Strength Of Ternary Blended Cement Sandcrete Containing Corn Cob Ash And Pawpaw Leaf Ash

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ABSTRACT

The compressive strength of ternary blended cement sandcrete containing corn cob ash (CCA) and pawpaw leaf ash (PPLA) was investigated in this work. 105 sandcrete cubes of 150mm x 150mm x 150mm were produced with OPC-CCA binary blended cement, 105 with OPC-PPLA binary blended cement, and 105 with OPC-CCA-PPLA ternary blended cement, each at percentage OPC replacement with pozzolan of 5%, 10%, 15%, 20%, and 25%. Three cubes for each percentage replacement of OPC with pozzolan and the control were tested for saturated surface dry bulk density and crushed to obtain their compressive strengths at 3, 7, 14, 21, 28, 50, and 90 days of curing. The 90-day strengths obtained from ternary blending of OPC with equal proportions of CCA and PPLA were 11.30N/mm^2 for 5% replacement, 10.90N/mm^2 for 10% replacement, 10.60N/mm^2 for 15% replacement, 10.10N/mm^2 for 20% replacement, and 9.70N/mm^2 for 25% replacement, while that of the control was 10.00N/mm^2. Thus, very high sandcrete strength values suitable for use in various civil engineering and building works could be obtained with OPC-CCA-PPLA ternary blended cement at longer days of hydration when good quality control is applied.

Key words: *Binary blended cement, corn cob ash, pawpaw leaf ash, pozzolan, sandcrete, ternary blended cement.*

INTRODUCTION

Shortage of accommodation is increasingly becoming one of the greatestproblems in South Eastern Nigeria. Since sandcrete is the most important element of low-cost buildings in the region, reducing the cost of cement used for sandcrete production is considered an essential contribution toward solving this problem. In order to achieve this purpose, agricultural by-products regarded as wastes in technologically underdeveloped societies could be used as partial replacement of Ordinary Portland Cement (OPC).It has already been established thatsupplementary cementitious materials prove to be effective to meet most of the requirements of durable concrete and blended cements are now used in many parts of the world (Bakar, Putrajaya, and Abdulaziz, 2010).

Incorporating agricultural by-product pozzolans such as rice husk ash (RHA) calcined at high temperatures has been studied with positive results in the manufacture and application of blended cements (Malhotra and Mehta, 2004). Elinwa and Awari (2001) found that groundnut husk ash could be suitably used as partial replacement of OPC in concrete making. Cisse and Laquerbe (2000) reported that sandcrete blocks obtained with unground Senegalese RHA as partial replacement of OPC had greater mechanical resistance than 100% OPC sandcrete blocks. Their study also revealed that the use of unground RHA enabled production of lightweight sandcrete block with insulating properties at a reduced cost. Agbede and Obam (2008) have also investigated the strength properties of OPC-RHA blended sandcreteblocks. They replaced various percentages of OPC with RHA and found that up to 17.5% of OPC can be replaced with RHA to produce good quality sandcrete blocks. Oyekan and Kamiyo (2011) reported thatsandcrete blocks made with RHA-blended cement had lower heat storage capacity and lower thermal mass than 100% OPC sandcrete blocks. They explained that the increased thermal effusivity of the sandcrete block with RHA content is an advantage over 100% OPC sandcrete block as it enhances human thermal comfort.

Many other researchers have also investigated the combination of OPC with different percentages of a pozzolan in making binary blended cement composites (Adewuyi and Ola, 2005; De Sensale, 2006; Nair, Jagadish, and Fraaij, 2006; Saraswathy and Song, 2007; Ganesan, Rajagopal, and Thangavel, 2008). Malhotra and Mehta (2004) reported that ground RHA with finer particle size than OPC improves concrete properties as higher substitution amounts result in lower water absorption values and the addition of RHA causes an increment in the compressive strength. Mehta and Pirtz (2000) investigated the use of rice husk ash to reduce temperature in high strength mass concrete and concluded that RHA is very effective in reducing the temperature of mass concrete compared to OPC concrete. Sakr (2006) investigated the effects of silica fume and rice husk ash on the properties of heavy weight concrete and found that these pozzolans gave higher concrete strengths than OPC concrete at curing ages of 28 days and above. Cordeiro, Filho, and Fairbairn (2009) investigated Brazilian RHA and rice straw ash (RSA) and demonstrated that grinding increased the pozzolanicity of RHA and that high strength of RHA, RSA concrete makes production of blocks with good bearing strength in a rural setting possible. Their study showed that combination of RHA or RSA with lime produces a weak cementitious material which could however be used to stabilize laterite and improve the bearing strength of the material. Habeeb and Fayyadh (2009) also investigated the influence of RHA average particle size on the properties of concrete and found that at early ages the strength was comparable, while at the age of 28 days finer RHA exhibited higher strength than the sample with coarser RHA. Rukzon, Chindaprasirt, and Mahachai (2009) studied the effect of grinding on the chemical and physical properties of rice husk ash and the effects of RHA fineness on properties of mortar and found that pozzolans with finer particles had greater pozzolanic reaction. Wada et al. (2000) demonstrated that RHA mortar and concrete exhibited higher compressive strength than the control mortar and concrete. Cordeiro, Filho, and Fairbairn (2009) further investigated the influence of different grinding times on the particle size distribution and pozzolanic activity of RHA obtained by uncontrolled combustion in order to improve the performance of the RHA. The study revealed the possibility of using ultrafine residual RHA containing high-carbon content in high-performance concrete. Many other researchers have also found sawdust ash a suitable agricultural by-product for use in formulating binary blended cements with OPC (Elinwa, Ejeh, and Mamuda, 2008; Elinwa and Abdulkadir, 2011).

