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Modelling the Strength properties of *Anadara granosa* Shells Incorporated Concrete

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ABSTRACT

This study investigated the use of ark clam shell as a replacement for granite in concrete production. This study adopted manual size reduction technique, weight batching method, sieve analysis for particle size distribution of aggregates; workability test, density, compressive strength, flexural strength and split tensile strength tests. Concrete samples of 150mm x 150mm x 150mm cubes, 500mm x 100mm x 100mm beams and 20mm x 100mm cylinders were casted and demould after 24hrs of setting. Varying percentage of 10%, 20%, 30%, 40%, 50% and 100% replacement of granite with *Anadara granosa* shell with 0% serving as the control mix. A total number of 63 cubes, beams and cylinders were casted and cured for 28 days while the strength properties of the concrete were conducted at 7, 14 and 28 days respectively. A design Expert was used for the modelling of the strength properties of the concrete samples. The results shows that the strength properties of the concrete increased with curing age of the concrete whereas a decrease in strength was observed as the AGS shell increased. After 28 days of curing, a maximum strength of 29.27N/mm² was recorded at 0% replacement (control mix) while a minimum strength of 21.89N/mm² was recorded at 100% replacement with 0.5 w/c. The flexural strength of the concrete with 0.5 w/c are as follows: 8.17 N/mm², 7.35 N/mm², 7.01 N/mm², 6.37 N/mm², 6.19 N/mm², 5.23 N/mm² and 4.08 N/mm². The split tensile strength with w/c of 0.5 has the following results of 7.87 N/mm², 6.70 N/mm², 6.12 N/mm², 5.90 N/mm², 5.57 N/mm², 4.83 N/mm² and 4.09 N/mm² respectively. A density of 2743.70kg/mm³ and 2641.98kg/mm³ were obtained at 0% and 100% replacement respectively after 28 days. The density and the strength properties met the standard ACI 211.2 for light weight concrete requirement.

Keywords Granite, Concrete, Compressive Strength, Flexural Strength, Split Tensile Strength

INTRODUCTION

Over the years, concrete which is a mixture of cement, sand and granite have been the first choice of material when it comes to construction in the construction industry, because of its enduring physical and chemical properties such as strength, durability, workability and flexibility which allows for easy handling. Despite all these good qualities of concrete, people around Nigerian localities have challenges when it comes to accessing granite due to quarry not found around their localities which makes purchasing of granite very costly. Aside from not having quarries close to localities, quarry activities have damaging effect to areas where they are found. Such effects include continuous vibration and consequent damage of houses due to flying rocks blasting (www.bbc.co.uk.2020).

Another challenge is that concrete has led to high cost in construction works because of its ingredients like cement and granite. Based on the expensive construction materials, residents around Nigeria localities, substitutes some natural materials for the replacement of granite. These materials are used for non – load bearing structures (light weight structures). Such materials include periwinkle, clam shells, saw dust, etc. Use of these local materials has also helped in reducing environmental hazards leading to sustainable development and also reducing the cost of construction. *Anadara granosa* commonly known as ark clam shell or cockle shell is a salt water specie whose mussels are rich in protein, carbohydrate, minerals, vitamins as well as one – 3 fatty acids (Anacleto *et al*., 2016). Their shells are often white, cream yellow or sometimes mixed with light brown color. Its shell shape is solid thick, globular and broadly oval to quadratic shape (Abbot and Morris, 1995). They can be found in riverside areas and coastal regions where they are used for food. A number of studies have been carried out on the consumable aspect of *Anadara granosa* but very few limited study had been conducted on its shell. Since origin *Anadara granosa* shells are removed and thrown away after getting the mussels. This act contributes to environmental pollution which leads to offensive odour and in most cases, if not disposed properly may cause injuries when stepped upon. They as well promote microbial growth and emit CO_2 in lesser extent as the biodegrade leading to environmental pollution (Suresh and Dhanaraj, 2018). These dumped shells becomes a habitat for harmful insects such as mosquitoes, tsetse fly etc. Also, sites where these shells are being dumped cannot be used for agricultural activities which leads to non – use of the land.

