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Development of strength model of saw dust ash self compacting concrete

Ayuba S[1*] and Uche O.A.U [2]

[1]Department of Civil Engineering, Bayero University Kano, Nigeria
[2,]Department of Civil Engineering, Bayero University Kano, Nigeria
*Email: solos4life@gmail.com

Abstract
The use of Response Surface Methodology (RSM) has significantly provided opportunity for adjustment during concrete production to avoid mistake and produce the required strength. Self-compacting concrete (SCC) offers numerous practical and economic benefits with good quality improvement in concrete constructions. The need to reduce challenges associated with cement making has been on the increase among the expertise globally, sawdust ash was used in the mix design to improve concrete properties and reduce the problem of poorly managed wastes by converting it to wealth. This paper presents the findings on the strengths of (SCC) containing Saw dust Ash (SDA) and development of strength prediction models of the concrete. The SDA used was obtained by incineration at 600 ^{o}C and sieved through 75 µm sieve. The compressive, splitting tensile and flexural strengths of (SDA-SCC) grade 40N/mm^2 were investigated at replacement levels of 0, 5, 10, 15, 20, 25 and 30 %, respectively, at curing ages of 3, 7, 28, 56 and 90 days in accordance with standard procedures. The strengths of SDA-SCC were modeled using (RSM). The investigations showed that the strength properties of SCC decreased with increase in SDA content. However 5% SDA replacement was considered as optimum for structural concrete. The models of SDA-SCC for compressive, splitting tensile and flexural strengths were developed with R^2 values of 0.9815, 0.9955 and 0.9968, respectively and is in good agreement with experimental results it confirm the validity of the proposed model and the model can be used to predict the strength of SDA-SCC.

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Keywords: *Response Surface methodology; Strength Properties; Saw Dust Ash; Self Compacting Concrete*

1. Introduction

The use of cement by construction industries has been long-established and continuously on the increase up-to-date especially ordinary Portland cement (OPC) commonly used in the making of concrete consumed in the development of shelter and other infrastructural facilities (Mehta, 2004). However, cement making requires high amount of raw material treated at high temperature with emission of toxic metal and gases contaminating the atmosphere, (Hasanbeigi *et-al.*, 2012). This increases severe global environmental challenges such as global warming (Lei, *et-al.*, 2017; Dunuweera and Rajapakse 2018). The need to reduce the economic and environmental challenges associated with cement making has been on the increase among the expertise globally (Bajare *et-al.*, 2013; Dunstan, 2011). At the moment, research on the suitability of mineral pozzolans as supplementary cementing materials has been intensified globally (Dembovska *et-al.*, 2018). It improves compressive strength and the durability properties of concrete such as, resistance to sulphate attack, lower the hydration heat and reduce the energy cost per cement (Ayuba *et-al.*, 2022; Abubakar and Aaron 2022; Ikumapayi *et al.*, 2015).

Several research has shown that the use of mineral admixtures improves the environmental approachability by reducing degradation cause due to incessant dumping of these materials as waste (Abubakar and Aaron 2022; Ikumapayi *et al.*, 2015), In addition, previous research has shown that Pozzolanas like rice husk ash has gained acceptability as supplementary cementing materials (Ahmed *et-al.*, 2019), which augments the cost of cement productions when used as a replacement of OPC (Arum *et-al.*, 2013). Presently, the utilization of pozzolanic materials as supplementary cementing materials in Portland cements pastes are on the upswing and at the same time proven to reduces significant amount of the clinker there by improving the performance of the hydrated cement (Dembovska *et-al.,* 2016). Some agricultural wastes such as millet husk ash, saw dust ash, palm oil waste, rice husk ash, corncob ash, groundnut husk ash have been used as pozzolans or secondary cementitious materials (Ikumapayi, 2014).

RSM is one of the strong mathematical and statistical methods of prediction that employed in research to assess the influence of the independent variables on the responses with a minimal number of experiments (Moodi *et-al.,* 2018; Ferdosian and Camões 2017; Lovato *et-al.,* 2012). In addition, RSM can be used to determine the relationships between a group of independent variables in-put parameters and one or more responses out-put parameters (Ayuba *et-al.,* 2022; Dahmoune *et-al.,* 2015). This method is mostly used when there are a number of input parameters affecting the output response. Currently (RSM) techniques have been generally used in the field of concrete materials to predict or to model its properties (Hammoudi *et al.,* 2019; Behnood and Golafshani, 2018). Although, there are many studies on the (RSM) in concrete, however, when it comes to reused concrete, there are limited studies conducted (Duan *et-al.,* 2013; Li *et-al.,* 2018; Ghafari *et-al.,* 2014). On the other hand, studies to predict the strength properties of SDA-SCC using RSM have not been conducted.

Nigeria is a major producer of sawdust with about 1.8 - 5.2 million tonnes of SDA per year (Sambo 2009 and Francescato *et al.,* 2008). These wastes are poorly managed on daily basis and habitually castoff as useless materials; it decomposes causing adverse environmental effects due to the unhealthy practice (Arimoro *et-al.,* 2007; Wihersaari, 2005). These refute the policies for sustainable development goal of managing and effective utilization of the waste without endangering the environmental atmosphere (Pianosi, 2012; IISD, 2016). SDA is an abundant waste that creates environmental pollution as efforts to reduce them through burning and decomposition has not being good enough. Therefore, reutilizing SDA waste as a building material could be a viable solution to the environmental problems. This research aimed at modeling the strength properties (compressive, flexural and splitting tensile strength) of SDA-SCC using (RSM) where very little research has been done. In this study, a single factorial design (SFD) in RSM model was developed to predict the strength properties SDA as cement replacement in SCC.

