Study on the Combined Strength Characteristics of Groundnut and Ripe Plantain ash as Cementitious Replacement to Cement

Orlando Ketebu, Salome .T. Farrow

Abstract*—Waste ripe plantain peels and groundnut shell constitute environmental pollution in the Niger Delta Area of Nigeria where it is not properly disposed. These wastes can be converted into useful products such as pozzolans as replacement for cement in Sandcrete block production, thus helping to conserve the environment and preserve the earth crust. This research work is aimed at determining if the compressive strength of blocks made from replacement of cement with these pozzolans obtained from waste ripe plantain peel ash and dry groundnut shell ash and their blends would meet regulatory standard for use as partial replacement for cement. The results obtained from the experiments carried showed that Plantain peel ash (PPA) and groundnut shell ash(GSA) contains cementitious properties and can be used as replacement for cement in sandcrete. The compressive strength of blocks produced decreases with increasing percentage replacement of the waste ash with cement. Sandcrete blocks made with plantain peel ash cannot be used in areas with lots of water because of the water absorption properties of plantain peel ash and the ternary blend (GSA/PPA) of the ashes proves to have greater compressive strength than individual binary mixture PPA and GSA respectively. The cement replacement by these pozzolans is best achieved at replacement up to 10% ash.

***Index Terms*— Comprehensive strength, Plantain and groundnut shell ash, Pozzolans and cementitious content**

I. INTRODUCTION

Sandcrete is a popular building material made from the mixture of cement, sand and water. It is an important building component of most Nigerian homes and in Western and Eastern Africa. Sandcrete blocks vary in strength, properties and quality depending on the mix ratio and the cement used. The sand used for sandcrete are majorly fine sand, sieved and free from clay, loam, dirt and any organic or chemical matter. The aggregates (sand) usually have specific gravity ranging from 2.6 to 2.7 [1]. Coarse sand with a little larger particle size is sometimes added to improve compressive strength. The water for used for Sandcrete is Fresh, colourless, odourless and tasteless that is free from organic matter of any kind. The cement often used is the ordinary Portland cement (OPC) with properties conforming to British Standards Institution [2].

The high cost of cement as binder in sandcrete blocks, cost of production, high energy demand, Co_2 emission, and limestone deposit depletion are some basic problems associated with mining and use of cement. Also increase in mining of cement due to a high demand for building constitute environmental effects including global warming, oxygen depletion, and instability of earth crust. These factors and effects have led to the search for other alternatives.

Research on alternative to cement has so far centered on the partial replacement of cement with different materials. Researchers have made much effort at sourcing for local materials with the possibility of replacing cement. Much effort has been made to ensure that this materials are renewable, sustainable, economical and environmentally friendly, thus the use of waste materials for this replacement has been adopted. Supplementary cementitious materials have been proven to be effective in meeting most of the requirements of durable concrete and blended cement and are now used many parts of the world[3],[4]. These cementitious replacements are called pozzolans and they are siliceous materials which in itself does not possess cementitious properties but in processed and finely divided form, react in the presence of water with lime $Ca(OH_2)$ to produce additional C-S-H (calcium-silicate-hydrate) which is the main cementing compound with low solubility. These pozzolans especially the wastes are usually used in their ash form and some includes: rice husk ash (RHA), rice straw ash (RSA), coconut husk ash (CHA) etc.

This research work is focused on the use of plantain plantain peels and groundnut shell waste as pozzolans for sandcrete blocks thus, reducing the over dependence on cement for construction and environmental pollution caused by these peels. Also because they contain carbon, iron, aluminum and other constituent that satisfies the minimum percentage requirement for pozzolanic mixture [5],[6].

Plantain (*Musa spp*) is a largely consumed food in Nigeria and all over the world with Nigeria being one of the largest producers of the crop. Plantain is consumed in different ways and is also used in the production of other materials. This versatility of the crop and its various increasing uses has brought about a rise in its demand and production. Local consumption of this produced crop generates a lot of waste and these wastes constitute nuisance and pollution to land and water ways.

Groundnut (*Arachis hypogaea*) is one of the most used crops in Nigeria with uses and importance cutting across every class in both the rural and urban areas. Groundnut is the 13th most important food crop in the world, the 4th most important

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Orlando Ketebu, Chemical/petroleum Engineering, Niger Delta University, Amassoma, Bayelsa State, Nigeria
Salome T. Farrow, Chemical/petroleum Engineering, Niger Delta University, Amassoma, Bayelsa State, Nigeria

edible oil and the 3rd most important source of vegetable protein [7]. The importance of groundnuts and its uses has led to an increasing trail of wastes from its discarded shell. The shell occupies 20-24% of the rough groundnut harvested and about 58 tons of groundnut shells are generated annually in the world [7].

Research has been carried out on the suitability and potentials use of groundnut shell ash as cementitious materials and partial replacement for cement [8]-[11]. Their results showed that groundnut can replace cement at varying percentages with less hydration. Although not much research work has been done on ripe plantain ash as cementitious replacement of cement. Few research work on plantain leaf ash and banana leaf ash as blended cement composite [12],[13] have been done. Other researchers focused on plantain peel ash as derived alkali in soap making [14].

