PARTIAL REPLACEMENT OF ORDINARY PORTLAND CEMENT WITH SAWDUST ASH IN CONCRETE

ABSTRACT

The investigation of sawdust ash (SDA) as a partial replacement for cement in concrete was studied owing to the high cost and increasing demand for cement in a harsh economy and considering the presence of limited construction materials and waste to wealth policy. Ordinary Portland Cement (OPC) was replaced by 0%, 5%, 10%, 15%, 20%, 25% and 30% of SDA. Slump test and consistency test (flow table apparatus test) were conducted on the freshly mixed concrete sample and compressive strength test was conducted on the hardened concrete cubes of 150mm^2, which was cured between 7, 14, 21 and 28 days. The results revealed that the slump decreases as the SDA content increases in percentage, while the consistency of the freshly mixed concrete remarkably moves from high, medium to low as the SDA content increases. The compressive strength of the hardened concrete undergone a decrease in strength, as the partial replacement of OPC with SDA increases. By the results interpretation, it is observed that 5% to 10% SDA when replaced with OPC can still result in the desired strength of concrete.

Keywords: Cement, Saw Dust Ash, Compressive Strength, Slump, Flow

INTRODUCTION

The increasing demand for cement in a harsh economy, in the presence of by-products such as sawdust, prompted this research in view of generating wealth from waste, as well as aid in the management of solid waste which has not just been a problem in the rural area but both in the urban cities. No doubt engineering knowledge is put to test in order to ascertain the suitability of cement replacement with SDA and in what recommendable proportion. On the other hand, cement industry is potential anthropogenic source of air pollution. It has estimated that cement production originates about 5% of global manmade CO2 emissions Rai et al., 2013). The typical gaseous emissions to air from cement production include NOx, SOx, CO, CO2, H2S, VOCs, dioxins, furans and particulate matters (Bashar et al., 2009; Babatunde et al., 2013; Hesham et al., 2012).

Concrete constitutes 25-40 % cement and 60-75 % aggregates, with 1-2 % voids with cement as its main constituent (Jackson, 1975). However, the increasing demand for cement is expected to be met by partial cement replacement (Coutinbo, 2003). Over the years, some researchers have shown that waste product which possesses pozzolanic properties can serve this replacement purpose in this wise, some of the product that has been studied for use in blended cement includes fly ash (Wang et al, 2008), silica fume (Lee et al, 2005), volcanic ash (Hossain, 2005), rise husk ash (Akeke et al, 2013) and corn cob ash (Raheem et al, 2010). The research contained herein adopts the use of sawdust ash due to its availability in the locality where the study has been carried out and it is aimed at generating wealth from waste and reduce the cost of construction. Saw dust is a waste material resulting from the mechanical milling or processing of timber (wood) into various shapes and sizes (Marthong, 2012). Dust from sawn timber is usually used as domestic fuel from where its resulting ash is known as saw dust ash (SDA) which is a form of pozzolan. Pozzolana is a siliceous aluminous material which possesses little or no cementitious value, but which is finely divided into various forms in the presence of moisture, reacts chemically with calcium hydroxide at ordinary temperature to form compound possessing cementitious properties (ASTM C618 Standard). . It is in abundance in Nigeria and other parts of the world (Obilade, 2014). Current engineering practice may permit up to 40% reduction in ordinary Portland cement (OPC) used in concrete mixture to replace with pozzolana (Liu et al., 2017 (Table 1). Interestingly, the ash derives from saw dust exhibits pozzolanic properties with index value of 75.9% (Goayii, 2004).

MATERIALS AND METHODS

Sawdust used in this research was collected from a local sawmilling industry in Bori, the sawdust was sun-dried, burnt in an incinerating metal drum, the ash from the burnt sawdust was ground with the aid of mortar and pestle to the required finesse and sieve through 425 micron, other material sieve were the fine and coarse aggregate. The cement used, is one of the available commercial brands of ordinary Portland cement (OPC), however, care was taken in the cement material purchase as well as the conducting of the necessary practical to ensure test reliability. Aggregates used were a coarse aggregate of 12 mm maximum size which was obtained from a quarry in Cross River State, while the fine aggregate was natural white color river bed sand obtained in Bori, Rivers State. Water used was collected from a potable water source within the Polytechnic campus. The fine aggregate was oven dried having determined its moisture content, to achieve a dry surface condition in order to ensure the actualization of materials void of saturation, so as not to affect the water-cement ratio, thereby bringing the aggregate to conform to BS 882 (1992) specification. Other tests and procedure carried out in this research includes grain size analysis, slump test, flow table test, cubes casting, curing and compressive strength test adopting a non-destructive approach with the use a Schmidt rebound hammer.

