Compressive strength Characteristic of Cowdung ash blended cement Concrete

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Abstract— This work reports on an investigation into the use of cowdung ash(CDA) as Supplementary Cementitious Material(SCMs) in concrete . Cement was replaced with cowdung ash (CDA) up to 30% at 5% interval. Setting times (initial and Final) and slump test were carried out on the fresh cement/CDA blended paste and concrete respectively. A total of 105mm cubes of 150mm dimensions were cast and cured in water for 7,14,28,60 and 90days and tested for compressive strength. The result of setting times indicates that as the percentage of CDA increases, the initial and final setting times increased by 12.2%-59.3% and 2.74%-43.90% respectively indicating the potential of Cowdung ash as a set retarder. The workability of concrete decreased as the cowdung ash content increases. The results on compressive strength showed a decrease with increasing cowdung ash content and an increase with curing age. There was no significant difference in compressive strength between the control concrete and those containing up to 15% Cowdung ash at 5% level of significance. A regression model showing the relationship between compressive strength, curing age and cowdung ash content was proposed which was highly significant and revealed that curing age and cowdung ash are useful predictor.

Index Terms— Cowdung ash, Portland cement, Compressive strength, Setting times, Standard consistency.

1 Introduction

Developing countries like; Nigeria, Sudan, Republic of Benin, Asia-Pacific region e.t.c, are seeking to improve their inadequate infrastructure, they are faced with many challenges which include high cost of cement, diminishing national income due to the global economic recession, rising debt profile, decreasing foreign aid, scarcity of building materials-Cement, etc. In order to improve their infrastructure, cement (binder) and related materials are needed. Cement is the main binder in the production of concrete.The production of strong and durable concrete is fundamental to building better roads, bridges, houses, and civil infrastructure. The rising cost of cement particularly in the developing countries has made it difficult for majority of the populace whom are low income earners to own houses. For instance, A 50 kg bag of cement, had, at a time, been sold for $17(N2500) in Nigeria, while it settles for around $12.5(N2000) now. In the Republic of Benin and Ghana, the same quantity sells for about $10(4500CFA) and $10.63(GH¢25.00) respectively as compared to 6$(N800.00) international price. Meanwhile, despite the huge increase in supply, the price of cement locally remains at least N2,000 per 50 kg bag, almost twice the international price of the same size of cement[1]-[4]. It can be duly noted that the exorbitant cost of cement production, government policies, among other factors has made housing developers build or construct structures with low quality concrete which manifest in week sub-structures, super-structures, leading to failures, total collapse of buildings and in worse cases, leading to loss of lives and property[5].

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Several attempts have been made to reduce the rising cost of cement production in developing countries with very little success. There is the need to seek alternative to conventional cement and to seriously consider the utilization of industrial and agricultural by-products as feedstock for the cement industry to produce blended cement. Utilization of some of these by products as partial replacement of cement will in addition to improving the properties of concrete also generate income (through sales) and Employment [6]. The problem of disposal of these by-products is minimized and the amount of green gases released into the atmosphere through cement-production processes is also greatly reduced [7].

Reference [8]-[10], studied on various aspect of utilizing Sawdust ash in concrete production. They all reported a decrease in workability and compressive strength with increasing ash content and an increase in compressive strength with prolong curing beyond 28days. They also observed a retardation in the initial and final setting times as the SDA content is increased and recommended an optimum cement replacement of 10%.

Reference [11]-[12] investigated the possibility of using Groundnut husk ash in concrete and Mortar respectively. The compressive strength of both concrete and Mortar cubes increased with increase in curing age for all replacement levels, while standard consistency and setting times decreases with addition of GHA. The workability of GHA/OPC blended concrete was affected to a greater degree by the addition of GHA.

Nigeria and most of West African countries are blessed with large number of livestock including cows. The cow population in Nigeria is approximately 16million [13]. It has been identified that ninety percent of this is in the Northern Part of Nigeria and forms more than fourty percent of cows in West Africa [14]. Nigeria alone is expected to produce approximately 264,000 tons of cowdung daily. The cowdung is mostly used as manure in the farmland, and source of fuel in some cases when dried. The ash usually from combustion of the cowdung is refered to as cowdung ash (CDA) and is mostly dumped as waste resulting in environmental pollution. Therefore, the aim of this study is to examine the effect of cement replacement with Cowdung ash on the compressive strength of concrete.

