Recycling Blends of Rice Husk Ash and Snail Shells as Partial Replacement for Portland Cement in Building Block Production*

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Abstract

This project was experimentally carried out to investigate the effect of a blend of Rice Husk Ash (RHA) and Calcined Snail Shells (CSS) as a partial replacement for Ordinary Portland Cement (OPC) on the formation of building blocks in the absence of chemical activation. A total of 24 building blocks of size 100 mm x 70 mm x 50 mm with different percentages by weight of a blend of 20 % RHA and 80 % CSS were used for the investigation. The percentage partial replacement of OPC was in the order of 0 %, 5 %, 10 %, 15 %, 20 %, 25 %, 30 % and 50 %. A ratio of one part of cement to three parts of sand was used to form the blocks. The blocks were tested at age 7 and 14 days for compressive strength. Test results indicated that the blocks formed were above the standard compressive strength of 3.5 N/mm^2 according to American Society for Testing of Materials (ASTM). Compressive strength of the blocks also increases with age of curing and generally decreases as the percentage of RHA and CSS content increases. The study arrived at an optimum replacement level of 25 % of cement in forming the building blocks.

Keywords: Rice Husk Ash, Calcined Snail Shell, Ordinary Portland Cement, Building Blocks

1 Introduction

Cement is the most expensive binding material in block making. Owing to the important role the cement industry plays in infrastructural development, affordable housing can be achieved if multiple efforts are made towards reducing the cost of production of Portland cement, reduce the consumption of raw materials for cement production as well as protect the environment. One way is to use suitable low-cost, sustainable and environmentally friendly materials as alternative binder or admixtures (Ettu *et al.*, 2013). The search for alternative binder or cement replacement materials has led to the discovery of the potentials of using industrial and agricultural by-products, otherwise regarded as wastes in technologically disadvantaged communities as cementitious materials (Raheem and Adesanya, 2011). If these materials have pozzolanic properties, they impart technical advantages to the resulting block and also enable larger quantities of cement replacement to be achieved.

Due to increasing industrial and agricultural activities, tonnes of waste materials are deposited in the environment with little effective method of waste management or recycling. Some of these deposits are not easily decomposed and their accumulation is a threat to the environment and people at large. These waste materials include rice husks, maize cobs, snail shells, palm-kennel shell, coconut shell, saw dust, groundnut shell etc. Global pollution coupled with resource depletion has challenged many researchers and engineers to seek locally available materials with a view to investigating their usefulness wholly as a construction material or partly as a substitute for conventional ones in concrete and block making. In search for new cost effective and more efficient materials which address these issues, pozzolana attracts much interest (Raheem *et al.*, 2013**)**.

The need to reduce the high cost of Ordinary Portland Cement in order to provide accommodation for the populace has also intensified research into the use of some available materials that could be used as partial replacement locally for Ordinary Portland Cement (OPC) in civil engineering and building works (Bakar *et al.*, 2010). Significant achievements have been made in this regard and the subject is attracting attention due to its functional benefit of waste reusability and sustainable development, reduction in construction costs and its indigenous technology and equipment requirements. This also promotes waste management and recycling at minimal cost, reduce pollution by the waste and increase the economic base of the farmer.

Rice Husk Ash (RHA) from parboiling plants and snail shell pose environmental threat and ways are being thought of to dispose them (Akeke *et al.*, 2013**).** Rice husk and snail shell constitute an environmental nuisance as they form refuse heaps

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in the areas where they are disposed. The use of RHA and CSS as a partial replacement for cement will provide an economic use of the by – product and consequently produce cheaper blocks for low cost building (Oyetola and Abdullahi, 2006). The compressive strength of blocks is considered one of the most important properties in the hardened state. For the purpose of structural design, the compressive strength is the criterion of quality for building blocks (Umoh and Olusola, 2012)

Extensive compressive strength tests and workability tests on RHA indicate that it can be used to substitute for Portland cement at up to 25% in the manufacture of concrete with no loss in workability or strength (Muga *et al.,* 2005, Akeke *et al.,* 2013b). Also, the mechanical performances of blended cements produced from raw materials (pozzolana) have revealed that the rate of strength development and compressive strength at a particular curing time decrease with increasing pozzolana content (20-35 %) of blended cements. Therefore, it was deduced that the raw material up to 30 % can be added to produce blended cements of the desired quality for mortar to make block (Alp *et al.*, 2009).

