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Research Article

Compressive strength of sandcrete blocks produced with spear grass ash as a partial replacement for cement

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Abstract

This work investigated the compressive strength of sandcrete hollow blocks produced with Spear Grass Ash (SGA) as a partial replacement for cement in sandcrete hollow block production. A total number of 18 sandcrete blocks were produced with a single mix ratio of 1:6 (cement: sand) using a standard mould of 450mm x 225mm x 225mm having two hollow size of 131mm x 154.5mm x 225mm. The river sand used has a fineness modulus value of 2.93 and an average bulk density of 1510.31kg/m^3. The percentage replacement of SGA with cement was varied from 10% to 50%. The sandcrete blocks produced were cured and tested for their 28-day compressive strength. The test result shows that the compressive strength value at 30% replacement of SGA with cement gave a highest value of 3.63N/mm^2. It was observed that after 30% replacement of cement with SGA, a rapid reduction in the compressive strength of the sandcrete block was observed.

Keywords: Sandcrete Block, River Sand, Spear Grass Ash (SGA), Compressive Strength

INTRODUCTION

In recent years, growing consciousness about global environment which has led to the increasing conversion of waste products to useful products has given rise to the use of these waste in civil engineering construction. The use of these waste products in civil engineering construction has gained considerable attention in view of the shortage and high costs of suitable conventional binding material (i.e. cement), and the increasing costs of waste disposal and environmental constraints. Due to current boom in the construction industry, cement demand has escalated which is the main constituent in concrete production. Also, the cement industry is one of the primary sources which release large amounts of major consumer of natural resources like aggregates and has high power and energy demand for its operation. The production of cement emits huge amount of CO_2 into the atmosphere that contributes to the greenhouse effect and the global warming of the planet. Use of supplementary cementing materials has become an integral part of high strength and high performance concrete mix design. These can be natural materials, by-products or industrial wastes, or the one requiring less energy and time to produce. Some of the commonly used supplementary cementing materials are fly ash, Silica Fume, Ground Granulated Blast Furnace Slag and Rice Husk Ash etc. Selection of suitable materials are important for the overall economy and safety of our environment. Initially the use of locally available material was in general practice. However, now-a-days due to heavy construction, it is required to transport superior material from one place to another. Use of waste materials coming from the industry and agricultural works are environmentally friendly and economical. Best way for the management of the solid waste is to reuse it in different application without changing the form of the waste. In Civil Engineering, construction there is potential to use such waste in bulk. This calls for the use of sustainable binders to reduce the quantity of cement used and one of such promising material can be grass ash. On an average, burning of grass produces 8–10% of ash by the weight of grass burnt and its composition can be highly variable depending on type of grass and method of burning. The most prevailing method for disposal of the ash is land filling and rest being either used as soil supplements. The characteristics of the ash depend upon biomass characteristics, combustion technology and the location where the ash is collected. The use of pozzolanas as alternatives for the commonly used Portland cement have been introduced in the last few decades either for cost reduction, performance, durability or environmental reasons. Grass can be burnt into ash that fulfils the physical characteristics and chemical composition of mineral admixtures. Pozzolanic activity of grass ash depends on (i) silica content, (ii) silica crystallization phase, and (iii) size and surface area of ash particles. In addition, ash must contain only a small amount of carbon. Suitable incinerator/furnace as well as grinding method is required for burning and grinding grass in order to obtain good quality ash. In this research, three methods of grass combustion were used based on combustion temperatures and burning periods. The produced ash was ground to ensure that it meets the requirements of BS 3892 standard. As grass ash primarily consists of fine particulate which can easily get air borne by winds, it is a potential hazard as it may cause respiratory health problems to the dwellers near the dumpsite or can cause groundwater contamination by leaching toxic elements in the water. As the disposal cost of the ashes is rising and volume of ashes is increasing, a sustainable ash management, which integrate the ash within the natural cycles, needs to be employed. So, utilization of such by products and agricultural waste ashes solves a twofold problem of their disposal as well providing a viable alternative for cement substitutes in sandcrete blocks production. Hence, incorporating the usage of grass ash as replacement for cement in blended cement is beneficial from the environmental point of view as well as producing low cost construction entity, which has brought about this research titled "The Compressive Strength of Sandcrete Block Produced with Spear Grass Ash as a Partial Replacement for Cement".