2.1 Materials and Methods.

Cow dung used for the study was collected from a grazing field near Dan jiya farms, Bauchi state Northeast Nigeria. The cowdung was then air-dried properly, pulverised and afterwards calcined to ash at a temperature of 500℃. The resultant ash was sieved using a sieve of 300µm and stored in an air tight container to prevent it from absorbing moisture. Ashaka brand of Ordinary Portland Cement (OPC) which conforms to BS 12: Part 2: Clause 5 (1971) was used for the study. Coarse aggregate of normal weight with maximum size of 20mm was used for the study. It was procured from Triacta Quarry site in Bauchi, North Eastern Nigeria. Figure 1 shows the particle size distribution of the Coarse and fine aggregates as well the cowdung ash (CDA). The coarse and fine aggregate both falls within zone 2 of the classification chart of BS 882 and as such it was considered good for concrete works. Pipe-bornewater almost fit for drinking was used for the laboratory experiments.

2.1.1 Characterisation of Cowdung ash (CDA)

Chemical analysis of a representative sample of the cowdung ash and Ashaka cement was carried out using XRF Spectrometer (Axios Cement Panalytical B.V 7602 Ea Almelo the Netherland) to ascertain the chemical consitutents. The test was conducted at the quality control laboratoty of Ashaka (Larfarge) Cement located in Gombe, north Eastern Nigeria. The result of the chemical composition of CDA and Ashaka cement is presented in Table 1.

2.1.2 Setting times of OPC/CDA blended Cement.

Setting times (initial and final) test was conduted on fresh cowdunga ash cement blended paste at cement replacement levels of 5%, 10%, 15%, 20%, 25%, and 30%. The test was conduted in accordance with ASTM C 191- 82.

2.1.3 Strength Activity Index (SAI)

This is the ratio of 20% replacement levels of cement with CDA to the control expressed as a percentage. The Strength Activity Index (SAI) Test was conducted in accordance with ASTM C 311-12.The test for strength activity index is used to determine whether the pozzolan will result in an acceptable level of strength development when used with hydraulic cement in concrete. The SAI was determined using equation (1).

$$SAI = \frac{Fcdax\ 100\%}{Fopc} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

F_{cda}=Average compressive strength of the three specimen made with 20 percent CDA

F_{opc}= Average compressive strength of the three specimen made with 0 percent CDA. (Control samples)

2.1.4 Slump Test

Slump of the freshly prepared concrete was determined in accordance to BS 1881:102:1993 specification. This is to examine the effect of CDA on workability of concrete which is an important property of concrete..

2.4.0 Compressive strength test

Concrete cubes of 150mmx150mmx150mm were cast using the mix proportion in Table 2, and cured for 7,14,28,60 and 90 days respectively by complete immersion in water. The compressive strength test was determined using the ELE digital compression machine in accordance with BS 1881: Part 116: 1983 specification. A total of one hundred and five (105) cubes were cast, cured and tested. For each curing period three (3) cubes were produced and the average of the three results recorded.

3.0 Results and Discussion

3.1 Chemical and Physical Properties of Cow dung ash (CDA).

The result of Chemical analysis conducted on cowdung ash is presented in Table 1. The composition of Cowdung ash reveals the presence of similar oxides to those of cement and other supplementary cementing materials which implies that it can be used as a cement replacement material if used in the right proportion.The sum of the oxides of silicon, Iron and Aluminum is 76.91% which exceeds the 70% minimum specified by ASTM C618-12 for raw or calcined pozzolana (class N).The combined alkali (Na_2O+ K_2O) percentage of 3.5 is low and thus reduces the possibility of the destructive aggregate alkali reaction which causes disintegration of concrete[15]. Also, high alkalis percentage has been observed to affect the setting time and the rate of strength gain[16]. One other interesting chemical present is sulphur trioxide (SO_3). The SO_3 of 1.36% present is below the 4% maximum specified by ASTM C618-12 which shows the tendency for improved durability and prevent unsoundness of the paste[17]. The loss on ignition (LOI) which is a measurement of organic and carbonate content and sediments in cowdung ash is 12.28% which exceeds the maximum of 10% specified by ASTM C618. The concern of high LOI is that it may affect the reactivity of the cowdung ash in concrete and may increase the water requirement of the concrete or mortar due to the presence of impurities [18]. The specific gravity of CDA is 2.55, while that of Ashaka cement is 3.15. This indicates that CDA is lighter than cement and more volume of CDA will be required to replace equal weight of cement in concrete. Replacement of cement with CDA may also lead to reduction in density of Concrete. The pH of CDA is 9.5, this value shows that the CDA is neither Acidic (pH<.7.0) nor alkaline (pH>11) but neutral (pH of between 7-9). This implies that CDA can be used in concrete without concerns for durability problems [19].