Oyetola and Abdullahi (2006) observed that lower percentage replacement level (of between 10 % and 20 % of RHA) ensures that silica from the pozzolana is in required amount which aids the hydration process to produce blocks with high compressive strength. However, in higher percentage replacement of 30 %, 40 % and 50 % RHA, the amount of rice husk ash in the mix is higher than the amount required to combine with liberated calcium hydroxide during hydration. Thus excess silica substitute part of the cementitious material and consequently causes a reduction in strength. Therefore the need to mix RHA with calcined snail shell ash for improved compressive strength of the blocks due to the presence of calcium oxide in the snail shell which is in maximum quantity in cement.

Snail shells are waste products which are obtained from the consumption of snails. Snail shells are very strong, hard and brittle material. The snails found in lagoons and mudflats of coastal areas are consumed by the people as food and the shell is disposed of as waste product. Large amount of snail shells are disposed of as waste in these areas, and the disposal already constitute a problem in such areas because they cannot find any use for it. Thus, large deposits have accumulated in the areas over the years (Zaid and Ghorpade, 2014).

The shell of the large land snail is brownish yellow in color with dark markings and is up to 10 cm or more in length; it is very hard. Snail shell has several important uses, which results from the hard nature of the shell. The shell protects the snail from physical damage, predators and dehydration (Jatto *et al,* 2010**).** Snail shells are made of mostly calcium carbonate. They also contain small amounts of protein. Fundamentally, the shell consists of calcium carbonate crystals organised within a matrix of protein. Calcium carbonate crystallizes in two principal forms, aragonite and calcite within the shell. The form present in a particular shell may depend on several factors. For example, the crystal type in the shell of the land snail Helix pomatia is normally aragonite, whiles the shells of many marine snails and bivalves normally contain calcite.

Rice husk is waste left behind after the grain of rice is taken. Rice husk ash is the ash obtained from the combustion of rice husk and this ash contains high amount of SiO_2 which is a major component of cement. These waste materials are not properly handled and are discharged into the environment which later causes environmental pollution. Rice Husk and Snail Shell have great potential to be used as building materials. The combination of high silica content from RHA, and CaO from the CSS has pozzolanic behaviour which influences the concrete strength.

Research has been done on the utilisation of various forms of CSS and RHA separately in replacing cement (Abalaka 2012; Abalaka *et al.,* 2007; Habeeb and Mahmud, 2010; Kartini, 2011; Zaid and Ghorpade, 2014) but little or no work on the combination of the two exists in the literature. Therefore this investigation seeks to determine the effects of partial replacement of cement with (Calcined Snail shell, CSS + Rice Husk Ash, RHA) on the formation of building blocks to ensure sustainable blocks production, save energy and make the environment friendlier.

2 Resources and Method Used

2.1 Materials

The snail shells (SS) (Fig. 1) used in this test were collected from Manso Amenfi in the Western Region of Ghana whilst the Rice husk (RH) (Fig. 2) was collected from Hohoe in the Volta Region of Ghana. Fine aggregates of sand and Ordinary Portland Cement (OPC, GHACEM Brand) were obtained from Tandoh and Sons Solid Rock Block Enterprise.

Fig. 1 Sample of Snail Shell utilised for the Investigation

Fig. 2 Samples of Rice Husk utilised for the Investigation

2.1.1 Preparation and Blending of Materials

The rice husk sample was dried. The sample was burned in an evaporating dish on a gas fired furnace at a temperature of about 800 °C. After about 4 hours the sample in the dish completely turned ash. The ash was allowed to cool and screened. A screen of aperture size 90 micron was used in the screening process. After screening, both the oversize and undersize rice husk sample were bagged.

The land snail collected was washed to remove impurities. The sample was dried and calcined at above 700 ºC in a furnace. After calcination, the shells were crushed using a lab size jaw and roll crushers at the Minerals Engineering laboratory of UMaT. The sample was further milled by using a laboratory size ball mill. The milled sample was screened using a screen of aperture size 90 microns.

2.1.2 Characterisation of Materials

The experimental materials (CSS, RHA and OPC) were characterised by XRF and XRD and the morphology of pulverised samples were observed using SEM analyses.

