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Effect of Curing Methods and Time on the Strength of Silicate Concrete made from Corn Cob Ash

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Abstract-* Corn cob, an agricultural waste material was converted to ash and used as a pozzolanic material in the partial replacement of cement in concrete. This is expected to reduce cost and promote green and sustainable environment. However, this research report presents the effect of curing methods and curing time in the strength of the silicate concrete so produced. M25 concrete with water/cement ratio of 0.45 was prepared with corn cob ash (CCA) replacements of 0, 10, 20 and 30%. They were cured for 14, 28, 42 and 56 days using different curing methods. Though the compressive strength improved over time, it however declined with increase of CCA content. The ponding method of curing gave the highest compressive strengths of 34.6N/mm 2 and 27.7N/mm 2 at 0% and 10% CCA replacements respectively While the spraying method produced the list strength. The CCA did not improve the compressive strength up to 56 days but may probably do beyond the date due to the slow hydration of pozzolanas.

***Keywords:* Corn Cob Ash, Compressive Strength, Curing Days, Silicate Concrete, Pozzolana**

I. INTRODUCTION

The wide use of concrete as a building material has made the cost of its components to increase enormously especially in developing countries where there are limited alternatives. The manufacturing process of ordinary Portland cement (OPC), an exceptionally important component of the concrete composite ranks as one of the highest energy consuming industries in the world and the carbon dioxide (CO_2) emissions associated with it makes its production environmentally unsustainable. Therefore, the high cost of cement is encouraging the development of silicate concretes or concretes from pozzolanic materials and geopolymers.

Corn cob ash (CCA) is a product of incinerated corn cob which is a natural agricultural postharvest waste that on its own constitutes an environmental nuisance. It is described as the agricultural waste product obtained from maize or corn which is the most important cereal crop in Sub – Saharan Africa (Elinwa, Ejeh, & Mamuda, 2008) .As a pozzolana CCA can be defined as siliceous material which possesses little or no cementing properties but when in a finely graded form in the presence of moisture will chemically react with calcium hydroxide (CaOH) at ordinary temperature to form compounds possessing these cementing properties (ASTMC311/C311M, 2018). This CaOH is a product of the hydration of OPC which combine with pozzolana to produce insoluble and cementitious calcium silicate hydrates. However, as the quantity of cement needed for construction projects increases; increasing amounts of raw materials from natural resources are consumed. If some of these raw materials can be replaced by cheaper materials of similar composition, the concrete production cost could be reduced without affecting its quality. Raw CCA has a large particle size and high in porosity, needing more water content in the concrete mixture. This reduces its concrete to a medium compressive strength. However, when it is grinded into small particles, the strength of the concrete may improve significantly (Olafusi & Olutoge, 2012). Other pozzolanas like the guinea corn husk ash (GCHA) (Ndububa & Nurudeen, 2015), (Aburime, Ndububa, & Kpue, 2020), rice husk ash (RHA) (Bhushan, Goche, Singh, & Bastola, 2017) and fonio husk ash (FHA) (Ndububa, Okonkwo, & Ndububa, 2016) All of these showed the same characteristic, usually may increase the concrete strength to an optimum value before declining.

On the whole, the strength of concrete, its durability and other physical properties are affected by curing methods adopted and curing time. The application of the various types has a relationship to the prevailing weather condition in a particular locality as curing is only one of many requirements for concrete production. It is important to study the effect of different curing method and time which best adapts to each individual casting process. Some of the methods

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and which are reported in this manuscript are Ponding, which requires total immersing of concrete into water, Plastic sheeting which requires the covering of the concrete samples with water proof materials and Spraying, which requires periodic spray. Fogging and forms of wet curing are known to have become necessary to maximize hydration (Neville, 2000).

