INVESTIGATION OF SOFTWOOD ASH,HARD WOOD ASH AND RICE HUSK ASH AS A PARTIAL REPLACEMENT OF ORDINARY PORTLAND CEMENT IN CONCRETE

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ABSTRACT

Cement is known globally to be the most expensive constituents of concrete. During its course of production, the CO_2 which is released has negative impacts both on human's health and other inhabitants in the community. These problems however have called for sourcing suitable and effective waste products as an alternative to cement in concrete. Hard wood ash(HWA), Soft wood ash (SWA) and Rice husk ash(RHA)were investigated experimentally to know their suitability as cementitous materials partially replaced for cement in concrete. The calcination was done under controlled temperature 450 ºC andSWA,HWA and RHA were found to belong to class N pozzolaniccementitous materials. The design concrete mixed was 1:2:4 at water cement ratio 0.6, and 0%. 5%, 10%, 15% and 20%percentage replacement were used. The results revealed a general trend of decrease in compressive strength of the concrete as percentage replacement with SWA, HWA and RHA increased but increased as curing age of concrete increased from 5% to 20%. All the samples had highest compressive strength at 5% replacement with 19.3N/mm², 19.1N/mm²and 16.3N/mm² for SWA, HWA and RHA respectively at curing age 28 day while the lowest values were observed when percentage replacement was 20% with 12.7N/mm², 12.5N/mm² and 9.7 N/mm² at the curing age 28 day for HWA, SWA and RHA accordingly.The type of used was found to have played major role in affecting the compressive strength and other parameters obtained for the concrete produced. However, 5% percentage replacement with the highest compressive strength at the curing age 28 day and the lowest water absorption values were observed to be the most suitable. The SWAwas therefore found to be the most suitable cementituous material followed by HWA and RHA was the least.

Keywords: Concrete, Compressive strength, Pozzolanic material, Workability and Cement

INTRODUCTION

Concrete is one of the oldest and the most widely used in constructions. It is a composite material mainly consists of both coarse and fine aggregates and cement pastes mixed with water. Most often, additives and reinforcementsare added in the mixture to achieve the desired physical properties of the finished material. Concrete is widely used in different areas such as structural buildings, bridges, highways and runways. The amount of concrete used globallyton for ton is twice that of steel, wood, plastics, and aluminium combined while it is only exceeded by that of naturally occurring water.

Cement,one of its constituent materials is used as binderin the mixture. The increase in the cost of cementhas led to a search for alternative. Besides the increase in cost, there are problems of high energy demand and emission of CO_2, which is responsible for global warming and depletion of lime stone depositsassociating with cement production. According to Adesanya and Raheem, (2009b), about 7% of 132 million metric tons of $CO_2$is released into the atmosphere during cement production, which has negative impacts on ecology and human health. Research on alternative to cement partially replaced with both industrial and agricultural waste materials which are pozzolanous in nature is one of the ways out of these problems.

Pozzolans as defined by Mehta and Pirtz(2000) are siliceous material, which by itself possesses no cementitous properties but in processed form and finely divided form, react in the presence of water with lime, to form compounds of low solubility having cementitous properties.

Research has shown that cementitious materials are supportive to make concrete durable (Bakar*et al.*,2010). Several research (Adesanya and Raheem, 2009a; DeSensale 2006; Saraswathy and Ettu*et al.*,

2013) carried out on the binary blends of Ordinary Portland Cement with different pozzolanic materials reported an appreciable increase in strength at the end of 28 days curing period.

Rice husk is an agricultural waste readily available in major rice producing countries. The husk surrounds the paddy grain. During milling process of paddy grains about 78 % of weight is obtained as rice while the remaining 22 % is husk. The Rice husk ash (RHA) contains about 85 % - 90% amorphous silica. According to Bui and Hu, 2005, about 500 million tons of paddies are produced worldwide annually. After the incineration, 20% of rice husk is converted ash. RHA consists of non-crystalline silicon dioxide with high specific surface area and high pozzolanic reactivity.Research has shown that grounded RHA improves concrete properties and reduces its water absorption rate (Mehta and Malhotra, 2004; Thanh Le *et al.,* 2014). Also, Husk and Low,(2007) and Tsai *et al.*,(2007) added that RHA reduces corrosion and increase durability of concrete structures.Premalal*et al.*,(2009) reported that both the mechanical properties and chemical compositions of RHA are affected by the burning process, and the silica content in the ash increases with higher temperature.

