IMPORTANCE OF AGRICULTURAL RESIDUES (CORN COB AND RICE HUSK ASH) TO CONSTRUCTION INDUCTRY IN NIGERIA: A REVIEW

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ABSTRACT
Agricultural residues are residues generated from agricultural processes. It has been discovered that the combustion of agricultural residues like corn cob and rice husk to ashes have pozzolanic properties, which means the sum of SiO_2, Al_2O_3, and Fe_2O_3 composition that meet the 70% minimum requirement according to ASTM C618-12 for a material that can partially replace cement as binding agent in construction works. The discussion of the review is on the method of chemical analysis, effectiveness, benefits, and recommended solutions on the use of corn cob and rice husk ash as alternatives to cement.

Keywords**:** Corn cob, Rice Husk, Ash, Pozzolanic properties, Agricultural residues.

INTRODUCTION

Agricultural residues are generated materials inform of residues from agricultural activities of growing and processing of agricultural products such as fruits, vegetables, meat, poultry, dairy products, and crops. They occur inform of liquids, slurries, or solids as animal wastes, crop wastes, and chemical wastes like pesticides, herbicides, insecticides, etc. (Obi *et al*., 2016).

As reported by Isu (2005), 87% of Nigerians disposes solid residues in an unsanitary way which constitute nuisance, ugly sight, produce unpleasant odour, and create a breeding ground for pests and diseases. Major percentages of agro-products are estimated to be residues, which have little or no economic value. There are some agriculturalresidues that when processed to ash has been discovered to possess cementitious properties, if the chemical composition of the ash has silicon oxide content, hence it can be called pozzolanic material.

Pozzolans are materials that have silicon and aluminium contents that can react with lime (calcium hydroxide) in the presence of water to undergo a chemical reaction, and form compounds that have cementitious properties. There is increase rate of using natural pozzzolans for partial replacement of cement. Pozzolans occur in two forms depending on the source where they are generated; they are natural and artificial forms. The natural pozzolans occur in an unprocessed state, examples are clay and shale calcined, pumicite, volcanic tuff, while examples of the artificial ones are agricultural residues ash and blast furnace slag(Arthanari *et. al.*, 1981). Hence, pozzolanic cements are cements from the addition of pozzolanic materials with Portland cement.

In developing countries like Nigeria, the readily available pozzolanic materials are agricultural residues. Agricultural activities are inevitable in Nigeria because it is one of the sectors that our economy relies on.

Cement is a material with cohesive and adhesive properties that binds atoms or molecules of its material or other materials together, in the presence of moisture or water to form other different compounds. Cement is used in construction industry every day in rehabilitation, maintenance works, constructing and renovation of buildings, drainages, roads, bridges.

Cement production in Nigeria started in the year 1957, with the commissioning of three cement plants by the northern, eastern and mid-western regional governments. Today in Nigeria, many cement plants have been established in all regions of the country(Nigeria's Cement Manufacturing Industry, 2016).

The problem faced by cement manufacturing industry is the issue of increasing demand that is always higher than supply, which means Nigeria; still rely on importation to meet up with the demand. The reasons for imbalance of demand and supply can be highlighted as: government policy, increase in population, and cement production is a capital intensive project.

Also, as Nigerian government is aspiring to become one of the world's top 20 economies by 2020, the Cement Manufacturing Association of Nigeria (CMAN) has advised the government in using concrete roads as an alternative to asphalt for filling the shortfall in road construction materials. (Nigeria Cement Sector Report, 2013).

The highlighted reasons has resulted to low local production, poor distribution of cement nationally, and high price of cement. One of the major challenges of cement production is environmental pollution in terms of green gas emission of CO_2at the production stage of cement, thereby adding to global warming (Owolabi *et al.,* 2015).

Fluctuations in putting and lifting of embargo on importation of cement by government have not yielded the expected results in terms of prices and supply, because most of Nigerian cement manufacturers lack the financial strength needed to operate on large scale of production that can cater for the ever increasing demand for cement, also the growth rate of Nigerian population at an average of 3% per annum is another challenge to cement supply, because cement is needed for many construction works.

