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Application of Industrial Waste (Saw-Dust Ash) in the Production of Self-Compacting Concrete

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Abstract - **This research study studies the use of sawdust ash as a Pozzolan in the production of concrete. It also proceeded as far as investigating the physical properties and chemical composition of saw dust, ash (SDA) as well as the workability, and compressive strength properties of the concrete produced by replacing 5%, 10%, 15%, 20% and 25% by weight of ordinary Portland cement with saw-dust ash (SDA). Slump and compacting factor tests were carried out on the fresh concrete and compressive strength test on hardened concrete was performed and found satisfactory though varying considerably. The concrete cubes were also tested at the ages of 7, 14, 21, and 28 days. From the result, the value obtained from the slump test corresponds to the designed slump range of 25mm-100. The slump, which increases from the control sample with a value of 60mm to 10% sawdust ash replacement and then decreases to 47mm for 25% replacement. Furthermore, there were increases in the self-compacting concrete shown in the concrete slump test 0%, 5%, 10%, 15%, 20% and 25% replacement of saw-dust ash slump at 3.5, 4.5, 6.5, 8.0, 11.5 and 18.0secs with the control having the least value of 3.5 seconds and the highest value coming from 25 percent replacement of sawdust ash. This shows that 25% replacement takes more time for slump to fail than others which was as a result of the more fiber bond between the cement material and sawdust which was still workable, but has high plasticity than that of the control showing that it serve as plasticizer and makes concrete for substructure work and rebar possible. It was also noted that the control sample has quite lower water absorption followed by 5% SDA has an average value of 0.82, 1.06, 1.84, 1.91, 2.05, and 2.23 which shows the total increase of 60% from 0% to 50% SDA indicating a high rate of sawdust ash absorption. It is recommended that the 5% and 10% ash replacement should be used in casting slabs, beams and columns due to its strength and surface texture.**

Keywords: Industrial waste, Compressive strength, Workability property, Saw-dust Ash, Physical and chemical properties of Concrete.

I. INTRODUCTION

Portland cement as an ingredient in concrete is one of the main construction materials widely used especially in developing countries. The increasing demand for cement is expected to be met by partial cement replacement (Coutinho, 2003). The search for alternative binder or cement replacement materials led to the discovery of potentials of using industrial by-products and agricultural wastes as cementation materials. These waste materials possess pozzolanic properties, they impart technical advantages to the resulting concrete and also enable larger quantities of cement replacement to be achieved (Hossain, 2003). Studies by Arikan, (2004) and Turanli et al. (2004) indicate that substantial energy and cost savings can result when industrial by-products are used as a partial replacement for the energy intensive Portland cement. The authors in their work argued that the presence of mineral admixtures from agricultural waste is also known to impact significant improvement in workability and durability of concrete. Genezzini et al. (2003) observed that the prevention of environmental contamination by means of proper waste disposal is an added advantage. The use of industrial and agricultural by-product in cement production is an environmental friendly method of disposal of large quantities of materials that would otherwise pollute land, water and air.

There is a need for affordable building materials in providing adequate housing for the teeming populace of the world. The cost of conventional building materials continues to increase as the majority of the population continues to fall below the poverty line. Thus, there is the need to search for local materials as alternatives for the construction of functional but low-cost buildings in both the rural and urban areas. Some of the local materials that have been used are earthen plaster (Svoboda and Prochazka, 2012), lateritic interlocking blocks (Raheem et al., 2012) and Palm kernel shell (Raheem et al., 2008).

Continuous generation of wastes arising from industrial by-products and agricultural residue creates an acute environmental problem both in terms of their treatment and disposal. The construction industry has been identified as the

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one that absorbs the majority of such materials as filler in concrete (Antiohos et al., 2005). If these fillers have pozzolanic properties, they impart technical advantages to the resulting concrete and also enable larger quantities of cement replacement to be achieved (Hossain, 2003). Appropriate utilization of these materials brings ecological and economic benefits. Some of these wastes include sawdust, red mud, pulverized fuel ash, palm kernel shells, slag, fly ash, which is produced from milling stations, thermal power station.

Self-compacting concrete is one of the latest promising advancements in the construction industry to improve both hardened and fresh properties of traditional vibrated concrete.

(Corinaldesi and Moriconi, 2011) mentioned that fresh self-compacting concrete provides good flow properties and resistance to segregation. Self-compacting concrete can reduce the construction period, enhance the compaction in congested sections where vibration is not possible and avoid noise pollution at construction site due to vibration (Okamura and Ouchi, 2003).