II. MATERIALS AND METHODS

2. 1 Materials and their Preparations

OPC of grade 43 and free from moisture was obtained from the "Dangote" brand of Obajana plant in Kogi State Nigeria. The river sand that served as fine aggregate was obtained from Jere River along Abuja – Kaduna highway. It was washed to remove sundry deleterious materials and dried. The coarse aggregates were granite chips obtained from a quarry in the Dutse area of Abuja. All of the aggregates were prepared in accordance with the relevant BS EN standards (BSEN12620, 2002), (BSENA1, 2008). Clean and clear borehole water was used for the mixing.

The corn cob was obtained at farm dumps in Zangon Kataf Area of Kaduna State, Nigeria (see Figure 1). They ground dried to approximately 4.0mm diameter using local corn miller machine as shown in Figure 2 before incineration at 600 o C. The burnt ash was further broken down by ball milling (see Figure 3) to passthrough a 75micronsBS sieve. The CCA sample is shown in Figure 4.

Figure 1: Corn cob dump

Figure 2: Grinding of corn cob

Figure 3: Ball milling using drum ball miller

Figure 4: CCA sample

2.2 Chemical composition of corn cob ash

The major oxide compositions of corn cob ash from two sources, (Adesanya & Raheem,2009) and (Owoyale & Yusufu, 2008) are as given in Table 1. This was adopted in this paper since similar corn specie are grown in the same research environment. The combined content of SiO_2 (silica), Al_2O_3 (alumina) and Fe_2O_3 (ferric oxide) were 83.03% and 72.8 respectively which are above the specified 70% for pozzolanas (ASTM C311/C311M-18, 2018). These indicate the suitability of CCA as a pozzolana.

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Table 1: Major oxide compositions in corn cob ash

Oxide	SiO_2	Al_2O_3	Fe_2O_3	CaO
Adesanya& Raheem (2009)	56.39	17.57	9.07	11.47
Owoyale &Yusufu (2008)	60.1	7.2	5.5	2.46

2.3 Sieve Analysis

In accordance with the relevant British standard (BSEN196-6, 2018), The aggregates were measured and passed through a mechanically operated sieve. The following parameters were determined;

Coefficient of uniformity, Cu -- (1)

Coefficient of curvature, Cc -- (2)

Fineness Modulus, FM -- (3)

Where, D10, D30 and D60 are 0.075, 0.15,0.30.

2.4 Workability

Slump tests were carried out on each of the mix proportions of wet concrete in accordance with the British standards (BS1881, 1991)

2.5 Mix Proportioning of the CCA-Concrete

The mix proportion used is shown in Table 2

Table 2: Mix proportion for CCA- Concrete sample by weight (Kg)

% CCA	OPC	Fine Aggregate	Coarse Aggregate	Water	CCA	w/c
0	372	560	1308	160	0	0.45
10	349	742	1113	155	41	0.45
20	324	660	1173	155	93	0.45
30	299	593	1204	145	159	0.45

2.6 Compressive strength and Density

The compressive strength is derived from cube crushing in accordance with British standards (BSEN12390, 2009). Cubes were casted from the samples into molds then crushed after the respective curing periods in a universal testing machine (UTM). To obtain the average compressive strength, three cubes were casted for each replacement levels to obtain the values.

Figure 5: Compressive strength test.