It was reported by Nigeria Cement Sector Report (2013) and Nigeria's Cement Manufacturing Industry (2016) that the demand for cement between 2006 and 2012 has risen from 10 to 19 million metric tonnes(Mt), which shows that there is increase in demand for cement annually as shown in Table 1.

It is therefore necessary to strategize plans to meet up with the shortage in supply of cement.

Table 1:Table Showing Major Cement Consuming Nations, 2006-2012

Country	2006(Mt)	2007(Mt)	2008(Mt)	2010(Mt)	2012(Mt)
China	1,200	1,320	1,372	1,850	2,160
India	152	166	174	221	242
USA	122	111	94	71	81
Brazil	41	45	52	60	69
Russia	52	61	61	49	63
Iran	36	41	45	55	59
Turkey	42	43	43	50	58
Indonesia	32	34	38	41	55
Saudi Arabia	25	27	30	41	53
Egypt	30	35	38	50	51
Vietnam	32	36	40	50	46
South Korea	48	51	54	46	44
Japan	59	56	51	42	43
Mexico	36	37	35	34	36
Germany	29	27	28	25	27
Thailand	27	25	26	25	27
Italy	47	46	42	34	26
Pakistan	17	21	21	23	25
Algeria	15	16	18	19	21
France	24	25	24	20	20
*Nigeria	11	13	13	16	19

Mt = Cement Consumption Unit in Metric Tonnes
Source: Nigeria Cement Sector Report (2013).

According to Nigeria's Cement Manufacturing Industry (2016), the current high price of cement estimated as N2500 for a 50kg bag of cement, this is an evidence that majority of the local farmers may not have the financial strength to purchase the required number of bag of cements that may be needed for construction works in farm. It is of this note that it is a necessity to research for an alternative or supplement to cement, and that is one the reasons to overview research works on some agricultural residues that can be used for partial replacement of cement in construction industry.

Agricultural residues are facing problems of disposal, thereby causing landfill. The disposal problem coupled with insufficient supply of cement for construction works has opened way for research work in recycling agricultural residues for use in the construction industry. Agricultural residues are used in concrete making as partial replacement for fine and coarse aggregates, binder (cement), and as reinforcement. Concrete comprises of fine and coarse aggregates bind together by a hydraulic binder called cement in the presence of moisture or water for the chemical reaction that leads to concrete.

The aim of this study is to review the potentials of corn cob and rice husk ash that are used as partial replacement of cement in construction activities, in order to improve on the future prospect of using agricultural residues as alternative source of cement in construction activities.

CORN COB ASH

Corn cob ash is the type of ash produced from corn cob. Corncob is the hard thick cylindrical central core of harvest and unharvests maize or corn, where the maize grains are borne. Corn cob is an agricultural residue that is obtained from corn or maize. Recent update of year 2016 in Africa maize production showed that ,Nigeria ranks second in maize production with an average annual production of 10.79 million tonnes, while South Africa ranks first, with an average annual production of 14.98 million tonnes (Retrieved from http://en.actualitix.com/country/afri/africa-maize-production.php). This figure shows that Nigeria has abundant corn cob residues that are useful for producing ash as alternative to cement.

Method of corn cob ash preparation

In preparing corn cob ash, the corn cobs should be aired and sundried between 2 – 3 days before combustion. According to Adesanya *etal.,* (2009), in order to obtain corn cob ash with good pozzolanic properties with very low carbon content, the corn cobs must be grinded to at least 4mm before burning to have more surfaces exposed to combustion. According to Raheem, *et al.,* (2011), Jimoh *et al.,*(2014), and Akinwumi *etal.,*(2015), if the corn cobs are properly grinded before burning, and exposed to temperature up to 650^{o}c monitored with digital pyrometer for 5 hours or 560^{o}c for almost 10 hours, the resulting fine ash will have good pozzolanic qualities, and easily passes through 0.075mm sieve openings.