2.0 Material and methods

2.1 Materials

The particles size distribution and physical properties of the materials is shown in Figure 1 and Table 2 respectively. Ordinary Portland cement (Dangote brand), with a specific gravity of 3.14 was used. The chemical composition analysis of the cement is shown in Table 3. The fine aggregate has a specific gravity of 2.64; bulk density of 1565 kg/m^3 moisture content of 2.25 % was used and classified as zone -2 based on BS 882 (1992) grading limits for fine aggregates. The coarse aggregate is crushed granite with dominant size between 10mm-14mm with a specific gravity of 2.71, moisture content of 1.15 percent and bulk density of 1664 kg/m^3. A super plasticizer of 7.49kg/m^3 as an additive in compliance with ASTM C494 and BS EN 5075 blended with optimum percentage of MHA-SCC was used.

The saw dust used was obtained from Kano State, Nigeria. The Ash (MHA) was obtained by a control burning method at temperature of about 600℃ in a kiln for about two hours and the ash was allowed to cool and sieved through 75μm sieves. The SDA has specific gravity of 2.25, bulk density of 645 Kg/m^3; moisture content of 2.95% and grain size distribution is shown in Figure 1. A chemical composition analysis of the SDA was conducted using X-Ray Flouresence (XRF) analytical method and shown in Table 1.

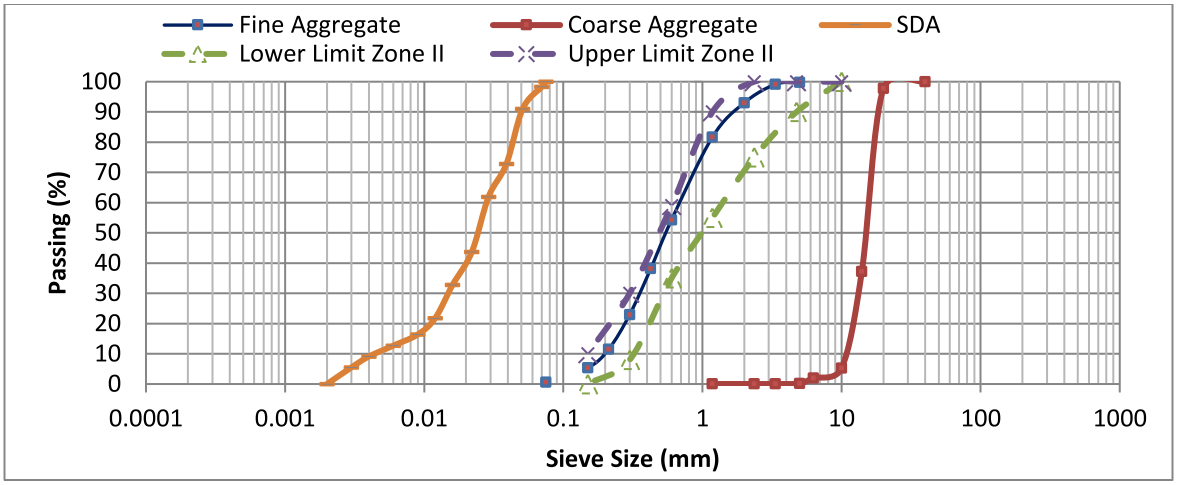

Figure 1: Particle Size Distribution of Aggregates and SDA

Table 1 Oxides composition of ash and binder

Oxides	Dangote Cement (%)	BSEN197-1(2000) ASTM C618(2005)	SDA (%)	BS EN 197-1(2000) ASTM C 618 (2005)
SiO_2	16.44	$CaO + SiO_2 \geq 50\%$ $CaO/SiO_2 \geq 2\%$ $SO_3 \leq 3.5\%$ $MgO \leq 5.0\%$ $Cl \leq 0.1\%$ $LoI \leq 5\%$	23.52	$CaO + SiO_2 + Fe_2O_3 \geq 70\%$ $LoI \leq 12\%$
AL_2O_3	3.21		3.25	
Fe_2O_3	4.40		2.54	
CaO	69.93		40.15	
MgO	1.38		3.49	
SO_3	1.99		1.16	
Na_2O	0.31		2.31	
K_2O	0.66		16.21	
P_2O_5	0.103		0.02	
Cl	0.1		0.15	
TiO_2	0.31		0.22	
Cr_2O_3	-		-	
BaO	0.18		0.02	
LOI	1.03		-	

Table 2: Physical Properties of Binders and Aggregates

Physical Properties	Cement	SDA	Fine Aggregate	Coarse Aggregate
Specific Gravities	3.14	2.25	2.64	2.71
Fineness (Retained on 45 µm sieve)	14	28	-	-
Fineness modulus	-	-	2.55	6.67
Bulk Density (kg/m^3)	1448	645	1565	1664
Loss on Ignition	1.25	4.85		
Colour	Dark grey	Grey		
Moisture content	0.65	2.95	2.25	1.15

2.1.1 Methods

2.1.1.1 Trial Mix design of grade 40 self-compacting concrete

Mix design was carried out in accordance with the guidelines laid out in BS EN 206 (2013) which involved the selection and proportioning of SCC constituents materials. The mix design for the control TM-00 (SCC without

SDA) was obtained via trial mixes using TM-00 as the control mix and TM-1, - TM-10, as shown in Table 3. Trial mix TM7 was selected having met the requirement for the design strength of grade 40 concrete. The requirement for fresh properties of SCC are slump flow 550mm-850mm, passing ability of 0.8-1.0, and segregation not greater than 15% as shown in Table 3.

