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The Use of Corn Cob Ash and Saw Dust Ash as Cement Replacement in Concrete Works

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ABSTRACT
The objective of the study is to enhance the reduction of corn cob and saw dust wastes and reduce the cost of concrete production by making use of locally available materials. Chemical composition of corn cob ash (CCA) and saw dust ash (SDA) as well as the workability and compressive strength properties of varying percentage of CCA – SDA cement concrete and 100% cement concrete of mixing ratio 1 : 2 : 4 and water – cement ratios of 0.5 which later increased to 0.6 and 0.7 were examined and compared. Slump test was carried out to check the effect of combination of CCA and SDA on the workability of fresh concrete. A total of 108 concrete cubes of size 150mm x 150mm x 150mm with different percentages by weight of combination of CCA and SDA to Portland cement in the order of 0%, 10%, 20%, 30%, 40% and 50% were cast. The concrete cubes were tested at the ages of 3, 7, 14, 21, 28 and 56 days. The results showed that the combination of CCA and SDA are a good pozzolan with combined SiO_2, Al_2O_3 and Fe_2O_3 of 76.67%. The slump value decreased as the combination of CCA and SDA contents increased indicating that concrete becomes less workable as the ashes content increased. The compressive strength of the concrete cubes increased as the days of curing increased and decreased with increasing ashes replacement. The compressive strength of concrete cubes with the combination of CCA and SDA was lower at early stages but improves significantly up to 56 days. The highest compressive strength was 25.52N/mm^2 and 23.99N/mm^2 at 56 days for 0% and 10% combination of CCA and SDA respectively. It was concluded that the use of combination of CCA and SDA as a partial replacement for cement in concrete, particularly in plain concrete works and non – load bearing structures, will improve waste to wealth initiative though only 10% CCA – SDA replacement is adequate to enjoy maximum benefit of strength gain.

***KEYWORDS**: concrete, corn cob ash (CCA), saw dust ash (SDA), ordinary Portland cement, chemical composition*

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I. INTRODUCTION

Concrete is a construction material that consists, in its most common form, of Portland cement, fine aggregates, coarse aggregates and water. Each of these components contribute to the strength their concrete possesses (Gambhir, 2004). Hence, the overall cost of concrete production depends largely on the availability and cost of its constituents. Concrete is used more than any other man made material on this planet. It is a low cost material and can be used for the construction of any type of structure. Because cement remains the most expensive ingredient in making a concrete and in Nigeria, the price of cement is increasing day by day, it is therefore important to find means of economizing the use of cement.In Nigeria, a 50kg bag of cement is averagely the most expensive in the production of any concrete. The production of cement is increasing annually by 3% according to Olutoge et al, (2010). The current cement production rate of the world is approximately 1.2 billion tons per year. This is expected to grow to about 3.5 billion tons per year by 2015. It was gathered that the production of every ton of cement emits carbon dioxide (CO_2) to the tune of about one ton. When expressing it in another way, it can be concluded that 7% of the world's carbon dioxide emission is attributable to Portland cement industry (Olutoge et al, 2010). Because of the significant contribution to the environmental pollution, to the high consumption of natural resources like limestone and the high cost of Portland cement etc, we can not go on producing more and more cement. There is need to economize the use of cement in concrete production. One of the practical solutions to economize cement in concrete production is to replace cement with supplementary cementitious materials like rice husk ash, groundnut shell ash, palm kernel shell ash, pawpaw leaf ash, corn cob ash and saw dust ash. The use of combination of corn cob ash and saw dust ash as a partial replacement for cement in concrete production is the focus of this study. Moreso, the significance of the study is to help reduce the cost of concrete production arising from the rising cost of cement, and reduce the volume of solid waste generated from corn cob and saw dust. Appropriate utilization of the combination of these two materials as a partial replacement for cement will bring ecological and economical benefits to the country.

