A. A. Raheem and O. K. Sulaiman / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 3, Issue 4, Jul-Aug 2013, pp.713-721

Saw Dust Ash as Partial Replacement for Cement in the Production of Sandcrete Hollow Blocks

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Abstract

This study investigates the use of Saw Dust Ash (SDA) as partial replacement for ordinary Portland cement (OPC) in sandcrete blocks. Some units of sandcrete hollow blocks were produced by partially replacing the cement content with 5% to 25% by weight of SDA, using vibrating block moulding machine. Sandcrete blocks without SDA serve as the control. The blocks produced were tested to determine their density, compressive strength and water absorption rate. The results indicated that compressive strength of sandcrete hollow blocks at 28 days are 2.16N/mm^2, 1.94N/mm^2, 1.64N/mm^2, 1.59N/mm^2,1.39N/mm^2, and 1.25N/mm^2 for Control, 5%, 10%, 15%, 20% and 25% SDA contents respectively. At 56 days, the compressive strength of blocks with 5% and 10% SDA replacement are 2.33N/mm^2 and 2.04N/mm^2 respectively, both of which surpassed the required standard of 2.00N/mm^2 specified by the National Building Code (2006) for non-load bearing walls. It was concluded that only sandcrete blocks with up to 10% SDA replacement can be used for non-load bearing walls.

1. Introduction

The basic necessity of man after food and water is shelter. One of the major components of any kind of shelter is its walling material. Walling material is of different types, the commonest in Nigeria is sandcrete hollow blocks. Seeley (1993) defines sandcrete blocks as walling material that is made of coarse natural sand or crushed rock dust mixed with cement in certain proportion and water, and moderately compacted into shapes. On moulding, they set, harden and attain adequate strength to be used as walling materials. The quality of sandcrete blocks is a function of the method employed in the production and the properties of the constituent materials (Raheem *et al*., 2012). Sandcrete blocks are available for the construction of load bearing and non-load bearing structures.

The materials used for production of sandcrete hollow blocks are cement, sand and water. Cement is widely noted to be the most expensive out of these materials. It could be asserted that both the limited raw materials and the industrial processes undergone by cement during the manufacturing stages may have accounted for its high cost. Thus, reduction in the cost of cement will definitely reduce the cost of production of sandcrete hollow blocks and ultimately that of the building.

In order to reduce the price of cement to be consumed in mortar, sandcrete hollow blocks and concrete production, the search for an alternative binder or partial cement replacement has led to the use of industrial and agricultural waste materials believed to have the potentials of exhibiting cementitious properties. These materials are known as pozzolanic materials. Previous studies on pozzolans include the use of corn cob ash (Adesanya and Raheem, 2009, 2010), bamboo leaf ash (Dwivedi *et al*., 2006), saw dust ash (Elinwa and Ejeh, 2004; Okunade, 2008; Raheem *et al.* 2012), bagasse ash (Chusilp *et al*., 2009) to partially replaced cement in concrete or mortar. In this research, saw dust ash was used to partially replace ordinary Portland cement in the production of sandcrete hollow blocks.

2. Materials and Method

The materials and method employed in the production and testing of the SDA sandcrete blocks are discussed below.

2.1 Materials

The saw dust used for this study was collected manually from sawmill along Ife – Ondo road, Ile-Ife, Osun State, Nigeria. Samples were carefully collected to avoid mixing with sand by collecting the newly produced ones with shovel and packing into sand bags. The saw dust collected was sun dried for 10 days to aid the burning process. The saw dust samples collected were burnt into ashes by open burning at temperature of 600^{o}C in a drum. The ash was then ground after cooling and the fineness and specific gravity determined.

The fine aggregates (sharp sand) with maximum size of 2.8mm, free of clay, loam, dirt and any organic or chemical matter, was used for this study, and this was obtained from a local supplier. The cement used for this study is ordinary Portland cement (OPC) from the West African Portland Cement Company, Ogun State, Nigeria with properties conforming to BS 12 (British Standards Institution, 1996). Fresh, colourless, odourless and tasteless potable water that is free from organic matter of any kind was used for mixing. It was obtained from deep well.

2.2 Chemical Composition of Saw Dust Ash (SDA)

The Chemical analysis of SDA to determine its Pozzolanicity was carried out in the laboratory of Lafarge Cement (WAPCO) Nigeria Plc, Sagamu Works, Ogun State, Nigeria.