Method of Chemical Analysis/ Determination of Chemical Composition

There are several laboratory methods used in analyzing the chemical compositions of bio-wastes ashes, they are used to analyze the major elements present in the ash. These laboratory techniques include Inductively Coupled Plasma-Atomic Emission Spectrometry (ICPAES), X-Ray Fluorescence (XRF), X-Ray Diffraction (XRD), Scanning Electron Microscopy (SEM) with Energy Dispersive X-Ray Spectrometry (EDX), and Ion Chromatography (IC), Atomic Absorption Spectrophotometer. Koukouzas *et.al*. (2011), Tan *et.al*. (2011), Li (2012), Wiinikka, *et.al.* (2013), Zhou *et.al,* (2015), Oyejobi *et.al.* (2014), Owolabi *et.al.*(2015), andAkinwumi *et.al*. (2015).

Effectiveness of Corn Cob Ash

Geographical factors, year of harvest, sample preparation and analysis methods may cause the differences in the chemical composition and analysis of burnt ash. Della *etal.* (2002).

There is increase rate of using natural pozzzolans for partial replacement of cement, because they form bond with cement and other aggregates in concrete work. Table 2showed the average chemical composition from three different lab analysis of corn cob ash at column 2, 3, and 4 by Jimoh *et. al* (2014), Owolabi *et.al*. (2015), and Raheem *et.al*.(2009) with their average percentage composition respectively.

Table 2: Percentage Chemical Composition of Elemental Oxides of the Corn Cob Ash from Three Different Chemical Analyses and Cement Composition

Chemical Constituents	Percentage Chemical Composition of Ash			Average % Composition of Ash	% Chemical Composition of Cement
SiO_2	63.60	64.90	66.38	64.96	20.70
Al_2O_3	5.85	10.79	7.48	8.04	5.75
Fe_2O_3	2.95	4.75	4.44	4.05	2.50
CaO	3.50	10.24	11.57	8.44	64.00
MgO	2.11	2.08	2.06	2.08	1.94
SO_3	1.14	2.53	1.07	1.58	2.75
K_2O	8.42	4.23	4.92	5.86	
Na_2O	0.45	0.43	0.41	0.43	
Mn_2O_3	0.06				
P_2O_5	2.42				
TiO_2	0.60				
LOI	8.55				1 – 3
$SR = SiO_2/(Al_2O_3 + Fe_2O_3)$	7.23	4.18	5.57	5.37	2.51
$AR = Al_2O_3/Fe_2O_3$	1.98	2.27	1.68	1.99	2.44
$\sum SiO_2 + Al_2O_3 + Fe_2O_3$	72.40	80.44	78.30	77.05	29.46
$CaO : SiO_2$	0.06	0.16	0.17	0.13	3.13

AR= Alumina Ratio, SR = Silica Ratio

ASTM C618-12 Requirement: $SiO_2 + Al_2O_3 + Fe_2O_3 \geq 70\%$

Source: Jimoh *etal.* (2014), Owolabi *etal.*(2015), Raheem *etal.*(2009) and Jackson *et al.* (1996).

In the study of corn cob ash by Jimoh *et al*. (2014), Owolabi *et al*. (2015), and Raheem *et al.* (2009), chemical analysis that was done on the corn cob ash showed that the corn cob ash has pozzolanic properties, with total of 72.4%, 80.44%, and 78.3% respectively of the sum for oxides of silicon, iron, and aluminium compositions as shown in Table 2. These results surpassed the minimum requirements of 70% set by ASTM C618-12 (1994) for identification and classification as a pozzolan.

The material that can substitute cement must have CaO : SiO_2, Silica Ratio (SR) range, Alumina Ratio (AR), and calcium oxide with composition of 3.13, 1.7 – 3.5, 2.44 and 60 – 67% respectively Jackson *et al.* (1996). Table 2 showed that corn cob ash is very low in CaO: SiO_2, small difference of silica and alumina ratios in the ash composition compared to cement composition. Also, CaO composition in corn cob ash is very low in the analyses when compared with the recommended 64.0% composition in cement (Jackson *et al.*, 1996). These findings showed that corn cob ash cannot totally replace cement as binder, but as partial replacement since the ash can give a total

composition of 70% of SiO_2 + Al_2O_3 + Fe_2 O_3 set as minimum requirement according to ASTM C618-12 (1994).
The findings from the results in Table 2 showed that corncob ash has pozzolanic qualities, which make it useful as partial replacement for cement in construction industry.