3.2 Strength Activity Index.

The test for strength activity index is used to determine whether the pozzolan will result in an acceptable level of strength development when used with hydraulic cement in concrete.

The strength activity index of Cowdung ash was determined to be 77.48% as shown in Table 3. This value is greater than the 75% minimum specified by ASTM C 618 which indicates that Cowdung ash may react well with ordinary Portland cement to produce concrete of acceptable strength levels.

Table 1: Chemical Composition of Cowdung ash and cement

Oxides	Weight (%)	
	Cowdung ash	AshakaCement
SiO_2	69.65	20.26
Al_2O_3	4.27	6.30
Fe_2O_3	2.99	3.26
CaO	12.55	65.51
MgO	2.22	0.96
SO_3	1.36	0.69
K_2O	2.94	0.88
Na_2O	0.57	0.99
P_2O_5	1.48	0.25
Mn_2O_5	0.63	0.21
TiO_2	0.33	0.24

Table 2: Some Physical Properties of Cement, Cowdung ash, Sand and Coarse Aggregate

Property	Cement	Cowdung ash	Sand	Aggregates
Specific Gravity	3.15	2.55	2.62	2.65
Bulk Density(Kg/m³)	-	-	1528	1410
pH		9.5	-	-
Loss On Ignition (%)	1.0	12.28	-	-
Fineness modulus	-	-	2.62	-
Blaines Fineness(m²/Kg)	370	338	-	-
Aggregate Crushing Value (%)	-	-	-	22.27

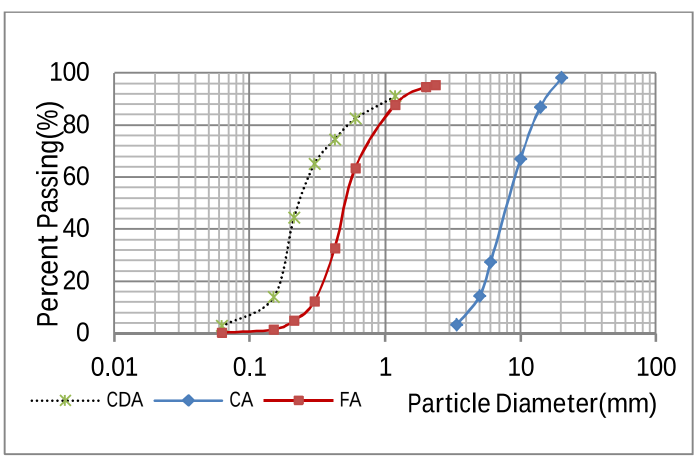

Figure 1: Particle size distribution curves for Aggregates cowdung ash (CDA)

Table 3: Test result of Strength activity index at 7days

Mix ID	Compressive Strength(MPa)	Average Comp. Strength(MPa)
CDA-00-01	14.80	
CDA-00-02	14.40	14.61
CDA-00-03	14.64	
CDA-20-01	11.16	
CDA-20-02	11.60	11.32
CDA-20-03	11.20	
	$SAI = \frac{11.32}{14.61} = 77.48$	

3.3 Workability of CDA/OPC Blended Concrete.

The results of the slump test carried out on concrete with varying percentage of cow dung ash (CDA) as cement replacement are presented in Table 4 while Figure 2 shows the plot of slump versus cowdung ash. All the slump values were the true Slump type and suitable for concrete works. The results shows that the slump decreases with increase in the amount of Cowdung ash(CDA),which indicates that more water is required to maintain the same consistency as the CDA content increases. For instance, 5%, 10%, 15%, 20%, 25% and 30% CDA content decreased the slump by 25%, 25%, 35%, 50%, 55% and 60% respectively. This implies that cowdung ash absorbs more water than Portland cement when added to the concrete mix. Concrete containing CDA of 5%, 10% and 15% with slump values of 15mm,15mm and 13mm respectively falls within the limits of Class S1 (10mm-40mm) specified by BS EN 206 - 1-2000 and approved for concrete works.