Research on Sandcrete construction materials in relation with partial replacement of cement for cost saving confirmed that mix ratio, materials quality, and mixing of the constituent materials affect the quality of sandcrete block [15]. Investigation has also been carried out on the strength properties of OPC-RHA (rice husk ash) and groundnut husk blended sandcrete blocks. They replaced various percentage of OPC with RHA and found that up to 17.5% of OPC can be replaced with RHA to produce good quality sandcrete block and that groundnut husk ash could be suitable as partial replacement of OPC in sandcrete block. [16], [17].

A. Portland Cement

For every building construction in Nigeria and majority of African countries, cement is a key component in their construction. It is the component that binds all the other components together. When mixed with other aggregates, a paste is formed called mortar. Cements are hydraulic materials meaning that they depend on a reaction with water, rather than air, for their strength development. When water is added to cement, a chemical reaction called hydration commences immediately and continues while water is still present. Cement generally hardens and gains strength by the evaporation of water and the absorption of carbon (iv)oxide from the atmosphere resulting in the gradual conversion of lime into calcium oxide. Portland cement are made from calcium carbonate and siliceous material and are manufactured by the wet and dry process. Portland cement contains four main components: Tricalcium Aluminate (C_3A), tetracalcium Aluminoferrite (C_4AF), Tricalcium silicate (C_3S) and Dicalcium silicate (C_2S) [17], [18]. The component of the cement that helps it work as binder is the quicklime or calcium oxide which reacts with water to form calcium hydroxide. The silicate and aluminate helps determine other properties of the cement. Cementitious materials also contain, to an extent these properties of cement which enables them with the possibility of replacing cement.

3. MATERIALS AND METHOD

A. Production of pozzolanic admixture

The ripe plantain peel obtained as wastes from roasted plantain rending shop in Amassoma, Bayelsa State and waste shell from dry edible groundnut was washed and cleansed from all debris, impurities and residual plantain fruit. The peel was then dried in the sun for a minimum of two days to reduce its moisture contents. The plantain peel and the groundnut shell were then placed in the furnace/kiln and ashed at average temperatures of 700 and 900^0c respectively. The resulting ash sample was then ground into powdered form using a hand mortar and pestle and kept in tight containers for analysis.

B. Specific gravity

The specific gravity of the ash samples was determined in accordance with the British Standard Institution method. The empty density bottle with stopper was weighed as w_1 and then filled with the ash example to about three quarter of the bottle and measured as W_2. The bottle containing the ash sample is then filled up with water and covered with the stopper and measured as W_3. The content of the bottle was then poured out and the bottle rinsed with water. The bottle was thereafter filled with water and this was measured as W_4. The specific gravity of each of the ash sample was determined by the formula

$$Spgr = \frac{w_2 - w_1}{(w_2 - w_1) - (w_3 - w_4)} \qquad (1)$$

C. Moulding

In this test, the pozzolans sample were ground to very small particles but were not sieved. For the batches of sandcrete, each pozzolans sample presented three different possible mixtures, 10 distinct mixtures were needed. Plantain peel ash was observed to be deliquescent making workability difficult as the ash can only be crushed or ground before it cools down making it not sieve able.

Molds of size 50x100x50 were used for casting all the sandcrete blocks. The molds were cleaned and oiled to enhance easy removal of the blocks after setting and prevent damage of the block. A binder to sand mix ratio of 1:6 was adopted due to the sand particle size. The mix quantity was determined by approximate volume method. The control block (0% pozzolan) was mixed thoroughly by means of a hand trowel on a non-absorbent tray to obtain a homogenous mixture. The mix was then placed in a mold and allowed to set for a day before removing. The molding process was repeated for cement replacement with 10%, 20%, 30% and 40% groundnut shell ash (GSA), 10% 20% 30% 40% plantain peel ash (PPA), 10% 20% 30% 40% GSA-PPA at equal ratio. The casted blocks was placed in water bath and cured for 7 days. This is done to maintain satisfactory moisture content as the hydration of the cementitious material continues long enough to achieve the required strength, durability and reduce shrinkage induced cracking in blocks [19].

D. Compressive strength

The blocks were removed from curing at the end of the 7 days period, dried and then taken to the compressive machine where each blocks from each pozzolans mixture was crushed. The crushing force of the bricks was recorded and compressive strength was calculated with the formula:

$$\text{Compressive strenght} = \frac{\text{Crushing load P}}{\text{Cross sectional area A}} \quad (2)$$

E. Mineral and chemical compositions

The mineral composition of the waste ripe plantain peels were obtained following similar procedure as adopted by [5] on dry matter basis (mmg/100g), and the chemical composition analysis of groundnut shell ash and Odinary Potland cement (OPC) was obtained following procedures adopted by [11].