RICE HUSK ASH

In Nigeria, rice is one of the major crops cultivated and consumed. According to Babafada *et al.* (2003) and Oyejobi *etal.* (2014), rice is the most popular cereal crop with 3.2 million tonnes per annum and the fourth cereal crop produced after sorghum, millet and maize.
According to Anbu *etal*. (2009), the outer layer covering the rice grain is called the rice husk. The rice husk is seperated from the grain through milling process. The rice husk has concentration of silica, which shows that it is highly pozzolanic. (Anwar, *et al.,* 2001 and Tashima, 2004).According toNick, (2009) and Oyejobi *et al.* (2014),rice husk composes of 20% in weight of the total raw grain. The composition of rice husk is 28 - 38% cellulose, 9 - 20% lignin, 18.80 - 22.30% silica and 1.9 -3.0% protein. Anbu *et al.* (2009).Rice husk ash (RHA) is a by-product from the combustion of rice husk under controlled temperature and time respectively. The challenges are that the rice husk causes landfill and environmental pollution at the milling center, while in some places, it is used as source of fuel through combustion activity, but the ash from the burnt rice husk has been discovered to be pozzolanic, which means it can be useful as partial replacement for cement in construction activities.

Method of preparation and chemical analysis of rice husk ash

The production of rice husk ash involves obtaining rice husk at rice mill unit. The combustion of the rice husk to rice husk ash takes place in the controlled blast furnaceat moderate temperature range (Habeeb, 2000 and Jinan *et al.*, 2010). The rice husk ash produced should be grinded and sieved with 0.09mm sieve, and the chemical composition can then be determined at the laboratory using any method mentioned for carrying out chemical analysis. Burning the rice husk beyond temperature of 700^{o}C will make the resulting ash to be converted to crystalline form and will become less reactive (Nick, 2009).Fig. 1, 2 and 3 shows the nature of raw rice husk, rice husk ash and controlled blast furnace. Table 3 shows the average chemical composition from three different lab analysis of rice husk ash at columns 2, 3, and 4 by Oyetola *et al*. (2006), Jinan *et al*.(2010), and Oyejobi *etal.*(2014) respectively.

Effectiveness of rice husk ash

The findings of the chemical analysis of the rice husk ash byOyetola *et al.* (2006),Jinan *etal.*(2010), and Oyejobi *et al*.(2014) respectivelypresented in Table 3, has indicated that the total composition of the percentage of SiO_2, Al_2O_3, and Fe_2O_3satisfied the minimum total percentage of 70% as recommended requirement for pozzolana, according to ASTM C618-12 (1994) for any material to have pozzolanic quality.
The findings in Table 3 showed that rice husk ash is a good pozolanna with the combine percentage composition of Silica,Al_2O_3,and Fe_2O_3 greater than 70%, which easily reacts with CaOH in the soil to form cementitious compounds with the soil. It was also reported from the study by Hamzat (2015) that between 10 to 12.5% addition of rice husk ash to clay soil can serve as stabilizing agent for soft soil improvement by improving on the soil quality.

Table 3: Percentage Chemical Composition of Elemental Oxides of the Rice Husk Ash from Three Different Chemical Analyses and Cement Composition

Chemical Constituents	Percentage Chemical Composition of Ash			Average % Composition of Ash	% Chemical Composition of Cement
SiO_2	67.30	87.50	77.27	77.36	20.70
Al_2O_3	4.90	0.50	3.59	3.00	5.75
Fe_2O_3	0.95	0.24	9.85	3.68	2.50
CaO	1.36	1.31	8.95	3.87	64.00
MgO	1.81	0.40	5.85	2.69	1.94
SO_3	2.80	1.70	-	1.50	2.75
K_2O	_	3.30	4.08	2.46	
Na_2O	_	1.20	2.90	1.37	
Mn_2O_3		0.07			
P_2O_5					
TiO_2					
LOI	17.78	3.05	4.84	8.56	1 – 3
SR = SiO_2/ (Al_2O_3 + Fe_2O_3)	11.50	118.24	5.75	45.16	2.51
AR = Al_2O_3/Fe_2 O_3	5.16	2.08	0.36	2.53	2.44
∑SiO_2 + Al_2O_3 + Fe_2 O_3	73.15	88.24	90.71	84.03	29.46
CaO : SiO_2	0.02	0.01	0.12	0.05	3.13