Table 3: Summary of Mix Design Proportion of Grade 40 SCC by Trial

Trial	Cement (kg/m^3)	Sand (kg/m^3)	Granite (kg/m^3)	Water (kg/m)	Passing Ability	Slump Flow (mm)	Segregation Resistance	Compressive strength (N/mm^2)	Super-plasticizer (kg/m^3)
TM1	520	840	890	182	0.73	531	5.9	38.4	7.49
TM2	520	860	870	182	0.78	544	7.4	40.39	7.49
TM3	520	880	850	182	0.81	651	9.4	41.36	7.49
TM4	520	900	830	182	0.84	658	11.7	43.87	7.49
TM5	520	920	810	182	0.85	682	17.6	42.81	7.49
TM6	520	840	890	192.4	0.78	584	6.6	40.22	7.49
TM7	**520**	**860**	**870**	**192.4**	**0.81**	**657**	**9.2**	**44.42**	7.49
TM8	520	880	850	192.4	0.83	672	12.6	42.68	7.49
TM9	520	900	830	192.4	0.84	689	15.1	44.89	7.49
TM10	520	920	810	192.4	0.87	722	18.6	45.52	7.49

2.1.1.2 Specific Gravity

The specific gravity test on SDA, fine aggregate and coarse aggregate were conducted in accordance with BS EN 12620 (2013), while the specific gravity of cement was determine using BS EN 196-6 (2005) as shown in equation 2.20 - 2.22 bellow.

$$G_{S=} \frac{(W_2-W_1)}{(W_4-W_1)-(W_3-W_2)} \quad 1$$

$$G_{SK=} \frac{(Wk_2-Wk_1)}{(Wk_4-Wk_1)-(W_{k3}-Wk_2)} \quad 2$$

$$G_{SC=} \frac{(Wc_2-Wc_1)}{(Wc_4-Wc_1)-(Wc_3-Wc_2)} \quad 3$$

2.1.1.3 **Development of Strength Predictive Model of MHA Self-Compacting Concrete**

Saw dust ash was used as partial replacement of cement in normal vibrated concrete with the aim of reducing cement production; minimize the emission of CO_2 to the atmosphere and the way of waste disposal. This research investigates the effect of partial replacement of cement with SDA in SCC using a statistical tool response surface methodology for the design and analysis of the strength development of hardened SCC properties. To evaluate the relationship and interactive effects of the individual parameters on the dependent variables (responses) response surface methodology was employed for designing the experiments based on one factors (SDA). Each parameter was varied in seven levels, SDA (0%, 5% 10%, 15%, 20%, 25% and 30%) by weight of the total binder. The responses were compressive strength, flexural strength and splitting tensile strength. The design expert software generates model equations and graphs that would best fit the experimental data. A comparison is then made between the actual value or observed value and the predicted value experimental data and data generated by the models and the residual evaluated.

Table 4 Material Batching for Self -Compacting – Saw Dust Ash

Mix No	SDA (%)	Cement (kg/m^3)	Sand (kg/m^3)	Granite (kg/m^3)	SDA (kg/m^3)	Water (kg/m^3)	Super Plasticiser (kg/m^3)
MC0	0	520	860	870	0	192.4	7.49
MC1	5	494	860	870	26	192.4	7.49
MC2	10	468	860	870	52	192.4	7.49
MC3	15	442	860	870	78	192.4	7.49
MC4	20	416	860	870	104	192.4	7.49
MC5	25	390	860	870	130	192.4	7.49
MC6	30	364	860	870	156	192.4	7.49

2.1.1.4 Hardened properties assessment of self-compacting – Millet Husk ash concrete

Reference to the design mix generated using RSM the test on the hardened properties self-compacting concrete – Millet husk ash was carried out on following tests; compressive, flexural and splitting tensile strengths in conducted in accordance to BS EN 12390-3,5,6, (2000)

3.0 Results and Discussions

3.1.1 Result of Compressive Strength of SDA- SCC

Figure 2 shows the effect of curing age on the compressive strength of SDA-SCC and attests that the compressive strength of SDA-SCC decreased with increase in ash content but, increases with curing age. However, the plot shows that at 28 days, compressive strength of SDA-SCC increases up to 5% replacement and meet up the design strength 40N/mm^2 though, less than that of control but decreases as replacement levels increase. This action could be due to the fact wood waste ash particles act more as filler material within the cement paste matrix than as binder material Ayuba *et-al.*, (2022). Therefore, increasing the ash content as cement replacement could lead to increase in surface area of filler material to be bonded by decreasing the amount of cement which causes a decline in strength, this observation agrees with the findings of Udoeyo *et-al.*, (2006) who worked on Potential of wood ash waste as an additive in concrete and in agreement with the works of (Raheem, *et-al.*, (2012); Cheah *et-al.*, 2015), who reveals that the compressive strength development of concrete containing SDA, though increased with curing ages, nonetheless deceased in relation to the control with increase in the percent replacement of cement with SDA. Similarly, the increased in compressive strength with curing age may be due to the hydration reaction of Portland cement and reduced with increasing SDA content due to the decreasing content of the cement. This statement is in line with Ettu *et-al.*, (2013)