Wood ash is a residue powder that is left after wood combustion in industries. Raheem et al.,(2012)established that 6-10% of the mass of burnt wood result in ash. The type of wood, combustion temperature and time are some of the factors that were reported to affect the quantityand chemical composition of the ash produced (Cheah and Ramli, 2012; Swaptik, 2015).

According to Cordeiro(2009), the percentage of CaO in wood ash varies from 4% to 70% and makes it a potential substitute in cement industry either in production or in application stage. This research therefore examined the use wood ash and rice husk ash as a partial replacement for cement in concrete.

MATERIALS AND METHODS

Samples collection and Preparation

Rice husk and wood (soft and hard) were sourced from Lanfenwa market and Eleweran sawmill both in Abeokuta,Ogun State. Both fine (granite dust) and coarse aggregates were obtained from the stocked pile at Civil Engineering Department, FUNAAB, Ogun State while ordinary Portland cement was bought from nearby cement seller at Abeookuta.

The rice husk and wood were converted to ashes by calcination at 450 ^{0}C under a control temperature(ban Cheah and Ramli, 2011) and Samples prepared, RHA, SWA, HWA and Cement were taken for elemental analysis using X-ray fluorescence energy dispersive..

Testing and Evaluating of Samples

Sieved analyses were carried out on the aggregates to determine their grading using a set of sieves with the largest diameter at the topmost to the smallest diameter at the bottom and the mass of samples retained by each sieve was recorded. The grain size distribution curves were drawn on the semi – log graph.

The chemical compositions of RHA and WA were determined in accordance with ASTM C618,and specific gravity for each also was calculated in accordance with BS 1337:1996. The initial and final setting time, soundness test of cement were determined.

Determination of compressive strengths of concrete

Concrete mix 1:2:4 by volume was used and cement replacement with RHA and WA 0%, 5%, 10%, 15%, and 20% each was done randomly. Water cement ratio 0.6 was adopted. Three (3) cubes (150 mm x 150 mm x 150 mm) were made for each percentage replacement. Slump and compressive strength were determined as specified in BS 1881:1983 Part 102 and BS 1881: 1983 Part 116 respectively. After 24 hours casting, the mould were stripped and concrete specimens were taken to the curing stands inside water tank.Compressive strengths were tested at 7, 14, 21 and 28 days after casting.

RESULTS AND DISCUSSION

Chemical Analysis

RHA, WA and Cement (OPC)

The chemical compositions of the RHA, WA and Cement (OPC) were shown in Table 1. It was observed that SiO_2, Al_2O_3 and Fe_2O_3which were mainly responsible the pozzolanic reactivity (Rajammа*et al.,* 2009) were present in the samples prepared and this made them suitable to replacecement in concrete production.

Table 1: Chemical Composition of RHA, HWA, SWA and OPC

Percentage composition (%)	WOOD ASH (WA)		RHA	Cement
	HWA	SWA		
SiO_2	65.8	64.5	73.5	22
Al_2O_3	5.3	6.2	0.6	6
Fe_2O_3	2.1	1.9	0.7	4.3
Na_2O	0.1	.2	0.2	0.9
K_2O	2.4	2.5	2.9	0.4
CaO	9.6	8.9	0.6	42.8
MgO	4.1	4.1	0.5	2.5
$CaCO_3$	7.9	8.1	5.9	7.9
LOI	4.3	4.0	5.81	0.9

RHA, SWA and HWAused in this research was compared with ASTM Specification (Table 2), and observed to be in class N, hence, it can fit into in as supplementary cementitous material.

Table 2: Comparison of test result on WA and RHA with ASTM Standard for PozzolanicMaterials

Mineral Admixture Class	N	F	C	Test Results		
				SWA	HWA	RHA
SiO2 + Al2O3 + Fe2O3 min, %	70	70	50	72.6	73.2	74.2
SO3 Max,%	4	5	5	0	0	0

Specific Gravity

The specific gravity of the samples used was presented in Table 3. The specific gravity of wood ash (SWA and HWA) and RHAwere 2.32, 2.41 and 2.02 respectively. Comparing these values with the specific gravity of cement (OPC) which is 3.15, it appears that replacement of cement with these materials by weight would result in a greater volume of cementitious material in the mix (Adenuga*et al*., 2010).