Corn cob is the hard thick cylindrical central core of maize (on which are borne the grains or kernels of an ear of corn). Adesanya and Raheem (2009a) described corn cob as the agricultural waste product obtained from maize or corn; which is the most important cereal crop in sub – Saharan Africa. According to Food and Agriculture Organization (FAO) data, 589 million tons of maize were produced worldwide in the year 2000 (FAO Records, 2002). The United States was the largest maize producer having 43% of world production. Africa produced 7% of the world's maize according to IITA Records (2002). South Africa has the highest production of maize in Africa with 8.04 million tons while Nigeria was the second largest producer of maize in Africa in the year 2001 with 4.62 million tons based on FAO Records (2002).Saw dust is a waste material from the timber industry. It is produced as timber and sawn into planks at saw mills located in virtually all major towns in the country. This process is a daily activity causing heaps of saw dust to be generated after each day. The need to convert this waste products (corn cob and saw dust) into a useful by – product is the focus of the study.

There had been various research efforts on the use of some industrial wastes as a replacement for cement in concrete. Elinwa et al (2008) assessed the fresh concrete properties of self compacting concrete containing saw dust ash. Raheem et. al (2010) investigated effects of admixtures on the properties of corn cob ash cement concrete. presented a comparative study on fly ash and ground Olutoge et. al (2010) granulated blast furnace slag (GGBF) high performance concrete. Adesanya and Raheem (2010) investigated the permeability and acid attack of corn cob ash blended cement. Adesanya and Raheem (2009) studied the workability and compressive strength characteristics of corn cob ash blended cement concrete. Cheah and Remli (2011), presented a study of the implementation of wood waste ash as a partial replacement for cement in the production of structural grade concrete and mortar. Raheem and Adesanya (2011) investigated the thermal conductivity of corn cob ash blended cement mortar. Raheem et al (2012) presented a study of the use of saw dust ash as partial replacement for cement in concrete. They concluded that the compressive strength generally increases with curing period and decreases with increased amount of saw dust ash and only 5% saw dust ash substitution is adequate to enjoy maximum benefit of strength gain. Olafusi and olutoge (2012) investigated the strength properties of corn cob ash concrete. They concluded that concrete do not attain their design strengths at 28 days and the strengths of corn cob ash concrete are dependent on its pozzolanic activities.

The present study considered both fresh and hardened properties of normal concrete in which corn cob ash and saw dust ash are incorporated into cement at the point of mix. The study was performed in Nigeria which is in West Africa. The country was the second largest producer of maize in Africa from which corn cob is obtained and the country also has thick forests with abundant tree from which saw dust is obtained during processing. Thus, there is an abundant raw materials for the research.The current practice with corn cob and saw dust are as fuel for domestic cooking and at times saw dust is also used for sand filling of ditches. In what ever case, the two materials constitutes environmental nuisance. Converting the waste products – corn cob and saw dust, into a useful by products – corn cob ash (CCA) and saw dust ash (SDA) have dual benefits. Environmental pollution would be controlled and job would be created for our teaming unemployed youths who could become agents for supplying the CCA and SDA to concrete industries that needed it. In the long run, the use of CCA and SDA as partial replacement for cement is expected to bring about reduction in the cost of concrete production since cement is the most expensive constituent of concrete.

II. EXPERIMENTAL PROCEDURE

2.1 Preparation and Collection of Materials

The corn cobs used for this study were obtained from Iwo, Sekona and Ede, all in Osun State of Nigeria. They were obtained in dry form and sundried for 1 week. The saw dusts used for the study also were collected from saw mills at 440 Area in Ede and Araromi Area in Iwo, Osun State of Nigeria. The samples were carefully collected to avoid mixing the saw dusts with sand. The collected samples were then burnt separately into ash by open burning in a metal container. The idea of burning them in a furnace was dropped because it will be time – consuming and uneconomical for most people especially those at the rural areas. Each burnt corn cob and saw dust was then grounded separately after cooling using mortal and pestle and the burnt ashes were sieved separately through British Standard sieve of 75µm. The portion passing through the sieve would have the required degree of fineness of 63µm and below according to Kolawole and Mbachu (1998) while the residue was thrown away.The ordinary Portland cement (Elephant Brand) used was obtained at cement seller along Polytechnic Road in Ede, Osun State of Nigeria. The choice of ordinary Portland cement for this project experiment conforms to the requirements of BS 12 (1978). River sand was used as fine aggregates and granite with maximum size of 20mm as coarse aggregates. The aggregates used were obtained from a local supplier in Ede, Osun State, Nigeria.