The mixed design adopted covers four (4) cubes of seven sets of sample which includes samples of 0% replacement of SDA as control and replacement at (5%, 10%, 15%, 20%, 25% and 30%), which was cured in potable water in a sheltered curing tank. These four samples were compared in terms of freshly mixed concrete and compressive strength in terms of hardened concrete. The concrete constituents were thoroughly mixed in a clean and dry manual tilting concrete mixing drum in accordance with BS 882: 1992 with its cubes totalling 28.

Slump test was conducted on the freshly mixed concrete sample and the results obtained are as shown in table 2. The slump test was carried out on both the control and SDA replaced samples to check workability in accordance with the procedural steps as given in BS 1881 Part 102 (1983). Another test conducted on the freshly mixed concrete is the flow table test as shown in table 3, the flow table test was aimed at observing the concrete sample consistency, cohesiveness and the degree of segregation. The flow table apparatus test was carried out in accordance with the procedure outlined in BS 1881 part 105 (1983). Compressive strength test was conducted on the hardened concrete cubes non-destructive at 7, 14, 21 and 28 days using a Schmidt rebound hammer. The cubes were all removed from its mould of 150mmx150mmx150mm after 24 hours of the cast and cured, and later removed from the curing tank according to the duration (days) of crushing and tested for its compressive strength. The results obtained are shown in table 4.

RESULTS AND DISCUSSION

Table 1: Chemical Composition of Saw Dust Ash and Ordinary Portland Cement (OPC)

Oxide	**Saw Dust Ash (%)**	**Ordinary Portland Cement (%)**
CaO	9.98	64.0
SiO	67.20	20.7
Al_2O_3	4.09	5.75
Fe O_3	2.26	2.50
SO_3	0.45	2.75
MgO	5.80	1.00
Na_2O	0.08	0.60
K_2O	0.11	0.15
MnO	0.01	0.20
P_2O_5	0.48	0.05