A few researchers have also investigated the possibility of ternary blended systems whereby OPC is blended with two different pozzolans. The ternary blended system has the additional environmental and economic advantages that it enables a further reduction of the quantity of OPC in blended cements and also makes it possible for two pozzolans to be combined with OPC even if neither of them is available in very large quantity. Tyagher, Utsev, and Adagba (2011) found that sawdust ash-lime mixture as partial replacement for OPC is suitable for the production of sandcrete hollow blocks. They reported that 10% replacement of OPC with SDA-lime gave the maximum strength at water-cement ratio of 0.55 for 1:8 mix ratio. Elinwa, Ejeh, and Akpabio (2005) had earlier investigated the use of sawdust ash in combination with metakaolin as a ternary blend with 3% added to act as an admixture in concrete. Frı´as et al. (2005)studied the influence of calcining temperature as well as clay content in the pozzolanic activity of sugar cane straw-clay ashes-lime systems. All calcined samples showed very high pozzolanic activity and the fixation rate of lime (pozzolanic reaction) varied with calcining temperature and clay content. Rukzon and Chindaprasirt (2006)investigated the strength development of mortars made with ternary blends of OPC, ground RHA, and classified fly ash (FA). The results showed that the strength at the age of 28 and 90 days of the binary blended cement mortar containing 10 and 20% RHA were slightly higher than those of the control, but less than those of FA. Ternary blended cement mixes with 70% OPC and 30% of combined FA and RHA produced strengths similar to that of the control. The researchers concluded that 30% of OPC could be replaced with the combined FA and RHA pozzolans without significantly lowering the strength of the mixes. Fadzil et al. (2008) studied the properties of ternary blended cementitious (TBC) systems containing OPC, ground Malaysian RHA, and fly ash (FA). They found that compressive strength of concrete containing TBC gave low strength at early ages, even lower than that of OPC, but higher than binary blended cementitious (BBC) concrete containing FA. Their results suggested the possibility of using TBC systems in the concrete construction industry and that TBC systems could be particularly useful in reducing the volume of OPC used.

Much of the previous works by researchers on ternary blended cements were based on the ternary blending of OPC with an industrial by-product pozzolan such as FA or silica fume (SF) and an agricultural by-product pozzolan, especially RHA. Tons of agricultural and plant wastes such as corn cob and pawpaw leaf are generated in many communities in South Eastern Nigeria due to intensified food production and local economic ventures. Little has been reported on the possibility of binary combination of these Nigerian agricultural by-products with OPC in developing blended cements and no literature exists on the possibility of ternary blending of two of them with OPC. This work is part of a pioneer investigation of the suitability of using two Nigerian agricultural by-products in ternary blend with OPC for sandcrete making. The compressive strength of ternary blended cement sandcrete containing corn cob ash and pawpaw leaf ash was specifically investigated. It is hoped that the successful utilization of corn cob ash and pawpaw leaf ash in ternary combination with OPC for making sandcrete would further add value to these agricultural by-product wastes as well as reduce the cost of building works and other civil engineering projects that make much use of sandcrete blocks.

METHODOLOGY

Corn cob was obtained from Aba district in Abia State and pawpaw leaf from Eziobodo in Imo State, both in South East Nigeria. These materials were air-dried, pulverized into smaller particles, and calcined into ashes in a locally fabricated furnace at temperatures generally below 650^{o}C. The corn cob ash (CCA) and pawpaw leaf ash (PPLA) were sieved and large particles retained on the 600μm sieve were discarded while those passing the sieve were used for this work. No grinding or any special treatment to improve the quality of the ashes and enhance their pozzolanicity was applied because the researchers wanted to utilize simple processes that could be easily replicated by local community dwellers.

