Acta Scientific Agriculture (ISSN: 2581-365X)

Volume 2 Issue 7 July 2018

Research Article

Evaluates Some Engineering Properties of Innovative Sustainable Cement Blocks as a Partial Replacement of Groundnut Shell Ash (GSA)

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Received: April 18, 2018; **Published**: June 04, 2018

Abstract

As a result of the rising cost of building materials, it has become necessary to find an affordable and economically available material which might be partially merged with cement in the production of blocks. This study investigated the result of groundnut shell ash merging with cement on some engineering properties of cement blocks. Groundnut shells were collected from a self-employment industry situated in Puttalam district Sri Lanka. These shells were clean and burnt in an open atmosphere and allowed to cool. Then the coal was further burnt in a muffle furnace at 600°C for 4 hours to get groundnut shell ash (GSA). Physical properties of GSA merged cement blocks were determined in accordance with standard specifications. The GSA was merged with the cement as a percentage varying from 0 to 25% with the step of 5%. A complete of 72 blocks comprising of 12 blocks for each GSA merge percentage of cement block size of 225 mm × 113 mm × 75 mm of merging ratio 1:6 and water-cement ratio 0.5 to 0.6 were cast, cured and crushed at 7, 14 and 21 days respectively.

Analysis of density, water absorption, compressive strength and flexural strength of the cement blocks showed that the 5 and 10% cement replacements is appropriate for load bearing outer walls whereas the 20% and 25% substitution was found additional appropriate for non-load bearing indoor walls. The 15% substitution was but found to be appropriate for non-load bearing outer walls.

It is therefore hope that this research work will provide a quick reference to practicing Engineer, who will find GSA as a good partial replacement for cement, thus reducing cost of cement block production.

Keywords: Groundnut Shell Ash; Cement Block; Engineering; Water Absorption; Compressive Strength; Sustainable

Introduction

Ecological solid waste management enhances maintenance of a healthy, aesthetic, and ecologically sound surroundings. Most of the people either dump waste in open areas or burn it, making water and air pollution. Waste management involves waste collection, sorting, storage, use and disposal [1]. To resolve the matter of inadequate housing and waste management, new construction materials should be thought of and determined if they will offer a less expensive different to standard building materials. According to Nasly., *et al*. [2], the utilization of those different construction materials has the potential to lower construction prices because of less standard materials needed and quicker completion times. Historically, stabilization of deficient or marginal soil is finished with standard materials like lime, cement and hydrocarbon. The value of those stabilizers increases in ever increasing construction add the tropics so the requirement to substitute with native additives become authoritative [3]. Groundnut shell is a secondary agricultural waste obtained from nut production industries. Hence, use of Groundnut Shell Ash (GSA) for soil stabilization ought to be inspired because it can significantly scale back the value of construction and yet scale back the environmental hazards. GSA has been categorized beneath pozzolana given its 16 -33% SiO_2, 2 - 6% Al_2O_3 and 0.5 - 5% Fe_2O_5 [4-7]. The SiO_2 in GSA will react with the CaOH, which liberates throughout hardening of cement to make cementations compound.

The manufacture of cement produces CO2, which could be a prime contributor to heating. Typically, cement production ends up in greenhouse emission of 0.9% [8]. Therefore, utilization of Groundnut Shell Ash (GSA) as a secondary building material to part replace proportions of the normal cement in soil stabilization can scale back the general environmental impact of the soil stabilization method. Thus, this study targeted on the performance of cement blocks stabilized victimization uncontrolled burnt GSA and cement. GSA will solely be used as a partial replacement for the dearer helpful agents (cement/lime) as a result of its inadequate cementation property needed to bind the fabric to a satisfactory strength [9].

This study investigated the result of GSA and cement stabilization on the density, water absorption and compressive strength of compacted cement blocks. This may result in reduction within the quantity of cement needed for stabilization and provision of additional durable cheap compressed cement blocks for housing in Sri Lanka.

Materials

Groundnut Shell Ash (BLA)

Naturally dried groundnut shells were collected from Puttalam district, Sri Lanka is shown in figure 1. These shells were cleaned and expended into coal in an open environment. Then groundnut shell ash (GSA) was acquired from the coal using a furnace by heated at 600oC for 4 hours. After that the GSA was allowed to cool and sealed in a glass container to avoid moisture absorption and other contamination. Chemical test was done by X-Ray fluorescence (XRF), utilizing a Philips PW 780 instrument and the results tabulated in table 1 that compared with the previous chemical test results. Oxide analysis of the GSA shows that the combination of Silicon Oxide (SiO_2), Aluminum Oxide (Al_2O_3) and Ferrous Oxide (Fe_2O_3) is less than 70% which is the minimum standard specified by ASTM (ASTM C 618, 2008) for pozzolanic materials [10]. These oxides are known to have cementitious property which upgrades the binding strength of the cement blocks.