2.3 Grading of Fine aggregates

The sieve analysis of fine aggregates was carried out as specified in BS 882:1992 using sieve sizes of 5.0mm. 2.8mm, 2mm, 1mm, 710um, 425um, 250um, 125um and 75um.

2.4 Production of Sandcrete Hollow Blocks

The blocks were manufactured with the use of a vibrating block moulding machine with single 6" (450mm x 225mm x 150mm) mould. A mix proportion of 1:12 cement-sand ratio; was used. The block has one-third of the volume void so as to produce the type of hollow sandcrete blocks commonly used for construction of buildings in Nigeria. Five levels of cement substitution with SDA (that is, 5, 10, 15, 20 and 25%) by volume were used. Hand mixing was employed and the materials were turned over a number of times until a homogeneous mix with uniform colour and consistency was attained. Water was added in sufficient quantity to ensure workability of the mixture. The water was judged to be sufficient when a quantity of the mixture pressed between the palms caked without bringing out water (Raheem, 2006). The composite mixture was then introduce into the mould in the block moulding machine and the block was vibrated for one minute to ensure adequate compaction as practiced by Raheem (2006). The green block on wooden pallet was removed from the block moulding machine and placed on the ground for curing. Water was sprinkled on the blocks, at least twice a day for proper curing for fifty six days.

2.5 Testing of the Blocks

The density, compressive strength and water absorption of the blocks produced were determined. The density of a block was determined by dividing the weight of the block prior to crushing, with the net volume. The density value was the average of three specimens.

Compressive strength test was carried out to determine the load bearing capacity of the blocks. The blocks that have attained the ripe ages for compressive strength test of 3, 7, 14, 21, 28, and 56 days was taken from the curing or stacking area to the laboratory, two hours before conducting the test, to normalize the temperature and to make the block relatively dry or free from moisture. The weight of each block was taken before being placed on the compression testing machine in between metal plates. The blocks were crushed and their corresponding failure loads were recorded. The crushing force was divided by the gross sectional area of the block to give the compressive strength. The strength value was the average of three specimens.

Water absorption was performed on the sandcrete blocks after curing for 28 days. Three samples per SDA content were removed from the curing area and sun dried until there is no further loss in their dry weights. The samples were then immersed in water for 24hours and allowed to drain for 10 minutes before taking their wet weights. The difference in weight is used to calculate the percentage water absorbed for each block as follows:

$$W_a = \frac{W_s - W_d}{W_d} \times 100 \quad \ldots\ldots\ldots\ldots\ldots 2.1$$

Where:

W_a = W

W_s = Weight of wet block

W_d = Weight of dried block

3. Results and Discussion

The results obtained from the various tests performed are discussed in the following sections.

3.1 Chemical Composition of SDA

The Chemical composition of Saw Dust Ash (SDA) is shown in Table 1. The average percentage composition of SiO_2 + Al_2O_3 + Fe_2O_3 is 74.89%. This satisfies the minimum percentage requirement for pozzolanas which is 70% according to ASTM C 618 (1994). As reported by Jerath and Hanson (2007), SDA falls under the category of Class F fly ash since the sum of (SiO_2 +Al_2O_3 +Fe_2O_3) is greater than 70%.

3.2 Sieve Analysis of Fine Aggregates

Figure 1 showed the grading of sharp sand used in the production of sandcrete blocks.

It could be observed from the figure that the coefficient of uniformity (Cu) and coefficient of curvature (Cc) for the sharp sand are 2.50 and 0.76 respectively. Thus, the sand can be said to be well graded. The sharp sand meet the British Standard requirements for fine aggregates under the fine grading zone as specified in BS 882:1992 and therefore suitable for use in the production of sandcrete block.

3.3 Density

The Density results are indicated in Tables 2 to Table 7. Generally, the tables indicate decrease in density with increase in percentage of SDA substitution. For all cases considered, the minimum density obtained was 1693.58kg/m^3 at 56days. This is above the minimum value of 1500kg/m^3 recommended for first grade sandcrete blocks by NIS 087, (2000).