MATERIALS AND METHODS

The materials used for this research includes cement, sand, granite, water, ark clam shell (*Anadara granosa*) and hardwood. The shells were cleaned and crushed using mallet and hammer by pounding on a hard concrete surface. A cubic mould of 150mm×150mm×150mm was used in producing the concrete cubes, 500mmx100mmx100mm mould was used to produce the beams whereas 200mmx100mm cylinder mould was used to produce the cylinders.

Production of Concrete Cubes, Beams and Cylinder, Curing and Testing of Compressive Strength, Flexural Strength and Split Tensile Strength

The constituents were measured in their suitable proportions and batched by weight. The mixing method for this research was done manually (hand mixing). The mix ratio for cement, sand granite was 1:2:4 respectively for this research. Granite was replaced by ark clam shell (*Anadara granosa*) in varying percentage range of 0%, 10% ,20% ,30% ,40% ,50% and 100% respectively. After mixing the concrete, standard slump test with code BS 1881:102 (1983) was carried out before casted. The concrete samples were cured for 28days. Compressive strength, flexural strength and split tensile strength tests were carried out on the concrete samples according to their curing age.

Density

Density test was carried out to determine the quantity of material in a cubic meter. The density of the cubes was determined using the following equation:

$$D(\ell) = m/v \qquad \textbf{(1)}$$

where, $D(\ell)$ = Density of cube (kg/m^3),
m = mass of the concrete cubes (kg)
v = volume of cube mould (m^3)

RESULTS AND DISCUSSION

A. Sieve Analysis

The results for sand in this research has a fineness modulus of 3.61, curvature of 2.78 and uniformity coefficient of 4.3 and this satisfied the code for particle gradation for aggregate. The sand for this research had more of medium size compared to fine and coarse size (3:5:2) using IS 383: 1970. The fineness modulus for granite and *Anadara granosa* shell were 4.69 and 4.5, uniformity coefficient for the granite and *Anadara granosa* shell were 3.33 and 3.11 and a uniformity curvature of 1.40 and 1.30 for both aggregates. The aggregates are well graded for construction work.

B. Specific Gravity

Specific gravity test was conducted for sand, cement and *Anadara granosa* shell in order to know the behaviour of the materials when submerged in water. The specific gravity for the sand was obtained as 2.6 according to the standard IS: 2386 (III) – 1963, which confirms it to be good for construction work.

The specific gravity for Dangote 3x cement conducted and found to be 2.90 which falls within the range specified by (IS 383: 1970). The specific gravity for the *Anadara granosa* shell resulted to be 2.5 which is within the range as been specified by IS:2386 (part 3): (1963), hence the shell can be used as construction material coarse aggregate category.

C. Slump Test

The slump values of 51mm, 54mm, 57mm, 60mm, 55mm, 50mm and 45mm respectively were obtained for granite replacement levels of 0%, 10%, 20%, 30%, 40%, 50% and 100%. It was also observed that as the replacement increases the workability increased but drops after 30% replacement. For a medium concrete which can be used for beams construction, slab, foundation laying etc., this result satisfies the workability for the aforementioned structures.

D. Density of Concrete

Figure 1 shows a maximum density of 2750kg/m³ and a minimum of 2641.98kg/m³ was recorded at 0% (control mix) and 100% replacement respectively. This results indicates that *Anadara granosa* shell can be used for construction of beams, foundation laying, slabs etc., even at 100% replacement (2641.98kg/m³) since it's density is within the range of normal weight for concrete construction work with respect to 28days curing.