2.2 Production of Concrete Cubes

The combination of CCA and SDA were used to replace ordinary Portland cement at 0%, 10%, 20%, 30%, 40% and 50% by weight of cement. Concrete cubes with 0% of CCA and SDA combination serve as the control experiment. The mix ratio used was 1 : 2 : 4 (cement – binder, sand and granite) with water to binder of 0.5 which was later increased to 0.6 and 0.7. Table 1 showed the batching information for each percentage combination of CCA and SDA used to replace cement for the concrete cubes cast. Concrete cubes were cast using 150mm x 150mm 150mm cube steel moulds. The cube steel moulds were assembled prior to mixing and properly lubricated with engine oil for easy removal of hardened concrete cubes. Each mould was then filled with prepared fresh concrete in three layers and each layers was tamped with tamping rod using thirty – five (35) strokes uniformly distributed across the seldom of the concrete in the mould . The top of each mould was smoothened and levelled with hand trowel and then the outside surfaces cleaned. The moulds and their contents were left in the open air for 24 hours. The concrete cubes were demoulded after 24 hours of the concrete setting under air and later kept in storage curing tank measuring 2.0m x 6.0m filled with tap water only for periods of 3, 7, 14, 21, 28 and 56 days respectively.

III. TESTING

3.1 Determination of Oxide Composition of Corn cob ash and Saw dust ash

Some quantity of corn cob ash and saw dust ash were taken to the laboratory (Hegada Scientific Services Limited, Samoda, Ibadan in Oyo State of Nigeria) and test were performed on each sample to know the oxide composition. The results were shown in Table 2 and compare it with that of ordinary Portland cement (OPC).

3.2 Slump Test

Slump test was carried out to check the effect of CCA and SDA on the workability of fresh concrete. The tests were carried out in accordance with the requirements of BS 1881 : part 102 (1983).

3.3 Compressive Strength Test

Before crushing, the cubes were brought out of the storage curing tank and kept for about 20 minutes for most of the water to wipe off. They were later weighed on a weighing balance and then taken to the digital compression machine with maximum capacity of 1000kN in accordance with BS 1881 : part 116 (1983). The compressive strength value was the average of three concrete cubes. The load on the cube was applied at a constant rate of stress equal to $0.01N/mm^2$ per second. The concrete cubes experienced cracks due to failure in their strength as a result of the load applied by the compression machine. The compressive strength was recorded to the nearest $0.01N/mm^2$.

IV. TEST RESULTS AND DISCUSSIONS

4.1 Chemical Composition

Table 2 shows the oxide composition of corn cob ash and saw dust ash samples. The result showed that CCA and SDA has combined percentages of (SiO_2 + Al_2O_3 + Fe_2O_3) of 76.67% which is more than 70%, indicating that the two samples is a good pozzolanic materials in accordance with the requirements in ASTM C 618 (1991). The combination of CCA and SDA has slightly lower combined SiO_2 content with a value of 66.11% as against that of rice husk ash (RHA) which is 76.00% (Oyekan and Kamiyo, 2011).

4.2 Workability

The results of the slump test carried out are shown in Table 3, indicating the workability of the CCA – SDA concrete. The table indicates that the slump value decreases as the percentage of CCA and SDA increases. From the result, it was observed that concrete became less workable as the percentage of CCA and SDA increases meaning that more water is required to make the mixes more workable. This was what led to increasing the water binder ratio from 0.5 to 0.7 for the 40% and 50% replacement since the mix was becoming stiff. The high demand for water as CCA and SDA increases is due to increased amount of silica in the mixture. This is the behaviour of pozzolan cement concrete in which the silica – lime reaction would require more water in addition to the water needed during hydration of cement (Hague and Kayali, 1998; Waswa – Sabuni et al, 2002; Adesanya and Raheem, 2009).