Objectives of Study

The main objective of this work is to perform an experimental investigation on the compressive strength of sandcrete block produced with Spear Grass Ash (SGA) as a partial replacement for cement. While the specific objectives are:

a. To characterize the constituent materials used in the production of the sandcrete block.
b. To mould, cure and crush the sandcrete block produced with SGA as partial replacement for cement.
c. To verify the optimum percentage of SGA in sandcrete block.
d. To make recommendations

MATERIALS AND METHOD

Materials

The materials used in this research work includes; cement, river sand, water and spear grass ash (GSA) gotten from a farmland as grass, then the grass was burnt in a controlled temperature until a uniform ash was gotten.

Methods

In carrying out this research work, various tests were conducted and they include;

a) Sieve analysis
b) Chemical composition and physical test on the spear grass ash
c) Bulk density
d) Compressive strength

Sieve Analysis

The sieving method adopted was dry sieving and a sample size of about 400g was used for the river sand. This test was carried out on the aggregate to determine the particle size distribution. This test was done in the laboratory using sieve size of different diameter and were stacked according to the size of sieve, that is, the largest ones on top while the smaller at the bottom. The equipment used in carrying out this test are; sieves of different diameter, a scoop which was used to collect the sample, a weighing balance which was used to determine the mass of the aggregate and a brush which was used to remove dirt from the sieve. Sieving was done mechanically using a sieve shaker.

Laboratory Test on Spear Grass Ash

Physical and chemical analyses were conducted on the spear grass ash to determine its physical and chemical compositions in order to ascertain its suitability as a material for sandcrete block production.

Bulk Density Test

Bulk density gives valuable information regarding the shape and grading of the aggregate. It refers to the mass of material per unit volume, including the voids between the particles. The dry method was adopted for the determination of the bulk densities of river sand, cement and spear grass ash (SGA), this test was carried out in accordance with BS 812: Part 2 and Part 1 07, (1990 and 1995). The net weight of the aggregate in the container was determined and the bulk density was calculated in kg/m^3.

Calculations/Materials proportioning by Weight

The constituent materials used in the production of the sandcrete block are calculated in terms of weight. All the materials are weighed using a weighing balance. The 225mm x 225mm x 450mm for hollow block of 40% void was used.

i. Type of Hollow Block, 225mm x 225mm x 450mm.

ii.

Volume for a full mould: 225 x 225 x 450 = $\frac{22781250\ mm^3}{10^9}$ = 0.02278125m^3

Volume of the void: (131 x 154.5 x 225) x 2 = $\frac{9107775\ mm^3}{10^9}$ = 0.009107775m^3

Therefore, volume of the full mould minus the void, 0.02278125 - 0.009107775 = 0.013673475m^3

iii. Density of sandcrete block, the density of sandcrete/concrete blocks is largely a function of the aggregate density, size and grading, degree of compaction or aeration and the block form. The typical range for dry density is 500 to 2200kg/m^3 with aerated and solid dense aggregate concrete blocks being on the lighter and heavier end of the scale respectively and light weight and dense aggregate concrete blocks of cellular and hollow form falling in the middle of the range or sole. Therefore, density = 1860kg/m^3

Density = $\frac{\text{Mass}}{\text{Volume}}$

Therefore, Mass = Density x Volume
Mass = 0.013673475 x 1860 = 25.4326635kg
Including a 10% waste, the weight of a mould would be 25.4326635 X 1.1 = 27.98kg
Take weight = 28kg.

The water-cement ratio and cement-sand ratio are kept constant while the percentage replacement of SGA with cement is varied, and mass of the constituents is shown in the Table 1 below.