II. RESULT AND DISCUSSION

A. *Specific gravity*

From the data gotten, the specific gravity of the plantain peel ash and the groundnut shell ash was calculated and imputed as shown in table 1. The weight and specific gravity of the ash samples were observed to be lower than that of cement but was within the British international standard range [2].

Table 1: specific gravity of ash samples.

Material	Specific gravity
Plantain peel ash	2.15
Groundnut shell ash	2.21

The results in Table 2 and 3 showed that both ripe plantain peel and groundnut shell ash contain most of the components found in ordinary Portland cement with varying percentages, and therefore can be used as partial replacement for ordinary Portland cement.

Table 2 Mineral composition (Dry matter) of grounded ripe plantain peel waste (mg/100g)

Mineral Composition	
Calcium (Ca)	122.1
Magnessium (Mg)	16.2
Sodium (Na)	314.5
Potassium (K)	33.0
Phosphorus (P)	146.0
Iron (Fe)	12.0

Table 3 Chemical Composition (%) of GSA and OPC

Constituents	GSA (%)	OPC (%)
Calcium Oxide(CaO)	8.65	63.20
Magnessium Oxide(MgO)	6.72	2.04
Sodium Oxide (Na_2O)	9.04	0.20
Silica (SiO_2)	16.24	21.5
Potassium Oxide (K_2O)	15.70	0.42
Ferrous Oxide (Fe_2O_3)	1.83	4.68
Sulphite (SO_3^{-2})	6.20	1.45
Aluminum Oxide (Al_2O_3)	5.92	5.05

The result in Table 4 shows the compressive strength of the sandcrete blocks produced from replacement of cement with each of the percentage ashes and their crushing load. It was observed the sandcrete block strength decreases with increasing percentage of pozzolans. The ternary mixture (GSA/PPA) had higher compressive strength than the individual binary blend with cement. From the result, strength of blocks made at 20% and 10% replacement levels were observed to be closer to the control (0% pozzolan), therefore the maximum replacement level to achieve maximum compressive strength is at 10%. The crushing load and compressive strength also decreases with increasing replacement of cement with pozzolans as shown in Figures 1and 2 respectively.

Table 4: Crushing load and compressive strength of sandcrete blocks

Crushing Load (KN)				Compressive Strength (N/MM^2)		
Percentage/ material	GSA	PPA	GSA/PPA	GSA	PPA	GSA/PPA
0	58	58	58	10.8	10.8	10.8
10	43	40	48	8.6	8	9.6
20	37	35	40	7.4	7	8
30	30	29	35	6	5.8	7
40	20	24	30	4.8	4.2	6

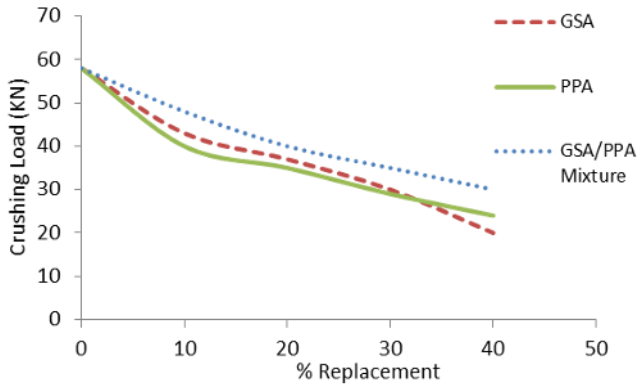

Fig. 1 Plot of Crushing load against % Replacement for GSA, PPA and GSA/PPA blend and % against comprehensive strength

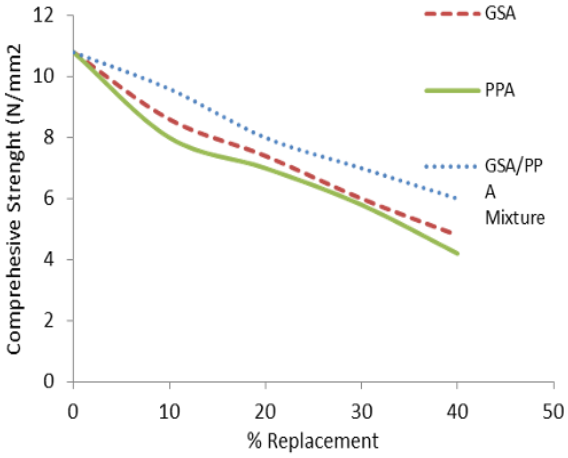

Fig. 2 Plot of Compressive strength against % Replacement for GSA, PPA and GSA/PPA blend

CONCLUSION

The results from this research work showed that Plantain peel ash and groundnut shell ash contains cementitious properties and can be used as replacement for cement in sandcrete. The compressive strength of blocks decreases with increase in percentage of the waste ash. .Sandcrete blocks made with plantain peel ash cannot be used in areas with lots of water because of the water absorption properties of plantain peel ash. The ternary blend (GSA/PPA) of the ashes proves to have greater compressive strength than individual binary mixture. The cement can only be replaced by up to 10% ash for, advisably, minor masonry work.

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