The CCA had a bulk density of 810 Kg/m^3, specific gravity of 1.95, and fineness modulus of 1.98. The PPLA had a bulk density of 790 Kg/m^3, specific gravity of 1.83, and fineness modulus of 1.36. Other materials used for the work are Ibeto brand of Ordinary Portland Cement (OPC) with a bulk density of 1650 Kg/m^3 and specific gravity of 3.13; river sand free from debris and organic materials with a bulk density of 1590 Kg/m^3, specific gravity of 2.68, and fineness modulus of 2.82; and water free from organic impurities.

A simple form of pozzolanicity test was carried out for each of the ashes. It consists of mixing a given mass of the ash with a given volume of Calcium hydroxide solution [$Ca(OH)_2$] of known concentration and titrating samples of the mixture against H_2SO_4 solution of known concentration at time intervals of 30, 60, 90, and 120 minutes using Methyl Orange as indicator at normal temperature. For each of the ashes the titre value was observed to reduce with time, confirming the ash as a pozzolan that fixed more and more of the calcium hydroxide, thereby reducing the alkalinity of the mixture.

A standard mix ratio of 1:6 (blended cement: sand) was used for the sandcrete. Batching was by weight and a constant water/cement ratio of 0.6 was used. Mixing was done manually on a smooth concrete pavement. For binary blending with OPC, each of the ashes was first thoroughly blended with OPC at the required proportion and the homogenous blend was then mixed with the sand, also at the required proportions. For ternary blending, the two ashes were first blended in equal proportions and subsequently blended with OPC at the required proportions before mixing with the sand, also at the required proportions. Water was then added gradually and the entire sandcrete heap was mixed thoroughly to ensure homogeneity. One hundred and five (105) sandcrete cubes of 150mm x 150mm x 150mm were produced with OPC-CCA binary blended cement, one hundred and five (105) with OPC-PPLA binary blended cement, and one hundred and five (105) with OPC-CCA-PPLA ternary blended cement, each at percentage OPC replacement with pozzolan of 5%, 10%, 15%, 20%, and 25%. Twenty one control cubes with 100% OPC or 0% replacement with pozzolan were also produced. This gives a total of 336 sandcrete cubes. All the cubes were cured by water sprinkling twice daily in a shed. Three cubes for each percentage replacement of OPC with pozzolan and the control were tested for saturated surface dry bulk density and crushed to obtain their compressive strengths at 3, 7, 14, 21, 28, 50, and 90 days of curing.

RESULTS AND DISCUSSION

The particle size analysis showed that both the CCA and the PPLA were much coarser than OPC, the reason being that the ashes were not ground to finer particles. The pozzolanicity test confirmed both ashes as pozzolans since they fixed some quantities of lime over time. The compressive strengths of the OPC-CCA and OPC-PPLA binary blended cement sandcrete as well as the OPC-CCA-PPLA ternary blended cement sandcrete are shown in tables 1 and 2 for 3-21 and 28-90 days of curing respectively.

As shown in tables 1 and 2, the variation of strength for sandcrete produced from OPC-CCA-PPLA ternary blended cements is similar to those of sandcrete produced from OPC-CCA and OPC-PPLA binary blended cements for all percentage replacements and curing ages. Also, sandcrete produced from ternary blend of OPC with equal proportions of CCA and PPLA have compressive strength values in between those of binary blends of OPC and CCA on one hand and OPC and PPLA on the other hand for all percentage replacements and curing ages. More significantly for civil engineering and building construction purposes, the 90-day strengths obtained from ternary blending of OPC with equal proportions of CCA and PPLA were 11.30N/mm^2 for 5% replacement, 10.90N/mm^2 for 10% replacement, 10.60N/mm^2 for 15% replacement, 10.10N/mm^2 for 20% replacement, and 9.70N/mm^2 for 25% replacement, while that of the control was 10.00N/mm^2. Thus, very high sandcrete strength values suitable for use in various civil engineering and building works could be obtained with OPC-CCA-PPLA ternary blended cement at longer days of hydration when good quality control is applied since the 90-day strength values obtained in this work for 5-20% replacement are higher than those of the control and the strength value for 25% replacement is very close to that of the control.