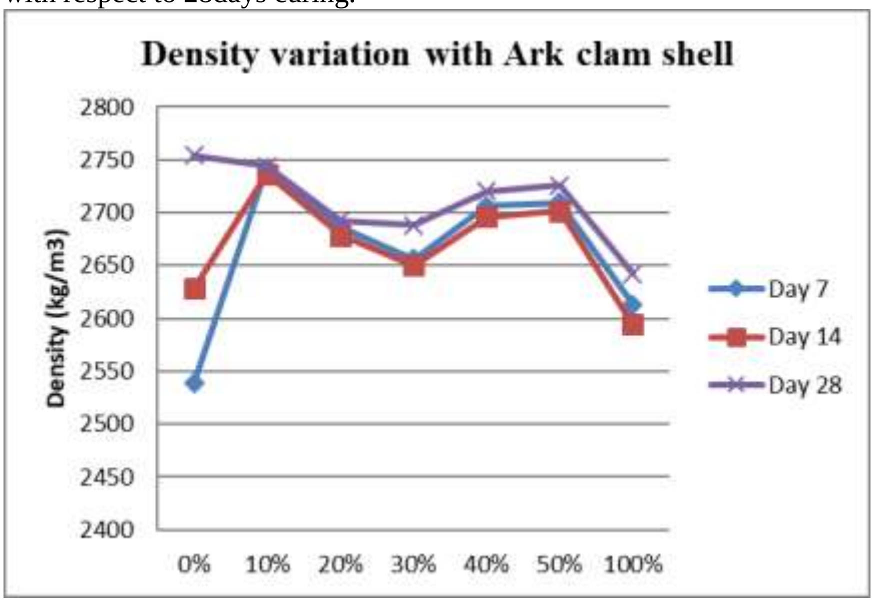

Figure 1: Graphical representation of Density.

Data Analysis and Model Development for Compressive Strength (CS)Test

As shown in Table 1, a linear regression model is the one that is suggested for analysis. This indicates that a straight line can fairly represent the relationship between the dependent variable and the independent variable or variables. Both the adjusted and anticipated coefficients of regression show how well the independent variables, after adjusting for the number of predictors in the model, explain the variability in the dependent variable. In this instance, the model's independent variable(s) account for almost 97% of the variance in the dependent variable, as indicated by the adjusted coefficient of regression of 0.9696. This seems to be a term unique to investigation, yet the expected coefficient of regression is 0.9578. The coefficient modified for certain expected conditions or changes may be referred to here. A statistical metric called lack of fit is used to evaluate how well a suggested regression model fits the data. A Lack of Fit rating of less than 0.0001 implies that the model fits the data quite well and that there is little evidence of lack of fit. The adjusted coefficient of regression shows that your linear regression model has a high degree of explanatory power and fits the data quite well. There is also minimal evidence to suggest that the model does not accurately capture the relationship between the variables. This suggests that the model can be utilized for additional analysis or prediction as it is good fit for the data.

Table 1: Model Fit Summary of the CS of AGS-GRL

Source	Sequential p-values	Lack of Fit p-values	Adjusted R^2	Predicted R^2	
L	< 0.0001		0.9205	0.8846	
2FI	0.0038		0.9696	0.9578	Suggested
Q	0.3599		0.9703	0.9004	
C			1.0000		Aliased

The statistical data from the analysis of variance (ANOVA) for the CS of AGS-GRL concrete are as indicated in Table 2

Table 2: ANOVA for the CS of AGS-GRL Concrete

Basis	Sum of Squares	df	Mean Square	F-value	p-value	
Model	593.40	9	65.93	75.48	< 0.0001	significant
A-AGS-GRL	149.47	1	149.47	171.12	< 0.0001	
B-W/C	50.83	1	50.83	58.19	< 0.0001	
C-CA	300.22	2	150.11	171.85	< 0.0001	
AB	5.01	1	5.01	5.74	0.0338	
AC	17.98	2	8.99	10.29	0.0025	
BC	7.52	2	3.76	4.31	0.0389	
Residual	10.48	12	0.8735			
Lack of Fit	10.48	7	1.50			
Pure Error	0.0000	5	0.0000			
Cor Total	603.88	21				

The signal effect of interest is substantially stronger than the noise random variability in the data, as shown by the significantly high F-value linked to the signal-to-noise ratio. This shows that there is a statistically significant association between the variables under investigation. The model's overall significance is measured by the model F-value, which is 75.48. This number shows that the independent variables together have a considerable impact on the dependent variable, suggesting that the model as a whole is highly significant. Since the model's F-value has a very low P-value (0.01%), it is highly unlikely that a random fluctuation would produce an F-value this significant. This demonstrates the model's importance in understanding the data's variability. Since the P-values of model terms A, B, C, AB, AC, and BC are less than 0.05, they are regarded as significant. For the purpose of illustrating how well the model fits the data both within and across variables, Table 4.5 most likely offers summary statistics pertaining to the fit of the model.