This substantial circulation ability of self-compacting concrete (SCC) assists you to load the formwork devoid of vibration (Khayat et al., 2004).

The significance of this study will impact the industry, both theoretically and practically, thus adding to the knowledge-base on the use of timber ash and ash in general as a cement replacement alternative and also add more potential for modified cement products to the industry that can be of the same use as ordinary cement.

The concrete design process has to be carried out through a series of trial and error method and the properties may vary according to the possible variations listed before (Felekoğlu et al., 2007). From the aspects of working conditions, (Rwamamara and Simonsson, 2012) found that self-compacting concrete requires much lesser physical activity which could lead to lower stress condition compared to ordinary vibrated concrete. The minor disadvantages of self-compacting concrete would be the high cost of materials, precise selection of materials, control and measurement in material properties and need for extensive trial tests (Naik et al., 2012).

An extensive literature survey was conducted to explore the present state of knowledge on the durability performance of self-consolidating concrete. However, because it usually requires a larger content of binder and chemical admixtures compared to ordinary concrete, its material cost is generally 20-50% higher, which has been a major hindrance to a wider implementation of its use. There is growing evidence that incorporating high volumes of mineral admixtures and micro fillers as partial replacement for Portland cement in self-compacting concrete (SCC) can make it cost effective.

The research work or study strictly focuses on determining the partial replacement of Portland cement with sawdust ash in the production of self-compacting concrete. The study is intended also to determine the general chemical composition of saw-dust ash and the evaluate the workability and strength of self-compacting concrete through the following laboratory examinations; Moisture content of aggregate, Relative index and water absorption test, Sieve test on aggregate, Aggregate crushing value (ACV), Aggregate impact value (AIV), Slump test and Concrete cube strength.

The primary aim of this study is to explore the feasibility of using self-compacting concrete (SCC) by examining its basic properties and durability characteristics i.e;

- Water absorption, shrinkage, and sulphate resistance and to study the physical properties and chemical composition of saw dust ash (SDA).
- To determine the workability, and compressive strength properties of the concrete produced by replacing 5%, 10%, 15%, 20% and 25% by weight of ordinary Portland cement with them.
- To find out the effect of adding these materials, on the properties of self-compacting concrete containing two admixtures.

II. MATERIALS/METHODOLOGY

2.1 Saw Dust Ash (SDA) Materials

The saw dust used for this study was collected from saw mill points at timber market Ahiaeke, Umuahia Abia State, Nigeria. The Sample was carefully collected to avoid mixing the sawdust with sand. The collected sample was burnt into ashes by open burning in a metal container. The sawdust ash (SDA) was ground after cooling using mortar and pestle. The yield calculation was done and tests were carried out to determine the physical and chemical properties of the saw dust ash (SDA). The saw dust ash (SDA) particles passing through the sieve of aperture 425μm was used for this study.

2.2 Coarse Aggregate Materials

Granite with a maximum size of 30mm as coarse aggregates was used. It was sourced from a quarry in Aba in Abia, Nigeria. The material which is retained in IS sieve no. 4.75 is termed as a coarse aggregate. The crushed stone is generally used as a coarse aggregate. The nature of work decides the maximum size of the coarse aggregate. The aggregates were washed to remove dust and dirt and were

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dried to surface dry condition. The aggregates were tested as per IS: 3831970.

2.3 Fine Aggregate Materials

The sand used in this research work was sourced from Umuahia, Abia state, Nigeria. The impurities were removed and it conformed to the requirements of BS882 (1992). The sand was first sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm and then was washed to remove the dust. Properties of the fine aggregate used in the experimental work are tabulated in Table. The aggregates were sieved through a set of sieves to obtain sieve analysis and the same is presented in Table. The fine aggregates belonged to grading zone III.

2.4 Water and Cement Materials

The Ordinary Portland cement (Dangote, Brand) used was obtained from a local supplier around at the timber market in Umuahia Abia State and it conformed to the requirements of BS EN 197-1: 2000.

The water used for the study was obtained from a free flowing stream. The water was clean and free from any visible impurities. It conformed to BS EN 1008 (2002) requirements. Generally, water that is suitable for drinking is satisfactory for use in concrete. Water from lakes and streams that contain marine life is also suitable. When water is obtained from sources mentioned above, no sampling is necessary. When it is suspected that water may contain sewage, mine water, or wastes from industrial plants or canneries, it should not be used in concrete unless tests indicate that it is satisfactory. Water from such sources should be avoided since the quality of the water could change due to low water or by intermittent tap water is used for casting.

