Production and Characterization of Wood Ash Pozzolan of Melina and Cashew Tropical Woods

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Abstract - *In an attempt to find an alternative binding material for construction industry, this study considered the use of wood ash from two different hardwoods namely: Melina wood ash and Cashew wood ash as a pozzolan in cement production. The study investigates the chemical composition (silica (SiO_2), aluminum oxide (Al_2O_3), ferric oxide (Fe_2O_3), calcium oxide (CaO), magnesium oxide (MgO), sulphur trioxide (SO_3), sodium oxide (Na_2O) and potassium Oxide (K_2O)) of the ashes and the clinker. The production of blended cements were carried out in the factory by replacing 5- 50% by weight of Ordinary Portland Cement Clinker with the ashes during the manufacturing process. The cement without wood ash serves as the control. The physical characteristic (fineness, initial and final setting times, heat of hydration and residue on 45μm sieve), and the chemical composition of the blended cements were also investigated. It was discovered that the wood ash used in this work was suitable to be used as pozzolan and suitable to be used as raw material in cement production.The compressive strength of concrete with 20% wood ash content increased appreciably at greater number of days. The optimum replacement of cement by wood ash therefore is at 20%. All wood ash samples shows almost similar properties.*

Keywords: additives; concrete; chemical composition; pozzolana.

1.0 INTRODUCTION

Population growth and urbanization has put the use of cement and wood on the high note. Wood is mostly used in the wood burning industries as fuel. For instance, woodchips, wood barks, sawmill scraps, hardships and wood sawdust is used as fuel source for production of electrical power. The use of wood or wood waste fuel produces a significant quantity of ash commonly known as wood ash (WA). The ash poses a serious environmental threat in many ways to life stock (Barathan and Gominath, 2013). A major portion (about 70%) of the wood ash produced is land filled as a common method of disposal (Campbell, 1990; Etiegni and Campbell, 1991; NCASI, 1993). But wood ash consist of highly fine particulate matters, which can be easily be rendered airborne by winds, such a means of disposal may result in subsequent problems such as respiratory health problems to residents dwelling near the disposal site. Moreover, contamination of ground water resources can also be expected to occur from leaching of heavy metal content of ash or by seepage of rain water (Udoeyo*et al*, 2006). Hence, disposal of wood ash by means of land filling need a properly engineered land fill which have implications in terms of the cost of disposal. Thus, such a method of disposal is highly uneconomical over long term especially in a third world country like Nigeria where poverty is on the high note. The disposal problem requires a more economical solution.

It is also worth to note that, the current boom in the construction industry due to population growth and urbanization mentioned earlier has caused a massive elevation of the demand for cement which is a major constituent material in the production of concrete. The processes involved in the production of cement make use of limestone and energy. This process at the same time releases high quantities of carbon dioxide (CO_2) into the atmosphere. Thus, the increased demand of cement implies a higher rate of environmental deterioration due to the limestone extraction activities, a higher requirement of fossil fuels and higher rate of greenhouse gas discharge. One way of addressing this issue is to reduce the CO_2 emission from cement manufacturing process by replacing cement with locally available by-products which are Pozzolanic in nature. Ashes are one such by-product available from various sources from industries to agriculture mostly regarded as waste. Rice husk ash and fly ash, are some of the major ashes already proven to be effective mineral admixtures pozzolan to cement at various percentages (Antiohos and Tsimas, 2005; Chindaprasirt*et al*, 2007).

Recent research (Udoeyo and Dashibil, 2002; Elinwa and Ejeh, 2004; Udoeyo*et al*, 2006; Naik*et al*, 2003) report on the

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investigation of the feasibility of the use of wood ash as a partial replacement material for the energy intensive process of hydraulic fracture for concrete production indicates promising results. The result show that wood ash has the required properties suitable for use as a partial replacement to cement during structural grade concrete production with acceptable mechanical and durability properties. Marathong suggested by analyzing the hydration characteristics of saw dust ash admixture cement that 10% addition of wood ash with cement is optimum. A research on wood ash would definitely provide a solution for the waste management problems of wood waste ash and also contribute towards minimizing the consumption of energy intensive hydraulic cement production of greener concrete material. The incorporation of wood ash as a cement replacement material in blended cement and concrete will not only be of benefit in environmental terms for concrete materials but also be of benefit in reducing production cost of the aforesaid material.

