Coconut Shell Ash As Partial Replacement of Ordinary Portland Cement In Concrete Production

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Abstract - The cost of cement used in concrete works is on the increase and unaffordable, yet the need for housing and other constructions requiring this material keeps growing with increasing population, thus the need to find alternative binding materials that can be used solely or in partial replacement of cement. Agricultural waste material, in this case, coconut shells, which is an environmental pollutant, are collected and burnt in the open air (uncontrolled combustion) for three hours to produce coconut shell ash (CSA), which in turn was used as pozzolana in partial replacement of cement in concrete production. Concrete cubes were produced using various replacement levels of 0, 10, 15, 20, 25 and 30 percent of OPC with CSA. A total of 54 cubes were produced and cured by immersing them in water for 7, 14 and 28 days respectively. Properties such as compressive strength, density, setting times and pozzolanic activity index were determined. The results showed that the densities of concrete cubes for 10 -15% replacement was above 2400Kg/m^3 and the compressive strength increased from 12.45N/mm^2 at 7days to 31.78N/mm^2 at 28 days curing thus meeting the requirement for use in both heavy weight and light weight concreting. Thus, 10 -15% replacement of OPC with CSA is recommended for both heavy weight and light weight concrete production.

Keywords: Compressive Strength, concrete, coconut shell ash, Cement

1 INTRODUCTION

The high cost of construction materials like cement and reinforcement bars, has led to increased cost of construction [1]. This, coupled with the pollution associated with cement production, has necessitated a search for an alternative binder which can be used sorely or in partial replacement of cement in concrete production. More so, disposal of agricultural waste materials such as rice husk, groundnut husk, corn cob and coconut shell have constituted an environmental challenge, hence the need to convert them into useful materials to minimize their negative effect on the environment [2]. Research indicates that most materials that are rich in amorphous silica can be used in partial replacement of cement [1], [3], [4], [5]. It has also been established that amorphous silica found in some pozzolanic materials reacts with lime more readily than those of crystalline form [6]. Use of such pozzolanas can lead to increased compressive and flexural strengths [7], [8]. The American society of testing materials (ASTM) defines Pozzolans as siliceous or aluminous materials which possess little or no cementitious properties but will, in the presence of moisture, react with lime [$Ca(OH)_2$] at ordinary temperature to form a compound with pozzolanic properties. Examples of pozzolans include class C fly ash, which contain more than 10% CaO, blast furnace slag and silica fumes [9]. ASTM C 618 – 78 specifies that any pozzolana that will be used as a cement binder in concrete requires a minimum of 70 % silica, alumina and ferric oxides. BS 3892: 1965 parts 1 and 2 specify a maximum loss on ignition of 12%, maximum MgO content of 4% and SO_3 of 2.5% respectively [10], [11].

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The aim of this study is to determine the suitability of coconut shell ash (CSA) for use in partial replacement of cement in concrete production. The objectives include ascertaining the optimum replacement level of Portland cement with CSA that will still give required compressive strength as well as compare the setting times of OPC paste with OPC- CSA pastes at various replacement levels.

2 MATERIALS AND METHODS

The materials used during the study include:
Coconut shell: this was obtained locally in Makurdi, Benue state. Cement: Dangote cement, a brand of ordinary Portland cement available locally in Nigeria was used. The oxide composition is presented in table 1 below. Water: portable water from the Department of Civil Engineering, University of Agriculture Makurdi was used both for the mixing of concrete as well as in curing of the cubes. The coconut shell was sun dried for forty eight hours to remove moisture from it. It was then subjected to uncontrolled combustion using open air burning for three hours and allowed to cool for about 12hours. The burnt ash was collected and sieved through a BS sieve (75 microns). The resulting ash, which has the required fineness, was collected for use. The oxide composition of the ash was determined and the result is shown in table 1 below. Using a mix design ratio of 1:2:4 and water binder ratio of 0.5, a total of 54 Concrete cubes of size 150mm x150mm x 150mm were cast using varying OPC-CSA Ratio of 100:0, 90:10, 85:15, 80:20, 75:25 and 70:30 respectively, i.e., 9 cubes per percentage replacement. The cubes were cured and crushed after 7, 14 and 28 days respectively to determine the compressive strength. The density and strength results are presented in table 4 below**.**

3 TEST RESULTS

Table 1 shows the oxide composition of CSA and OPC respectively, while table 2 is the result of the average setting times for various OPC-CSA mixes. Table 3 is the result of the density and compressive strength test at 7, 14 and 28 days respectively and table 4 give the pozzolanic activity index of various mixes at 7, 14 and 28 days respectively.