Table 1. Compressive strength of blended OPC-CCA-PPLA cement sandcrete at 3-21 days of curing

OPC Plus	Compressive Strength (N/mm²) for					
	0% Poz.	**5% Poz.**	**10% Poz.**	**15% Poz.**	**20% Poz.**	**25% Poz.**
	Strength at 3 days					
CCA	2.80	2.10	2.00	1.90	1.80	1.80
PPLA	2.80	2.00	1.90	1.80	1.70	1.60
CCA & PPLA	2.80	2.00	1.90	1.90	1.80	1.70
	Strength at 7 days					
CCA	4.90	3.20	3.10	2.90	2.80	2.40
PPLA	4.90	3.10	2.90	2.70	2.40	2.20
CCA & PPLA	4.90	3.10	3.00	2.80	2.60	2.30
	Strength at 14 days					
CCA	7.00	4.50	4.30	3.50	3.30	3.00
PPLA	7.00	4.40	3.90	3.40	3.10	2.80
CCA & PPLA	7.00	4.40	4.10	3.40	3.20	2.90
	Strength at 21 days					
CCA	7.90	5.30	5.20	4.90	4.20	3.90
PPLA	7.90	4.90	4.70	4.50	4.00	3.60
CCA & PPLA	7.90	5.10	4.90	4.70	4.00	3.80

Table 2. Compressive strength of blended OPC-CCA-PPLA cement sandcrete at 28-90 days of curing

OPC Plus	Compressive Strength (N/mm²) for					
	0% Poz.	**5% Poz.**	**10% Poz.**	**15% Poz.**	**20% Poz.**	**25% Poz.**
	Strength at 28 days					
CCA	9.20	7.60	6.40	5.90	5.40	4.90
PPLA	9.20	6.50	6.20	5.50	5.00	4.50
CCA & PPLA	9.20	7.20	6.30	5.70	5.30	4.70
	Strength at 50 days					
CCA	9.80	10.00	9.30	8.60	7.70	6.90
PPLA	9.80	9.50	8.80	8.30	7.40	6.40
CCA & PPLA	9.80	9.80	9.10	8.40	7.60	6.70
	Strength at 90 days					
CCA	10.00	11.40	11.00	10.70	10.30	9.80
PPLA	10.00	11.20	10.70	10.40	10.00	9.40
CCA & PPLA	10.00	11.30	10.90	10.60	10.10	9.70

It can also be seen in tables 1 and 2 that 100% OPC sandcrete (the control) strength increased steadily till the age of about 28 days, after which it increased only gradually until the age of 90 days. Table 1 further shows that the strength values of OPC-CCA-PPLA ternary blended cement sandcrete are very low compared to those of the control sandcrete at early ages of 3 to 21 days of hydration. The low early strength gets more pronounced with increase in percentage replacement of OPC with CCA-PPLA combination as shown in table 2. The low early strength could be due to the fact that pozzolanic reaction was not yet appreciable at early ages of hydration. The pozzolanic reaction set in after some days and increased with days of hydration such that the strength of blended cement sandcrete increased more and more with age than that of the control. Thus, very high strength could be achieved for OPC-CCA-PPLA ternary blended cement sandcrete with 5 to 25% replacement of OPC with pozzolans at 50 to 90 days of curing, as suggested by table 2.

Tables 1 and 2 further show that the strength values of OPC-CCA binary blended cement sandcrete are greater than those of OPC-PPLA binary blended cement sandcrete at all percentage replacements of OPC with pozzolan and at all curing ages. The strength value of OPC-CCA-PPLA ternary blended cement sandcrete consistently lies in-between the two for all percentage replacements and curing ages. This suggests that a greater proportion of CCA than PPLA should be used for optimization of the strength of OPC-CCA-PPLA ternary blended cement sandcrete.

CONCLUSIONS

The variation of strength for OPC-CCA-PPLA ternary blended cement sandcrete is similar to those of OPC-CCA and OPC-PPLA binary blended cement sandcrete for all percentage replacements and curing ages. Also, ternary blended cement sandcrete produced from blending OPC with equal proportions of CCA and PPLA have compressive strength values in between those of binary blended OPC-CCA and OPC-PPLA cement sandcrete for all percentage replacements and curing ages. More significantly, the 90-day strengths of OPC-CCA and OPC-PPLA binary blended cement sandcrete as well as those of OPC-CCA-PPLA ternary blended cement sandcrete are higher than the control values for 5-20% replacement of OPC with pozzolans and very close to the control value for 25% replacement. This suggests that very high values of OPC-CCA-PPLA ternary blended cement sandcrete strengths could be obtained if high target strength is intentionally designed for and good quality control is applied. Thus, OPC-CCA-PPLA ternary blended cement sandcrete could be used for various civil engineering and building works where early strength is not a major requirement.

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