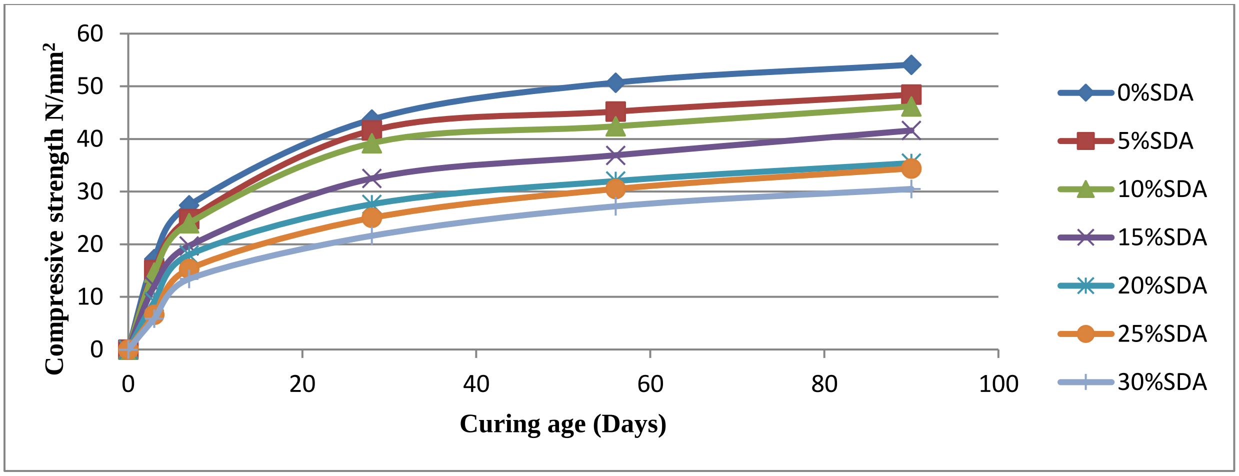

Figure 2: Effect of Curing Age on Compressive strength of SDA-SCC

3.1.2 Result of Splitting Tensile Strength of SDA-SCC

Figure 3: shows the splitting tensile strength of SDA-SCC, as expected the splitting tensile strength increases with curing age but decrease with increase content of SDA from 5% - 30% SDA. It was observed SDA successfully replace up to 10% of cement in SCC and give same strength with control strength. At 5% cement replacement by SDA, the tensile splitting strength gotten as 1.04 to 4.84 between 3 to 90 days of curing and 10% had a range of 1.20 to 4.88N/mm^2. The increase in strength with age of curing is due to continuous hydration of cement and pozzolanic reaction of SDA. This is in consistent with conclusion of Chowdhury *et-al.*, (2014). The decrease in strength could be due to the effect of increasing SDA replacement having low cementitious properties reduces cement composition which lead strength reduction. This submission is in line with the work of Naik, *et-al.*, **(**2002) who studied the effect of SDA at early ages up to 28 day curing on the splitting tensile strength of concrete and revealed the strength decreases with increasing content of SDA.

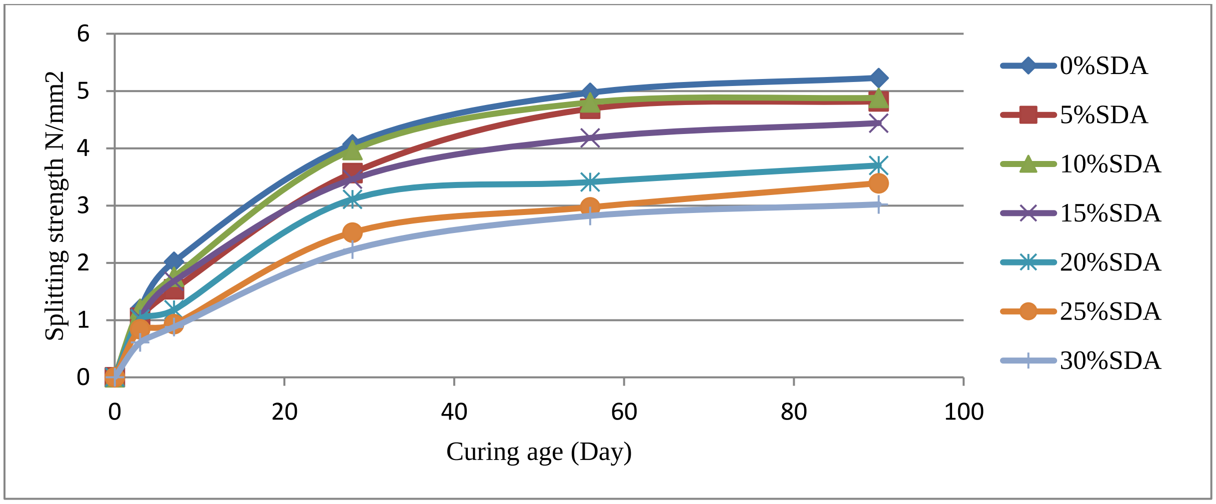

Figure 3: Effect of Curing Age on Splitting Tensile Strength of SDA-SCC

3.1.3 Result of Flexural Strength of SDA-SCC

The flexural strength of SDA-SCC samples deceased with increase content of SDA and increase with curing age. The trend was proven by the works of (Abhishek and Kumbar 2017; Rajamma *et-al.*, 2009 and Naik *et-al.*, 2002) as shown in figure 4. However, the inclusions of SDA in SCC as a replacement for cement, the flexural strength of SCC increases up to 5% and after which it started declining. Maximum reduction in strength was recorded at 30% SDA at all ages of curing, while the maximum increase was shown at 10% replacement of cement with SDA throughout the ages of curing.

