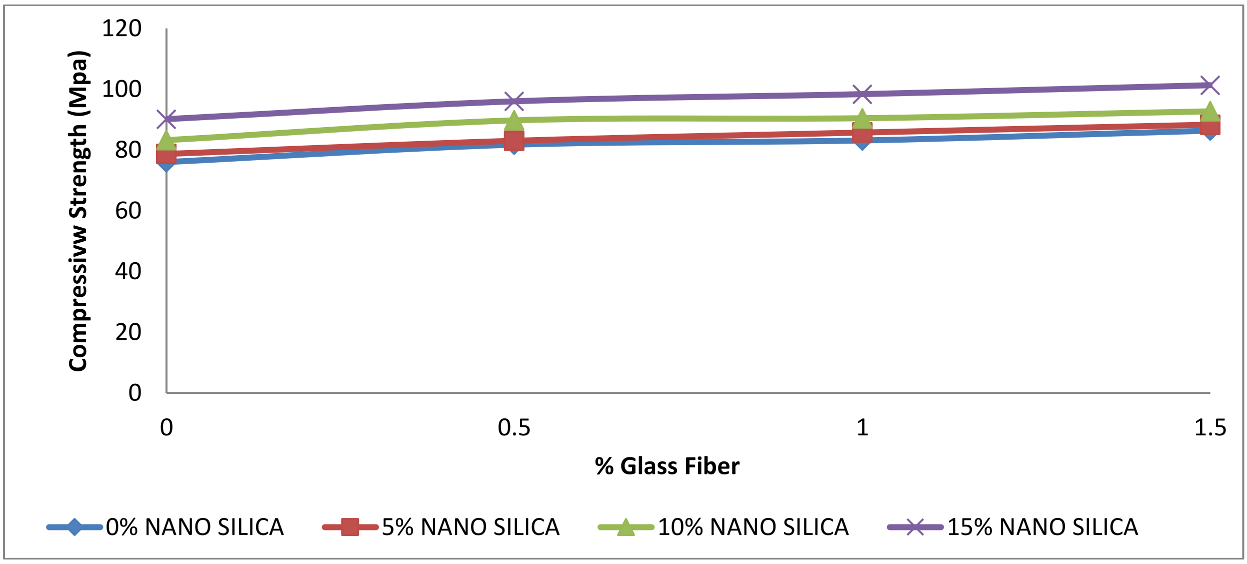


Figure 2: Compressive Strength of UHPFRC for 7 DAYS

From Figure 2, it was observed that the compressive strength of the concrete after 7 days of curing increases on increasing amount of glass fiber up to 1.5% with the introduction of Nanosilica content. At 0% Nanosilica content, the compressive strength is observed to increase by 7.5%, 9.2% and 11.45% at 0.5%, 1.0% and 1.5% by volume inclusion of glass fiber. At 5% Nanosilica content, the compressive strength is observed to increase by 5.51%, 8.78% and 11.81% at 0.5%, 1.0% and 1.5% by volume inclusion of glass fiber. At 15% Nanosilica content, the compressive strength is observed to increase by 6.42%, 9.32% and 11.92% at 0.5%, 1.0% and 1.5% inclusion of glass fiber.