Table 3: Summary of Fit Statistics

Std. Dev.	0.9346	R^2	0.9826
Mean	20.56	Adjusted R^2	0.9696
C.V. %	4.55	Predicted R^2	0.9578
		Adeq Precision	30.3471

When the variance is smaller than 0.2, it indicates that the data surrounding the mean are substantially less variable. This suggests that the fitted regression line is the center of a close clustering of the data points. When the number of predictors is taken into account, an adjusted R-squared of 0.9696 means that the independent variables in the model account for around 96.96% of the variance in the dependent variable. This is a high number, indicating that the model does a good job of fitting the data. With a predicted R-squared of 0.9578, it appears that the model will be successful in forecasting the dependent variable in upcoming observations as well. The strength of the signal, or the effect of interest, in relation to the noise, or random fluctuation, in the data, is measured by the signal-to-noise ratio. A substantial signal is shown by a ratio of 30.347, while a ratio larger than 4 is deemed sufficient precision. This implies that the model is helpful for navigating the design space and generating predictions since it gives a strong signal in comparison to the noise. These findings collectively imply that the model is quite robust and dependable, which qualifies it for outcome analysis and prediction in the design space.
The formulated model is represented by the following equation, 2, 3 and 4 respectively

$$Fcm7 = 37.20826 - 0.143088G - 36.01042W + 0.193875G * W \quad (2)$$

$$Fcm14 = 33.55669 - 0.203232G - 17.87750W + 0.193875G * W \quad (3)$$

$$Fcm28 = 41.67875 - 0.166904G - 24.07708W + 0.193875G * W \quad (4)$$

Where;

Fcm = Target CS of concrete composed of AGS as partial replacement for granite cured at age 7, 14 and 28 days (N/mm^2)

G = percentage of AGS present in mix as replacement for granite (%)

W = water to cement ratio employed in concrete production

These models depict the way the elements change over time and impact the reaction. Figure 2 shows how the variables that the models describe relate to one another. All things considered, these models and graphs are crucial for comprehending how the elements affect the reaction over time and for forecasting the reaction depending on the component levels. They offer insightful information about the dynamics of the system being studied.

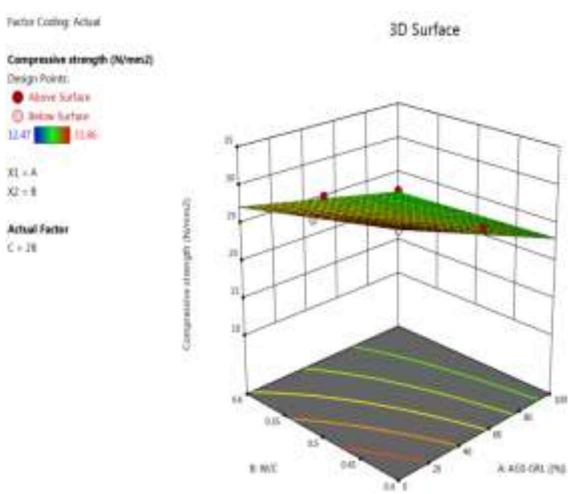

Figure 2: Simulation of model for the CS of AGS-GRL at 28 days

Compressive strength is impacted noticeably by higher AGS content, as Figure 2 demonstrate. Compressive strength (CS) demonstrates a consistent downward trend over the course of the investigated curing durations. When the water-to-cement ratio rises, the amount of CS decreases linearly. Higher water-to-cement ratios typically lead to poorer compressive strength because of decreased cement hydration, which is a common finding in concrete mix design. This suggests that lower concentrations of AGS mitigate the effects of increasing water-to-cement ratio on CS. Model diagnostics, which evaluate the predictive model's performance, are displayed in Figure 3 when strength levels rise, there appears to be a discernible improvement in the model's prediction accuracy as seen by a large decline in the difference between expected and actual values. The model's ability to reliably navigate the design space is further supported by the lack of notable outliers in the linear slope. All things considered, these results offer insightful information about how many parameters, like the amount of AGS and the ratio of water to cement, affect the compressive strength of concrete.