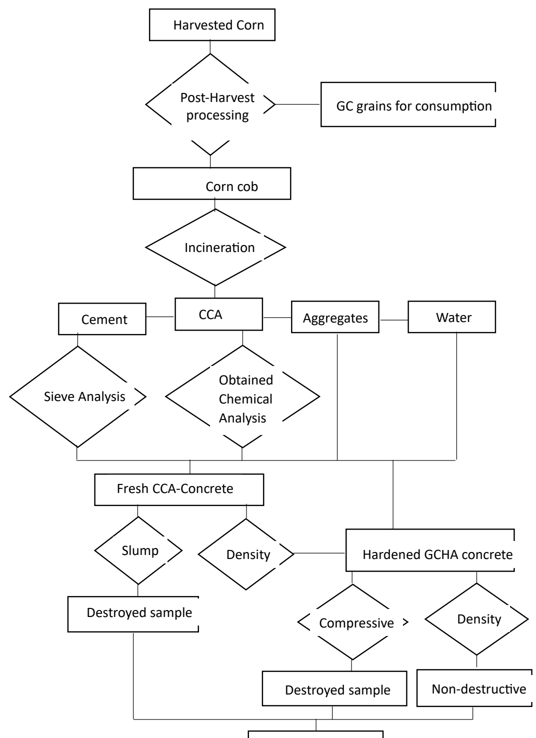

Figure 6: Flowchart of research work

III. RESULTS AND DISCUSSIONS

3.1 Sieve Analysis of fine aggregate and coarse aggregate

The results of the sieve analysis showing the particle size distribution of fine and coarse aggregates are presented in Tables 3 and 4. The grading curves are also presented respectively in Figures 7 and 8.

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Table 3: Sieving results of fine aggregates (1000g)

S/N	Sieve Size	Mass Retained	%Retain	Cumulative % Retained	Cumulative % Passing
1	2.000	0	0	0	100
2	1.700	20	2	2	98
3	1.180	20	2	4	96
4	1.000	10	1	5	95
5	0.850	40	4	9	91
6	0.600	180	18	27	73
7	0.425	400	40	67	33
8	0.300	150	15	82	18
9	0.150	105	10.5	92.5	7.5
10	0.075	30	3	95.5	4.5
11	0.063	25	2.5	98	2
12	0.045	20	2	100	0

Table 3: Sieving results of coarse aggregates (1000g)

S/N	Sieve Size	Mass Retained	%Retain	Cumulative % Retained	Cumulative % Passing
1	25.40	0	0	0	100
2	19.05	365.4	34.8	34.8	65.2
3	12.70	428.4	40.8	75.6	24.4
4	9.52	212.1	20.2	95.8	4.2
5	4.76	18.9	1.8	97.6	2.4
6	2.36	12.6	1.2	98.8	1.2
7	1.18	5.25	0.5	99.3	0.7
8	0.60	4.2	0.4	99.7	0.3
9	0.30	2.1	0.2	99.9	0.1
10	0.15	1.05	0.1	100	0

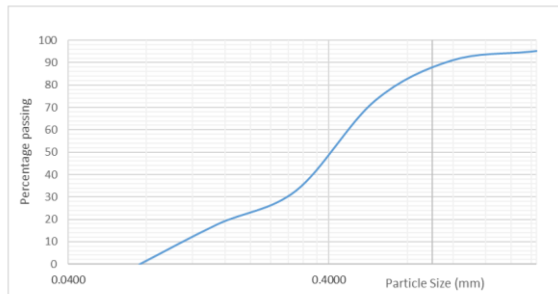

Figure 7: The grading curve of fine aggregate.

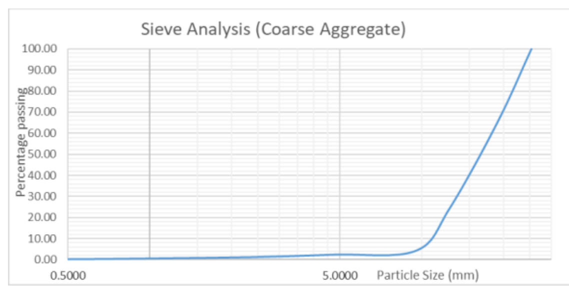

Figure 8: The grading curve of coarse aggregate

From Equations (1), (2) and (3), the values of the coefficient of uniformity (Cu) of the fine and coarse aggregates were 3.75 and 1.33 respectively. Cc values for the two were 0.94 and 1.33 respectively. The values for FM were 5.82 and 8.02 this shows that the value of fine and coarse aggregate is slightly different and can affect the workability of fresh concrete. Since Cu is greater than 1 and Cc is between 0 &1, the fine and coarse aggregates may be classified as poorly graded in accordance with BS (BSEN196-6, 2018)

3.2 Workability of Fresh CCA Concrete.

Table 5 and Figure 8 show the slump values and wet density of the fresh CCA concrete. The results show that the slump value decreased as the percentage of CCA increased indicating that the concrete became

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less workable as the percentage of CCA increased. It therefore meant more water is required to make the mix more workable. On the other hand, the concrete became lighter with increase of CCA as shown in the density values. However, this does not confer light-weight property on it as the least density from the samples is within the range of normal concrete density.