3.4 Setting times of CDA/OPC Blended Paste.

The test result for setting times of CDA/OPC paste is presented in Table 4 while Figure 3 shows the plot of the respective setting times versus CDA (%). The result of setting times indicates thatas the percentage of CDA increases; the initial and final setting times increase. At 5%, 10%, 15%, 20%, 25% and 30% substitution level, the initial setting time increased by 12.2%, 16.5%, 27.0%, 34%, 48.7% and 59.13% respectively. Similarly, the final setting time at 5%, 10%, 15%, 20%, 25% and 30% cement replacement with CDA increased by 2.74%, 11%, 13.20%, and 19.20% 24.7% and 43.90% respectively.This may be due to the modification of the crystal morphology of the paste so that there is more efficient barrier to further hydration and consequently prolonging the setting times[20].With these results, it could be opined that CDA is a very effective set retarder for use in hot weather concreting[

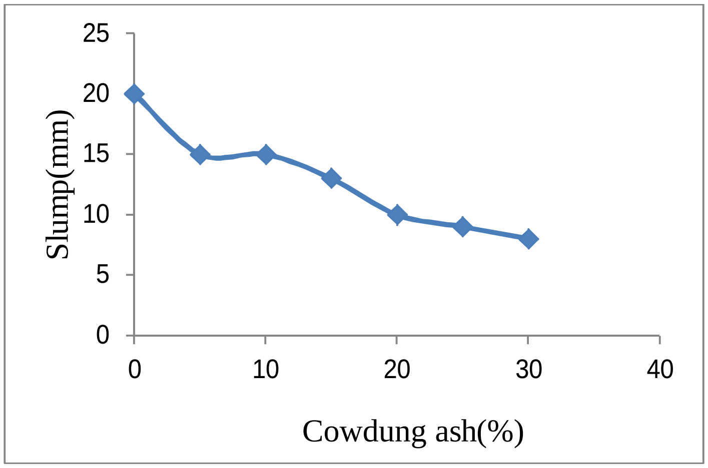

Figure 2: Plot of Slump of CDA concrete versus CDA

Table 4: Setting Times and Slump of OPC/CDA Paste and Concrete respectively

Mix ID	Slump(mm)	Setting Times(Min) Initial	Final	Retardation relative to control (Min). Initial	Final
CD-00	20	115	182	0	0
CD-05	15	129	187	14	5
CD-10	15	134	202	19	20
CD-15	13	146	206	31	24
CD-20	10	160	217	39	35
CD-25	09	171	227	56	45
CD-30	08	183	262	68	80