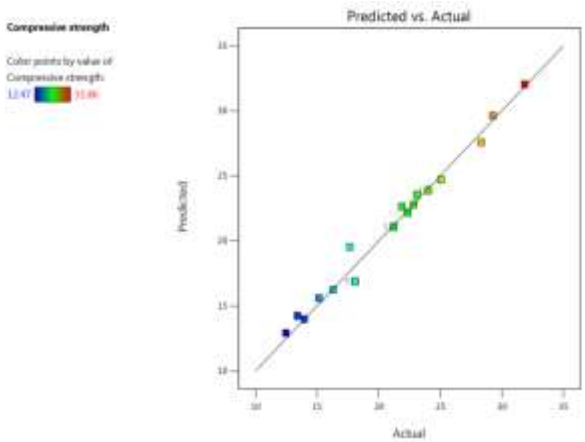

Figure 3: Simulation of model for the CS of AGS-GRL at 28 days

Data Analysis and Model Development for Flexural Strength (FS)Test

A linear regression model is the one that is advised for analysis as illustrated in Table 4. When the number of predictors in the model is taken into account, the adjusted coefficient of regression determines how well the independent variables account for the variability in the dependent variable. Since the independent variable(s) in the model account for roughly 87.97% of the variability in the dependent variable, the adjusted coefficient of regression of 0.8797, it is likely that the coefficient acquired by forecasting outcomes in new data is meant to be by the anticipated coefficient of regression of 0.8299. An indicator of a well-fitting model is a Lack of Fit value of less than 0.0001, which implies minimal evidence of lack of fit in the model.

Table 4: Model Fit Summary of the FS of AGS incorporated concrete

Source	Sequential p-value	Lack of Fit p-value	Adjusted R^2	Predicted R^2	
Linear	< 0.0001		0.8797	0.8299	Suggested
2FI	0.1315		0.9097	0.8089	
Quadratic	0.9339		0.8931	0.6778	
Cubic			1.0000		Aliased

The statistical data from the analysis of variance (ANOVA) for the FS of AGS incorporated concrete are as shown in Table 5.

Table 5: ANOVA for the FS of AGS incorporated concrete

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	40.94	4	10.24	39.40	< 0.0001	significant
A-AGS-GRL	28.34	1	28.34	109.08	< 0.0001	
B-W/C	3.76	1	3.76	14.47	0.0014	
B-W/C	3.76	1	3.76	14.47	0.0014	
C-CA	4.76	2	2.38	9.17	0.0020	
Residual	4.42	17	0.2598			
Lack of Fit	4.42	12	0.3680			
Pure Error	0.0000	5	0.0000			
Cor Total	45.36	21				

Table 5 makes this clear, that the model's overall significance is measured by the model F-value, which is 39.40. This F-value has a low probability (0.01%), indicating that it is very unlikely to occur by chance alone. This suggests that the model is statistically significant overall. Since the P-values of model terms A, B, and C are less than 0.05, they are regarded as significant.

