IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 14, Issue 4 Ver. V (Jul. - Aug. 2017), PP 24-29
www.iosrjournals.org

On the Properties of Concrete composites with Corn admixtures

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Abstract: *This work presents the use of grinded Corn (Guinea Corn (Sorghum bicolor L.) and maize (Zea Mays L.)) seeds as admixtures of concrete composites. Cement concrete with different concentration of admixtures were tested to deduce the admixture effect on concrete properties like consistency, workability and compressive strength. The results obtained, using both admixtures were compared using the F-statistics to check for significant difference between the concrete properties. Models to predict the concrete properties for different concentration of grinded corn seeds were developed and compared with results from experiments. The results from models corroborated those obtained from the experiments with very good correlation coefficient values. Further validation of the models using F-statistics at 5% level of significance showed it was highly adequate. From the comparative studies of both procedures, there was no significant difference with respect to strength and workability unlike the consistency of the concretes.*

Keywords: *Sorghum, Maize, Admixture, Consistency, Workability.*

Date of Submission: 10-07-2017 Date of acceptance: 10-08-2017

I. Introduction

Cement concrete is a mixture of cement, fine aggregate, coarse aggregate and water. To achieve the desired quality and strength of concrete, certain control measures towards effective use of the concrete must be put in place. These measures include: use of right quality of materials, the type of cement, proper design of concrete mix, use of admixtures, environmental conditions, etc.

1.1 Cement and Admixture

Admixtures are natural and artificial substances added to cement concrete to alter the properties of concrete when introduced into the concrete either immediately before or during mixing of concrete. These admixtures are usually added as partial replacement of cement in concrete production. Admixtures have been proven to accelerate or decelerate setting time, improve strength, improve workability and also enhance finishability of concrete [1], [2]. The specific effect of any admixture on cement concrete properties vary with the ambient temperature, dosage of admixture, etc [2]. Some common examples of admixtures are Rice Husk Ash (RHA), Corn leaves Ashes (CLA), Corn Cob Ashes (CCA), etc.

Grinded corn seeds such as Sorghum and Maize seeds are members of the grass family which thrive in hot areas with little rainfall (such as Northern parts of Nigerian). Their seeds have been established as good source of carbohydrate, protein and minerals such as Calcium, Selenium, Manganese and Iron [3], [4]. According the Food and Agricultural Organization (FAO) – United Nations [5] Corn is produced worldwide with United States of America being the largest producer with 43% of world's production and Nigeria the fourteenth largest producer of corn in world with 1.04% of world production.

1.2 Relevant Properties of Cement Concrete

The properties of cement concrete are those attributes that determines the quality and aesthetics of cement concrete. Some relevant cement concrete properties include; consistency, workability and compressive strength. Workability of concrete is the ease at which concrete can be transported, placed and finished sufficiently without segregation [6]. Setting time, which is the illustration of consistency of concrete, is the time taken from cement paste to become a solid mass and compressive strength is the capacity of concrete to withstand loads tending to reduce its size. These properties are seriously affected by the type and dosage of admixture used, and cement used in the cement concrete production [6].

1.3 Researches on the Synthesis and use of Admixtures in Cement Concrete

There had been various research efforts on the use of admixtures and other pozzolana in cement concrete production. Olutoge et al [7] presented a Comparative Study on Fly-Ash and Ground Granulated Blast Furnace Slag (GGBS). Adesanya and Raheem [8] studied the workability and compressive strength characteristics of Corn Cob Ash (CCA) blended Cement Concrete. Ogunfolami [9] considered the mixing of the Corn Cob Ash with Ordinary Portland cement at the point of need.

II. Materials and Methods

2.1 Materials

The corns (Maize and Sorghum or Guinea corn) used for this study were obtained from a local market in tropical Port Harcourt, Nigeria. The corns were washed, dried and then sieved using 150μm sieve size.
The cement used was Dangote cement (R.42.5, CB 4227) in accordance with the requirement of BS 12 [10] obtained from a local market shop in Port Harcourt. The fine aggregate used for this study was that portion passing through sieve No. 200 after the sieving process. The coarse aggregate of 20mm size were used to prepare the concrete.
The water used for this study was fresh and free of organic materials with pH value of 7.00.