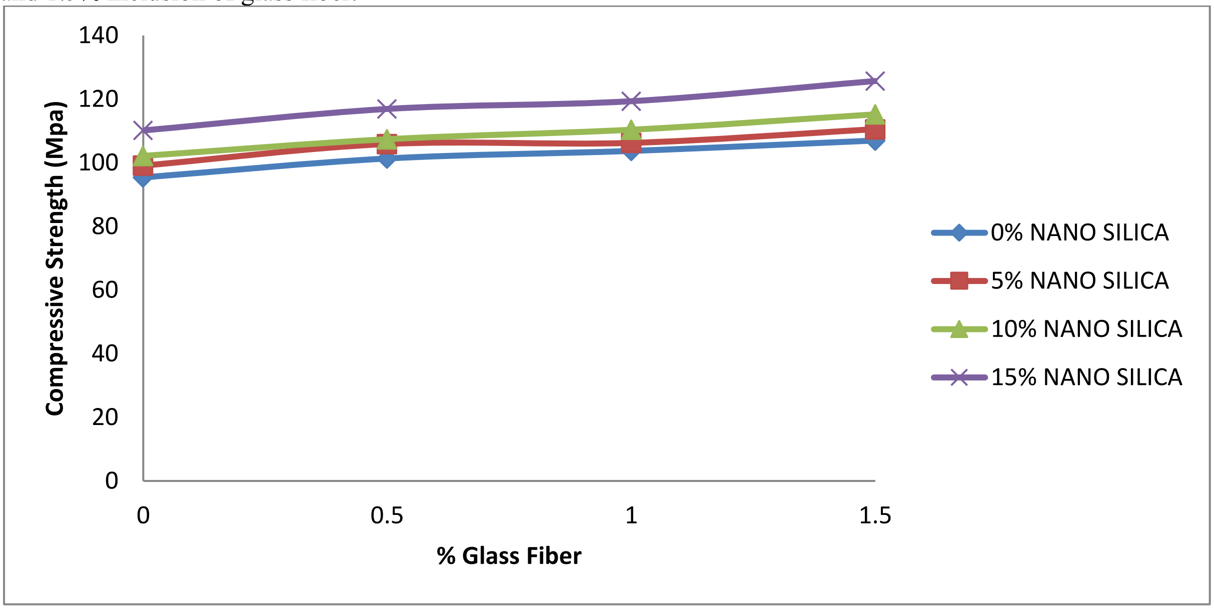


Figure 3: Compressive Strength of UHPFRC for 14 Days

Figure 3, it was observed that the compressive strength of concrete after 14 days increases on increasing amount of glass fiber up to 1.5% with the introduction of Nanosilica content. At 0% Nanosilica content, the compressive strength is observed to increase by 6%, 8.55% and 11.65% at 0.5%,1.0% and 1.5% by volume inclusion of glass fiber. At 5% Nanosilica content, the compressive strength is observed to increase by 6.85%, 7.18% and 10.7% at 0.5%, 1.0% and 1.5% by volume inclusion of glass fiber. At 10% Nanosilica content, the compressive strength is observed to increase by 5.12%, 7.9% and 12.29% at 0.5%, 1.0% and 1.5% inclusion of glass fiber content. At 15% Nanosilica content, the compressive strength is observed to increase by 6.1%, 8.2% and 13.51% at 0.5%, 1.0% and 1.5% inclusion of glass fiber content.