Figure 1: Groundnut shells collected from Puttalam distract, Sri Lanka.

Oxide syntheses	Present study	TC Nwofor and S Sule. [4]	Mara Wazumtu and Egbe-Ngu Ntui Ogork. [5]	Ala-badan., *et al.* [6]	H. Mahmoud., *et al.* [7]
SiO_2	30.16	16.21	22.00	33.36	26.96
Al_2O_3	6.27	5.93	2.00	6.73	5.82
Fe_2O_3	1.33	1.80	5.04	2.16	0.50
CaO	10.20	8.69	24.10	10.91	9.5
MgO	5.73	6.74	3.00	4.72	5.60
MnO	-	-	0.42	-	0.32
Na_2O	13.27	9.02	-	25.38	1.15
K_2O	18.95	15.73	21.90		20.02
TiO_2	-	-	1.70	-	0.69
SO_3	5.87	6.21	1.05	6.40	1.86
CO_3	-	-	-	6.02	-
BaO	-	-	0.57	-	-
V_2O_3	-	-	0.05	-	-
P_2O_5	-	-	1.08	-	2.00
ZnO	-	-	0.12	-	-
Cr_2O_5	-	-	0.04	-	-
NiO	-	-	0.02	-	-
CuO	-	-	0.14	-	-
SrO	-	-	0.30	-	-
ZrO_2	-	-	0.43	-	-
LOI	2.65	-	4.36	-	22.00

Table 1: The oxide syntheses of Groundnut Shell Ash (GSA).

Sand

Sand is fine particle material that has unequalled bond of segments in concrete. It offers quality by filling during tiny fillers in a mix. It provides strength by serving as tiny fillers during a mixture. Cement binds sand particles along forming one solid-sand combine. River sand that utilized in this study was liberate from clay, loam, dirt and organic matter of any description.

Ordinary Portland Cement (OPC)

Ordinary Portland Cement (OPC) was used in this study, which is chief material use for concreating structures all over the world. OPC is a standard cementitious material recognized by the standards such as Sri Lankan Standard (SLS 855:1989) [11].

Water

Fresh water was utilized to blend the materials, which was free from natural issues of any sort as depicted in Sri Lankan Standard

(SLS 855:1989) [11]. It enacts the compound response in the cement and with different materials and structures concrete gel.

Experimental Methodology

The GSA-Cement blocks were cast in size of 185 mm × 85 mm × 65 mm and its optimum mix ratio was 1:6. These blocks were cast in different merging ratios of 0%, 5%, 10 %, 15%, 20% and 25% of the total weight of mixture which consists 7 blocks in each ratio is shown in figure 2 and table 2. Traditional (man) mixing technology was applied, and the materials were twisted until an even colour and steadiness were acquired. Water was added as required, and the materials were further twisted over to secure adhesion. Then the mixture was put into a wooden mould, compressed and shaped off with a steel face smoother. After removing form, the mould, blocks were laid and left to dry for 2 days under direct sunlight. Each block was allowed to cure for 7, 14 and 21 days in a water tank. This is because to find out the correct curing time which uses to obtain the stress measurement from a hydraulic press machine for compressive strength tests. Density, water absorption and compressive strength measurements were taken to analyze the new product.

Figure 2: GSA-Cement block casting process.

Proportions			Block
Sand	(Cement % + GSA %)	w/c ratio	
6	1 (100%+0%)	0.55	A
6	1 (95%+5%)	0.55	B
6	1 (90%+10%)	0.55	C
6	1 (85%+15%)	0.55	D
6	1 (80%+20%)	0.55	E
6	1 (75%+25%)	0.55	F

Table 2: The cement-sand-GSA and w/c ratio of the cement block.

Experimental investigation of brick properties

Density, Water absorption and Compressive strength were investigated, and the results of these properties were compared with the Sri Lankan (SLS), British (BS) and Indonesian (SNI) Standards.

Investigation of Particle Size

Particle size can be investigation by various size of sieves. The investigation was not done, because the main objective of this study is to distribute the new technology to the local community to improve their self-employment and easily protect the environmental pollution.