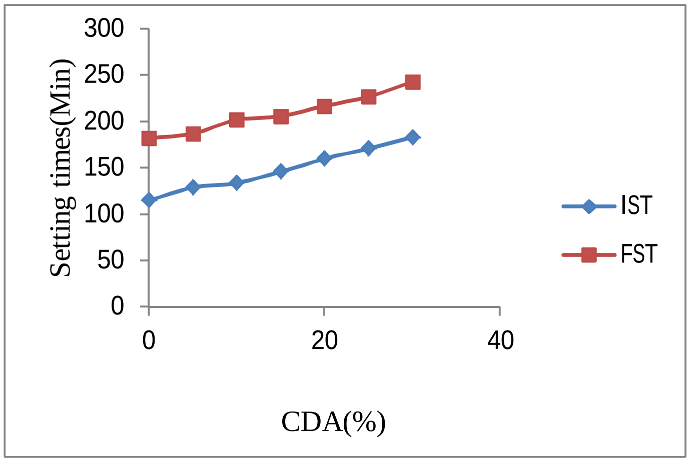

Figure 3: Effect of CDA on setting time of Cement Paste

3.5 Compressive Strength of OPC/CDA Concrete.

Figure 4 shows the plot of compressive strength of CDA/OPC concrete versus percentage of CDA used to replace cement. It can be seen from the plot of Figure 4 that the compressive strength decreases as the percentage of CDA increases irrespective of the curing age. For example 5% CDA exhibited strength decrease of 7.04%, 19.3%, 22.9%, 10.63% and 3.90% compared to the control specimen at the end of 7,14,28,60 and 90days of curing respectively days of curing. Similarly, 10% CDA exhibited strength decrease of 19.4%, 24.4%, 24.56%, 14.5% and 15.20% after 7,14,28,60 and 90days of curing respectively. Concrete containing 15% CDA exhibited strength reduction of 23.7%, 26.9%, 28.70%, 21.6%, and 20.6% at the end of 7,14,28,60 and 90days of curing respectively. Similarly, concrete containing 30% CDA exhibited strength reduction of 50.7%, 56.1%, 50.9%, 44.4%, and 34.6% compared to the control sample at the end of 7,14,28,60 and 90days of curing respectively. From all the results presented, it can be observed that higher CDA additions results in greater reduction of Compressive strength. Also, the percentage reduction in compressive strength becomes lower with curing age which is a strong indication of the pozzolanic ability of CDA [22]. This behavior may be attributed to two reasons. First, the replacement of cement with CDA in concrete, results in the reduction of tri-calcium silicates (main strength contributing compound) through the replacement of cement with CDA [23]. Secondly, the fineness of CDA is lesser than that of OPC and consequently cannot hydrate as quickly as cement (within the first 28days) to give the desired strength compared to plain OPC concrete [24].

Figure 5 shows the plot of compressive strength of CDA/OPC concrete versus its curing age (days). It can be duely noted that the compressive strength of the concrete containing CDA increases as the curing age is prolonged irrespective of the replacement levels. According to the experimental findings, 5% CDA exhibited 7.04% decrease in strength after 7days curing compared to the control concrete. However, this difference becomes 19.2%, 22.9%, 10.63% and 3.90%at the end of 14, 28, 60 and 90 days respectively. Similarly, 10% CDA exhibited 19.4%, 24.4%, 24.56%, 14.5%, and 15.2% decrease in strength compared with the corresponding strength of the plain concrete at the end of 7, 14, 28, 60 and 90days of curing. 15% CDA exhibited 23.70%, 26.90%, 28.70%, 21.60% and 20.60% decrease in strength compared with the corresponding strength of the plain concrete at the end of 7, 14, 28, 60 and 90days of curing. 30% CDA exhibited 50.70%, 56.10%, 50.90%, 44.40% and 34.60% decrease in strength compared with the corresponding strength of the plain concrete at the end of 7, 14, 28, 60 and 90days of curing. It can be seen from the values presented above that the percentage decrease for all percentage of CDA used increases up to 28days curing period. However, the percentage decreases significantly after 60 and 90days of curing.This shows that there is a significant strength gain with prolong curing[25]. The maximum compressive strength recorded when CDA was added was at 5% replacement cured for 90days and it represents a 15% increase compared to the value of the control sample cured for 28days. Except for 10%CDA at 60days, all values of 5% and 10% CDA cured for 60 and 90 days gave better compressive strength than the 28days control sample. These are all strong indication of the pozzolanic characteristics of CDA[26]. The possible explanation to this behavior is that at early ages (28days and below), the CDA act as a filler in the concrete with no significant contribution to strength, but at latter ages(beyond 28days) CDA react with Calcium Hydroxide released in what is called the pozzolanic reaction to produce the strength forming calcium silicate hydrates(C-S-H). The C-S-H formed is a stable compound and is responsible for the significant latter strength gain [27]-[29].

Table 6 shows the result of regression analysis on compressive strength results. The regression equation is given by:

$$f_c = 14.4 - 0.343a + 0.273b + 0.00171a^2 - 0.00138b^2 - 0.000755a \quad \ldots(2)$$

Where a and b (predictor variables) are curing age and Cowdung ash respectively, while f_c is the compressive strength (Response variable). The P-values is a measure of the likelihood that the true coefficient is zero. From the p-values of the terms in the model (constant, a, b, a^2, b^2 and a*b), it can be seen that the constant, a, b and b^2 are highly significant ($P< 0.05$) and thus are useful predictors of the regression model. However, a^2 and a*b (interaction between Cowdung ash and curing period) are not significant ($P>0.05$) and thus are not useful predictors of the regression model. Therefore, it can be concluded that with the exception of a^2 and a*b, all other predictor variable significantly influences the response (Compressive strength in this case).The coefficient of variation of the selected Model gave an R-Squared value of 98.0%. This value is expected to be as high as possible to prove the relationship or connections between two or more variables in a model [30]. Coefficient of variation of 98.0% implies that 98.0% of variation in the compressive strength is explained by the regression model with curing age and CDA content as variables [31]. This shows a perfect correlation and the generated Model is highly significant [32].