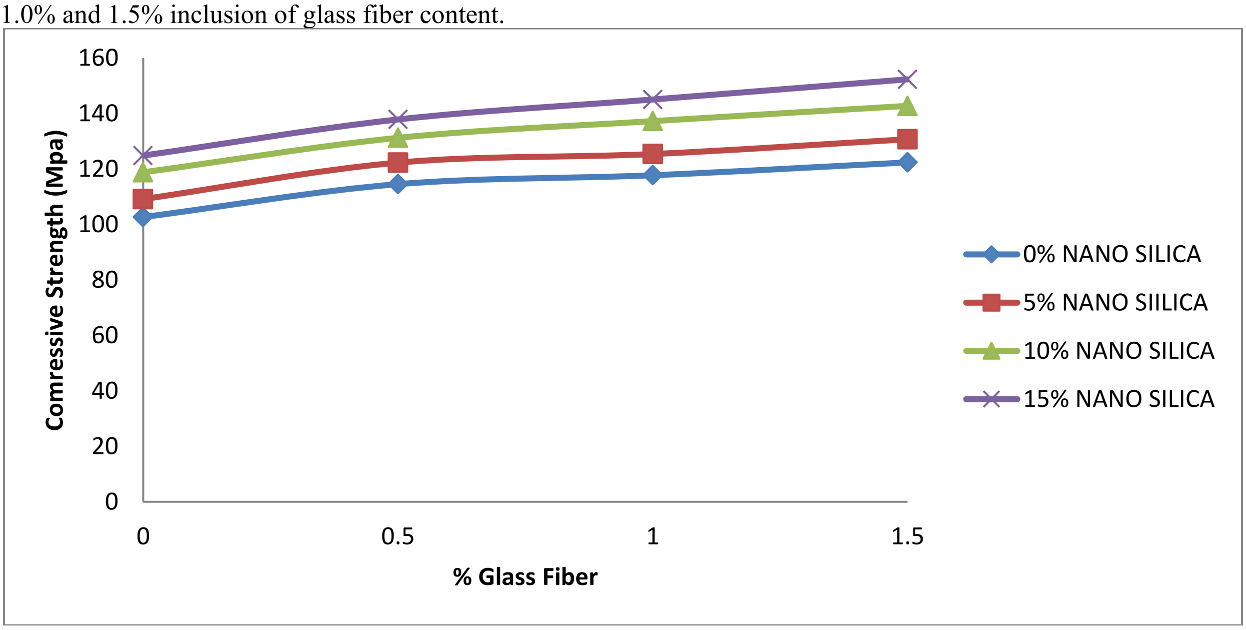


Figure 4: Compressive Strength of UHPFRC for 28 Days

From 4, it is observed that the compressive strength of concrete after 28 days increases on increasing amount of glass fiber up to 1.5% with the introduction of Nanosilica content. At 0% Nanosilica content, the compressive strength is observed to increase by 11.5%, 14.3% and 18.25% at 0.5%,1.0% and 1.5% by volume inclusion of glass fiber. At 5% Nanosilica content, the compressive strength is observed to increase by 12.2%, 14.8% and 19.05% at 0.5%, 1.0% and 1.5% by volume inclusion of glass fiber. At 10% Nanosilica content, the compressive strength is observed to increase by 11.3%, 15.8% and 20.19% at 0.5%, 1.0% and 1.5% inclusion of glass fiber content. At 15% Nanosilica content, the compressive strength is observed to increase by 9.4%, 15.6% and 22.6% at 0.5%, 1.0% and 1.5% inclusion of glass fiber content.

3.1 Discussion of Regression Results

From the regression output, based on the stepping criteria, 10mm coarse aggregate and fine aggregate were excluded from the final models.

7 Days Compressive Strength Model

Table 2 presents the coefficients of the independent variables as related to the dependent variable for the 7 days compressive strength.

Table 2: Model Coefficients for 7 Days Compressive Strength

Variable	Unstandardized Coefficient	Standardized Coefficient	T	Sig	Pearson Correlation Coefficient
Constant	46.982		2.544	.064	
20 mm coarse aggregates	-4.707	-.487	-1.696	.165	-.330
Cement content	-1.779	-1.322	-4.939	.008	-.937
Nanosilica	-.053	-.390	-1.456	.219	.914
Glass fibre	-.021	-.159	-.553	.610	.323

From Table 2, the exponential model for the estimation of seven days compressive strength is given by equation 12.

$$CS_7 = e^{46.982} \times X_1{}^{-4.707} \times X_2{}^{-1.779} \times X_3{}^{-0.053} \times X_4{}^{-0.021} \quad (12)$$

Where CS_7 = Predicted seven days compressive strength [MPa], X_1 = 20 mm coarse aggregate weight density [kg/m^3], X_2 = cement content [kg/m^3] and X_3 = nanosilica content [kg/m^3] and X_4 = glass fiber content [kg/m^3].
From the model summary table and ANOVA table as detailed in the appendix, evaluation of the above model can be captured from the parameters outlined in Table 3.

Table 3: Regression Statistics of 7 Days Compressive Strength Predictive Model

R	R-Squared	Adjusted R Square	Standard Error of the Estimate	F	Sig.	Durbin-Watson
0.996	0.992	0.985	0.008044052072	128.899	0.000	1.425

From Table 3.above, the coefficient of determination (R^2) of the estimated model for 7 days compressive strength is 0.992 indicating 99.2% influence of the independent variable in the estimation of compressive strength. The value shows high influence on the estimation of compressive strength by the included independent variables considering that other constituent materials could have affected the compressive strength, though not considered in the model due to constant values. The standard error of the estimate is very low as indicated in the table above. This shows that the model has higher level of accuracy in the estimation of compressive strength. The F-statistics (128.899) is statistically significant based on its significance value, 0.000 which is less than 0.05 benchmark used to measure significance level of model developed using 95% confidence interval as implemented in the current model development.

14 Days Compressive Strength Model

Table 4.below presents the coefficients of the independent variables as related to the dependent variable, compressive strength at age 14 days.

Table 4. Coefficients for Fourteen Days Compressive Strength

Variable	Unstandardized Coefficient	Standardized coefficient	T	Sig	Pearson Correlation Coefficient
Constant	91.478		4.532	0.011	
20 mm coarse aggregates	-10.596	-1.213	-3.495	0.025	-.0458
Cement content	-2.570	-2.112	-6.528	0.003	-0.849
Nanosilica	-0.156	-1.280	-3.956	0.017	0.804
Glass fibre	-0.093	-.765	-2.202	0.092	0.434

From Table 4.above, the nonlinear model for the estimation of fourteen days compressive strength is given by equation 13 below.

$$CS_{14} = e^{91.478} \times X_1{}^{-10.596} \times X_2{}^{-2.570} \times X_3{}^{-0.156} \times X_4{}^{-0.093} \quad (13)$$

Where CS_{14} = Predicted fourteen days compressive strength [MPa], X_1 = 20 mm coarse aggregate weight density [kg/m^3], X_2 = cement content [kg/m^3] and X_3 = nanosilica content [kg/m^3] and X_4 = glass fiber content [kg/m^3]. From the model summary table and ANOVA table as detailed in the appendix, evaluation of the above model (Equation 13) can be captured from the parameters outlined in Table 5.