4.3 Compressive Strength

The compressive strength of the concrete cubes for different percentages combination of CCA and SDA with curing ages is shown in Table 4. The relationship of the compressive strength with curing ages for different percentages of the combination of CCA and SDA is also expressed graphically in Figure 1 while the effect of different percentages combination of CCA and SDA on the compressive strength of concrete is shown in Figure 2. The figures show that compressive strength generally increases with curing ages and decreases as the percentage of CCA and SDA increases. This is due to hydration of cement and ash possesses little cementing properties compared to a Portland cement. The concrete cubes with 0% combination of CCA and SDA had the highest rate of early strength development.At 3 days, the result showed a decrease in strength from 14.85N/mm^2 for 0% to 3.25N/mm^2 for 50% CCA and SDA replacement. Similar trend was observed at 7 days as shown in Figure 2. These results indicate that concrete containing CCA and SDA gain strength slowly at early curing age. This is in line with previous findings that concrete containing pozzolanic materials gained strength slowly at early curing ages (Raheem et. al, 2012; Hossain, 2005, Adesanya and Raheem, 2009).At 14 days, there was continuous increase in compressive strength for all the percentages of ashes with values ranging from 18.14N/mm^2 for the 0% to 5.13N/mm^2 for 50% CCA and SDA replacement. The 0% which serves as control still has the highest compressive strength at this age.

At 21 days, the compressive strength was also increase for all the percentages of CCA and SDA with values of 19.43N/mm^2 for 0%, 17.32N/mm^2 for 10%, 14.95N/mm^2 for 20%, 13.29N/mm^2 for 30%, 10.75N/mm^2 for 40% and 5.96N/mm^2 for 50% ashes replacement.At 28 days, there was significant improvement in strength development as shown in Figure 2 with values of 23.55N/mm^2, 20.07N/mm^2, 15.84N/mm^2, 14.63N/mm^2, 11.69N/mm^2, and 7.21 N/mm^2 for 0%, 10%, 20%, 30%, 40% and 50% ashes replacement. According to BS 8110 (1985), a grade 20 concrete of 1 : 2 : 4 mix design without any blending of the cement should have required a strength of 13.5N/mm^2, within the first 7 days of wet curing and 20N/mm^2, within 28 days. Based on the above and the results obtained from this study, cement / CCA and SDA ratio of 90 / 10 would be suitable for concrete.

The results at 56 days indicated that pozzolanic action had commenced as evident from the higher percentage increase in compressive strength by CCA and SDA concrete over that of the control. The percentage increase with respect to the 28 days strength for control was 8.37% while it was 19.53%, 17.10%, 10.53%, 13.60% and 11.37% for 10%, 20%, 30%, 40% and 50% CCA and SDA replacements. The increase in compressive strength can be attributed to the reaction of CCA and SDA with calcium hydroxide [$Ca(OH)_2$] librated during the hydration of cement. The strength gain can also be attributed to the cementitious products formed as a result of hydration of cement and those formed when lime reacts with the pozzolan in corporated (Balendran and Martin – Buades, 2000). As could be seen from the Figure 2, there is a general decrease in compressive strength as the percentage of CCA and SDA content increases. Since all the concrete cubes meet the minimum strength of 6N/mm^2 after 28 days of curing recommended by BS 5224 (1976) for masonry cement, CCA – SDA concrete could be used for general concrete works where strength is of less importance such as in floor screed, mortar and mass concrete.

V. TABLES AND FIGURES

Table 1 : Batching Information For CCA – SDA Concrete

% Combination of CCA and SDA Replacement	Cement (kg)	Corn cob Ash (kg)	Saw dust Ash (kg)	Sand (kg)	Granite (kg)	Water (kg)	$\frac{W}{b}$
0	20.83	0	0	41.66	83.32	10.42	0.5
10	18.75	1.04	1.04	41.66	83.32	10.42	0.5
20	16.67	2.08	2.08	41.66	83.32	12.50	0.6
30	14.59	3.12	3.12	41.66	83.32	12.50	0.6
40	12.51	4.16	4.16	41.66	83.32	14.58	0.7
50	10.43	5.20	5.20	41.66	83.32	14.58	0.7