4 DISCUSSION OF RESULTS

Tables 1 show the oxide composition of the CSA and OPC respectively. From table 1, CSA contains 37.97% SiO_2, 24.12% Al_2O_3 and 15.48% Fe_2O_3. This gives 77.57% of SiO_2+ Al_2O_3+Fe_2O_3 which is in line with ASTM C 618-78 requirement of 70% minimum for pozzolanas. Thus, CSA meets the requirement for a pozzolana. The LOI of 11.94 and SO_3 of 0.71 all falls within agreeable limits. Table 2 shows the average setting times of the various OPC-CSA combinations. Fig. 1 is a plot of the initial and final setting time verses the various percentage replacements. The setting times increases with increase in the amount of coconut shell ash. The initial setting time increases from 1 hour 5minutes at 0% replacement to 3 hours 26 minutes at 30% replacement while the final setting time increases from 1 hour 26 minutes at 0% replacement to 4 hours 22 minutes at 30% replacement. However, BS12 (1978) recommends initials and final setting times to be not more than 45 minutes and 10 hours respectively of which the CSA/OPC pastes passes in final setting time. From table 4, it can be seen that the average density decrease with percentage replacement from 2525.5Kg/m^3 for OPC to 2314Kg/m^3 at 30% replacement. This is expected, since the density of cement is higher than that of the CSA. Table 3 shows the pozzolanic activity index at various OPC-CSA replacement levels and age. The index decreases with increasing percentage replacement of OPC with CSA. There is a decrease of the pozzolanic activity index with increased curing age at 15% and 30% replacement but no discernable trend is observed with increase in curing age at 10, 20 and 25% replacement levels. From Fig. 3, we notice a decrease in pozzolanic activity with increasing percentage replacement, which is expected, since the strength decrease with increasing percentage replacement of OPC with CSA. The compressive strength decreases with increasing percentage replacement of OPC with CSA. This can be seen in fig 2. The 7 days strength decreases from 13.78N/mm^2 for OPC to 6.43N/mm^2 for 30% replacement with CSA. The strength after 28 days curing decreases from 34.22N/mm^2 for OPC to 13.11N/mm^2 30% replacement with CSA. The optimal 28 days strength for OPC-CSA mix is recorded at 10% replacement (31.78N/mm^2).

5 CONCLUSION AND RECOMMENDATION

From the results obtained, CSA/OPC mix showed some promise for use in reinforce concrete as well as mass concrete structures in building construction. The compressive strength of the cubes at 28 days curing indicates that 10% and 15% replacement levels meet the requirement of BS EN 206-1: 2000 for class C25/30 and C20/25 respectively for heavy weight concreting and LC25/28 and LC20/22 respectively for light weight concreting. In conclusion, the study reveals that 10 to 15% partial replacement of OPC with CSA using W/C ratio of 0.5 are suitable for production of both heavy weight and light weight concrete. Further areas of research are recommended. This includes the use of CSA calcined under controlled conditions, since the Calcination temperature and time appears to have a marked effect on the amorphosity of the ash and altering water/cement ratio.

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Table 1: Oxide composition of Coconut Shell Ash (CSA) and Ordinary Portland Cement (OPC).

Oxide	Percentage composition (%)	
	CSA	OPC
SiO_2	37.97	20.70
Al_2O_3	24.12	5.75
Fe_2O_3	15.48	2.50
CaO	4.98	64.0
MgO	1.89	1.00
MnO	0.81	0.20
Na_2O	0.95	0.60
K_2O	0.83	0.15
P_2O_5	0.32	0.05
SO_3	0.71	2.75
LOI	11.94	2.30

Table 2: Average setting times for OPC-CSA mix

% replacement	Initial setting Time (mins.)	Final setting Time (mins.)
0	65	83
10	253	330
15	275	375
20	289	401
25	305	425
30	326	442

Table 3: pozzolanic activity index

% replacement	Pozzolanic activity index		
	7days	14days	28days
0	0	0	0
10	90.35	93.30	92.87
15	80.62	70.12	67.88
20	62.84	66.10	57.80
25	48.40	48.41	48.71
30	46.81	46.07	38.31