2.2 Mixing and Moulding

A mould of size 100 mm × 70 mm × 50 mm (Fig. 3) was used for casting all blocks. The overall sample mass for sand, cement, rice husk ash and calcined snail shell used for forming the blocks are 16.80 kg, 7.54 kg, 0.43 kg and 1.72 kg respectively. A ratio of 1: 3 of sand to cement was used. A blend of 20 % of RHA and 80 % of CSS was the mixture of the cementitious material used as replacement for forming blocks. The percentage replacement used are 0 %, 5 %, 10 %, 15 %, 20 %, 25 %, 30 % and 50 %. The 0 % replacement was used as the control sample. The quantities of materials obtained from the mix design were measured in each case with the aid of an electronic balance. The particle size of the sand used is oversize of 0.56 mm. Details of the cast blocks are shown in Table 1.

Fig. 3 The Mould used for the Investigation

The mixture was mixed thoroughly by means of a trowel to obtain homogenous mixture. Water was sprinkled on the mixture.

Table 1 Percent Replacement and their Respective Masses of Raw Materials

%Replacement	Mass of Material (g)			
	Sand	Cement	RHA	CSS
0	2400	1383.20	0	0
5	2400	1314.04	13.83	55.33
10	2400	1244.88	27.68	110.66
15	2400	1175.72	41.49	165.98
20	2400	1106.56	55.32	221.31
25	2400	1037.40	69.16	276.64
30	2400	968.24	82.99	331.97
50	2400	691.60	138.32	553.28

2.3 Casting and Curing

The uniform mixture which was slightly wet was then transferred into the mould to cast the block (Fig. 4). A total of 24 blocks were cast. After each block was cast, small amount of water was sprinkled into the metal mould to avoid the block sticking onto its walls. Curing was performed after 24 hours after casting the blocks. Samples of the Control and experimentally cast blocks are shown in Fig. 5 and Fig. 6, respectively.

Fig. 4 Mould filled to the Brim

Fig. 5 Control Block Samples

Fig. 6 Cast Blocks Samples

2.4 Testing Procedure

Compressive test was carried out to determine the effect of the admixture on the strength of the blocks. After casting and the samples were air dried until the testing ages of 7 and 14 days. The compressive strength was determined with CONTEST Compressive Strength Testing Machine (Type GDIOA, Serial Number 3688), Fig. 7, with maximum capacity of 2000 kN. The test was carried out in the Geological Department Laboratory, University of Mines and Technology, Tarkwa.

Fig. 7 Compressive Test Machine

3 Results and Discussion

3.1 Characterisation of Materials

3.1.1 XRF Analyses of RHA, CSS and Cement

The XRF analyses of the samples are illustrated in Table 2. It is apparent from Table 2 that whereas RHA is dominated by SiO_2 with negligible amount of CaO (< 1%), CSS is dominated by CaO with negligible amount of SiO_2 (< 1%). Accordingly, suitable blends of RHA and CSS should be able to conveniently replace cement in building blocks, since cement contains reasonable amounts of both CaO and SiO_2. To ensure that the content of CaO will be higher than that of SiO_2, the ratio of RHA: CSS in the replacing blend was set at 4:1. Table 2 gives an LOI of 43.08%. This value is inclusive of the CO_2 that was expelled from CSS during the calcination process.

Table 2 Chemical Analyses (XRF) of Samples utilised for the Investigation

Component	CSS (wt %)	RHA (wt %)	Cement (wt %)
CaO	57.92	0.75	53.43
SiO_2	0.82	85.77	21.62
Al_2O_3	0.14	0.28	4.80
Fe_2O_3	0.22	0.30	3.04
K_2O	0.06	3.90	0.68
SO_3	0.01	0.37	2.56
Na_2O	0. 06	0.26	0.58
MgO	<0.01	1.50	3.41
LOI	43.08*	2.34	9.40

*LOI includes expelled CO_2 from calcination of SS

3.1.2 XRD Analyses of RHA, CSS and Cement

The XRDs are shown in Figs. 8, 9 and 10 for CSS, RHA and cement, respectively. It is seen from the XRDs that Snail shell is crystalline and is dominated by sharp and well-defined peaks of calcite ($CaCO_3$). RHA is, however, amorphous and its XRD consists of amorphous SiO_2. The XRD of cement, as illustrated in Fig. 9, consists of peaks three distinct compounds, viz., SiO_2, Ca_2SiO_4 and Ca_3SiO_5.