2.2 Experimental Equipment

a) Vicat Apparatus *(Model 63-L0028, Indiamart, India)* was used in this study to determine the setting time of concrete which meets requirements of BS 4550 [11].
b) Slump Cone *(Model HM-40, Gilson Company, USA)* was used for this study to determine the workability of concrete which meets the requirement of BS 1881-102 [12].
c) Compressive strength Machine *(Model 4207D, Chandler Eng. USA)*, was used for this study to determine the compressive strength of concrete which meets the requirements of BS 1881:115 [13].

2.3 Procedure

The Grinded Corn (Maize and Sorghum) seeds were used to replace Ordinary Portland cement at 2%, 4%, 6%, 8%, 10% and 12% by weight. The fine aggregate (sand) and coarse aggregate were prepared to BS 1017; Parts 1 and 2 [14] and BS 882 [15]. The sand belongs to zone 2 after grading it in accordance with BS 812; 103 [16]. The 1:2:4 mix was employed as the mix design with water-cement ratio of 0.6.

The setting time test (for consistency check), the slump test (for workability check) and the compressive strength tests are the major test employed in this study. Concrete cube specimens of 150mmx150mm x150mm size were produced and tested. The concrete specimen were prepared by filling each mould in three layers, compacted and cured for 28 days in accordance with the requirements of BS1377 Part 4 [17] using the compression machine *(Model 4207D, Chandler Eng. USA)*. The load at which the specimen failed was recorded and compressive strength calculated using Equation (1).

$$F_c = \frac{Maximum\ load\ at\ failure}{Cross\ sectional\ Area\ of\ cube} \quad (1)$$

III. Results and Discussions

3.1 Results from Experimental Tests

The results of the consistency (setting time) tests, workability (slump height) tests and compressive strength tests for both Grinded corn seeds are clearly illustrated in Figure 1, Figure 2 and Figure 3, respectively. The compressive strength of each cube was determined based on 28 days curing.

3.1.1 Consistency

The optimal consistency (setting time) for maize and Sorghum were 545 minutes and 605 minutes corresponding to 6% and 8%wt admixture concentration, respectively. This strength characteristics can be attributed to the lower cohesion between admixture molecules compared to the higher adhesion between them and cement in the concrete composite matrix in the pre-optimal condition. This situation is reversed as more quantity of admixture in introduced beyond the optimal concentration. Hence, the replacement of Ordinary Portland cement by Grinded corn seeds as shown by Figure 1 reduces the tricalcium silicate in the pastes, thereby prolonging the consistency (setting time) of the concrete pastes. This makes them good cement admixtures for hot weather and long distance transportation of concrete.

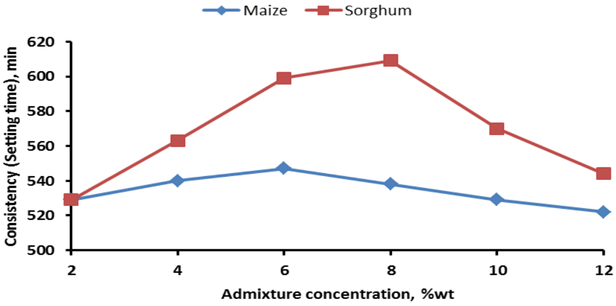

Figure 1, Concrete consistency (Setting time) variation with admixture concentration

3.1.2 Workability

From Figure 2, it is obvious that the workability of the cement concrete increases with the concentration of the constituent admixtures present. This relationship can be attributed to the relative density of the admixture compared to that of cement, culminating in the overall reduced density (hence higher workability or slump) of the cement-admixture concrete composite. Comparing Figure 2 with Figure 1, the enhanced workability of the composite for admixture concentrations above 6% and 8%wt for maize and Sorghum, respectively is associated reduction in the consistency.

Hence, Figure 2 shows that the workability of concrete is increased with increase in percentage replacement of ordinary Portland cement with grinded corn seeds. The workability (slump height) is increased from 54mm to 72mm for maize and from 56mm to 74mm for Sorghum (Guinea corn).

