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PARTIAL REPLACEMENT OF CEMENT WITH CORN COB ASH IN CONCRETE PRODUCTION

Bala A[1*]., H. O. Aminulai[1]., M. Abubakar[1], H. S. Abdulrahman[1] and U. Musa[2]

[1]Department of Civil Engineering, Federal University of Technology, Minna, Nigeria
[2]Department of Chemical Engineering, Federal University of Technology, Minna, Nigeria
*balhaji80@yahoo.com/08065260435

ABSTRACT

The research investigated the effects of partial replacement of cement with corncob ash (CCA). Physical properties of the aggregates and mechanical properties of CCA cement concrete at 0.5 water–cement ratio and mix ratio of 1:2:4 were examined. Sixty concrete (60) cubes of size 150x150x150mm with different percentages by mass of corncob ash to Portland cement in order of 0%, 3%, 6%, 9% and 12% corncob ash were cast and crushed. The specific gravity of corncob ash was 1.16, while a twenty eight (28) day compressive strength of 29.4N/mm^2 was obtained at 3% replacement level, which shows that the 3% CCA replacement for cement is the optimum. While 12% CCA replacement for cement offers the lowest strength (18.6N/mm^2). Hence, the use of supper plasticizers and accelerators may be required to enhance the strength and workability at this replacement level.

Keywords: *Compressive Cube Strength, Corncob Ash, Partial replacement, Cement*

1. INTRODUCTION

Concrete is one of the engineering materials commonly used in building component such as slabs, columns, beams, staircase, foundation, retaining wall, dams etc. However, concrete is the most versatile heterogeneous or composite construction materials and impetus of infrastructural development of any nation. Civil engineering practice and construction work around the world depend to a very large extent on concrete. Concrete is a synthetic construction material made by mixing cement, fine aggregate, coarse aggregate and water in a specified proportion. Each of the components contributes to the strength development of the concrete. Hence, the overall cost of concrete production depends largely on the availability and cost of its constituent material. In Nigeria, cement is averagely the most expensive ingredient in the production of any concrete (Adesanya & Raheem, 2009). Because of the negative impact due to the environmental pollution, degradation of natural resources such as limestone and high cost of Portland cement, there is, therefore, need for cheaper and available substitute for cement in concrete production. One of the practical and economical solution is through the utilization of agricultural and industrial waste such as rice husk ash, coal fly ash (pulverized fuel ash), granulated blast furnace slag, silica fume, met-kaolin (calcium clay), rice husk ash, palm kernel shell ash, and Shea nut shell ash.

In addition, corncob is the hard thick cylindrical central core of maize, however, corn cob is describe as the agricultural waste product obtained from maize or corn, which is the most important cereal crop in sub-Sahara Africa. According to food and agricultural organization data, 589 million tons of maize was produce worldwide in the year 2008 (FAO, 2009). The United States was the largest maize producer having 52% of world production. Africa produce 9% of the world maize (IITA, 2008), Nigeria was the second largest producer of maize in Africa in the year 2001 with 4.62 million tons (FAO, 2009). Subsequently, facility study reveals that, in Niger state most peasant or subsistence farmer cultivate cereal crop (Grass family crop) such as genuine corn, rice, corn (maize) and so on. However, these further imply that availability of corn cob as a by-product of maize is be assured. However, the significance of this research is to help reduce the cost of concrete production arising from increasing cost of cement, and reduce the volume of solid waste generated from corncob using this waste-to-wealth initiative.

2. METHODOLOGY

Materials used for this study are:

Cement;

The cement used for this research work is Ordinary Portland cement (OPC). The cement was purchased from Kowa cement store located at Gbakungu in Minna, Niger state.

Corncob ash (CCA);

The corncob was collected from Kudu in Mokwa local government, a major corn producing rural community in Niger state, the cob was dried thoroughly and burnt using open air burning. Finally the product was sieve using sieve number 200.