Table 5: Slump of CCA concrete

% Replacement of cement	Slump (mm)	Wet Density (kg/m3)
0	11	2.532
10	7	2.516
20	5	2.508
30	4.3	2.489

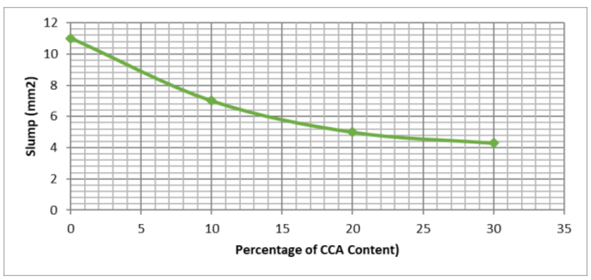

Figure 9: Slump of CCA concrete

3.3 Compressive Strength Test and Density Results.
Tables 6 to 9 show the results of the compressive strength tests and density for 14, 28, 42 and 56-days curing periods with the curing methods adopted. The hardened CCA concrete density values are written in brackets.

Table 6: Compressive strength and density of 0% CCA-concrete for different days and curing methods

Curing days → / Curing Methods ↓	14	28	42	56
Immersion	21.0 (2375.3)	26.9 (2370.3)	30.8 (2419.8)	34.6 (2449.4)
Plastic sheeting	20.4 (2375.3)	25.6 (2380.2)	29.1 (2533.3)	32.9 (2565.3)
Spraying	18.1 (2365.4)	22.7 (2562.9)	26.2 (2360.5)	29.3 (2533.3)

Table 7: Compressive strength and density of 10% CCA-concrete for different days and curing methods

Curing days → / Curing Methods ↓	14	28	42	56
Immersion	18.0 (2355.4)	21.7 (2390.1)	24.6 (2380.4)	27.7 (2523.4)
Plastic sheeting	16.1 (2256.8)	20.3 (2375.3)	23.3 (2562.9)	26.2 (2575.3)
Spraying	14 (2263.7)	17.9 (2365.4)	20.3 (2375.3)	22.7 (2562.9)

Table 8: Compressive strength and density of 20% CCA-concrete for different days and curing methods.

Curing days → / Curing Methods ↓	14	28	42	56
Immersion	10 (2365.5)	13.2 (2204.4)	15.3 (2237)	16.7 (2254.8)
Plastic sheeting	9.1 (2365.4)	11.5 (2143.2)	13.2(2204.4)	15.2(2237.0)
Spraying	7.3 (2153.1)	9.1 (2365.4)	10.4(2365.5)	11.5 (2143.2)

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Table 9: Compressive strength and density of 0% CCA-concrete for different days and curing Methods

Curing days → / Curing Methods ↓	14	28	42	56
Immersion	3.9 (1918)	4.5 (1921.7)	7.6 (2298.3)	8.7 (2365.4)
Plastic sheeting	3.3(1905.9)	3.7 (1915.0)	6.1(1873.0)	7.1 (2153.1)
Spraying	1.6 (1812.3)	1.8 (1822.2)	3.3 (1906.2)	3.7 (1915.0)

The results show that compressive strength increased with curing age for all curing methods. This is expected as concretes general harden over time under curing conditions. The CCA-concrete is proving to be no exception. However, there was a general decline in strength as CCA was added and increased, with the three % replacements. These are graphically shown in Figures 10 and 11 with 28 and 56 days of curing respectively. The densities also declined as ash percent increased, giving the prospect of medium-weight concrete at 30% CCA replacement. The results show that if used to design a load-bearing structure the CCA concrete should not use with CCA replacement exceeding 20%. Even at that, 20% replacement should be for medium-load bearing structure.