AR= Alumina Ratio, SR = Silica Ratio

ASTM C618-12 Requirement: SiO_2 + Al_2O_3 + Fe_2 O_3 $\geq$70%

SOURCE: Oyetola *et al.* (2006), Jinan *et al.* (2010), Oyejobi *et al.*(2014) and Jackson *et al.* (1996).

The requirements of a material that will replace cement is that it must have CaO : $SiO_2$of 3.13, Silica Ratio (SR) range of 1.7 –2.51, Alumina Ratio (AR) of 2.44, and calcium oxide composition of 60 – 67% respectivelyJackson *et al.* (1996). The CaO: SiO_2 of the three results are very low, silica ratios (SR) are high and the analysis byJinan *etal.*(2010) is very high (118.24), because SiO_2composition decreases the strength of concrete when the composition is very high, alumina ratios (AR) may be classified satisfactory from the average percentage composition except the findings by Oyejobi *et al*.(2014) that is low (0.36), and the calcium oxide compositions are very low respectively. High CaO composition is very important in a binding agent because it dictates the level of strength that can be achieved when binding aggregates in the presence of water in concrete works.

Table 3 revealed that rice husk ash cannot be substituted for cement, but as partial replacement for cement, since it meets up the 70% minimum requirement for a material with good pozzolanic properties set byASTM C618-12 (1994).

Fig. 1. Raw Rice Husk

Fig. 2. Processed Rice Husk Ash

Fig. 3. Controlled Blast Furnace

Source: Oyejobi *et al*. (2014)

Benefits/Advantages of Using Rice Husk and Corn Cob Ash as Pozzolanic Materials

The advantages in using these agro wastes in partial replacement of cement are:

i. Low cost of production, low CO_2 emission that causes global warming in comparison with cement production.
ii. They are readily available, affordable and encourage good waste management at low cost.
iii. Employment opportunity, improvement in economic status of farmers by selling the residues and limestone conservation for other purposes. Dashan *etal.* (1999).
iv. The presence of silica in theses agricultural residues will make the concrete to be durable with promising good strength at 10 - 15% replacement of cement mortar at age of 90 days by Jinan *et al.* (2010).
v. Rice husk ash with partial replacement of cement significantly increases the initial and final setting time of concrete work.
vi. The aluminium oxide and low diffusion rate of chloride ions will improve the resistance to steel to corrosion attack in concrete work. Oyejobi *et al.* (2014) andFeng *et al*. (2004).
vii. Addition of pozzolans that has low carbon content to replace cement in concrete will improve the workability of pozzolans, reduction in bleeding (appearance of water at the concrete surface at plastic state when freshly formed before setting begins) and segregation, low heat of hydration/low evolution of heat, lower creep and shrinkage in concrete work.
viii. The presence of less calcium hydroxide and lower permeability of the ash is an added advantage by making concrete to be highly resistant to chemical attack. Feng *et al*., 2004.
ix. According to research by Feng *et al*., 2004, the contents of unburnt carbon and metal ions in the ash have effects on the resulting colour and purity of ash.
x. Use of agricultural residues' ashes help in reducing greenhouse gas and other adverse air emissions when used to replace cement.

CONCLUSION

The research in corn cob ash and rice husk ash has established the fact that they are good pozzolanic materials, and have the quality and potential of partially replacing cement as binders in construction works.

RECOMMENDATION

Different research works going on agricultural residues have shown that there is great potential of using these residues for useful purpose like construction activities in Nigeria, where the price of cement is being inflated everytime, because of production factors, government policies, and consistent demand for cement. Application of these innovations of agricultural residues will make impact in Nigeria, if applied the way it is done in some countries. Also, the addition of hydrated lime or carbide can improve the strength of combination of agricultural residues and cement in concrete works. Research works should not stop, but be encouraged, on the usefulness of agricultural residues in construction sector.

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