Table 1. Mix Proportions for 225mm x 225mm x 450mm sandcrete block for compressive strength test

Mix N$_o$	% Replacement	Water (kg)	Cement (kg)	Sand (kg)	SGA (kg)
M$_0$	0	2.0	4.0	24	0
M$_{10}$	10	2.0	3.6	24	0.4
M$_{20}$	20	2.0	3.2	24	0.8
M$_{30}$	30	2.0	2.8	24	1.2
M$_{40}$	40	2.0	2.4	24	1.6
M$_{50}$	50	2.0	2.0	24	2.0

Production of Sandcrete Specimen

1. The floor surface was cleaned, wetted and dried to prevent loss of the water cement ratio and prevent excess water being added into the mix. Batching of the materials was done by weight using a weighing balance of 50kg

capacity. The inside surface of the mould were coated lightly with medium viscosity oil and then placed on a clean, level and firm surface. The mould is made of metal.

2. Mixing of the constituents was done manually using shovels. The production process involved collection of sand which was left to dry, the sand which had been previously completely dried were mixed to a constant colour with cement and SGA. Water was finally added and the mixing continued until the colour of the paste was uniform. The mixture was then loaded into the moulds it was compacted manually and demoulded immediately.

3. 18 blocks were made, each mix had 3 specimens. Each block was inscribed for identification.

4. All the blocks were cured under shade, for twenty-eight days by sprinkling them with water obtained from the laboratory daily.

Compressive strength

The blocks were crushed after twenty-eight days of curing using electrical Universal Testing Machine (UTM). The machine has a testing range of 0KN – 1000KN. The blocks were placed in between two steel plates and the plates are wide enough as to cover the top and bottom of the blocks. The switch of the machine was turned on, then force was applied to the block until the block fails in compression. The strengths of the blocks were determined using equation 1. Four samples each were tested for a particular mix number and the average value taken as the compressive strength for the mix.

$$\text{Compressive strength} = \frac{\text{crushing load}}{\text{cross sectional area}} \qquad (1)$$

Results and Analysis

Sieve analysis results

The results of sieve analysis test for river sand is presented in Tables 2. The gradation chart for the river sand is shown in Figure 1

Table 2. Grain size distribution of river sand

Sieve size (mm)	Mass of empty sieve(g)	Mass of sieve + soil (g)	Mass of soil retained (g)	Cumulative mass of soil retained (g)	Cumulative % passing	Cumulative % retained
4.75	373.29	382.13	8.84	8.84	99.47	0.53
2.36	353.09	443.71	90.62	99.46	94.04	5.96
1.18	398.21	896.28	498.07	597.53	64.17	35.83
0.60	372.63	880.22	507.59	1105.12	33.73	66.27
0.30	318.27	738.92	420.65	1525.77	8.50	91.50
0.15	298.38	325.56	27.18	1552.95	6.87	93.13
0.075	311.1	312.84	1.74	1554.69	0.10	
Pan	273.02	274.65	1.63	1556.32		
Fineness modulus = 293.24/100 = 2.93						∑ = 293.24