Wood ash waste produced in industries and in domestic consumption of wood has posed great challenges to the environment over the years in two ways-the carbon dioxide emission during the production process and the disposal of the ash. Global focus on energy and environment aims at critical researches which seek to address substantial reduction of carbon emission in energy utilization on one hand and the conversion of waste to wealth on the other. The rise in infrastructural development in developing countries, like Nigeria, is closely linked to the availability and affordability of cement. This research will attempt to address the problem of capacity utilization of cement in construction industries through the use of wood ashwaste as a way of converting waste to wealth.

2.0 MATERIALS AND METHODOLOGY

2.1 Materials

The materials used in this research include;

i. Gmelinaarborea (melina) wood ash and
Anacardiumoccidentale (cashew) wood ash

ii. OPC cement of 53 grades was used.

iii. Coarse aggregate: Gravel was used as coarse aggregate.

iv. Fine aggregate: Sand from a river was used as fine aggregate.

v. Water: Portable fresh water was used for this study.

2.2 Wood Ash Collection and Production/Sieve Analysis

The wood ash used in this work was burnt at 700^0C for 1hours and was powdery, amorphous and was sourced locally from woods factory in Makurdi, Benue State. The wood ash was passed through BS sieve 0.075mm (75Micron) size; this was done at the Mechanical Engineering laboratory of University of Agriculture, Makurdi. Similar sieve analysis was also conducted on fine aggregate and coarse aggregate.

2.3 Chemical Analysis of Wood Ash

Chemical analysis of wood ash used in this research work was done using X-Ray Fluorescence (XRF) analysis. The analysis was carried out at the Chemistry Department, Ahmadu Bello University, Zaria using X-ray fluorescence spectrometry (POWD-12^{++}). This analysis was done to determine the elemental composition of the wood ashes produced.

2.4 Concrete Production

For concrete production, the cement, gravel, sand and wood ash were mixed thoroughly by manual method. Cement replacement with wood ash was done at 0%, 10%, 20%, 30% and 40% by weight. Approximately 25% of water was added and mixed thoroughly to obtain a uniform mix, the balance of 75% of water was added and mixed thoroughly again in order to still have a uniform mix. The mould cubes of size 150 X 150 X 150 mm was used and removed after a period of 24hours.

2.5 Compressive Strength Test

The concrete samples were cured using water for 7 days, 14 days, 21 days and 28 days before the strength test was carried out. The test was carried out to measure the maximum compressive load the produced concrete samples can bear before fracturing as well as the optimum replacement of Cement by Wood Ash. The test samples were compressed between the platens of a compressive testing machine at the Civil Engineering laboratory of the Federal University of Agriculture, Makurdi.

3.0 RESULT AND DISCUSSION

3.1 Results of Chemical Analysis of Wood Ash

XRF result in Table 3 shows that Melina wood ash and cashew wood ash contains three out of the four (Sio_2, Al_2O_3, CaO and Fe_2O_3) major pozzolanic compounds. The compounds present include; SiO_2, CaO and Fe_2O_3, only Aluminum oxide (Al_2O_3) is missing. In all the two wood ash samples mentioned, CaO have the highest percentage, followed by SiO_2 and the Fe_2O_3. The results also shows the presence of the following impurities such as K_2O, TiO_2, P_2O_3, SO_2, MnO, V_2O_5, CuOZnO, Y_2O_3, BaO, Ag_2O, among others though in very small quantities.

Wood Ash Samples	Melina Wood Ash	Cashew Wood Ash
Compound	Composition (%)	Composition (%)
SiO_2	17.60	12.40
P_2O_5	2.20	9.35
SO_3	0.80	1.77
K_2O	12.50	34.88
CaO	55.19	33.50
TiO_2	1.03	0.814
V_2O_5	0.055	0.03
MnO	0.12	0.518
Cr_2O_3	----	----
Fe_2O_3	7.36	5.71
ZnO	0.17	0.41
CuO	----	0.093
Y_2O_3	0.10	----
Ag_2O	2.12	----
BaO	0.58	0.47
Eu_2O_3	0.03	----
Re_2O_7	----	0.03
HgO	0.20	----
CeO_2	----	----

Table 1: below is the result of chemical analysis of various sources of wood ash by X-ray fluorescence (XRF)

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3.2 Scanning Electron Microscopy (SEM) Results

The result attached below is the results of scanning electron microscopy. Four samples of wood ash from different sources were studied.