Investigation of Density of the block

Density is the ratio of dry mass, m, and the volume, V. The strength of block depends on the volume and the density. Denser blocks evidently enhance its engineering properties and durability. BS 2028 stated that the minimum limit of the density is 1940 $kg.m^{-3}$ [17]. Moreover, Neville stated that the density of the light weight concrete lies in the limit 400 - 1950 $kg.m^{-3}$ and normal weight concrete lies in the limit below 2400 $kg.m^{-3}$ [15,18].

$$\rho = m / V \quad \textbf{(1)}$$

Investigation of Water Absorption (WA)

Water absorption was investigated as per SLS 855: Part 2: 1989 [12]. As per the BS 5628: Part 1:2005 [13] and Indonesian Standard SNI 15 - 2094 - 2000 this property lies in the limit of 12 to 20 % [14]. This is a valuable unique property to determine some other parameters. Water absorption was investigated for three blocks in each type. Initially, blocks were allowed to dry in the sunlight of temperature of 35°C to 40°C for seven days and the dry weight of each block was measured using a mechanical balance of accuracy 1g. Then the blocks were place inside a water tank consist water of temperature in the range of 25 to 30°C as shown in figure 3. After one day the block were taken out, allowed for 5 mins to settle down and the wet weights were measured. Water absorption percentage was determined by equation (2), and the mean values were determined for each type and cure days.

$$WA = [(M_{WW} - M_{DW}) / M_{DW}] \times 100\ \% \quad \textbf{(2)}$$

Where M_{DW} – mass of the dry block and M_{WW} – mass of the wet block after one day.

Figure 3: GSA-Cement blocks were immersed into the water for one day in the temperature range of 25 to 30°C.

Investigation of Compressive Strength (CS)

Compressive strength was investigated using Universal Testing Machine available in the Department of Physics, Eastern University, Sri Lanka. The testing method was followed as per the Sri Lankan Standards 855: Part 1: 1989 [12], which is similar to ASTM C67 - 05. The block was setup as shown in figure 4 for investigation. The compressive strength was calculated with the aid of a pressure gauge of sensitivity 2 $kg.cm^{-2}$ fixed to the Universal Testing Machine. The maximum force applied to just break the block (or force failure), Fm ($kg.cm^{-2}$), width, d (mm), and length, l (mm), of the block were noted. Three blocks from each type was investigated and the average compressive strength was calculated and compared with the standards.

$$CS = F_m / d \times l \quad \textbf{(3)}$$

Figure 4: (a). GSA-Cement block was ready to measure the point of force failure and (b) Formation of crack indicates the point of force failure.

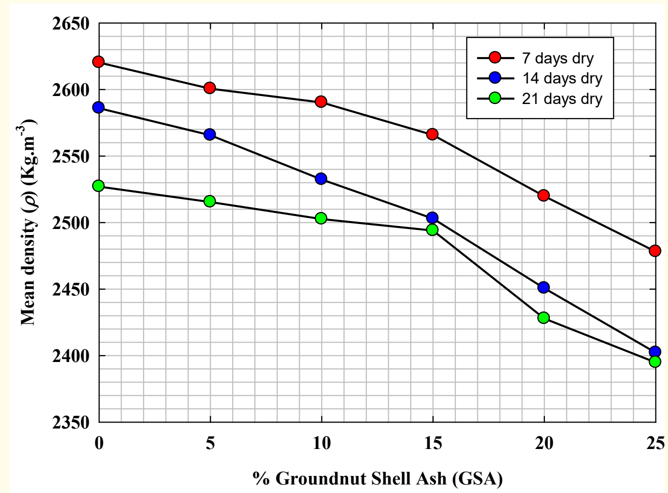

Figure 5: Mean density of the cement block as a function of groundnut shell ash.

Results and Discussion

Mean density of the GSA merged cement block

Initially, the dry weights of the cement blocks were measured to determine the density of the cement blocks. Thus, the blocks were allowed to dry well under the sun light of temperature 40-45°C for one week from molding. Figure 5 dispatched the mean density of cement blocks decrease with GSA as well as drying day increases. However, entire cement blocks have mean density above 2400 kg.m^{-3} which is the normal minimum standard weight of the cement blocks [15,18]. This effect might be due to the absorption of mixing water by the GSA as well as the occupied pores in the block. However, the major dominant fact is the bulk density of the cement (1356.55 kg.m^{-3}) [19] and river sand (1655.5 kg.m^{-3}) [5,20,21] are superior to that of the GSA (254.55 - 678 kg.m^{-3}) [4,5,22]. Moreover, the above mention effect evident that the density decreases with increases the drying days which implies that the materials are highly bind and consists few voids and pores.

Mean water absorption of the GSA merged cement block

Water absorption of the cement block increases with increase GSA merging ratio but decreases with increase curing days as described in figure 6. This behaviour may be due to the existence of; (i). phosphorous (v) oxide in GSA that is an effective drying and dehydrating agent [16], (ii). formation of high denser bonds between the materials due to more curing days or (iii). presence of less pores and voids which reduces the capillary rise in the blocks. Water absorption is a main basics property which will affect the density, compressive and flexural strength and the other engineering properties of the block. However, the entire block has the absorption property below the optimal standard limit. Thus, these blocks well suit for loading and non-loading building construction works.