Table 2 : Oxide Composition of Corn cob ash and Saw dust ash

Oxide	Percentage Composition (%)						
	Corn Cob Ash (CCA)			Saw Dust Ash (SDA)			OPC
	Sample 1	Sample 2	Average	Sample 1	Sample 2	Average	BS 12 Limits
SiO_2	67.85	66.97	67.41	64.52	65.07	64.80	17 – 25
CaO	10.53	11.21	10.87	9.21	9.83	9.52	60 – 67
Al_2O_3	8.43	8.35	8.39	5.34	4.98	5.16	3 – 8

Fe_2O_3	4.81	5.19	5.00	2.54	2.60	2.57	0.5 – 6.0
MgO	1.98	2.55	2.27	4.06	3.82	3.94	0.1 – 4.0
SO_3	1.43	1.75	1.59	1.41	1.25	1.33	1 – 2

Table 3 : Slump value of CCA – SDA Conrete

% Combination of CCA and SDA Replacement	0	10	20	30	40	50
Slump (mm)	100	90	83	83	72	72

Table 4: Compressive Strength (N/mm^2) of Concrete Cubes For Different Percentages of combination of CCA and SDA With Curing Ages

% Combination of CCA and SDA Replacement	**Curing Ages**					
	3	**7**	**14**	**21**	**28**	**56**
0%	14.85	15.37	18.14	19.43	23.55	25.52
10%	13.21	14.06	16.15	17.32	20.07	23.99
20%	11.63	12.71	13.03	14.95	15.84	19.55
30%	11.22	11.04	12.51	13.29	14.63	16.17
40%	7.53	8.24	10.06	10.75	11.69	13.28
50%	3.25	4.07	5.13	5.96	7.21	8.03

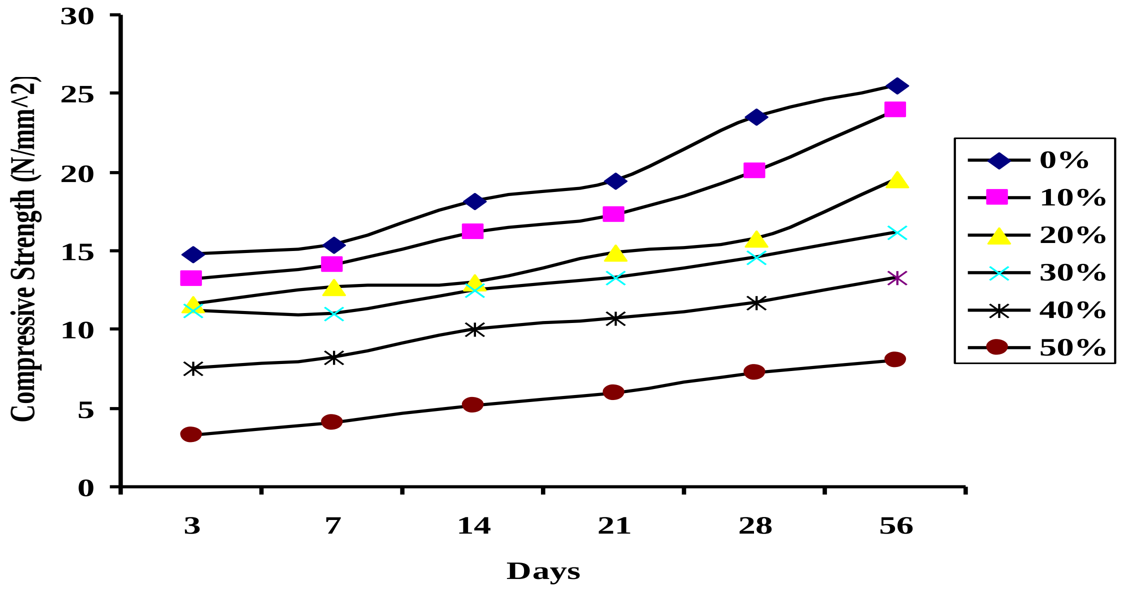

Figure 1: Effect of Curing Age on the Compressive Strength of Different Percentages Combination of CCA and SDA