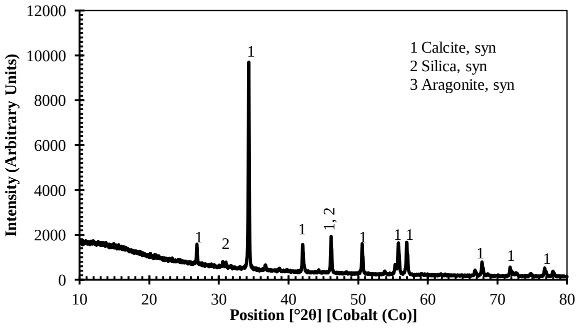

Fig. 8 XRD Patterns of Sea Shells showing Peaks of Calcite ($CaCO_3$)

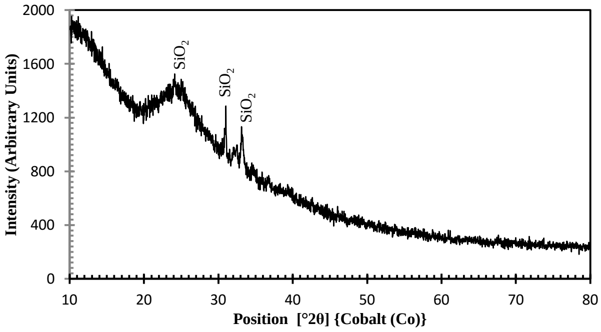

Fig. 9 XRD Patterns of RHA showing Amorphous Peaks of SiO_2

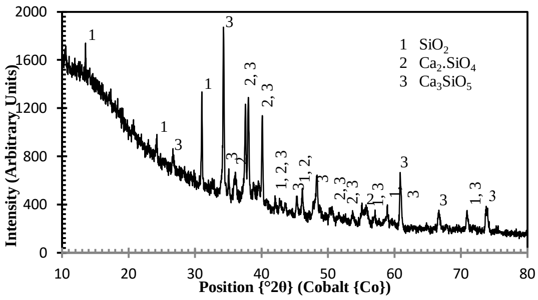

Fig. 10 XRD Patterns of OPC

3.1.3 SEM Analyses of RHA, CSS and Cement

The SEM photomicrographs of SS, CSS, RHA and OPC are shown in Figs (11, 12, 13 and 14), respectively. The SEM of the pulverised SS consists of well-defined tubular structures whereas interspersed between irregularly shaped and irregularly sized structures.

Fig. 11 SEM Photomicrographs of Pulverised Snail Shells Utilised for the Investigation

Calcination of the SS results in more uniform spherically shaped structures as displayed in Fig. 11. The SEM photomicrographs of RHA and OPC show structures that are irregularly shaped.

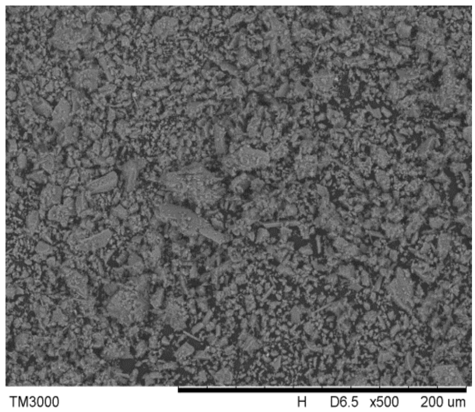

Fig. 12 SEM Photomicrographs of Calcined Snail Shells Utilised for the Investigation