Coarse Aggregate (Gravel);

Crushed granite used was obtained from Triacta crushing plant located at Maikunkele in Minna, Niger state. The aggregate was clean, strong and sharp, free from clay, loam, dirt or organic matters conforming to the requirement of BS EN 12620 (2008).

Fine Aggregate (Sharp Sand)

The sharp sand used was obtained from river located at Gidan-mongoro along Federal University of Technology, Minna. It was air dried for 72 hours in other to reduce the moisture present in it. The sand was also clean and sharp, free from clay, loam, dirt or organic matters and conform to the requirement of BS EN 12620 (2008).

Water;

Tap water was used for mixing and curing of the concrete at the civil engineering laboratory, Federal University of Technology Minna. The physical examination of the water shows that it was clean, free from impurities and fit for drinking as recommended by the standard. BS EN 1008 (2002)

Production of Concrete;

Moulds of (150×150×150) mm were used. They were lubricated with engine oil in order to reduce friction and to enhance removal of cubes from the moulds. They were then filled with concrete in three layers and each layer was tamped 25 times. The moulds containing the cubes were left for 24 hours under a room temperature for the cubes to set before removing the mould. The cubes were removed after 24 hours and were taken to curing tank (BS EN 12390, 2002).

Curing of Cubes;

The method use for curing in this work is the total immersion of the cubes in water for specific age of 7, 14, 21 and 28 days from the day of casting (BS EN 12390-2:2000)

Compressive Strength Test

The concrete cubes were crushed at 7, 14, 21, and 28 days in order to determine the compressive strength of the cubes. The compressive strength is determined by dividing the maximum of failure load of the specimen during the test by the cross sectional area of the specimen, BS EN 12390 (2002).

Compressive strength is evaluated using the relation;

$$compressive\ strength\ (N/mm2) = \frac{crushing\ load}{cross\ sectional\ area\ of\ concrte\ cube} \quad (1)$$

3. RESULTS AND DISCUSSIONS

Specific gravity;

The result of specific gravity test for both fine and coarse aggregates as presented in Table 1.0 fall within the specification 2.6 -3.0 for natural aggregate.

Bulk density;

The result of bulk density of both fine and coarse aggregates are given in Table 1.0 (loose and compacted bulk density) as 1460.10kg/m^3, 1600.05kg/m^3 and 1477.0kg/m^3, 1644.0kg/m^3 respectively. These values are within the specified range of 1650kg/m^3 to 1850kg/m^3 as reported by Abdullahi and Oyetola (2006).

Table 1.0 Physical Properties of the Aggregates

Parameter	Sand	Gravel	CCA	Cement
Specific gravity	2.68	2.75	1.16	3.16
Compacted Bulk density (kg/m^3)	1600.05	1644	-	-
Uncompacted bulk density (kg/m^3)	1460.10	1477	-	-
Aggregate impact value (AIV)	-	465	-	-

Sieve analysis

The result obtained for sieve analysis of both gravel and sharp sand was plotted as shown in Tables 2.0 and 3.0. However, from Figure 1.0 the curve shows as S-curve showing that the sharp sand is well graded, which was adequate for producing a workable concrete. Also, Figure 2.0 shows a smooth grading curve which is an indication that the aggregate is adequate for production of workable concrete.

Table 2.0 Sieve analysis of the gravel

Sieve size (mm)	Weight Retained (g)	% Retained	% Cum Passing
37.5	0.000	0.00	100
19.00	12.000	1.20	98.80
13.2	84.000	8.42	90.38
9.5	268.200	26.87	63.52
4.75	625.300	62.64	0.88
Pan	8.790	0.88	0.00
TOTAL		100.00	353.58