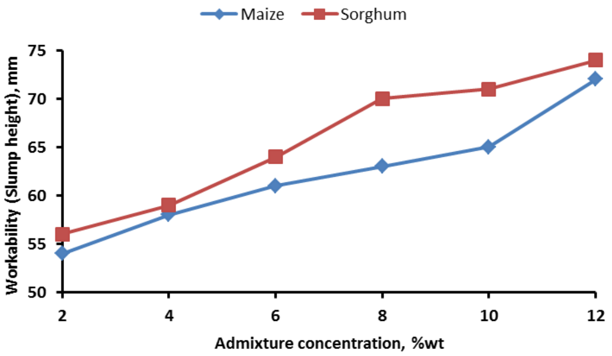

Figure 2, Workability (Slump height) variation with admixture concentration

3.1.3 Compressive strength

Figure 3 shows the trend of the compressive strength of the concrete composites derived from the Corn admixtures. The compressive strength variation with admixture concentration in Figure 3 shows an optimal strength of 26.02MPa and 26.85MPa at 5%wt and 6%wt admixture concentration for Maize and Sorghum, respectively. Without the use of admixtures (that is 0% admixtures concentration), the compressive strength of the concrete is well below 25MPa.

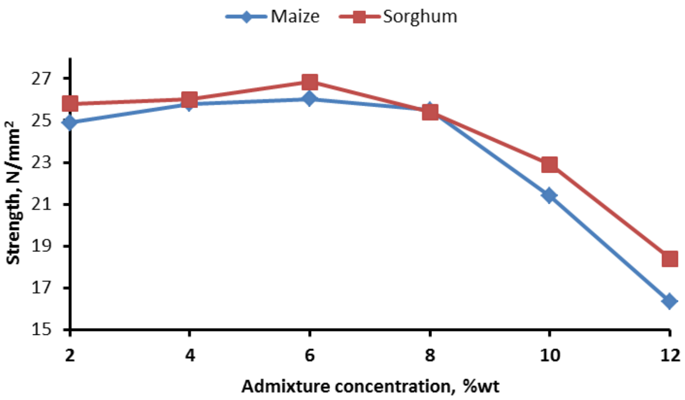

Figure 3, Concrete compressive strength variation with admixture concentration

3.2 Comparative Properties Analysis

The F-statistics tool is employed as the statistical tool for comparison of the cement concrete produced from both admixtures using the concrete properties. The hypothesis used here is thus presented;

Ho: Represents no significant difference in the two methods of cement concrete production with respect to concrete property.

H_1: Represents significant difference in the two methods of cement concrete production with respect to concrete property.

If F-calculated is less than F-tabulated (from F-distribution table), accept Ho otherwise accept H_1. F-statistics for setting time is presented in Table 1

Table 1, F-statistics test for setting time

T_o	T_g	$T_o-\overline{T_o}$	$\overline{T_g}-T_g$	$(T_o-\overline{T_o})^2$	$(T_g-\overline{T_g})^2$
529	529	-5.167	-40.00	26.694	1600.000
540	563	5.833	-6.000	34.028	36.000
547	599	12.833	30.000	164.694	900.000
538	609	3.833	40.000	14.694	1600.000
529	570	-5.167	1.000	26.694	1.000
522	544	-12.167	-25.000	148.028	625.000
$\overline{T_o}$ = 534.167	$\overline{T_g}$ = 569.000			$\Sigma(T_o-\overline{T_o})^2$ = 414.832	$\Sigma(T_g-\overline{T_g})^2$ = 4762.000

where T_M and T_S are the Consistency (setting time) value for maize concrete and sorghum concrete, respectively. Stepping through the same algorithm as above, the F-statistics is thus summarized in Table 2.

Table 2, Summary of F-Statistics for Property Comparison

Concrete property	Consistency (Setting time)	Workability (Slump height)	Compressive strength
F-calculated	11.480	1.348	1.470
F-tabulated	5.050	5.050	5.050
Decision	Significant difference (Reject H_o)	No significant difference (Accept H_o)	No significant difference (Accept H_o)

3.3 Modelling the properties of the concrete composites

A polynomial model of the form of Equation (2) is assumed for this study. This assumption is appropriate as evident from Figure 1, Figure 2 and Figure 3 where a polynomial relationship was depicted, thus all models used in this study, were assumed to follow the third degree polynomial regression model.

$$y = \lambda_3 X^3 + \lambda_2 X^2 + \lambda_1 X + \lambda_o \quad (2)$$

Where; λ_3, λ_2, λ_1, λ_0 = coefficients of the polynomial equation;

y = specific cement concrete property (consistency value, workability value and compressive strength value)

x = percentage of admixture added to cement concrete.