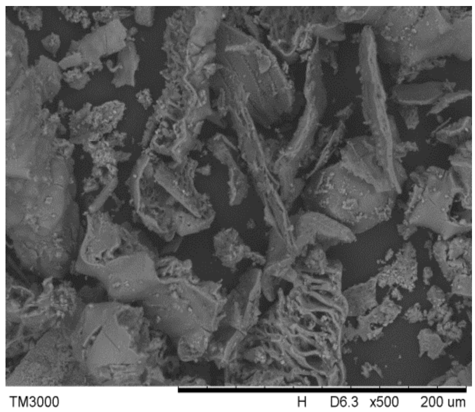

Fig. 13 SEM Photomicrographs of RHA Utilised for the Investigation

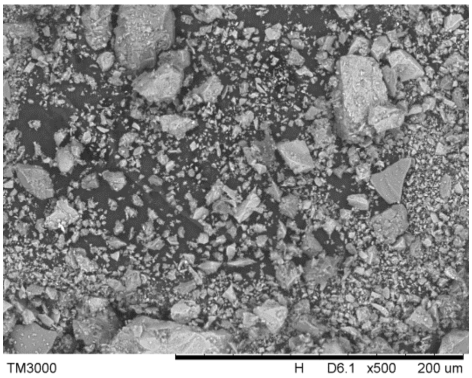

Fig. 14 SEM Photomicrographs of OPC Utilised for the Investigation

3.3 Compressive Strength

The stages involved in the measurement of the compressive strengths of the blocks are illustrated in Fig. 15.

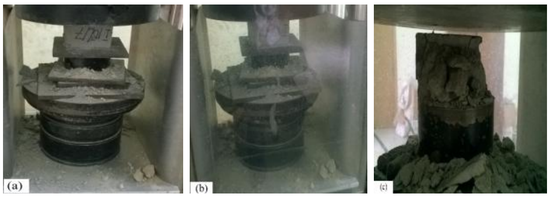

Fig. 15 Various Stages during Testing. (a) Initial stage, (b) Compression stage and (c) Final stage

The effect of curing ages on the compressive strength of building block is presented in Table 3. Table 3 indicates that compressive strength generally increases with curing age and decreases with increased amount of pozzolanic materials added. The results at 14th day showed a percentage increase of 6.15 %, 10.6 %, 88.36 % and 27.45 % for control (0 %), 20 %, 25 % and 30 % partial cement replacement, respectively from the 7th day. However, there was a decrease in compressive strength for the 5 %, 10 %, 15 % and 50% replacement with values 33.57 %, 14.71 %, 19.57 %, 10.6 4%, 26.26 % respectively.

The results at 14th day indicated that pozzolanic action had commenced as evident from the higher percentage increase in compressive strength by the 20 %., 25 % and 30% replacement. However, the control still had the highest compressive strength at this age. But the 25 % replacement gave the highest percentage increase in compressive strength. The result can be attributed to the right requirement of the silica in the block formed in the 20 %., 25 % and 30% replacement to react with water during the hydration of cement to increase the compressive strength. This then confirms the observation by Oyetola and Abdullahi (2006) that for lower percentage replacement level of 10 % and 20 % RHA the silica from the pozzolana is in the required amount, which aids the hydration process to produce blocks with high compressive strength. Therefore 20 %, 25 % and 30 % had right requirement of silica in the blocks formed.

A high value of 88.36 % increase of strength from the 7th day to the 14th day was obtained for building block with 25 % replacement of RHA and CSS. Therefore it is the optimum partial percentage replacement for forming blocks. All the blocks formed meet the minimum strength of 3.5 N/mm^2 for a standard block (Oyetola and Abdullahi, 2006b) for all ages.

It must be mentioned here that blocks were produced without chemical activation. Accordingly, strength development appears to be generally slow and irregular. Further work is ongoing aimed at the influence of chemical activation agents on compressive strength development in a bid towards sustainable production of affordable building blocks production.

Table 3 Weight, Load and Compressive Stress of the Blocks

	7 Days			14 Days		
% Replacement	Weight (g)	Load (kN)	Stress (MPa)	Weight (g)	Load (kN)	Stress (MPa)
0	715	59.53	12.52	712.30	63.75	13.29
5	694	60.10	12.78	677.00	40.30	8.49
10	686.50	54.10	11.15	670.00	48.50	9.51
15	680.60	37.60	7.51	665.90	29.00	6.04
20	673.60	43.30	8.65	653.20	46.90	9.37
25	658.40	28.60	5.67	642.30	51.02	10.68
30	649.80	40.00	8.16	636.20	50.50	10.40
50	639.50	27.40	5.56	628.50	25.40	4.10

4 Conclusions

From this work it can be concluded that:

(i) RHA and CSS can be used as partial replacement for cement in building blocks production.

(ii) The compressive strength of the blocks generally increases with age at curing but decreases as the content of RHA and CSS increases.

(iii) All the building blocks produced had compressive strength higher than the minimum required strength of 3.5 N/mm^2 for a standard block.

(iv) The optimum addition of RHA and CSS as partial replacement for cement to form building blocks is 25%.

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