Table 3.0 Sieve analysis of the sharp sand

Sieve size (mm)	Weight Retained (g)	% Retained	Cum % Retained	Cum % Passing
5.00	4.94	0.49	0.49	99.51
3.35	6.50	0.65	1.14	98.86
2.00	24.90	2.49	3.63	96.37
1.18	97.90	9.79	13.42	86.58
850	113.65	13.17	26.59	73.41
600	158.50	15.85	42.44	57.56
425	155.91	15.59	58.03	41.97
300	119.95	11.99	70.02	29.98
150	218.43	21.84	91.86	8.14
75	33.15	3.32	95.18	
Pan	48.17	4.82	100	

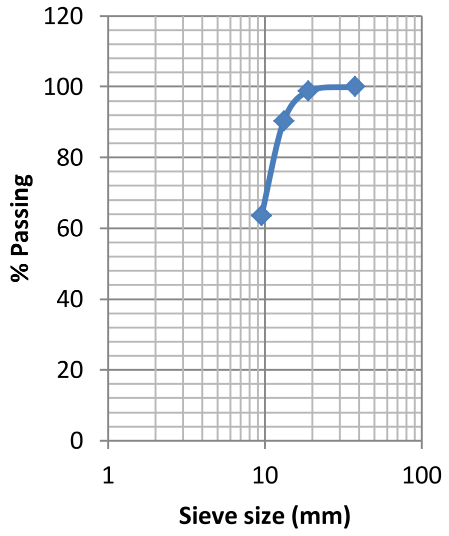

Fig 1: Sieve Analysis of the Gravel

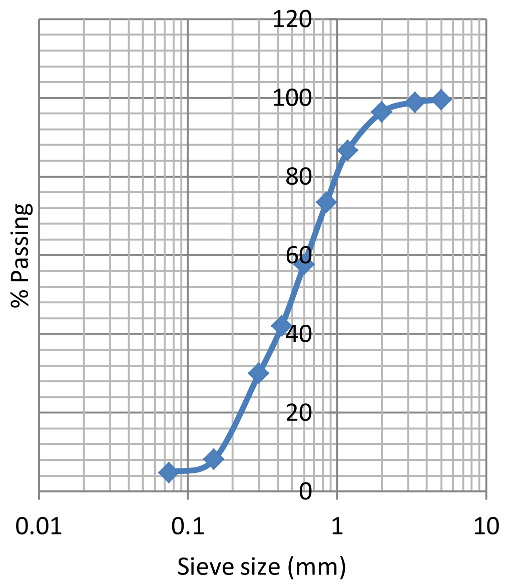

Fig 2: Sieve Analysis of Sharp Sand

Chemical analysis of CCA;

Table 4.0 shows the chemical composition of corn cob ash. The total percentage composition of iron oxide (Fe_2O_3=2.95), Silicon dioxide (SiO_2=68.60) and Aluminum oxide (Al_2O_3=5.15) was found to be 76.7%. The value is within the required value of 70% minimum for Pozzolanas as specified by ASTM C618 (2005). This values a little more than the value obtained by Abdullahi and Oyetola (2006) for rice husk ash (73.15%) which implies that CCA is more pozzolanic.

Table 4.0: Chemical Analysis of Corn Cob Ash

	% Composition	ASTM C618-12 Requirement
SiO_2	68.60	$SiO_2+Al_2O_3+Fe_2O_3 \geq 70\%$
Al_2O_3	5.15	
Fe_2O_3	2.95	
CaO	4.50	
MgO	2.80	
SO_3	1.44	
K_2O	8.42	
Na_2O	0.45	
Mn_2O_3	0.06	
P_2O_5	2.42	
LOI	8.55	10% max. for Classes N and F, 6% max. for Class C
Specific Gravity	2.50	

Compacting Factor;

The results obtained for the compacting factors of fresh CCA concrete for 0%, 3%, 6%, 9% and 12% were within the range of 0.94 and 0.95. These values fall within the required limit of 0.85-0.98 (Wilby, 1983), which indicates that the workability is satisfactory.