III. RESULTS ANALYSIS/DISCUSSIONS

3.1 Particle Size Distribution

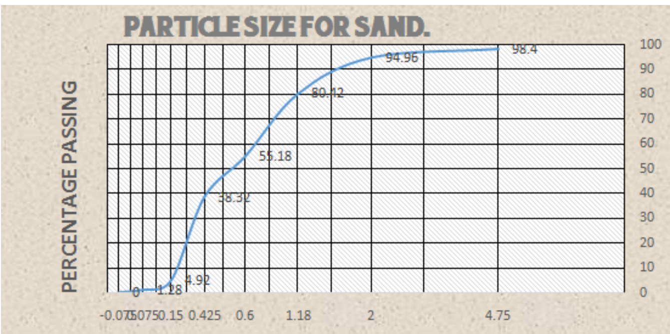

Figure 1: A graph of sieve analysis result of fine Aggregate (Sand)

The result of sieve analysis of fine aggregate, the result shows that all sieve sizes retained aggregate. It shows that sieve size of 0.150 retained the highest proportion of the aggregate. This falls under the category rich gradation, a rich gradation refers to a sample of aggregate with high proportion of fine particles.

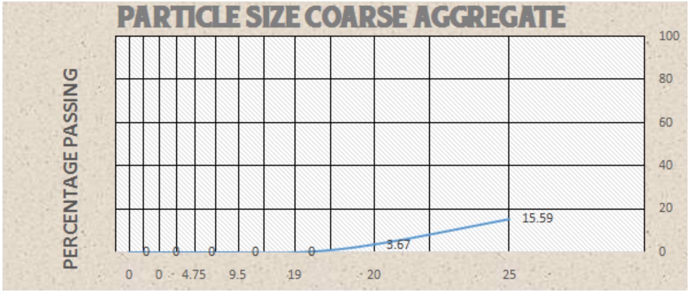

Figure 2: A graph of sieve analysis result of coarse aggregates

The sieve analysis result of 1inch for crushed coarse aggregate, it was observed that the mass retained on 25mm sieve is greater than the one that retained in 20mm sieve and 19mm sieve showing that the aggregate are not uniformly graded in terms of size. This fall in the category of gap gradation, a gap gradation refers to a sample with very little aggregate to medium size range.

This only result in coarse aggregate, the curve is horizontal at the end ort towards the end of the gradation graph.

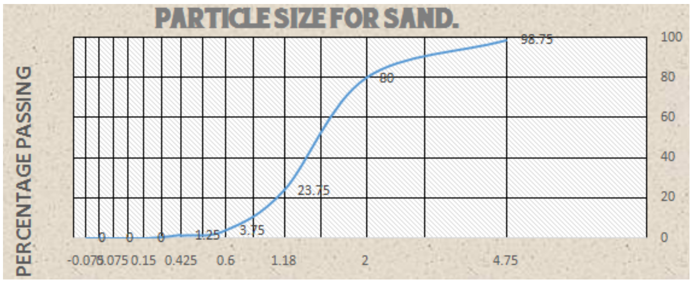

Figure 3: A graph of sieve analysis result of Sawdust

The result of sieve analysis of sawdust, the result shows that all sieve sizes retained aggregate apart from pan and sieve 0.075. It shows that sieve size of 1.18 retained the highest proportion of the aggregate. This falls under the category rich gradation, a rich gradation refers to a sample of aggregate with high proportion of fine particles.

This only result in coarse aggregate, the curve is horizontal at the end ort towards the end of the gradation graph.

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3.2 Specific Gravity of Aggregate

From table 1, 2 and 3 the specific or unit weight of coarse aggregate, sand and sawdust ash having an average of 2.67, 2.65 and whereas that of saw dust is 0.69 this which is approximately 3.5 and 4 times lighter than sand and stone used to make it a great light aggregate to reduce the overall weight of the concrete.

The specific gravity of the various which was carried out at room temperature, thus yielding the following results.

TABLE 1
Specific Gravity of Coarse Aggregate and Water Absorption

DESCRIPTION	SAMPLE A	SAMPLE B
Mass of Air Dried Sample (A)	2836.9	2227.7
Mass of Basket + Sample in Water (B)(g)	2045.09	1655.7
Mass of Basket in Water (C) (g)	232.9	232.9
Mass of Oven Dried Sample (D) (g)	2807.2	2198
P= $\frac{A}{A-(B-C)}$	$\frac{2836.9}{2836.9-(2045.09-232.29)}$ = **2.768**	$\frac{2227.7}{2227.7-(1655.7-232.9)}$ = **2.7676**
Average Specific Gravity	2.76	
Water Absorption = $\frac{100(A-D)}{D}$	$\frac{100(2836.9-2807.2)}{2807.2}$ = **1%**	$\frac{100(2227-2198)}{2198}$ = **1.3%**
Average Water Absorption	1.15%	