LOI	11.94	2.30

Source: ASTM C618 Standard

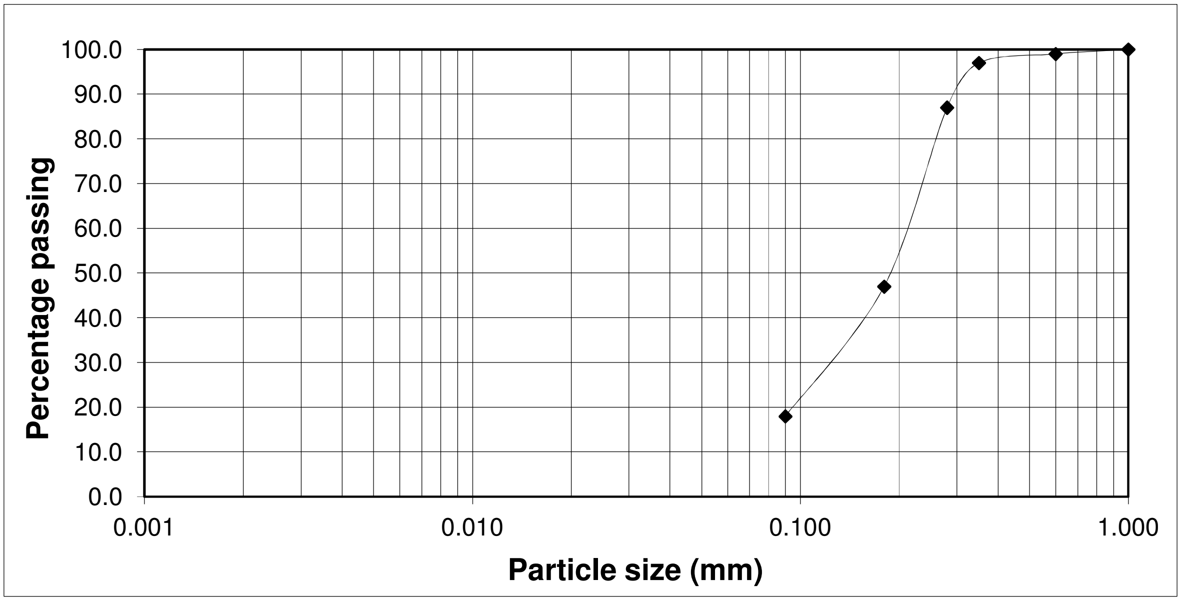

Figure 1: Particle Size Distribution Curve for Saw Dust Ash (SDA)