Given n set of measurements, the least square estimates can thus be obtained. The sum of squared deviations of the experimental and predicted values is given as shown by Equation (3).

$$S = \Sigma(y - \lambda_3 X^3 - \lambda_2 X^2 - \lambda_1 X - \lambda_0)^2 \quad (3)$$

Minimizing and setting the partial derivative of the above equation with respect to λ_3, λ_2, λ_1, and λ_0 equal to zero, Equations (4) – (7) were developed.

$$\Sigma y = \lambda_3 \Sigma X^3 + \lambda_2 \Sigma X^2 + \lambda_1 \Sigma X + \lambda_0 n \quad (4)$$

$$\Sigma X y = \lambda_3 \Sigma X^4 + \lambda_2 \Sigma X^3 + \lambda_1 \Sigma X^2 + \lambda_0 \Sigma X \quad (5)$$

$$\Sigma X^2 y = \lambda_3 \Sigma X^5 + \lambda_2 \Sigma X^4 + \lambda_1 \Sigma X^3 + \lambda_0 \Sigma X^2 \quad (6)$$

$$\Sigma X^3 y = \lambda_3 \Sigma X^6 + \lambda_2 \Sigma X^5 + \lambda_1 \Sigma X^4 + \lambda_0 \Sigma X^3 \quad (7)$$

3.3.1 Coefficient of Models and their R^2 Values

In the determination of model coefficients, tables of the form of Table 3 are used representing values from Equations (4) – (7) of model development. Table 3 shows the deduction of coefficients of setting time model of maize.

Table 3, Determining the Coefficients in Consistency Models for Concrete with Maize admixture

X	Y	X^2	X^3	X^4	X^5	X^6	Xy	X^2y	X^3y
2	529	4	8	16	32	64	1058	2116	4232
4	540	16	64	256	1024	4096	2160	8640	34560
6	547	36	216	1296	7776	46656	2382	19692	118152

8	538	64	512	4096	32768	262144	4304	34432	275456
10	529	100	1000	10,000	100,000	1,000,000	5290	52900	529000
12	522	144	1728	20736	248,832	2,985,984	6264	75168	902016
Σx = 42	ΣY = 3205	ΣX^2 = 364	ΣX^3 = 3528	ΣX^4 = 36400	ΣX^5 = 390432	ΣX^6 = 4298944	ΣXY = 22358	ΣX^2Y = 192948	ΣX^3Y 1863416

By substituting into Equations (4) – (7) deduced for mathematical model development, Equations (8) – (10) were obtained.

$$3205 = 3528\lambda_3 + 364\lambda_2 + 42\lambda_1 + 6\lambda_0 \qquad (8)$$

$$22358 = 36400\lambda_3 + 3528\lambda_2 + 364\lambda_1 + 42\lambda_0 \qquad (9)$$

$$1863416 = 2985984\lambda_3 + 390432\lambda_2 + 36400\lambda_1 + 3528\lambda_0 \qquad (10)$$

Resolving the above system of linear equations by Guassian elimination method produced the coefficients as; $\lambda_3 = 0.09$; $\lambda_2 = 2.583$; $\lambda_1 = 19.97$; $\lambda_0 = 498$.
Similarly, stepping through the same algorithm as above the mathematical models describing the Consistency (setting time), Workability (slump height) and compressive Strength for Maize and Sorghum admixtures in Concrete composite were deduced.