Table 3: Specific Gravity of Samples used

Properties		WOOD ASH		RHA	OPC	FINE AGGREGATE
		SWA	HWA			
Colour		Dark Brown	Dark Brown	Light Brown	Grey	
Specific Gravity (Ave.)		2.32	2.41	2.02	3.15	2.58
Setting time	Initial (mins) Final (mins)				146 255	

Workability of the concrete

The results of the slump indicated the workability of the concrete with samples used as replacement materials of cement as shown in Figure 1. It was observed that the slump values decrease as percentage replacement of HWA, SWA and RHA increase from 5% to 20%. The decrease is likely due to anincrease in amount of silica present in the mixture, and to attain the required workability, mixes containingHWA, SWA and RHAwill required higher water content than the corresponding conventional mixes Manju*et al*., 2015; Adesanya and Raheem, 2009. Similarly, the compacting factor decreases as the HWA, SWA and RHA content increases (Table 5) which means that the compacting factor also reduces as the pozzolan increases. The compacting factor values reduced from 1.1 to 0.89 as the percentage replacement increased from 0% to 20 % for HWA, 1.0 to 0.87 and 0.91 to 0.80 for SWA and RHA respectively. It mean that the concrete with these mixtures becomes less workable (stiff) as their percentage increases indicating that more water is required to make the mixes more workable. The high demand for water as the content increases is due to increased amount of silica in the mixture. This is typical of pozzolan cement concrete as the silica-lime reaction requires more water in addition to water required during hydration of cement (Bui *et al.* 2005)

Table 5: Compacting Factor

Percentage Replacement (%)	HWA	SWA	RHA
0	1.1	1.0	0.91
5	0.96	0.96	0.89
10	0.92	0.94	0.87
15	0.92	0.93	0.82
20	0.89	0.87	0.80