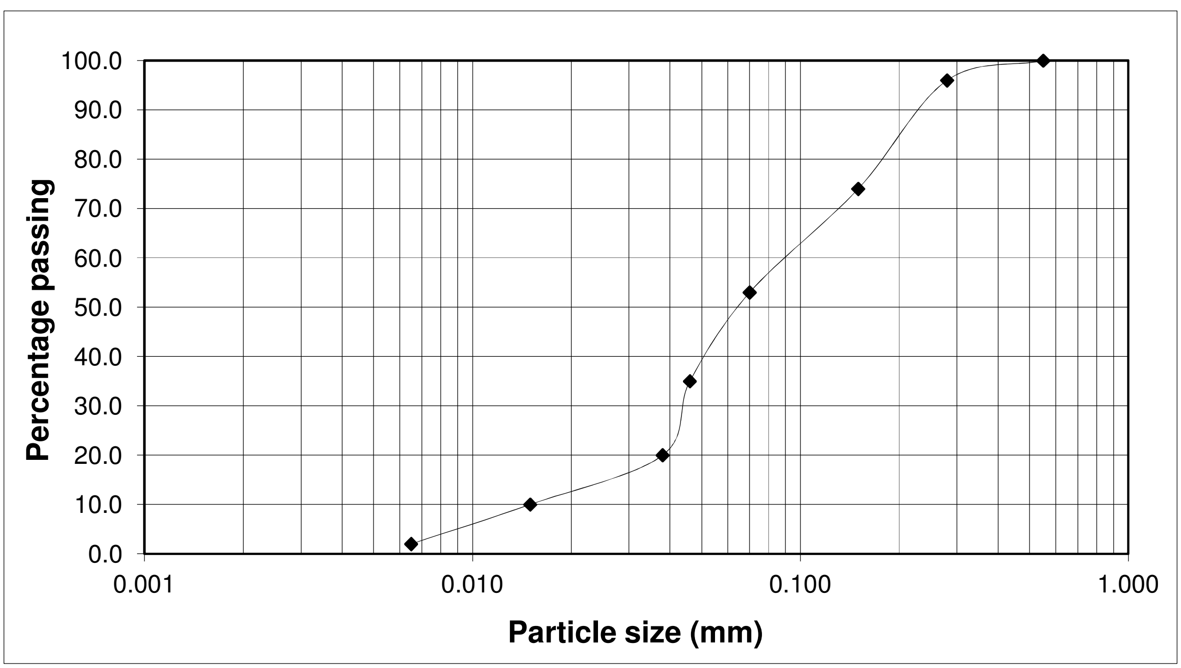

Figure 2: Particle Size Distribution Curve for Fine Aggregate

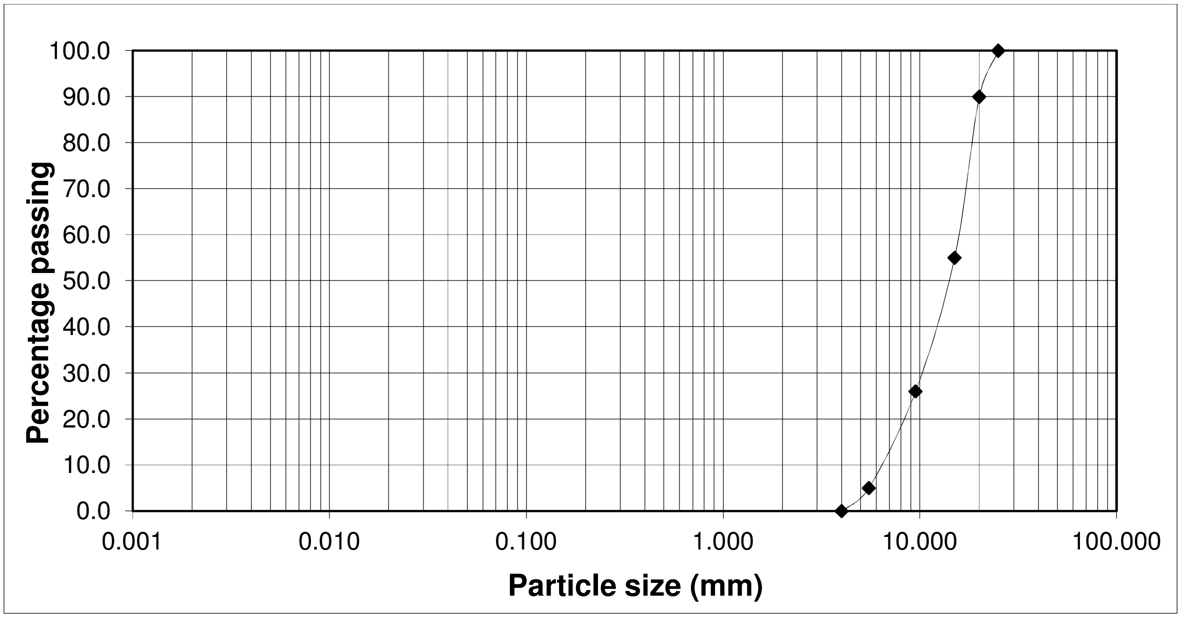

Figure 3: Particle Size Distribution Curve for Coarse Aggregate

Table 2: Slump Test Result

S/No	SDA (%)	Slump (mm)	Workability
1	0	100	High
2	5	86	Medium
3	10	70	Medium
4	15	66	Medium
5	20	61	Medium
6	25	62	Medium
7	30	50	Low

Table 3: Flow Table Test Result

S/No	SDA (%)	Initial Concrete Base Diameter (cm)	Average Concrete Diameter (cm)	Flow Percentage	Flow Consistence Remark
1	0	25	62	148	High
2	5	25	58	132	High
3	10	25	53	112	High
4	15	25	47	88	Medium
5	20	25	42	68	Medium
6	25	25	37	48	Low

7	30	25	34	36	Low

Table 4: Average Compressive Strength

Description	**Age (Days)**	**Strength (N/mm^2)**
Control Mix, 0% SDA	7	14.80
	14	18.73
	21	24.10
	28	33.40
5% SDA	7	11.75
	14	18.00
	21	21.53
	28	31.00
10% SDA	7	11.95
	14	16.59
	21	20.51
	28	31.35
15% SDA	7	10.55
	14	13.91
	21	18.10
	28	24.75
20% SDA	7	9.15
	14	11.42
	21	16.95
	28	21.71
25% SDA	7	7.54
	14	9.95
	21	15.00
	28	18.01
30% SDA	7	6.59
	14	8.64
	21	12.81
	28	14.54