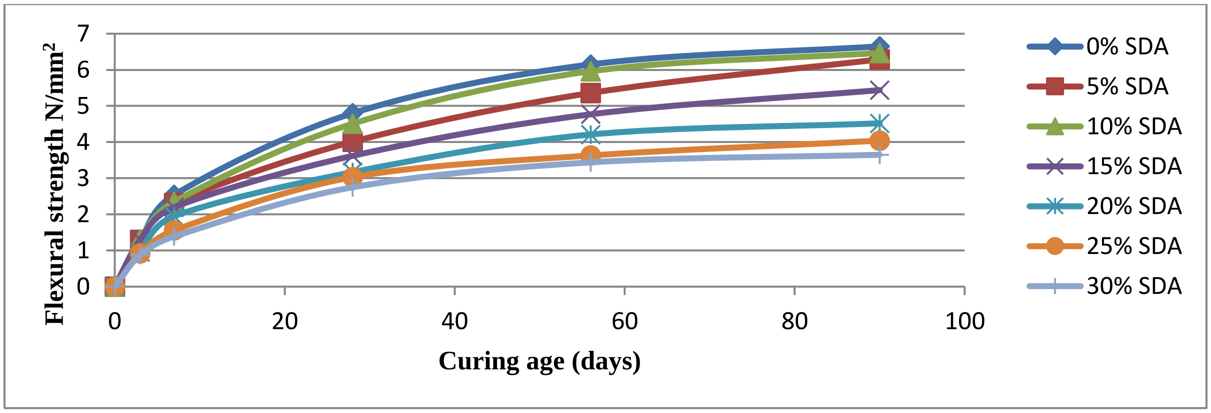

Figure 4: Effect of Curing Age on Flexural Strength of SDA-SCC

The anova for the compressive strength of SDA-SCC is shown in tables below

Table 5: Experimental design parameters and their responses SDA-SCC

Runs	Variables SDA-SCC (%)	Responses		
		Compressive Strength(N/mm^2)	Flexural Strength(N/mm^2)	Splitting Tensile strength(Nmm^2)
1	0	43.7	4.75	4.07
2	5	41.6	4.01	3.57
3	5	40.5	3.95	3.65
4	10	39.2	4.45	3.97
5	15	33.2	3.62	3.6
6	15	31.8	3.5	3.57
7	15	32.5	3.55	3.5
8	20	27.6	3.2	3.11
9	25	25	3.03	2.62
10	30	22	2.75	2.2
11	30	21.6	2.8	2.23

Table 6: Anova for SDA-SCC Compressive Strength for Response Surface Linear Model

Source	**Sum of Squares**	**df**	**Mean Square**	**F-Value**	**Prob > F**	**Remark**
Model	615.72	1	615.72	478.19	< 0.0001	significant
A-SDA	615.72	1	615.72	478.19	< 0.0001	
Residual	11.59	9	1.29			
Lack of Fit	9.92	5	1.98	4.77	0.0777	not significant

As shown in Table 6, the model has a high F- value of 478.19 and low p value of less than 0.0001. This indicates that the model selected was significant and has only 0.01 % chance that the F-value of 478.19 could occur due noise. The significance of the model terms was examined using t-test at 5 % level of significance. From the table, model term A was found to have p-value of more than 0.05 and hence considered insignificant. This also indicates that the term A does not have any impact on the compressive strength response. The "Lack of Fit F-value" of 4.77 implies there is a 7.77% chance that a "Lack of Fit F-value" this large could occur due to noise. The final model equation for compressive strength of SDA-SCCC with all the model terms is presented in Eqn. 4.7.

$$\text{Compressive Strength } F_{c(y)} = +44.60044 - 0.77591y \qquad 4$$

Table 7: SDA-Compressive strength model validation

Response	S. D	µ	R^2	Adj. R^2	Pred. R	P
Compressive strength (N/mm^2)	1.1	32.61	0.9815	0.9795	0.9743	48.109

Where S.D: Standard deviation, µ: mean, R^2: correlation coefficient, Adj.R^2: adjusted correlation coefficient, Pred. R^2: predicted R^2, AP: adequate precision.

The adequacy and quality of the developed model could be explained by its high degree of correlation. As shown in Table 7, the model has a very high R^2 value of 0.9815, which is close to 1. The "Predicted R-Squared" of 0.9743 is in reasonable agreement with the "Adjusted R-Squared" of 0.9795; i.e. the difference is less than 0.2. "Adequate Precision" measures the signal to noise ratio. A ratio greater than 4 shows the developed model is desirable; ratio of 48.109 indicates an adequate signal. This model can be used to navigate the design space. Similarly, Figure 5 shows the relationship between the predicted and experimental results. It can be observed that the predicted data provide by the model is well fitted with the experimental results as the data points are evenly distributed along the straight line. Figure 6 was plotted to check the distribution of the results the results lie almost on the line of equality and highly represented by S-shaped distribution. A linear trend showed normality in the error term and the experimental results did not show any signs of problems. This confirmed that the results are normally distributed.

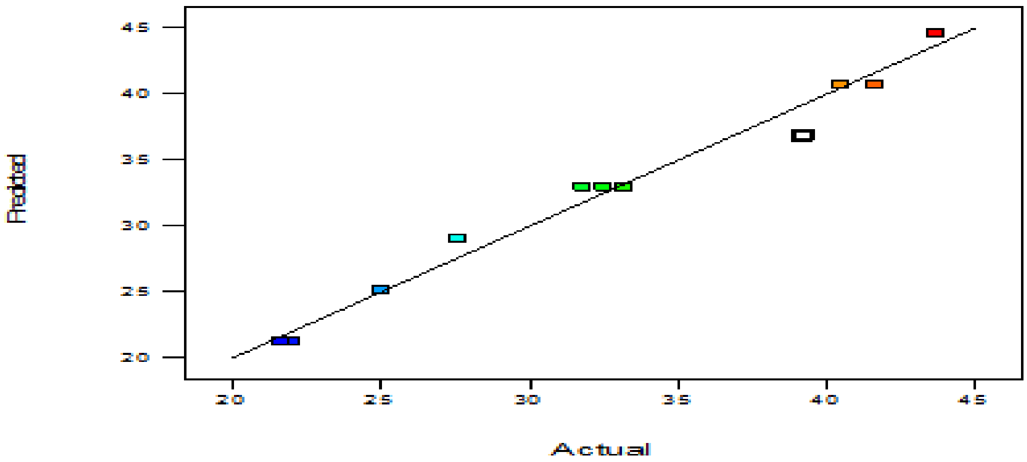

Figure 5: Predicted Versus Actual of SDA-SCC compressive strength model validation