Plate 1-2 below shows the result of Scanning Electron Microscopy (SEM) analysis. This shows the microstructure of wood ash particles, in other word, the result shows the morphology of the wood ash samples. These micrographs reveal wood ashes as heterogeneous mixture of particles of varying sizes. They are generally angular in shape and partially hydrated, unhydrated and hydrated compounds of Calcium. Despite the fact that the wood ashes contained high content of CaO with less SiO_2 content and no Al_2O_3, the ashes were used as partial replacement for cement in concrete production.

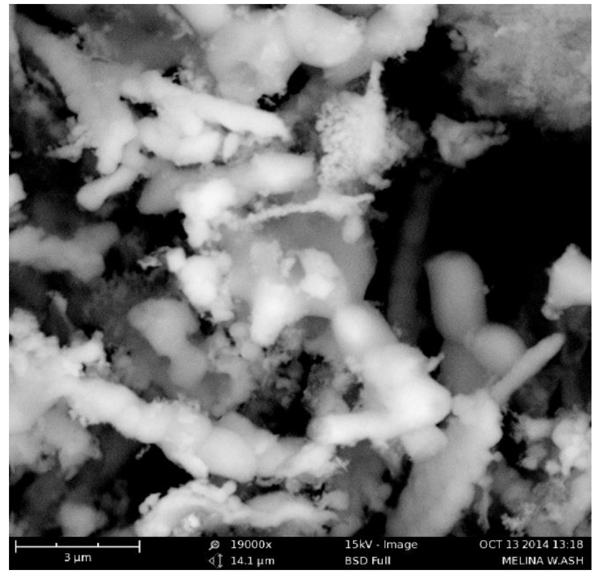

Plate 2: Morphology of Melina wood ash

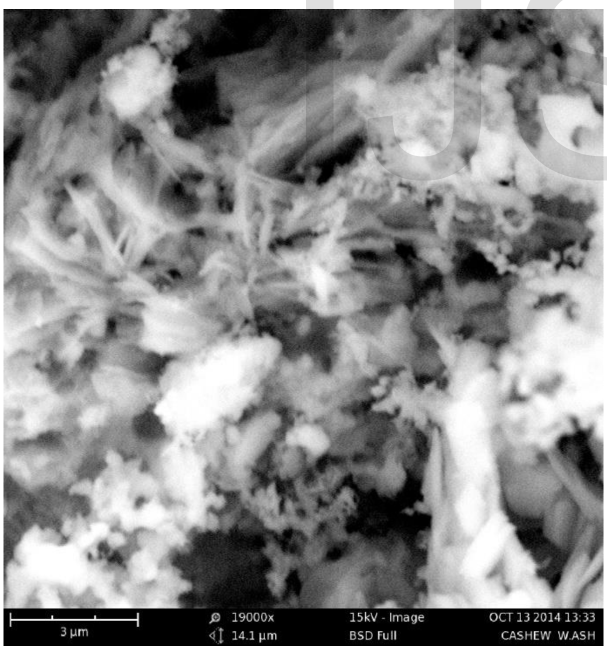

Plate 1: Morphology of Cashew wood ash

3.3 The compressive strength test results of the four samples of wood ash.

Number of days	Strength at 0% (N/mm^2)	Strength at 10% (N/mm^2)	Strength at 20% (N/mm^2)	Strength at 30% (N/mm^2)	Strength at 40% (N/mm^2)
7	1.65	2.55	4.60	4.95	4.55
14	2.05	3.20	5.95	5.20	5.05
21	2.55	3.65	7.15	5.75	5.50
28	3.00	4.15	9.50	6.45	6.05

Table 2: Compressive strength for Melina wood ash/OPC concrete for particle size of 0.075mm (75 micron) and the associated graph in fig. 1