Table 6: Summary of Fit Statistics

Std. Dev.	0.5097	R^2	0.9026
Mean	5.66	Adjusted R^2	0.8797
C.V. %	9.00	Predicted R^2	0.8299
		Adeq Precision	21.8816

From Table 6, the adjusted R-squared of 0.8797 shows that the independent variables in the model account for about 87.97% of the variability in the dependent variable. In close agreement with the modified R-squared is the predicted R-squared of 0.8299. This implies that the model achieves good performance on both new data and the data that was used to fit the model. An almost perfect match is seen by the less than 0.2 discrepancy between the adjusted and anticipated R-squared values. This indicates that the model performs consistently across many datasets. With sufficient precision, the signal-to-noise ratio is calculated, with a target ratio of more than 4. The signal level is considered good at 21.882. This suggests that the influence of interest, or the signal, is significantly larger than the noise, or random fluctuation, in the data, which is necessary for accurate forecasts and deductions.
The developed model is as shown in equation 5, 6 and 7 respectively.

$$Fcm7 = 9.35052 - 0.031275 - 5.24463W \quad (5)$$

$$Fcm14 = 9.67514 - 0.031275G - 5.24463W \quad (6)$$

$$Fcm28 = 10.49107 - 0.031275G - 5.24463W \quad (7)$$

Where;
Fcm = Target FS of concrete composed of AGS as partial replacement for granite cured at age 7, 14 and 28 days (N/mm^2)
G = percentage of AGS present in mix as replacement for granite (%)
W = water to cement ratio employed in concrete production
Most frequently, the predictive equation shows a mathematical relationship between a number of variables and the reaction under investigation. It makes it possible to forecast the reaction based on these components' values. Figure 4, illustrations how the variables that the models describe relate to one another.
Additionally, the lack of notable outliers in the linear slope implies the model's robustness and dependability, suggesting that it is appropriate for navigating the design space. This suggests that there are no significant anomalies or discrepancies between the model's predictions and actual observations

over a wide range of strength levels as displayed in Figure 5. These results imply that the model is operating effectively and is reliable for generating predictions inside the allotted design space. It emphasizes how well the model captures the connection between strength values and expected results, which is crucial for informing decision-making processes across a range of applications.

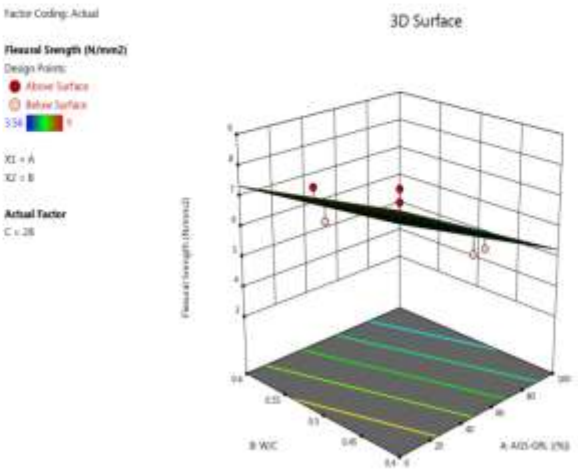

Figure 4: Simulation of model for the FS of AGS-GRL at 28 days

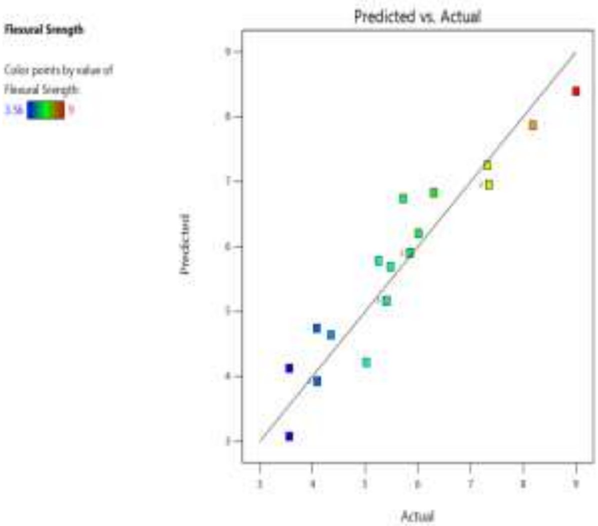

Figure 5: Simulation of model for the FS of AGS-GRL at 28 days

Data Analysis and Model Development for Split Tensile Strength (STS).