Table 5: Regression Statistics of Fourteen Days Compressive Strength Predicted Model

R	R-Squared	Adjusted R Square	Standard Error of the Estimate	F	Sig.	Durbin-Watson
0.994	0.989	0.977	0.008790973500	87.866	0.000	1.419

From Table 5, the coefficient of determination (R^2) of the estimated model for fourteen days compressive strength is 0.989 indicating 98.9% influence of the independent variable in the estimation of compressive strength (dependent variable). The values shows high influence level of the predictors on the model, however the exclusion of some independent variable. The standard error of the estimate is very low as indicated in the table above. This shows that the model has higher level of accuracy in the estimation of compressive strength. In assessing the statistical significance of the model, the F-statistics (87.866) is statistically significant based on its significance value, 0.000 which is less than 0.05 benchmark used to measure significance level of model developed using 95% confidence interval as implemented in the current model development. The Durbin-Watson value indicates positive autocorrelation of errors as its value is less than 2.

3.2 28 Days Compressive Strength Model

Similarly, the 28 days compressive strength results obtained from experimental test were regressed against the independent variables and results obtained.

Table 6. presents the coefficients of the independent variables as related to the dependent variable, compressive strength.

Table 6: Coefficients for 28 Days Compressive Strength

Variable	Unstandardized Coefficient	Standardized coefficient	t	Sig	Pearson Correlation Coefficient
Constant	45.855		2.228	0.090	
20 mm coarse aggregates	-5.995	-0.567	-1.939	0.124	-0.509
Cement content	-0.315	-0.213	-0.784	0.477	-0.849
Nanosilica	0.095	0.645	2.368	0.077	0.855
Glass fibre	-0.009	-0.058	-0.198	0.853	0.502

From Table 6.above, the nonlinear model for the estimation of twenty-eight days compressive strength is given by equation (14).

$$CS_{28} = e^{45.855} \times X_1{}^{-5.995} \times X_2{}^{-0.315} \times X_3{}^{0.095} \times X_4{}^{-0.009} \quad (14)$$

Where CS_{28} = Predicted twenty-eight days compressive strength [MPa], X_1 = 20 mm coarse aggregate weight density [kg/m^3], X_2 = cement content [kg/m^3] and X_3 = nanosilica content [kg/m^3] and X_4 = glass fiber content [kg/m^3].
From the model summary table and ANOVA table as detailed in the appendix, evaluation of the above model (Equation 4.3) can be captured from the parameters outlined in Table 7.

Table 7: Regression Statistics of Twenty-eight Days Compressive Strength Predicted Model

R	R-Squared	Adjusted R Square	Standard Error of the Estimate	F	Sig.	Durbin-Watson
0.996	0.992	0.984	0.008962243374	124.556	0.000	1.547

From the table shown above, the coefficient of determination (R^2) of the estimated model for twenty-eight days compressive strength is 0.992 indicating 99.2% influence of the independent variable in the estimation of compressive strength (dependent variable). The values shows high influence level of the predictors on the model, however the exclusion of some independent variable. The standard error of the estimate is very low as indicated in the table above. This shows that the model has higher level of accuracy in the estimation of compressive strength.In assessing the statistical significance of the model, the F-statistics (124.556) is statistically significant based on its significance value, 0.000 which is less than 0.05 benchmark used to measure significance level of model developed using 95% confidence interval as implemented in the current model development.

IV. Conclusions

Based on the results obtained from the study, the following conclusions are made:

i. The adopted Particle Parking Method (PPM) of mix design, provided an acceptable results for the fresh and hardened state properties of the Ultra High Performance Fiber-Reinforced concrete. Thus, this mix design method is proposed for the production of Ultra High Performance Fiber-Reinforced Concrete (UHPFRC) because the compressive strength above 150MPa.

ii. The replacement of cement with Nanosilica reduced voids in the concrete thereby achieving above the proposed compressive strength in the production of UHPFRC. Therefore, Nanosilica is recommended to be adopted as a replacement for cement in the production of UHPFRC to achieve the proposed strength of concrete.

iii. The incorporation of glass fiber increased the ductility of UHPFRC and thereby increased the compressive strength of the concrete.

iv. Sulphate ions attack and weaken the concrete. The sulphate ions may either come from the concrete itself, that is, when the sulfate content of the cement is excessively high or from external sources, when the environment in which the concrete is placed is rich in sulfates. In this study, the strength and mass losses were negligible. That is the high tensile strength will resist the concrete cracking.

v. Development of regression model to predict the structural properties of UHPFRC was adequate, using F-Statistics at 5% of Significant level.

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