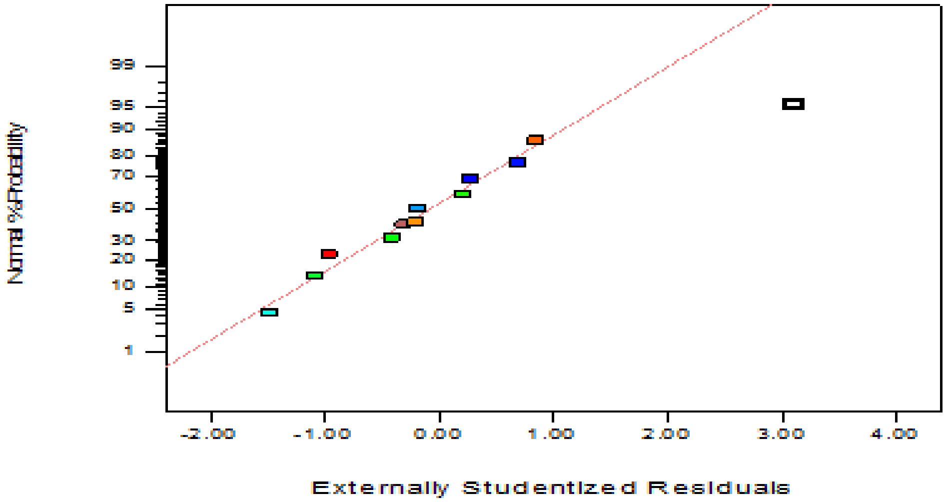

Figure 6: Normal Plot versus Studentized Residuals of SDA-SCC compressive strength model validation

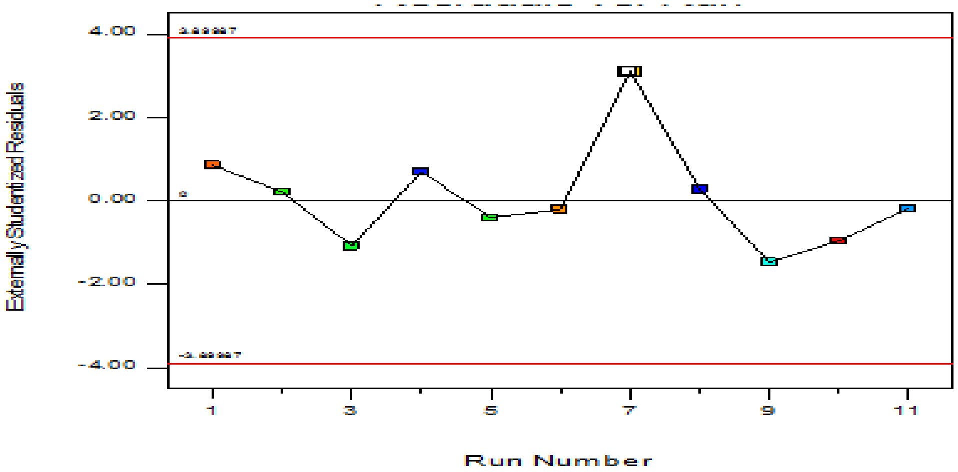

Figure 7: Residuals versus Run Number of SDA-SCC compressive strength model validation

3.1.4 Anova for SDA-SCC Splitting Tensile Strength Response surface Model

Table 8: Anova for SDA-SCC Splitting Tensile strength Quartic model

Source	Sum of squares	Degree of freedom	Mean square	F-value	Prob>F	Remarks
Model	3.97	4	0.99	323.64	< 0.0001	significant
A-SDA	0.24	1	0.24	79.64	0.0001	
A^2	0.23	1	0.23	75.83	0.0001	
A^3	0.019	1	0.019	6.12	0.0482	
A^4	0.13	1	0.13	43.26	0.0006	
Residual	0.018	6	3.063E-003			
Lack of Fit	9.461E-003	2	4.731E-003	2.12	0.2354	not significant

Splitting tensile strength response of SDA-SCC is shown in table 8. Fitted quartic model was developed for the prediction of splitting tensile strength of SDA-SCC. The model was chosen based on the highest order polynomial in which the additional terms were significant The Model F-value of 323.64 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A, A^2, A^3, A^4 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. The "Lack of Fit F-value" of 2.12 implies the Lack of Fit is not significant relative to the pure error. There is a 23.54% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good -- we want the model to fit.

$$\text{Splitting strength } F_{s(y)} = +4.05872 - 0{,}18035y + 0.025248y^2 - 1.35120E - 003y^3 + 2.13970E - 005y^4 \qquad 5$$

Table 9: SDA-Splitting Tensile strength model validation

Response	S. D	μ	R^2	Adj. R^2	Pred. R	P
Compressive strength (N/mm^2)	0.055	3.26	0.9955	0.9923	0.8470	49.263

Table 9 show the "Pred R-Squared" of 0.8470 is in reasonable agreement with the "Adj R-Squared" of 0.9923; i.e. the difference is less than 0.2. "Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 49.263 indicates an adequate signal. This model can be used to navigate the design space.