Table 1: Chemical Composition of Saw Dust Ash

Chemical constituents	Percentage Composition (%)			
	Sample 1	**Sample 2**	**Sample 3**	**Average**
SiO_2	66.74	64.93	64.25	65.31
Al_2O_3	5.67	6.27	6.34	6.09
Fe_2O_3	3.39	4.02	3.05	3.49
CaO	1.85	4.52	6.27	4.21
MgO	3.72	3.33	3.11	3.39
SO_3	2.54	2.92	3.21	2.89
K_2O	12.67	9.92	10.67	11.09
Na_2O	0.92	1.11	0.98	1.00
PK_2	2.50	2.98	2.12	2.53
Total SiO_2+ Al_2O_3+Fe_2O_3	75.80	75.22	73.64	74.89

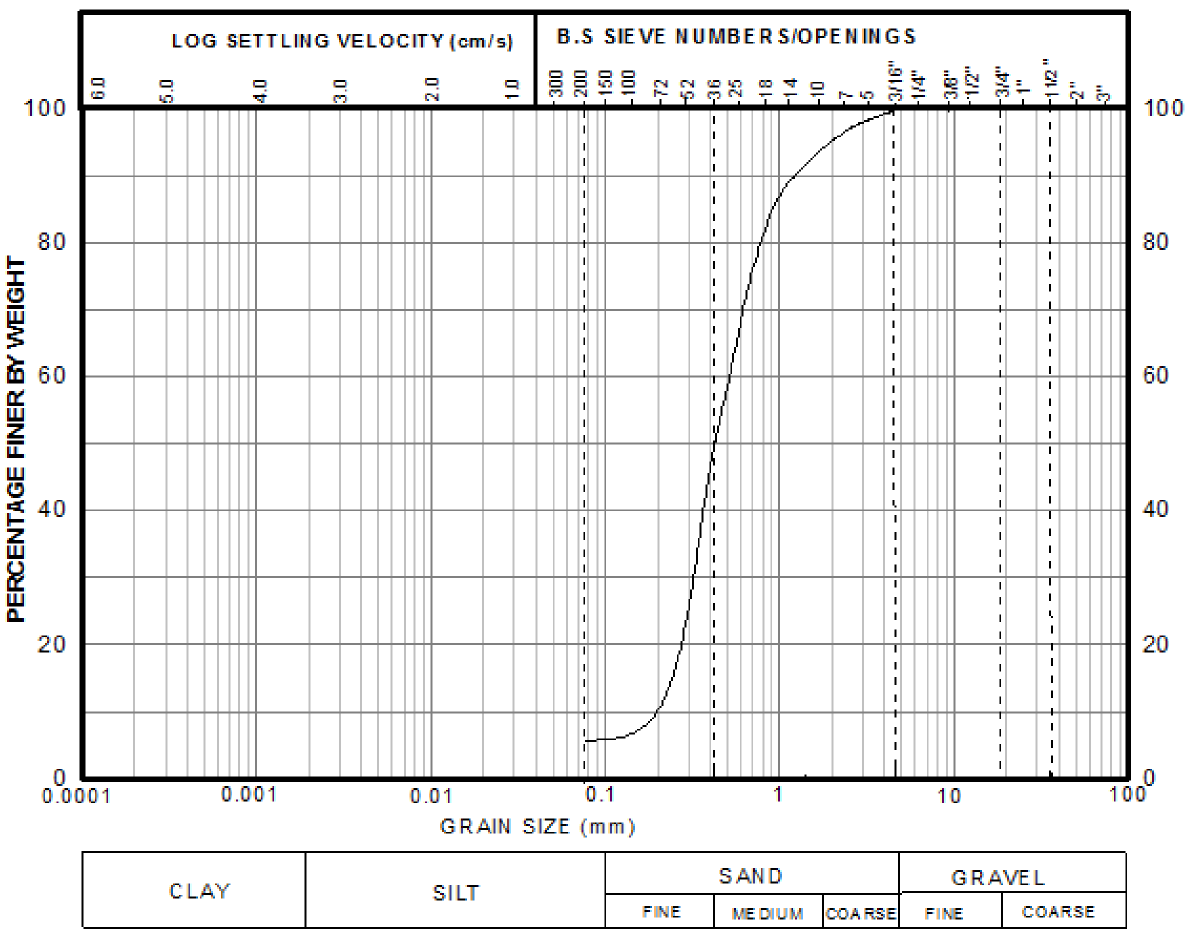

Figure 1: The grading curve for the sharp sand used as fine aggregates

Table 2 showed the results of sandcrete hollow blocks without SDA. The density ranges from 1848.77kg/m^3 to 2930.20kg/m^3. These values are slightly lower than those of Raheem (2006) which range from 2073.5 kg/m^3 to 2166.3 kg/m^3. This may be due to differences in the physical properties of the sand used which depend on the source. However, the values were above the minimum value of 1500kg/m^3 recommended for first grade sandcrete blocks by NIS 087, (2000).