Figures 12, 13 and 14 graphically show the impact of the curing methods and % CCA replacement of cement on the compressive strength of the CCA concrete. They show that water immersion or ponding method produced the highest values followed by plastic sheeting and the water spraying. The reason for this is suggested to be that with total water immersion, the samples had most adequate moisture to aid hydration of cement which created strongest bonding. The graphs also show that increase of CCA decreased compressive strengths as earlier mentioned. This is not different from results in the past about pozzolanas where strengths increased up to particular % replacements before declining. In a previous report (Aburime, Ndububa, & David, 2020), the optimum % replacement guinea corn husk ash and fonio husk ash (Ndububa, Okonkwo, & Ndububa, 2016) were 5% respectively. Probably the increase in this case of corn cob ash (CCA) may have been at some figures below 10% replacement.

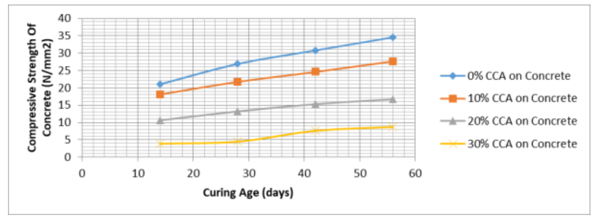

Figure 12: Compressive strength of CCA concrete with Immersion curing method

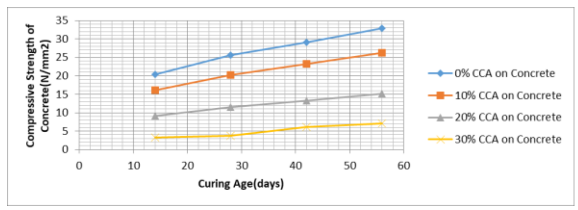

Figure 13: Compressive strength of CCA concrete with Plastic sheeting curing method

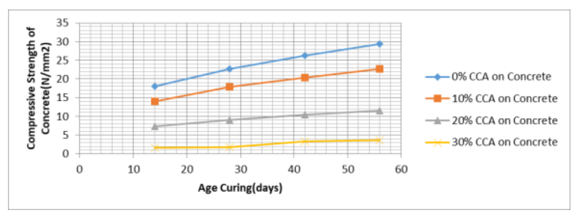

Figure 14: Compressive strength of CCA concrete with Spraying Water curing method

IV. CONCLUSION

Based on the findings from this study, the following conclusions can be made;

1. Workability is more difficult as the Slump of the fresh CCA concrete decreases with increase in CCA replacement levels. Therefore, more water will be needed for mixing when compared to mixing plain concrete
2. The compressive strength of CCA concrete increased with age but decreased with increasing CCA replacement levels at 0%, 10%, 20%, 30%.
3. Total immersion in water or ponding method of curing presented the best compressive strength

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results with Plastic sheeting next before Water spraying method.

4. Since corn cob is a cheap agro-waste material. Its use in concreting and building should be encouraged in order to reduce cost, minimize green-house gas emissions and enhance environmental sustainability.

V. RECOMMENDATION

1. More work should be done on reducing the replacement levels and increasing the curing days these are because most pozzolanas initially increase strength of concretes up to some levels below 10% before the strengths declined. There is need to k=determine that optimum level for CCA. Also, since silica concretes generally hydrate over longer period of time, curing may be extended beyond 56 days.
2. Water reducing Admixtures may be added to enhance workability instead of increasing the water content to avoid the incidence of weaker concrete.
3. Further works on durability and other strength parameters can be carried out on each of the curing methods used in this study.

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