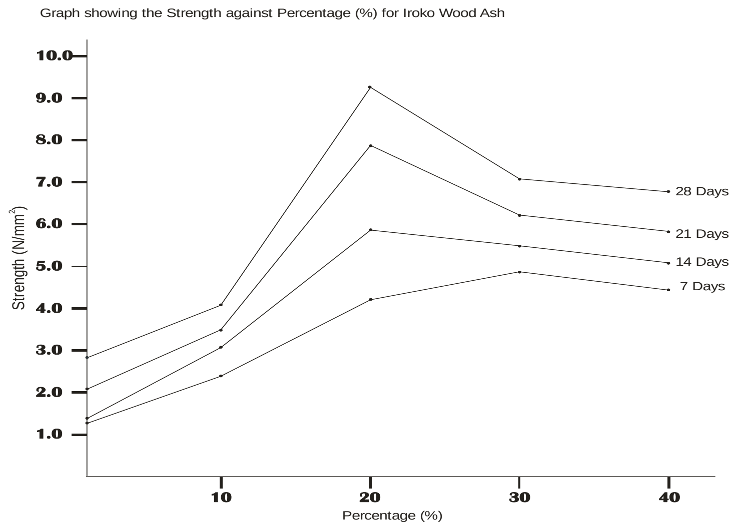

Fig. 1: Graph of strength against percentage (%) for Melina wood ash/OPC concrete.

Number of days	Strength at 0% (N/mm^2)	Strength at 10% (N/mm^2)	Strength at 20% (N/mm^2)	Strength at 30% (N/mm^2)	Strength at 40% (N/mm^2)
7	1.40	2.30	4.45	4.85	4.30
14	1.80	3.10	6.05	5.05	4.90
21	2.25	3.75	8.45	6.50	6.05
28	2.95	4.25	10.05	7.55	7.10

Table 3:Compressive strength for cashew wood ash/OPC concrete for particle size of 0.075mm (75 micron) and the associated graph in fig 2

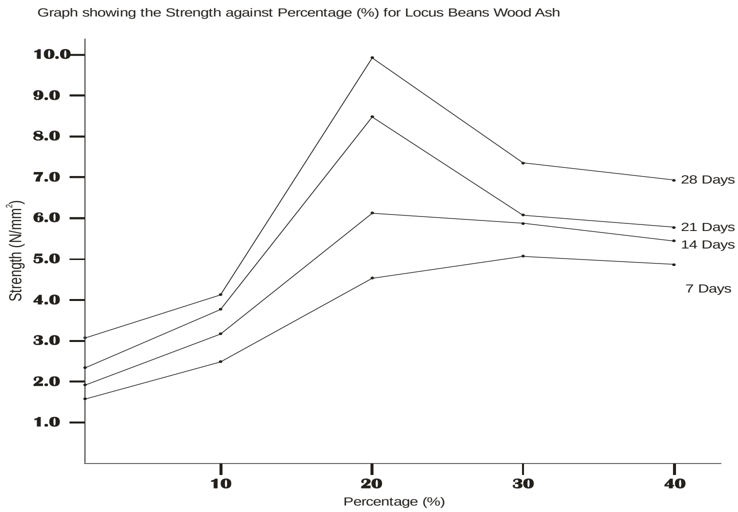

Fig. 2: Graph of strength against percentage (%) for cashew wood ash/OPC concrete

Table 2-3 contains the result of compressive strength of wood ash/OPC concrete at 7days, 14days, 21days and 28days for each wood samples and the associated graphs in fig1-2. According to the result, cubes containing 0% wood ash have the lowest compressive strength. The concrete cubes containing 20% wood ash have higher compressive strength than that containing 10% at 7days, 14days, 21days and 28days. The reason is because silica provided by 10% wood ash is not enough to react with the calcium hydroxide produced by the hydration of cement. Also increasing wood ash contents beyond 20% result in a reduction in compressive strength at 7, 14, 21 and 28days. This may be due to excess amount of silica needed to combine with calcium hydroxide from the hydrating cement. The excess silica does not have any pozzolanic value but only serve as filler.

Finally, the compressive strength of concrete containing 20% wood ash increased considerably in all samples. This means that greater strength of wood ash/OPC concrete can be obtained at greater days as shown in all the samples and at 20% wood ash replacement of cement, strength of cubes higher at 28days, follow by 21days, 14days and then 7days. The result also shows that the optimum replacement of cement by wood ash is 20%.

4.0 CONCLUSION

Based on the result obtained in this work, the following conclusions are made; that wood ash used in this work was suitable to be used as pozzolana and suitable to be used as raw material in cement production.The compressive strength of concrete with 20% wood ash content increased appreciably at greater number of days. The optimum replacement of cement by wood ash therefore is at 20%. All wood ash samples shows almost similar properties.

Therefore, research work is needed in order to investigate the nature of volatile substances and/ or gases emitted during the combustion of wood ash, also more research work is needed to explain the effect of equipment used for the production of wood ash on chemical and physical properties of the ash. Moreover, wood ash from Cashew and Melina had met the requirement for use as a raw material in cement production.

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