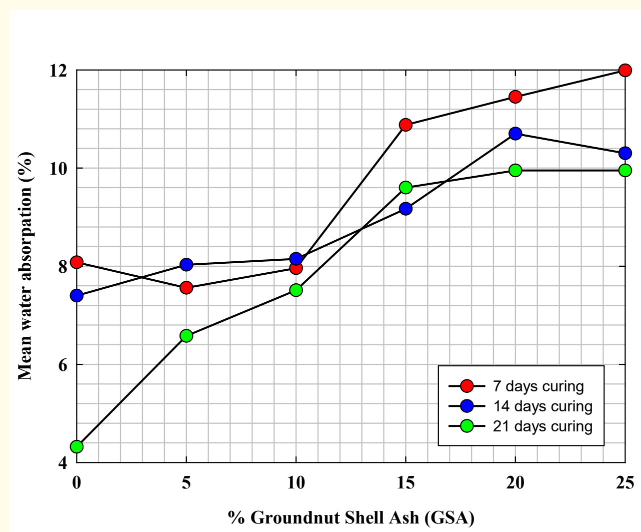

Figure 6: Mean water absorption of the cement block as a function of groundnut shell ash.

Mean compressive strength of the GSA added cement block

Figure 7 describe that compressive strength increases with increasing the curing days and decreases as the merging of GSA increases. This behavior is due to hydration of cement with the GSA and possesses modest cementing gel binder compared to a Portland cement. This nature produces early strength improvement in the highest rate. At 0% GSA served as the control block has compressive strength of 0.85 N.mm^{-2} at 7 days, 1.05 N.mm^{-2} at 14 days and 1.18 N.mm^{-2} at 21 days. The compressive strength increment is about 72.03% from 7 days to 21 days. Moreover, the ccompressive strength of 10% GSA increased from 1.18 $N.mm^{-2}$ to 1.77 $N.mm^{-2}$ at 7 to 21 curing days respectively that is about 66.66% increment. GSA > 10%, the compressive strength decreases sharply with GSA increasing merging, but increases with the curing days. However, the values are lower than the control and the 10% GSA block.

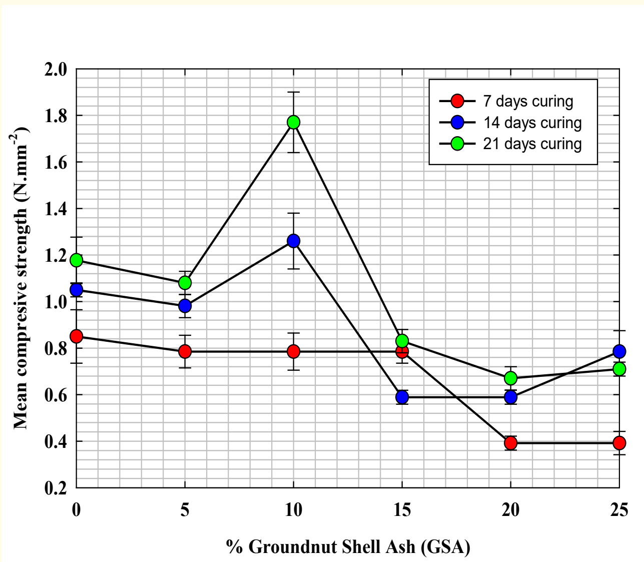

Figure 7: Mean compressive strength of the cement block as a function of groundnut shell ash.

Conclusion

As per the SLS 107: Part 2:2008 [26] the minimum optimal strength of the cement sand block is 2.5 $N.mm^{-2}$. According to SLS 855: Part 1:1999, the required minimum strength of the cement sand block is 1.2 $N.mm^{-2}$ and 2.5 $N.mm^{-2}$ for a single and double floor building respectively [27]. Based on the SLS standards and the result obtained from this study, shows that 10% GSA merged cement block is suitable for any construction works. According to the FAO [23] report, cement mixed with pozzolanas materials would fabricate 65 to 95% strength of OPC cement blocks in 28 days. Also, they stated that their compressive strength usually improves with days of curing since pozzolanas materials react more slowly than the OPC due to various compositions and could be obtained the same strength after one year. Sideris and Sarva, [24] and Sengul., *et al.* [25] were investigated and confirmed this behaviour. They stated that the merging of OPC by a pozzolanic material normally has positive effects on cement's durability for 1.5 years [24]. Also, the sand: OPC-GSA ratio 1:6 cement blocks are the most economical and have the compressive strength above the standards. Hence, from the result and literature, it can be concluded that 10% GSA merged blocks are most suitable for any construction.

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