For 5% SDA replacement as shown on Table 3, it was observed that there was decrease in density as the curing age increases. The density obtained for the blocks ranges from 1845.08 kg/m3 to 3047.21 kg/m^3. The densities were lower than that of the control but above the minimum value of 1500kg/m^3 recommended for first grade sandcrete blocks by NIS 087, (2000).

Table 4 showed the density of sandcrete hollow blocks with 10% SDA. There was decrease in density as the curing age increases. The density obtained for the blocks ranges from 1809.36 kg/m^3 to 3061.99 kg/m^3. The densities were lower than those of control and 5% SDA content, but above the minimum value of 1500kg/m^3 recommended for first grade sandcrete blocks by NIS 087, (2000). The variation could be because of percentage substitution of SDA for OPC.

For 15% SDA replacement as shown on Table 5, the density obtained for the blocks ranges from 1781.03 kg/m^3 to 3100.17kg/m^3. The densities were lower than those of the control, 5% SDA, and 10% SDA content, but above the minimum value of 1500kg/m^3 recommended for first grade sandcrete blocks by NIS 087, (2000).

Table 6 showed the density of sandcrete hollow blocks with 20% SDA content. Like the observations from previous results, there was decrease in density with increase in curing age. The density obtained for the blocks ranges from 1809.36kg/m^3 to 2883.40kg/m^3. The densities were lower than those of control, 5%, 10% and 15% SDA contents but above the minimum value of 1500kg/m^3 recommended for first grade sandcrete blocks by NIS 087, (2000).

The density results for 25% SDA replacement as shown in Table 7 followed the same trend with decrease in density as curing age increases. The density obtained for the blocks ranges from 1693.58kg/m^3 to 3544.82kg/m^3. The densities were lower than that of the control, 5%, 10%, 15% and 20% SDA contents but above the minimum value of 1500kg/m^3 recommended for first grade sandcrete blocks by NIS 087, (2000).

Table 2: Density of Sandcrete Hollow Blocks without SDA (Control)

Age of block (Days)	Weight (kg)			Average Weight (kg)	Density (kg/m^3)
	Sample1	Sample 2	Sample 3		
3	23.35	24.55	23.47	23.79	2930.20
7	17.23	16.98	17.37	17.19	2139.45
14	16.29	16.205	15.95	16.148	1988.94
21	16.11	16.225	16.30	16.212	1996.82
28	15.813	16.413	15.813	16.013	1972.31
56	14.99	14.93	15.11	15.01	1848.77

Table 3: Density of Sandcrete Hollow Blocks with 5% SDA

Age of block (Days)	Weight (kg) Sample1	Sample 2	Sample 3	Average Weight (kg)	Density (kg/m^3)
3	26.55	23.05	24.62	24.74	3047.21
7	17.60	16.59	16.84	17.01	2106.20
14	17.01	15.15	16.20	16.12	1985.49
21	15.83	15.78	16.45	16.02	1973.17
28	15.40	15.81	16.76	15.99	1969.48
56	15.11	14.77	15.06	14.98	1845.08

Table 4: Density of Sandcrete Hollow Blocks with 10% SDA

Age of block (Days)	Weight (kg) Sample1	Sample 2	Sample 3	Average Weight (kg)	Density (kg/m^3)
3	24.99	24.55	25.04	24.86	3061.99
7	17.29	16.68	16.64	16.87	2077.87
14	15.82	16.45	16.52	16.26	2003.23
21	16.32	15.39	16.75	16.15	1989.56
28	15.95	15.54	15.70	15.73	1937.46
56	14.87	14.78	14.42	14.69	1809.36

Table 5: Density of Sandcrete Hollow Blocks with 15% SDA

Age of block (Days)	Weight (kg) Sample1	Sample 2	Sample 3	Average Weight (kg)	Density (kg/m^3)
3	25.30	25.95	24.26	25.17	3100.17
7	17.21	17.01	16.89	17.04	2098.81
14	15.92	15.42	15.81	15.72	1935.73
21	16.11	15.25	15.21	16.230	1999.04
28	15.66	15.66	16.57	15.967	1966.65
56	15.11	14.07	14.20	14.46	1781.03