From Table 7, the adjusted coefficient of regression for the "Linear" model is 0.9066, while the anticipated coefficient of regression is 0.8622. With an adjusted coefficient of regression of 0.9638 and a forecasted coefficient of regression of 0.8280, the "quadratic" model performs well. When considering the criteria and objectives of the investigation, the quadratic model was chosen over the linear one, indicating that the quadratic model either fits the data better or provides more accurate predictions of the splitting tensile strength of concrete with AGS partially replacing granite. The models' goodness of fit, the rationale of employing a quadratic connection theoretically, or the practical ramifications for applying the models in actual situations are probably some of the factors that went into this decision as depicted in Table 7.

Table 7: Model Fit Summary of the STS of concrete composed of AGS as partial replacement for granite

Source	Sequential p-value	Lack of Fit p-value	Adjusted R²	Predicted R²	
Linear	< 0.0001		0.9066	0.8622	Suggested
2FI	0.1323		0.9298	0.7523	
Quadratic	0.0147		0.9638	0.8280	Suggested
Cubic			1.0000		Aliased

Table 8: ANOVA for the STS of Concrete composed of AGS as partial replacement for granite

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	54.04	11	4.91	51.81	< 0.0001	significant
A-AGS-GRL	24.28	1	24.28	256.00	< 0.0001	
B-W/C	5.20	1	5.20	54.81	< 0.0001	
C-CA	10.67	2	5.34	56.27	< 0.0001	
AB	0.2489	1	0.2489	2.63	0.1363	
AC	0.2135	2	0.1068	1.13	0.3623	
BC	1.25	2	0.6254	6.59	0.0149	
A²	0.9546	1	0.9546	10.07	0.0099	
B²	0.2286	1	0.2286	2.41	0.1516	
Residual	0.9483	10	0.0948			
Lack of Fit	0.9483	5	0.1897			
Pure Error	0.0000	5	0.0000			
Cor Total	54.99	21				

The model's overall importance is indicated by its Model F-value of 51.81. The splitting tensile strength of concrete containing AGS is the dependent variable in this case, and a large F-value indicates that the model is statistically significant, indicating that the independent factors collectively have a substantial effect on it. It is doubtful that the observed F-value could have happened by chance alone, as there is a 0.01% probability that a large F-value like this would occur due to noise. As a result of their P-values being less than 0.05, the model terms A, B, C, BC, and A^2 in this case are considered significant. This suggests that these parameters significantly affect the response variable (STS). Table 9 offers extra fit statistics that assess the model's ability to simulate relationships between and within variables. The model may perform better if certain changes are made, such eliminating unnecessary phrases. For more information about the model's performance and fit, see Table 9 most likely.

Table 9: Summary of Fit Statistics

Std. Dev.	0.3079	R²	0.9828
Mean	5.01	Adjusted R²	0.9638
C.V. %	6.15	Predicted R²	0.8280
		Adeq Precision	25.9584

After adjusting for the number of predictors, the Adjusted R^2, which measures the percentage of variance in the dependent variable (splitting tensile strength), is 0.9638. With such a high result, it can be inferred that the model accounts for approximately 96.38% of the data's variability. The percentage of the dependent variable's variance that the model can predict from fresh data is indicated by the Predicted R^2, which stands at 0.8280. The model predicts approximately 82.80% of the variability in the dependent variable, according to a value of 0.8280, which is still fairly high but somewhat less than the Adjusted R^2. The consistency of the model's explanatory power and predictive capacity is demonstrated by the less than 0.2 difference between the Adjusted R^2 and the Predicted R^2. This implies that in addition to the data used for model fitting, the model also functions effectively on fresh data. It is determined that the signal-to-noise ratio is 25.958, which is regarded as a strong signal. With a signal strength of 25.958, the technique is considered adequate for experimenting with the design space.