The compressive strength results were further subjected to a one way analysis of variance (ANOVA).The computation is presented in Table 7. Although, the concrete cubes containing CDA have lower compressive strength compared to the control samples, there was no significant difference between the compressive strength of control samples and those of concrete containing up to 15% CDA ($P > 0.05$) at 5% level of significance. Thus, CDA above 15% is not recommended for use where strength is a criterion. . The constant variance assumption was checked with residual versus fits plots shown in Figure 6. The plot as expected showed a random pattern of the residuals on both sides of the zero error line. As it can be seen, the noise (residuals) has no recognizable pattern. (i.e. the variance is constant), there were very few unusual observations such as outliers, high leverages and influential cases which further confirms the adequacy of the proposed model. The population normality was checked with the Normal probability plot as shown in Figure 7. It can be clearly seen that the residuals (dots) aligns themselves closely and tend to resemble a straight line with not so much variation

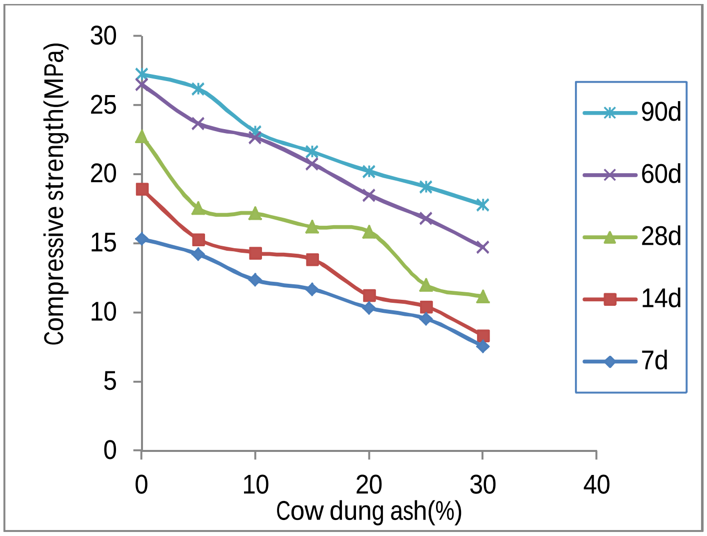

Figure 4: Plot of Compressive Strength versus Cowdung ash

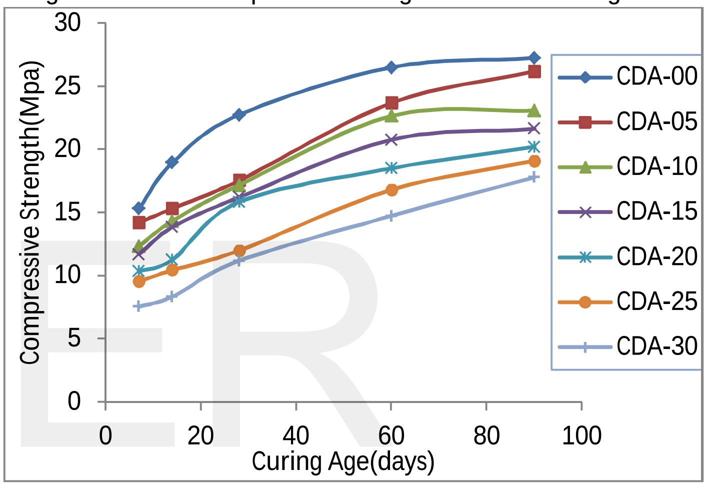

Figure 5: Plot of Compressive Strength versus curing period.

Table 6: Regression Analysis of Compressive strength.

Predictor	Coeff	SE Coeff	T	P	Significance
Constant	14.4164	0.5220	27.62	0.000	Yes
a	-0.34313	0.05240	-6.55	0.000	Yes
b	0.27319	0.02160	12.65	0.000	Yes
a^2	0.00171-	0.00158	1.08	0.288	No
b^2	0.00138	0.00021	-6.64	0.000	Yes
a*b	-0.00075	0.00044	-1.71	0.098	No
Basic ANOVA					
Source	DF	SS	MS	F	P
Regression	5	950.15	190.0	289.6	0.000
Error	29	19.02	0.66		
Total	34	969.17			

Table 7: Analysis of one way ANOVA for the Compressive strength results at a Significance level of 5%