Table 4: Density and average compressive strength test results

% replacement	Curing age (days)	Average Density (Kg/m^3)	Average Strength (N/mm^2)
0 percent	7	2525.5	13.78
	14	2522.0	18.82
	28	2514.5	34.22
10 percent	7	2504.5	12.89
	14	2517.5	17.56
	28	2514.5	31.78
15 percent	7	2471.5	11.11
	14	2475.0	14.89
	28	2456.0	23.23
20 percent	7	2450.5	8.66
	14	2427.5	12.44
	28	2388.0	19.78
25 percent	7	2357.0	6.67
	14	2338.5	9.11
	28	2340.5	16.67
30 percent	7	2314.0	6.45
	14	2322.5	8.67
	28	2543.0	13.11

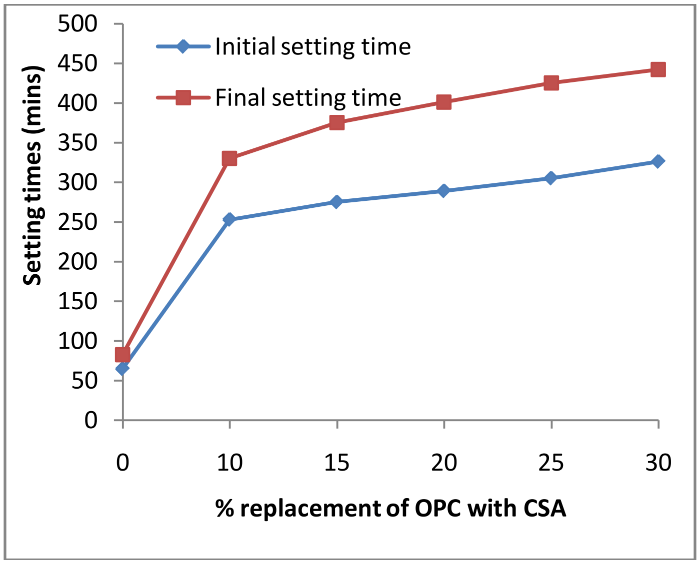

Fig. 1: Initial and Final setting time or RHA/OPC Paste

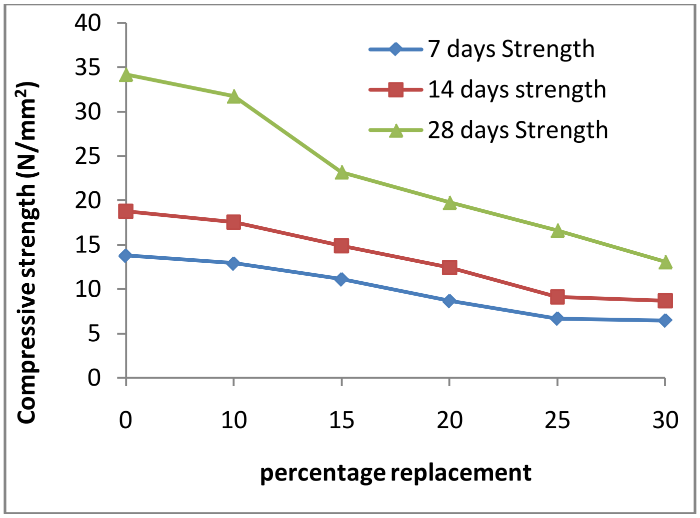

Fig. 2: Compressive strength at various percentage replacements 0-30%.

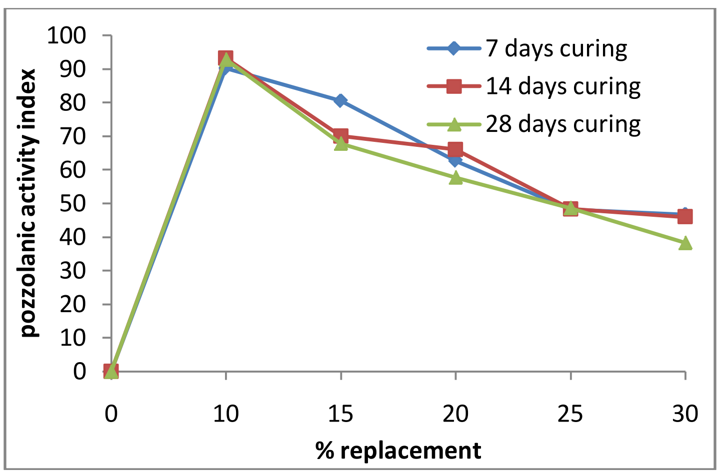

Fig.3. Pozzolanic activity index of RHA-CSA mix at different replacement levels.