Table 6: Density of Sandcrete Hollow Blocks with 20% SDA

Age of block (Days)	Weight (kg)			Average Weight kg)	Density (kg/m^3)
	Sample1	Sample 2	Sample 3		
3	23.10	26.54	24.32	24.65	3036.13
7	17.08	16.72	16.56	16.79	2068.01
14	15.75	16.210	16.32	16.09	1982.17
21	16.25	16.10	15.38	15.91	1959.63
28	15.51	16.63	16.01	16.05	1976.99
56	14.00	14.59	14.04	14.21	1750.24

Table 7: Density of Sandcrete Hollow Blocks with 25% SDA

Age of block (Days)	Weight (kg)			Average Weight (kg)	Density (kg/m^3)
	Sample1	Sample 2	Sample 3		
3	28.94	29.67	27.72	28.78	3544.82
7	16.03	16.53	16.24	16.27	2003.97
14	15.41	16.25	15.33	15.66	1929.08
21	15.87	16.15	15.75	15.92	1961.23
28	16.67	15.48	15.66	15.94	1962.95
56	13.97	13.87	13.41	13.75	1693.58

3.4 Compressive Strength

The compressive strength results of sandcrete hollow blocks are presented in Figure 2. The compressive strength of sandcrete blocks made with 100% OPC (the control) ranges from 1.20 N/mm^2 to 2.74 N/mm^2 from 3 to 56 days. The compressive strength obtained at 28days is higher than those of commercially produced sandcrete blocks in Ogbomoso township which has compressive strength ranging from 0.53 - 1.59 N/mm^2 as obtained by Raheem (2006). Also, at 28 days hydration period, sandcrete blocks made with 100% OPC gives a value of 2.16N/mm^2 which met the minimum required standard of 2.0N/mm^2 specified by the Nigeria National Building Code (2006) for non-load bearing walls.

The results obtained for sandcrete blocks with 5% SDA content as shown in Figure 2 indicated that the compressive strength ranges from 0.78 N/mm^2 to 2.33 N/mm^2 from 3 to 56 days. When compared with commercial sandcrete blocks produced in Ogbomoso township with compressive strength ranging from 0.53 - 1.59 N/mm^2 as obtained by Raheem (2006), blocks with 5% SDA content gave higher values of compressive strength. At 56 days, the compressive strength is 2.33N/mm^2 which met the minimum required standard of 2.0N/mm^2 specified by the Nigerian National Building Code (2006) for non-load bearing walls.

The compressive strength obtained for blocks with 10% SDA content ranges from
0.65 N/mm^2 to 2.04 N/mm^2 from 3 to 56 days. These values compare favourably with those of commercial sandcrete blocks produced in Ogbomoso township with compressive strength ranging from 0.53-1.59 N/mm^2 as obtained by Raheem (2006). The compressive strength at 56days is 2.04 N/mm^2, which met the minimum required standard of 2.0N/mm^2 by the Nigerian National Building Code (2006) for non-load bearing walls.

The results for 15%, 20% and 25% SDA contents followed a similar pattern with compressive strengths ranging from 0.51 – 1.85 N/mm^2, 0.46 - 1.81 N/mm^2 and 0.37 - 1.68 N/mm^2 from 3 to 56 days respectively. These results did not meet the required minimum standard of 2.0N/mm^2 as specified by the Nigerian National Building Code (2006) for non-load bearing walls.