Slump Test;

The variations of the slump with increase in CCA is presented in Table 5.0. The result of the slump test obtained for 0%, 3%, 6%, 9% and 12% CCA are 32mm, 30mm, 28.5mm, 27mm and 27.5mm respectively. According to Wilby, 1983 a very low slump ranges from 0 - 25mm. Hence, from the above range of values it shows that the workability is also satisfactory.

Table 5.0 Slump and Compacting Factor Result CCA Concrete

% CCA	0% CCA	3% CCA	6% CCA	9% CCA	12% CCA
Slump (mm)	32	30	28.5	27	27.5
M_1 (kg)	7038	6882	7661	7933	7614
M_2 (kg)	7650	7580	8150	8350	8100
Compacting factor	0.92	0.90	0.94	0.95	0.94

Compressive Strength of Hardened Corncob Ash (CCA) Concrete;

The values obtained for the compressive strength test for hardened CCA concrete are given in Table 6.0 for 0%, 3%, 6%, 9% and 12%. The strength increases with the increase in age of curing. The mixes containing CCA exhibited downward result as the CCA content increases. It is observed that the value of compressive strength obtained at 28days crushing for the respective percentage replacement of CCA are 32.1N/mm^2, 29.4 N/mm^2, 23.8 N/mm^2, 21.5 N/mm^2 and 18.6 N/mm^2. This indicates that the optimum replacement level for corncob ash is 3%.

Table 6.0 Summary of Copmressive Strength

% CCA replacement	Compressive Strength (N/mm^2)			
	7days	14days	21days	28days
0%	28.0	30.2	30.5	32.1
3%	25.7	28.3	28.8	29.4
6%	20.5	22.6	23.6	23.8
9%	17.9	18.2	18.6	21.2
12%	15.2	17.4	18.0	18.6

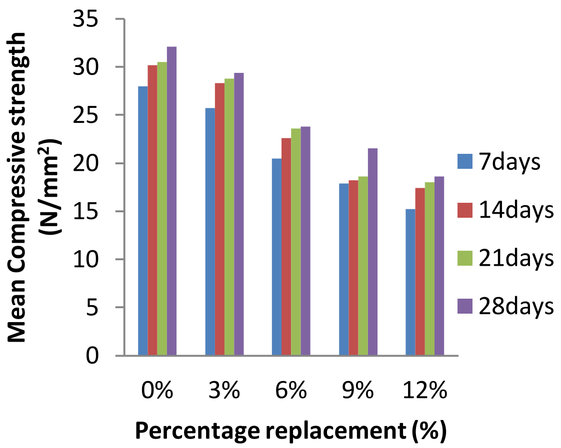

Figure 1: Compressive Strength against % Replacement

4. CONCLUSION

From the tests conducted on OPC/CCA concrete as presented in various sections, the following conclusions are made;

1. Corncob ash is pozzolanic and is therefore suitable for concrete production.
2. The water requirement increases with increase in percentage CCA replacement.
3. The compressive strength of concrete made with OPC/CCA increases with age of curing and decreases as the percentage of CCA increases.
4. The utilization of the corncob for production of concrete will go along way in not only the reduction of overall cost of the concrete, but also reduce the quantity of the waste in the environment.
5. The optimum replacement level of OPC with CCA is 3%

Recommendation

1. 3 percent replacement level of cement with CCA is satisfactory and thus, recommended
2. Concretes with the presence of ash content should be allowed to cure for 90days, by which pozzolanic activity of ash would have been concluded.
3. The use of locally available materials in infrastructural development will be met with the use of corn cob ash as a construction material and ultimately help meet our millennium development goals (MDG), thereby also enhancing the economic power of the rural dwellers if they are encouraged to plant maize from which these corn cobs could be gotten. The global green environment initiative will be greatly influenced by the reduction in solid waste disposal.
4. The volume replacement attempted to get high strength concrete should be enhanced with super-plasticizers and a further reduction in the water-cement ratio so that concrete of very high strength can be achieved.

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