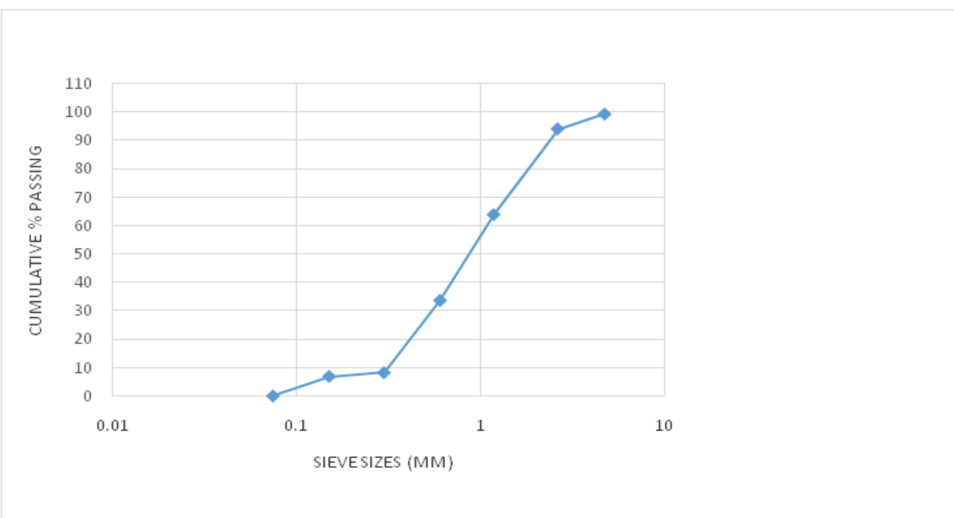

Figure 1. Gradation curve for river sand and quarry dust

From the Fig 1, the values of D_{10}, D_{30}, and D_{60} for river sand are gotten and computed to get values for Coefficient of uniformity, (C_u) and Coefficient of gradation, (C_c)

D_{10} = 0.32
D_{30} = 0.55
D_{60} = 1.2

$$\text{Coefficient of uniformity, Cu} = \frac{D60}{D10} = 2.I8$$

$$\text{Coefficient of gradation, Cc} = \frac{(D30)^2}{(D60 \times D10)} = 0.99$$

Bulk Density

The results of the bulk density test of river sand is presented in Table 3.

Table 3. Bulk density of river sand

Trial run	Trial 1	Trail 2	Trial 3
Mass (kg)	6.35	6.34	6.34
Volume of bottle (m^3)	0.0042	0.0042	0.0042
Bulk density (kg/m^3)	1511.90	1509.52	1509.52
Average bulk density (kg/m^3)		1510.31	

Chemical and Physical test result on water treatment plant sludge

The chemical and physical properties of water treatment plant sludge are given in Table 4

Table 4. Test result of water treatment sludge

Chemical property	
Element	**Result (%)**
Silicon oxide, (SiO_2)	73.42
Aluminium oxide, (Al_2O_3)	10.22
Iron oxides, (Fe_2O_3)	1.57
Calcium oxide, (CaO)	5.35
Magnesium oxide, (MgO)	1.05
Sodium oxide, (Na_2O)	0.2
Potassium oxide, (K_2O)	2.82
Sulphates, (SO_3)	0.27
Phosphorus pentoxide (P_2O_5)	7.22
Physical property	
Property	**Value**
Bulk density	1055kg/m^3
Specific gravity	2.05

Compressive Strength Test Results

The compressive strength of the sandcrete blocks are as presented in Table 5 and Figure 2

Table 5. Twenty eight (28) day compressive strength test result on the Sandcrete block

water-Cement Ratio	Block No.	Mass (Kg)	Density (Kg/m^3)	Av. Density (Kg/m^3)	Failure Load (KN)	Comp. Strength (N/mm^2)	Av. Comp. Strength (N/mm^2)
	$M0_1$	28.80	2106.27		218	3.58	
0.50	$M0_2$	28.65	2095.30	2092.86	214	3.51	3.51
	$M0_3$	28.40	2077.01		210	3.45	
	$M10_1$	27.80	2033.14		214	3.51	
0.50	$M10_2$	28.05	2051.42	2046.55	220	3.61	3.55
	$M10_3$	28.10	2055.08		216	3.55	

Continuation of Table 5

	$M20_1$	27.72	2027.28		218	3.58	
0.5	$M20_2$	27.50	2011.20	2020.22	222	3.64	3.60
	$M20_3$	27.65	2022.17		218	3.58	
	$M30_1$	26.92	1968.78		220	3.61	
0.5	$M30_2$	27.06	1979.02	1976.58	224	3.68	3.63
	$M30_3$	27.10	1981.94		220	3.61	
	$M40_1$	26.55	1941.72		215	3.53	
0.5	$M40_2$	27.15	1985.60	1962.44	218	3.58	3.54
	$M40_3$	26.80	1960.00		215	3.53	
	$M50_1$	26.55	1941.72		195	3.20	
	$M50_2$	26.05	1905.15	1942.94	202	3.32	3.21
	$M50_3$	27.10	1981.94		190	3.12	