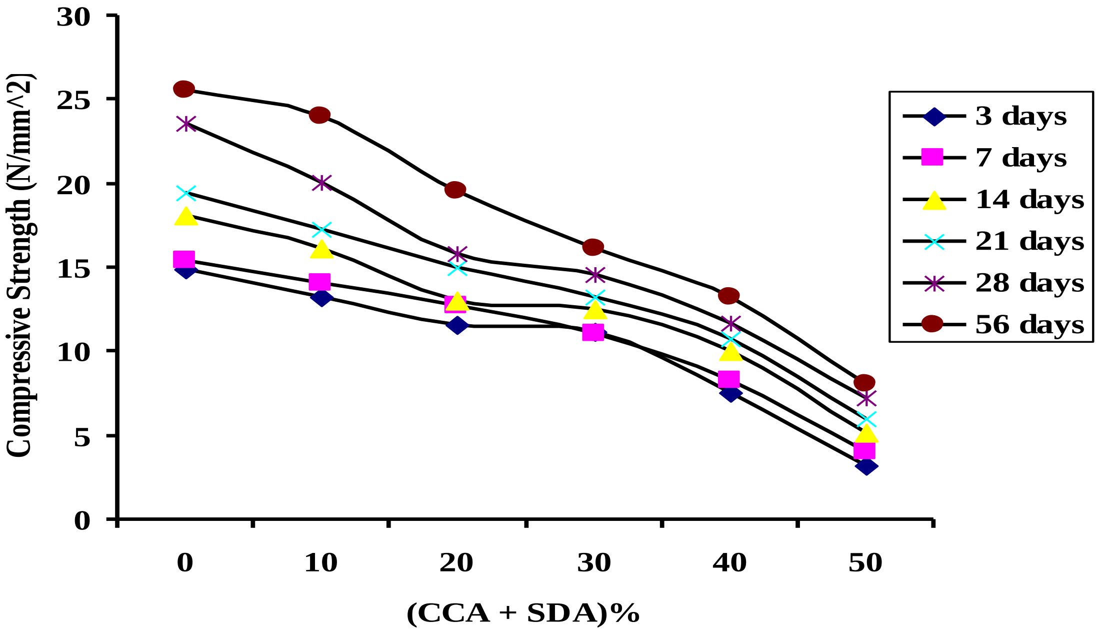

Figure 2: Effect of Different Percentages Combination of CCA and SDA on the Compressive Strength of Concrete

VI. CONCLUSIONS

[1] From the results of the various tests carried out, the following conclusions can be arrived at:
The combination of CCA and SDA are suitable materials for use as a pozzolan, since it satisfied the
[2] requirement for such a material by having a combined (SiO_2 + Al_2O_3 + Fe_2O_3) of more than 70%.
[3] Concrete becomes less workable as the percentage combination of CCA and SDA increases meaning that
[4] more water is required to make the mixes more workable. This means that the use of combination of
[5] CCA and SDA in cement to produce concrete has higher water demand.
[6] The compressive strength of the concrete cubes always increases with curing ages and decreases with
[7] increased amount of the percentage combination of CCA and SDA. Only the percentage combination of
[8] CCA and SDA up to 10% replacement of Ordinary Portland cement in concrete would be acceptable to
[9] enjoy maximum benefit of strength gain.
[10] Although the strength of CCA – SDA concrete was lower than that of the control, it can still be used for
[11] general concrete works where strength is of less importance such as floor screed, mortar and mass
[12] concrete.

VII. RECOMMENDATIONS

Based on the results obtained from the various tests carried out, the following recommendations can be made:
[1] Further studies should be done on 0 – 50% replacement of cement with combination of CCA and SDA
[2] and at an interval of 5%.
[3] Concretes with the combination of CCA and SDA as partial replacement for cement should be allowed
[4] to cure for 120 days, by which pozzolanic activity of ashes would have been concluded.

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