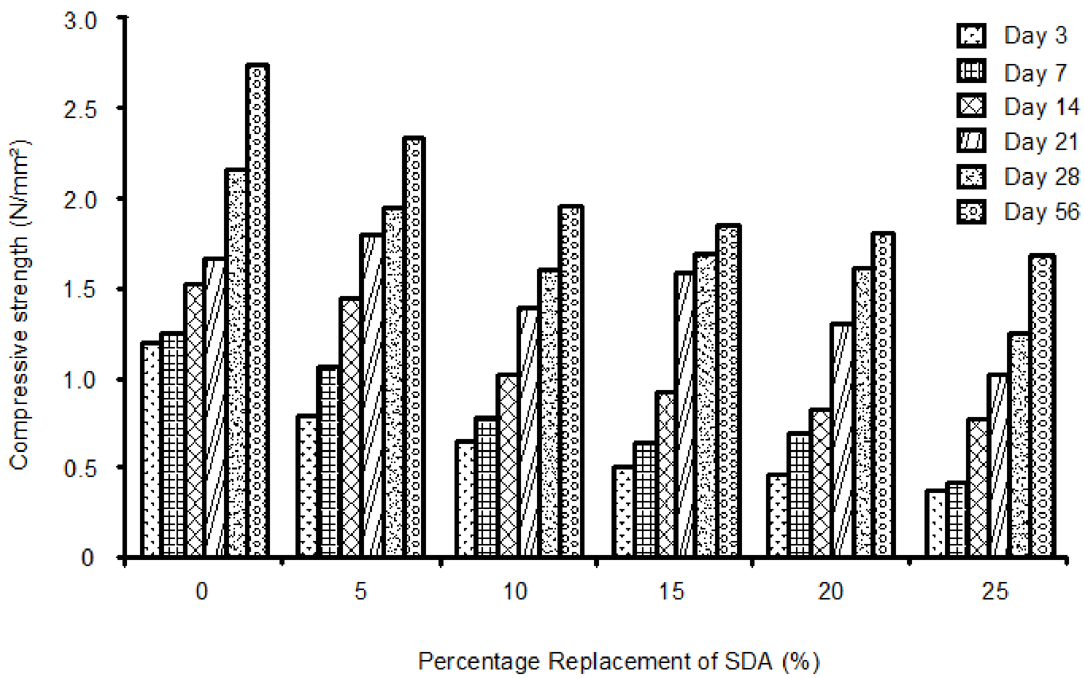

Figure 2: Effect of percentage replacement of SDA on compressive strength of Sandcrete Blocks.

3.5 Water Absorption

The results obtained for water absorption is presented in Table 8. The water absorbed at 28th day for sandcrete blocks with Saw Dust Ash replacement of 0%, 5%, 10%, 15%, 20% and 25% are 1.60, 1.90, 2.44, 2.53, 2.97 and 3.11 Kg respectively. It was observed that the water absorption increases as the percentage replacement of SDA for OPC increases. Sandcrete blocks with 25% SDA replacement is the most porous with the absorption rate of 19.51%. This absorption rate is higher than 16.95% obtained by Anosike and Oyebade (2011) and the acceptable value of 12% according to BS 5628: Part 1: 2005.

The reason for increase in absorption may be as a result of trapped air bubbles due to porosity of the SDA. Only the control and 5% SDA content satisfied the minimum requirement as stated above.

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Table8: Water Absorption of Sandcrete Hollow Blocks

Percentage Replacement of SDA	Dry weight of Sandcrete Hollow Blocks (Before Immersion in Water) (Kg)				Wet weight of Sandcrete Hollow Blocks (After 24hours of Immersion in Water) (Kg)				Weight of water absorbed (Kg)	Water Absorption Rate %
	1	2	3	Av. Weight	1	2	3	Av. Weight		
0	15.81	16.41	15.81	16.01	17.34	18.23	17.25	17.61	1.60	9.99
5	16.76	15.81	16.77	16.47	18.23	18.67	18.21	18.37	1.90	11.54
10	16.49	15.44	16.50	16.14	18.54	18.83	18.37	18.58	2.44	15.12
15	15.66	15.66	16.57	15.96	18.73	17.89	18.85	18.49	2.53	15.85
20	15.51	16.63	16.01	16.05	18.76	19.27	18.93	19.02	2.97	18.51
25	16.67	15.48	15.66	15.94	19.08	18.73	18.52	18.77	3.11	19.51

4. Conclusions

The following conclusions are drawn from the present study;

1. Saw Dust Ash (SDA) satisfies the requirement of combined SiO_2, Fe_2O_3 and Al_2O_3 of more than 70% which makes it a good pozzolan.
2. The density of sandcrete blocks decreases as the Saw Dust Ash increases but increases as the curing days increases.
3. The compressive strength of sandcrete blocks increases as the curing age increases but decreases as the SDA content increases.
4. Only up to 10% SDA replacement is adequate for use in sandcrete hollow blocks for non-load bearing walls in buildings.

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