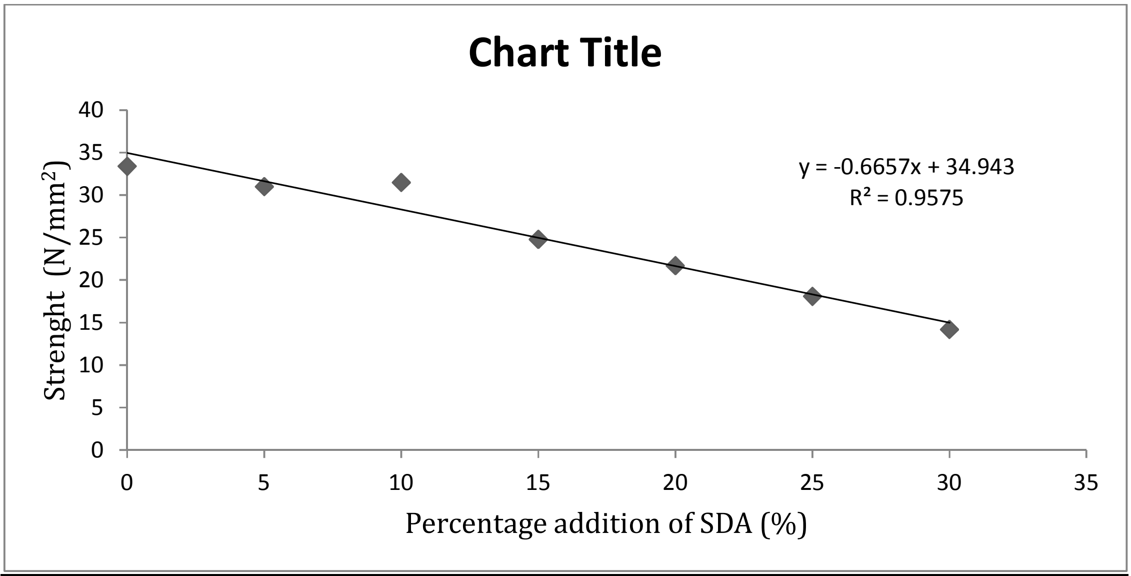

Figure 4: Compressive Strength against percentage addition of SDA (day: 28)

DISCUSSION

Figure 1-3 shows the particle size distribution curve of these constituents starting from SDA, fine aggregate and coarse aggregate respectively. The concrete mix adopted a mix ratio of 1:2:4 and water-cement ratio (WCR) of 0.65 after conducting trail mixes with varied WCR. Batching of the constituents was done by volume which represents the actual approach of batching at construction sites as well as in considering differential in the specific gravity of the constituents.

The particle size distribution (sieve analysis) curve, starting with the SDA the curves shows a closely or more commonly uniformly graded, as it has its major part steep and the rest part extended over a limited range with most particle tending to be about the same size as presented in figure 1. In the case of the fine aggregate, the curve is observed to be too steep and constant over the full range of graph indicating a well-graded material with its coefficient of uniformity (Cu) equal to 4.75. Finally, the coarse aggregate, the analysis presents a steeper curve which indicates the material contains a large number of particles which are essential of the same size. By interpretation, the curve represents a poorly graded sample with a coefficient of uniformity (Cu) equal to 1.0. The results presented in tables 2, 3 and 4 are explicit, it can be observed that the control mix cured for 28 days has a compressive strength of 33.40N/mm^2 with 5% and 10% addition of SDA having a compressive strength of 31.00N/ mm^2 and 31.35N/ mm^2 respectively. This implies that 5% to 10% of SDA can partially replace cement without any or much loss in the concrete strength thereby, reducing the waste generated from sawdust and as well creating wealth from the waste in an emerging economy. The flow table test which is practically suitable for freshly mixed concrete was conducted and in subjecting the samples to this test, it was clearly observed that the presence of SDA at various percentages in the concrete especially at 5% or 10% SDA which resulted to 132 and 112 flow percentage indicating high flow consistency when compared to 0% SDA control sample with 145 flow percentage also indicating high flow consistence presenting high workability.

CONCLUSION

Having obtained and conducted the various practical and analysis on SDA in percentages as partial replacement for cement and strength test ascertained which conform to standard, the following conclusion can be considered; SDA is a suitable construction material for use as pozzolan in light of the research contained herein as, as it satisfies the requirement for material possessing (SiO_2 + Al^2 + $Fe2O_3$). The increased addition of SDA reduces workability; hence the concrete mixes containing SDA should best be used in an unrestricted construction area. That is if more SDA percentage is to be adopted. Finally, to ensure durability, rapid strength gain, avoidance of cracks, water tightness, abrasion resistance, volume stability, resistance to freeze and thaw and as well as resistance to deicing chemicals of concrete structures containing SDA as partial replacement for cement, 5% or 10% of SDA can best be substituted for cement.

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