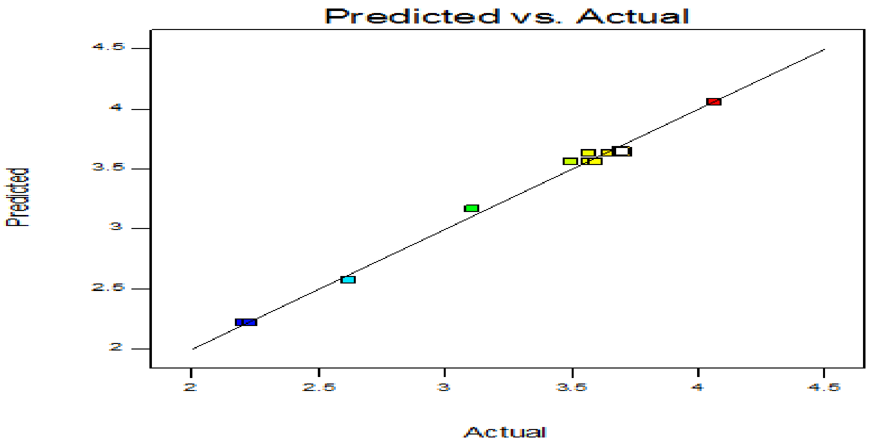

Figure 8: Predicted versus Actual of MHA-SDA-SCC Splitting strength model validation

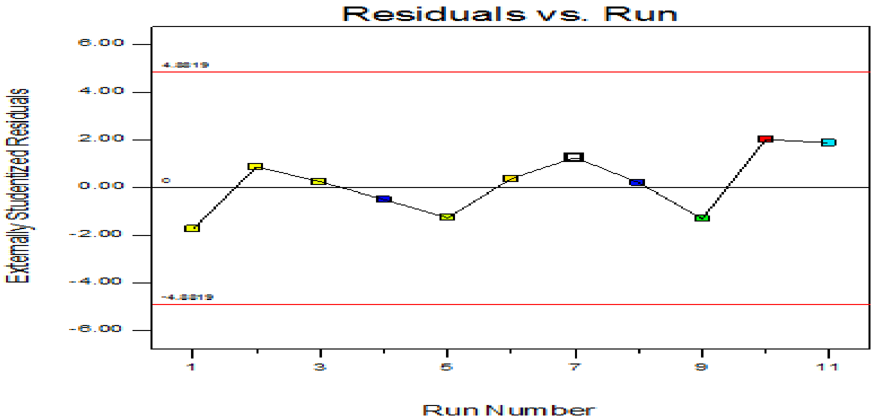

Figure 9: Residuals versus Run Number of SDA-SCC splitting tensile strength model validation

3.1.5 **Anova for SDA-SCC Flexural Strength Response surface Model**

Table 10: Anova for SDA-SCC Flexural strength Response Surface Fifth model

Source	Sum of squares	Degree of freedom	Mean square	F-value	Prob>F	Remarks
Model	3.47	5	0.69	314.56	< 0.0001	significant
A-SDA	0.100	1	0.100	45.26	0.0011	
A^2	0.014	1	0.014	6.31	0.0537	
A^3	0.011	1	0.011	4.83	0.0793	
A^4	0.038	1	0.038	17.19	0.0089	
A^5	0.018	1	0.018	8.15	0.0356	
Residual	0.011	5	2.203E-003			
Lack of Fit	6.992E-004	1	6.992E-004	0.27	0.6301	not significant

The Model F-value of 314.56 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant as shown in table 10. In this case A, A^4, A^5 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. The "Lack of Fit F-value" of 0.27 implies the Lack of Fit is not significant relative to the pure error. There is a 63.01% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good -- we want the model to fit.

$$\text{Flexural strength } F_{f(y)} = +4.75105 - 0.32499y + 0.050144y^2 - 3.82329E - 003y^3 + 1.27843E - 004y^4 - 1.55063E - 006y^5 \tag{6}$$

Table 11: Anova for SDA-SCC Flexural strength Model Validation

Response	S. D	μ	R^2	Adj. R^2	Pred. R^2	AP
Flexural strength (N/mm^2)	0.047	3.54	0.9968	0.9937	0.8594	56.987

Where S.D: Standard deviation, μ: mean, R^2: correlation coefficient, Adj.R^2: adjusted correlation coefficient, Pred. R^2: predicted R^2, AP: adequate precision.

The "Pred R-Squared" of 0.8594 is in reasonable agreement with the "Adj R-Squared" of 0.9937; i.e. the difference is less than 0.2. "Adeq Precision" measures the signal to noise ratio as shown in table 11. A ratio greater than 4 is desirable. The ratio of 56.987 indicates an adequate signal. This model can be used to navigate the design space.