Mix- ID	Mean Strength	Variance	P	Remarks
CDA-00	22.168	-	-	-
CDA-05	19.398	27.908	0.4216	NS
CDA-10	17.930	23.447	0.2123	NS
CDA-15	16.840	18.600	0.1107	NS
CDA-20	15.238	18.945	0.0485	S
CDA-25	13.584	17.382	0.0190	S
CDA-30	11.924	18.772	0.0081	S

*NS means Not Significant, * S means Significant

Table 8: Mix Proportions of Constituent Materials used for CDA Concrete production (1m³)

Mix ID	Constituent Material (Kg/m³)				
	Binders		Aggregate		Water
	CDA (Kg)	Cement (Kg)	Course (Kg)	Fine (Kg)	(Kg)
CD-00	0	300	1164	776	165
CD-05	15	285	1164	776	165
CD-10	30	270	1164	776	165
CD-15	45	255	1164	776	165
CD-20	60	240	1164	776	165
CD-25	75	225	1164	776	165
CD-30	90	210	1164	776	165

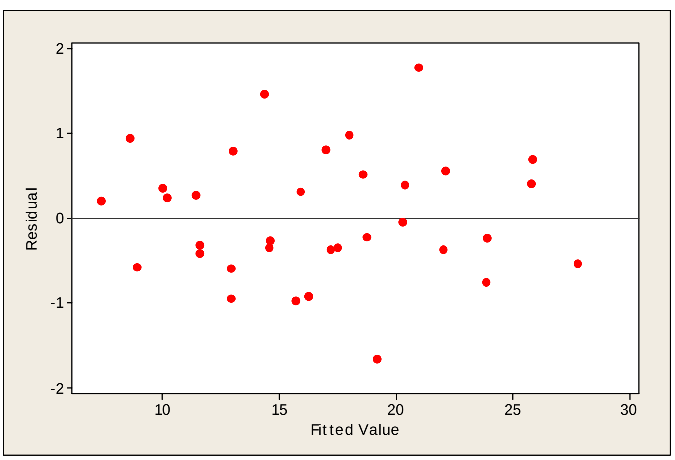

Fig 6: Plot of residual versus fitted value for compressive strength of CDA/OPC Concrete.

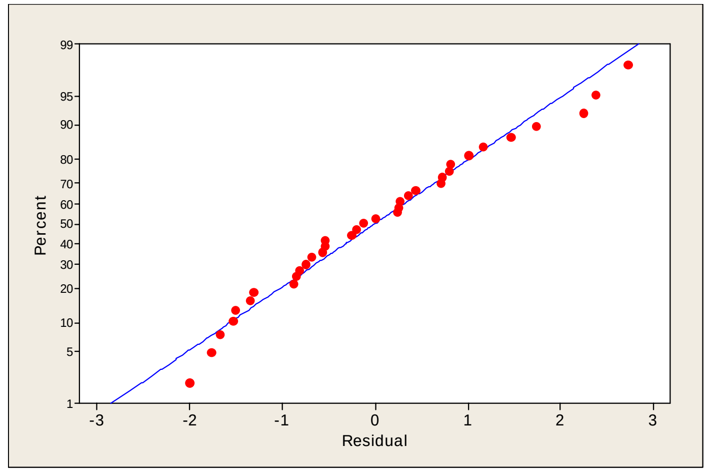

Fig 7: Normality Probability Plot for Compressive strength of CDA/OPC concrete

4.0 CONCLUSIONS

Based on the outcome of this research, the following conclusions can be inferred:

- Cowdung ash (CDA) has pozzolanic traits and thus can be classified as pozzolana.
- The use of CDA in concrete retards its setting times and hence can be used as a set retarder for concreting in hot weather.
- Workability is reduced by incorporating CDA in concrete; hence vibration of concrete made with CDA/OPC blend is required or the use of a super plasticizer to achieve the desired workability.
- Compressive strength of CDA/OPC blended concrete decreases as CDA content increases and increases with curing age.
- For this study, a replacement of no more than 15% can be considered for the production of strong and quality concrete.
- Cement replacement of 5%, 10%and 15% in concrete with CDA showed no statistically significant loss in strength compared to the control sample.
- Cowdung ash and Curing Period are useful predictors of the regression model for compressive strength.
- Regression Model for compressive strength is given by:

$$f_c = 14.4 - 0.343a + 0.273b + 0.00171a^2 - 0.00138b^2 - 0.000755a$$

R^2=98.0%.

Where a, b are CDA content and curing age respectively. This shows a perfect correlation; hence the generated model is highly significant.

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