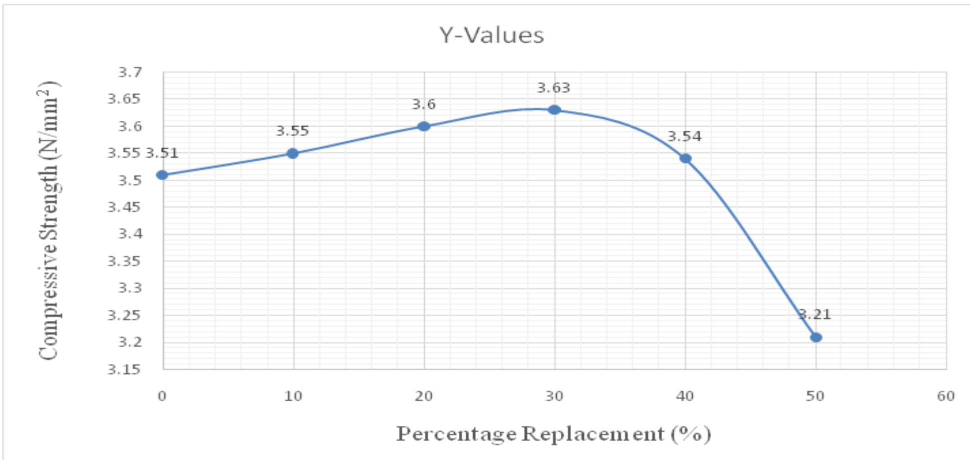

Figure 2. Line chart of the average compressive strengths

Analysis of Sieve analysis results

Results of sieve analysis show that both the river sand fall within Zone II of the grading of fine aggregates as given in BS-882, (1992). From Tables 4.1 the fineness modulus of river sand is 2.93 and this fall within the allowable range of 2.3 – 3.1, for fine aggregates in concrete work (ACI E701, 2007).

The coefficient of uniformity (C_u) and coefficient of gradation (C_c) for river sand were calculated as 2.18 and 0.99 respectively. This result shows that the river sand is almost uniformly graded as stated in BS-882, (1992).

Analysis of Bulk Density Test Results

The values for bulk density of river sand shown in table 5 are within the range for the respective materials. The values for the bulk densities for river sand was found to be 1510kg/m^3 and this value can be compared favourably with the values in the exiting literatures. Values of the bulk density of the materials obtained may vary, however, owing to the nature and properties of the parent materials.

Analysis of Water Treatment Sludge Test Result

From table 5, the result of the chemical properties of the sludge gotten from a water treatment plant shows similar properties with one of the known pozzolan (fly ash) shown in table 2.1, so sludge from a water treatment plant could be considered to be used as a constituent of sandcrete and concrete.

Analysis of Compressive Strength Results

Table 5 presents the results of the compressive strength test carried out on the sandcrete blocks. Blocks produced with SGA as partial replacement to cement for a mix ratio of 1:6. It was observed that the compressive strength increases as the percentage replacement increases up to 30%, then a reduction was observed from 40% down to 50% replacement.

From figure 2, it can be seen that the compressive strength value of sandcrete block produced with SGA as partial replacement for sand gave an optimum compressive strength values of 3.63N/mm^2 at a 30% partial replacement of cement

CONCLUSION

The main objectives of this work were to investigate the compressive strength of sandcrete hollow blocks produced with SGA as partial replacement for cement. From the results obtained after several laboratory test carried out, as well as the analysis, the following conclusion were arrived at;

a) Sandcrete blocks made with SGA as partial replacement for cement gives its best compressive strength result at 30% replacement with a value of 3.63N/mm^2

b) As the percentage of replacement of SGA is increased, the compressive strength increases up to 30% replacement, after which the compressive strength reduces as the percentage replacement increases to 40% and 50%.

Recommendations

After a successful completion of this project work, the following recommendations are made:

a) A 30% replacement of SGA with a cement in the production of sandcrete blocks.

b) Further research should be done in producing sandcrete blocks with other fine aggregate material to experiment its effects.

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