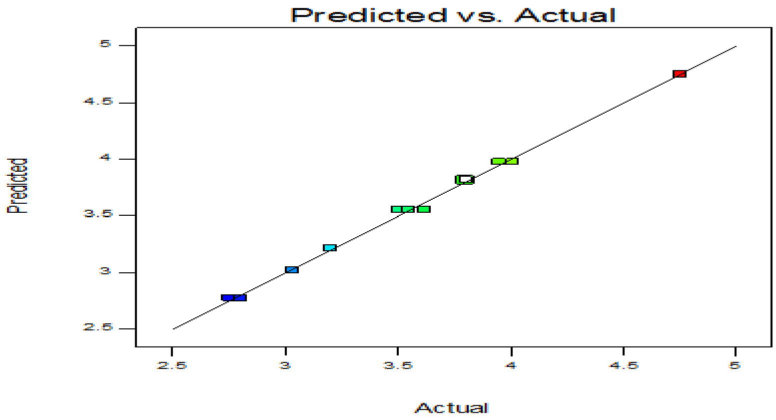

Figure 10: Predicted versus Actual of SDA-SCC flexural strength model validation

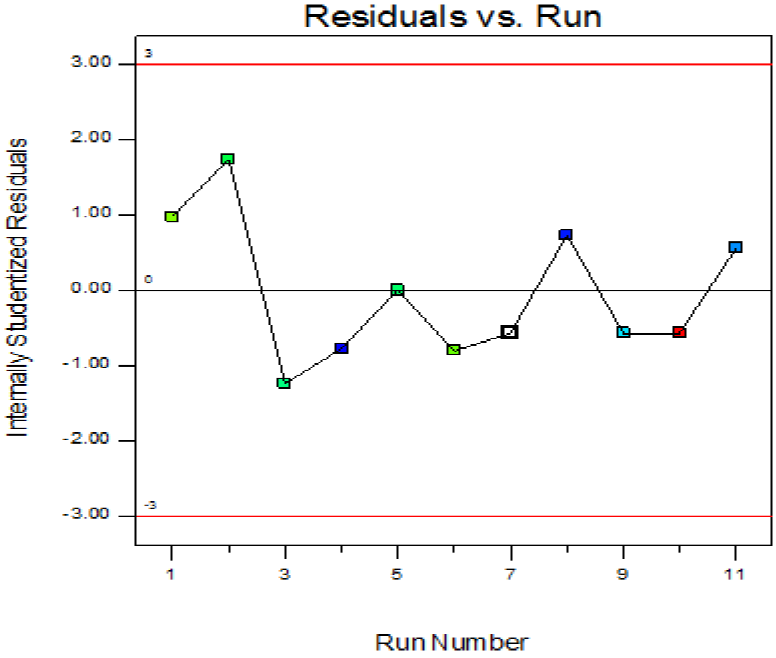

Figure 11: Studentized residual versus Run number SDA-SCC flexural strength model validation

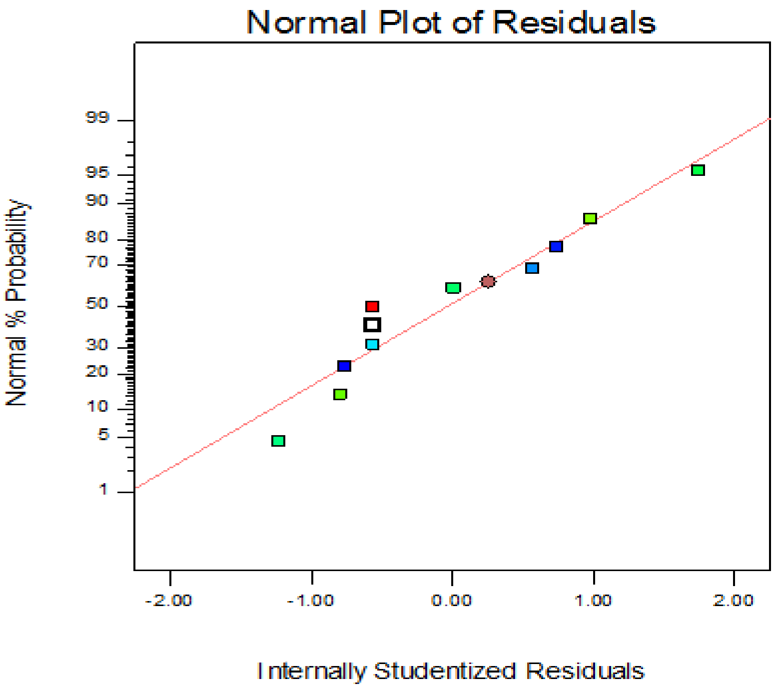

Figure 12: Normal plot of residual versus Studentized residual SDA-SCC flexural strength model validation

4.0. Conclusion

From the research conducted the following conclusions were made;

1. In this study an experimental investigation using response surface methodology (RSM) based on single factorial design, the significance of the proposed model and all the model terms were evaluated using a t-test at 5% significance level for optimum compressive strength of SDA-SCC.
2. A very high correlation coefficient R^2 of 0.9815, 0.9955 and 0.9968 close to 1 indicate the acceptability and quality of the model developed. The model for predicting strengths of SDA-SCC show a high degree of correlation and predictability with percentage error less than 10%.
3. The physico – chemical properties of SDA showed that SDA have not meet the requirement for BS-EN 197-1 (2000) and ASTM C 18 for SiO_2, Al_2O_3 and Fe_2O_3. Hence not a good pozzolana but has cementitous properties.
4. The compressive strength, flexural strength and splitting tensile strength reduce as % replacement of SDA increases, the compressive strength of SDA increase up to 5% replacements at 28 days and 10% and 15% at 56 and 90 days respectively. MHA improves the compressive strength of SDA up to 5%. The flexural strength and splitting strength of MHA increase up to 5%.
5. Also, the study has proved that modeling using RSM is superior to the conventional use of first-order regression and second-order regression for problems involving a number of independent variables. Based on the mix proportions of the SCC, the proposed model is faster in estimating the strength properties of concrete to a certain degree of accuracy. This will help technical personnel in charge of mix design to make workable decisions and avoiding multiple trials with different mix proportions.

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