The developed model is as shown in equations 8, 9 and 10.

$$Fcm7 = 16.65626 - 0.071923G - 33.62601W + 0.044071G * W + 0.000207G + 23.37245W \qquad (8)$$

$$fcm14 = 17.06691 - 0.074627G - 32.50388W + 0.044071G * W + 0.000207G + 23.37245W \qquad (9)$$

$$Fcm28 = 14.93510 - 0.078973G - 25.87601W + 0.044071G * W + 0.000207G + 23.37245W \qquad (10)$$

Where;

Fcm = Target STS of concrete composed of AGS as partial replacement for granite cured at age 7, 14 and 28 days (N/mm^2)

G = percentage of AGS present in mix as replacement for granite (%)

W = water to cement ratio employed in concrete production

To predict the reaction with respect to particular levels of each element, use the equation given in actual factors. It's crucial to specify these levels in terms of the original units that correspond to each element. The models expressed as relativity between variables at age 7, 14 and 28 days are as shown in Figure 6

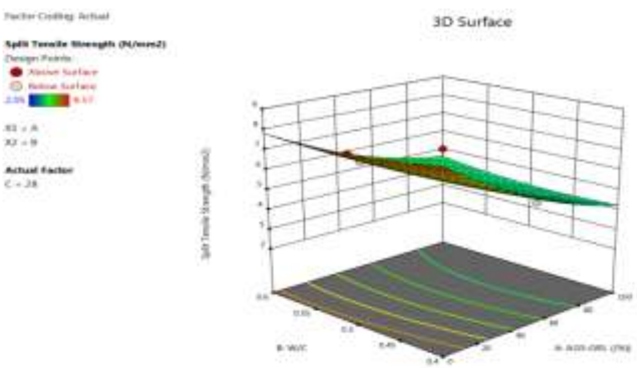

Figure 6: Simulation of model for the STS of AGS-GRL at 28 days

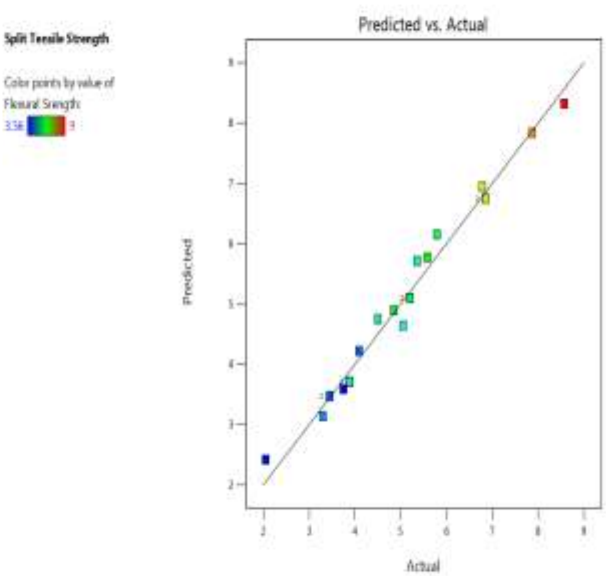

Figure 7: Simulation of model for the STS of Concrete composed of AGS as partial replacement for granite.

As the strength values grow, the model diagnostics, as displayed in Figure 6, shows a significant decrease in the difference between the predicted and actual values. The linear slope's lack of notable outliers indicates that the response variable (strength values) and the predictor variables have a constant association over the entire observed range. This increases the model's dependability and shows that predictions made inside the examined design space can be made with confidence. Given the model diagnostics shown in Figure 7 and the lack of notable outliers, the model appears to be stable and dependable, especially as strength levels rise. This shows that it may be confidently used to investigate and decide on concrete with AGS mixed in as a partial substitute for granite inside the design space.

F. CONCLUSION

In conclusion, the aggregate particles exhibited a well-distributed size distribution, and their specific gravity values fell within the acceptable limits necessary for construction purposes. All levels of AGS included in the concrete showed an increase in the CS, STS, and FS as time and cure length increased. However, a drop in strength was observed with an increase in the concentration of AGS. Design Expert version 13.0.5.0 was used to evaluate the experiment's data. It became clear that the concrete's mechanical qualities were greatly influenced by the replacement levels and curing age. The null hypothesis was rejected as a result of the developed models' acceptable signal-to-noise ratios and satisfactory coefficient of regressions (R^2 values). These models were validated with the data generated by the model serving as projected data and the data retrieved experimentally as actual data. Every model that was examined showed average similarity indices that were higher than 90%.

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