(a) Consistency (Setting time) models

The models obtained for the consistency (setting time) of concrete composites with Maize and Sorghum admixture are expressed in equation (11) and (12), respectively. The corresponding coefficient of determination for the Maize consistency and Sorghum consistency models are $R^2 = 0.966$ and $R^2 = 0.933$, respectively.

$$Y_{CM} = 0.09X^3 - 2.583X^3 + 19.97X + 498 \qquad (11)$$

$$Y_{CS} = -0.016X^3 - 2.338X^3 + 36.96X + 461.6 \qquad (12)$$

(b) Workability (Slump height) models

The models obtained for the workability (slump height) of concrete composites with Maize and Sorghum admixture are expressed in equation (13) and (14), respectively. The corresponding coefficient of determination for the Maize consistency and Sorghum consistency models are $R^2 = 0.995$ and $R^2 = 0.986$, respectively.

$$Y_{WM} = 0.038X^3 - 0.753X^3 + 5.769X + 45 \qquad (13)$$

$$Y_{WS} = -0.02X^3 + 0.366X^3 + 0.244X + 54 \qquad (14)$$

(c) Strength Models

The models obtained for the workability (slump height) of concrete composites with Maize and Sorghum admixture are expressed in equation (15) and (16), respectively. The corresponding coefficient of determination for the Maize consistency and Sorghum consistency models are $R^2 = 0.992$ and $R^2 = 0.994$, respectively.

$$Y_{SM} = -0.011X^3 + 0.029X^3 + 0.684X + 23.4 \qquad (15)$$

$$Y_{SS} = -0.01X^3 + 0.064X^3 + 0.24X + 25.05 \qquad (16)$$

3.4 Further Adequacy Tests

The models obtained were further tested for adequacy using the F-statistics at 5% level of significance. The tabulated F values were far greater than the calculated F-value showing good reliability of the models. Table 4 shows the F-statistics test of setting time model for maize.

Table 4, F-Statistics Test of Adequacy of Consistency (Setting Time) Model

Experimental	**Predictive**				
Y_0	Y_p	$Y_o - \overline{Y_o}$	$Y_p - \overline{Y_p}$	$(Y_o - \overline{Y_o})^2$	$(Y_p - \overline{Y_p})^2$
529	528.33	-5.17	-5.68	26.729	32.262
540	542.31	5.83	8.30	33.989	68.69
547	544.27	12.83	10.26	164.609	105.268
538	538.53	3.83	4.52	14.669	20.430
529	529.40	-5.17	-4.61	26.729	21.252
522	521.21	-12.17	-12.80	148.109	163.84
$\overline{Y_o}$ = 534.17	$\overline{Y_p}$ = 534.01		$\sum(Y_O - \overline{Y_O})^2 = 414.834$		$\sum(Y_P - \overline{Y_P})^2 = 411.942$

where Y_0 and Y_p were the experimental and model concrete property values, respectively.
The sample variances So^2 and Sp^2 are determined as follows;

$$So^2 = \frac{414.834}{6} = 69.139$$

$$Sp^2 = \frac{411.942}{6} = 68.657$$

F is calculated as the ratio of both sample variances as follows;

$$F = \frac{69.139}{68.657} = 1.007$$

From F distribution table,

$F_{0.95}\,(5,5) = 5.05$
Since 1.007 is much less than 5.05, the model is thus satisfactory.
Stepping through the same algorithm as above, the F-statistics is summarized in Table 5.

Table 5, Summary of F-Statistics for model comparison

	Maize			Sorghum		
	Consistency	Workability	Strength	Consistency	Workability	Strength
F-calculated	1.007	1.048	1.137	1.072	1.128	1.492
F-statistics	5.05	5.05	5.05	5.05	5.05	5.05

IV. Conclusion

From the comparative analysis in this study, it was observed that the sorghum seed as admixture was preferable to maize seed considering longer distance travel of cement placement as it takes longer time for the sorghum seed cement concrete to form a solid paste compared to maize seed cement concrete. There was no significant difference between the use of both admixtures in respect of concrete strength and workability; hence, any of the two admixtures can be used where distance is not an issue. The results of cement concrete properties values obtained from formulated models corroborated the corresponding values obtained from experiment. The models coefficients of determination (R^2-value) are significant and can be reliably utilized to predict the consistency (setting time), workability (slump height) and compressive strength of cement concrete admixtures. This fact was further supported by the F-statistics where the F-calculated values were far less than the tabulated F-values.

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