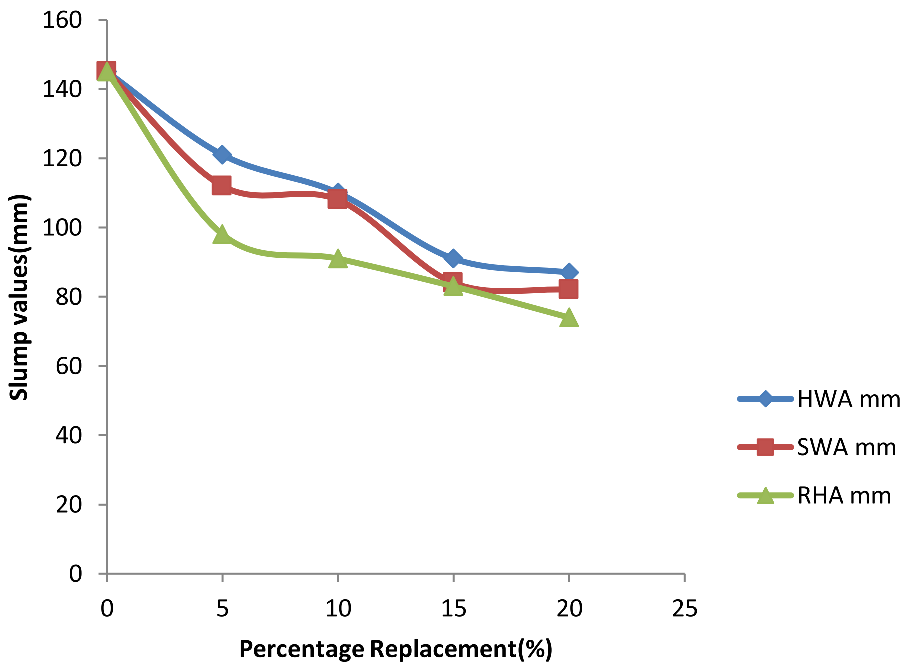

Figure 1: Workability of the Concrete

Compressive strength Test

The effect of curing ages on the compressive strength of HWA, SWA and RHA concrete is presented in Figure 2. The results of the compressive strength of concrete cubes show that the compressive strengths reduce as the percentage of HWA, SWA and RHAin the concrete increases. However, the compressive strengths increased as the number of days of curing increased for each percentage of HWA, SWA and RHA replacement.The results show that SWA has the highest value for percentage replacement 5% and 10% followed by RHA while HWA has the least which indicated that the trend of gaining strength at early curing age. The three samples (SWA, RHA and HWA) had the highest compressive strength when cured for 28 days at 5% replacement with the values 19.3N/mm^2, 19.1N/mm^2 and 16.3N/mm^2 for SWA, RHA and HWA respectively and compressive strength was reduced by 7.66%, 8.61% and 22% comparing these values with control sample.The least values were observed at 20% replacement. As percentage replacement increases from 10% to 20%, HWA was observed to have the highest values while RHA has the least out of the three samples. This is in agreement with Swaptik (2015)that types of wood affects its chemical composition and roles when used as partial replacement in concrete. The least values were observed at curing age 28 day with 20% replacement for the three samples. This observation is in agreement with **Hossain (2005),**Adesanya and Raheem (2009a,b) in their previous findings that concrete containing pozzolanic materials gained strength slowly at early curing ages. At 21days, there was continuous increase in compressive strength for all the classes of concrete. This increase in compressive strength can be attributed to the reaction of HWA, SWA and RHA with calcium hydroxide liberated during the hydration of cement.

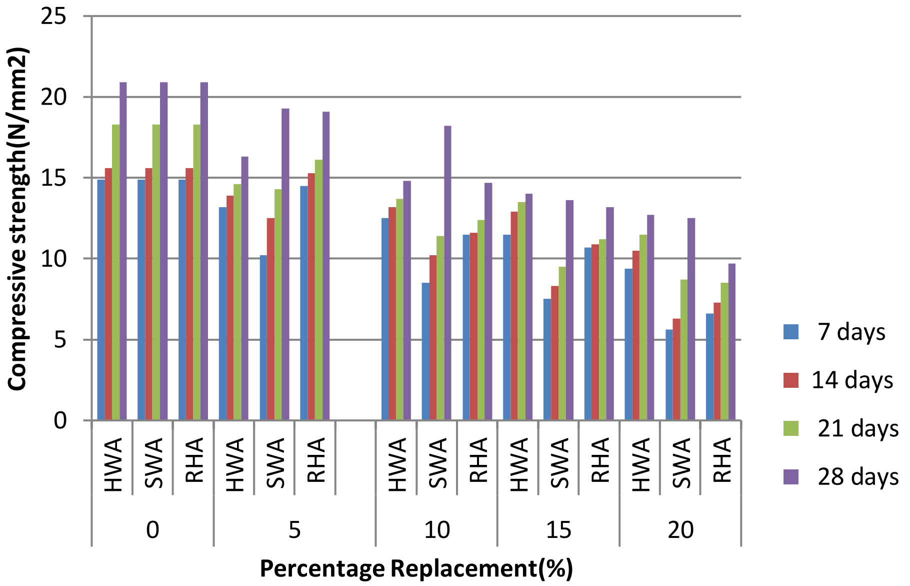

Figure 2: Compressive Strength of concrete Partially Replaced with HWA,SWA and RHA

Water Absorption Test

The test results for water absorption were as shown in Table 6. SWA has the least water absorption rate at 5% (0.5) replacement followed by HWA (0.56) and RHA (1.28). Water absorption increases with increase as percentage replacement increases. This implied that SWA gave the best result at 5% replacement followed by HWA while RHA came last.

Table 6: Water Absorption Rate

Percentage Replacement	SWA	HWA	RHA
5	0.5	0.56	1.28
10	0.62	0.71	1.49
15	0.7	0.79	1.64
20	0.74	0.82	1.86

CONCLUSION

i. The workability and compacting factor for all the concrete specimen containing wood ash (hardwood and softwood) and rice husk ash were lesser than that of the control mix with constant 0.6 ratio of W/C (water to cement), the compacting factor for HWA, SWA and RHA at 0% replacement were 1.1, 1.0 and 0.91 respectively while at 5% replacement the compacting factor were 0.96, 0.96 and 0.89 respectively,this means that more water is required to make the concrete mix more workable.

ii. The compressive strength for all the mixes increased with increase in curing age.

iii. Thestrength of the concrete containing Hardwood and Softwood were not the same in the mixes used and it inferred that types of wood affect it pozzolanic behaviour of the wood materials used and this affected the compressive strength obtained for each of them.

iv. The three samples (Hardwood, Softwood and Rice husk ash) are suitable cementitious materials to replace cement in concrete production at 5% Replacement.

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