TABLE 2
Specific Gravity of Sand

DESCRIPTION	SAMPLE A	SAMPLE B
Mass of vessel (g)	414.8	414.8
Mass of vessel + sample (g)	791.9	782
Mass of sample (A) (g)	377.1	367.2
Mass of vessel + sample + water (B) (g)	1410	1407
Mass of vessel + water (C) (g)	1176.5	1176.5
Gs=$\frac{m2-m1}{(m2-m1)-(m3-m4)}$	$\frac{791.9-414.8}{(791.9-414.8)-(1410-1176.5)}$ = **2.6**	$\frac{782-414.8}{(782-414.8)-(1407.3-1176.5)}$ = **2.7**
Average specific gravity	2.65	

TABLE 3
Specific Gravity of Saw Dust

DESCRIPTION	SAMPLE A	SAMPLE B
Mass of vessel (g)	593	418
Mass of vessel + sample (g)	645	465
Mass of sample (A) (g)	54.1	47
Mass of vessel + sample + water (B) (g)	1494	1147
Mass of vessel + water (C) (g)	1538	1157
P= $\frac{A}{A-(B-C)}$	$\frac{54.1}{54.1-(1494-1538)}$= **0.55**	$\frac{47}{47-(1147-1157)}$ = **0.825**
Average specific gravity	0.687	

3.3 Specific gravity of Dangote Cement

The specific gravity was determined on relative paraffin value for the OPC cement (Dangote) at room temperature to obtain the results below.

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TABLE 4
Specific gravity of Dangote Cement

DESCRIPTION	SAMPLE A	SAMPLE B
Mass of empty bottle(W1) (g)	28.0	27.6
Mass of bottle +cement (W2) (g)	50.1	49.5
Mass of bottle+cement+ kerosene (W3)	85.0	85.4
Mass of bottle +kerosene (W4) (g)	68.4	68.0
Mass of bottle + water (W5) (g)	77.8	78.4
SPof kerosene= $\frac{W_4-W_1}{(W_5-W_1)}$ =	0.81	0.80
SP of Cement $\frac{W_2-W_1}{(W_3-W_1)-(W_5-W_1)}$ =	3.06	3.13
Average specific gravity	3.09	

3.4 Aggregate Impact value of coarse aggregate

A total mass of 8kg was used for the impact test on of which masses passing 14mm, 10mm and 2.0mm BS test sieve.

TABLE 5
Aggregate Impact Value

DESCRIPTION BS:812-110(1992)	SAMPLE A	SAMPLE B
Mass retained on 14mm sieve (g)	7381	7225
Mass retained on 10mm sieve(g)	579	715
Mass passing 2.0mm sieve (g)	44	60
Mass retained after impact (g)	535	655
AIV= $\frac{M_2 \times 100}{M_1}$	$\frac{44 \times 100}{579}$ = **7.6%**	$\frac{60 \times 100}{715}$ = **8.39%**
Average (Aggregate Impact Value)	8.00%	

From the table above, the average value of 8.00% was obtained which the percentage ratio is passing 2.36 mm BS test sieve. This value which is adequate for coarse aggregate for concrete mix of strength up to 40N/mm^2. BS 812-110(1992), IS: 2386(Part111)

3.5 Slump and Self Compacting Concrete of the Fresh Concrete Mix

From the result, the value obtained from the slump test corresponds to the designed slump range of 25mm-100. The slump, which increases from the control sample with a value of 60mm to 10% sawdust ash replacement and then decreases to 47mm for 25% replacement. Furthermore, there were increases in the self-compacting concrete with the control having the least value of 3.5 seconds and the highest value coming from 25 percent replacement of sawdust ash which was as a result of more fiber bond between the cement material and sawdust which was still workable but has high plasticity than that of the control showing that it serve as plasticizer and makes concrete for substructure work and repair possible. Thus shown in the fig below:

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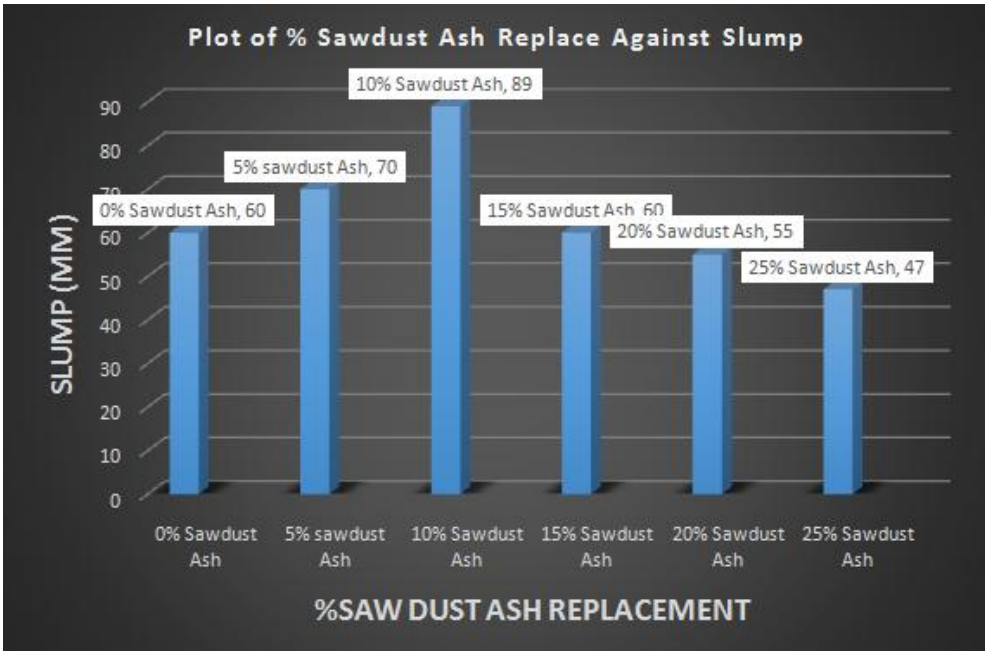

Figure 4: Results for Slump Test

3.6 Water Absorption of Concrete after the Curing Period

The composite is made with material having different water absorption rate, of which the difference in bulk weight of the concrete from the control sample to 25% sawdust ash replacement, the percentage absorption for the different sample replacement was then obtained and recorded in the table below using the expression Wabs = $\frac{100(water\ absorbed)}{mass\ of\ sample\ before\ cure}$ thus the result tabulated below.Sample calculation for 7days absorption of control concrete. Wabs = $\frac{100(0.01)}{8.18}$= 0.12%. From Fig 5 the control sample has quite lower water absorption followed by 5% SDA has an average values of 0.82,1.06, 1.84, 1.91, 2.05, and 2.23 which showed a constant 30% increase from 5%SDA- 15% and then 8% increase from 15% SDA-55% SDA.

Thus the total increase of 63% from 0% to 50%SDA indicating a high rate of sawdust ash absorption. The figure showed a maximum of 2.24 which is within the permissible range of 1-4 for Fcu 25N/mm^2 concrete.

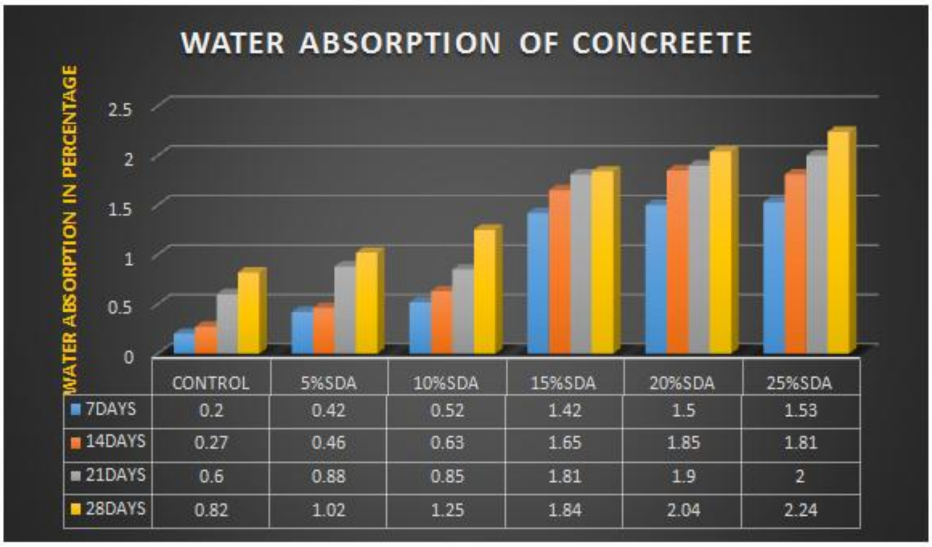

Figure 5: Water Absorption for Concrete at 7-28 days Curing

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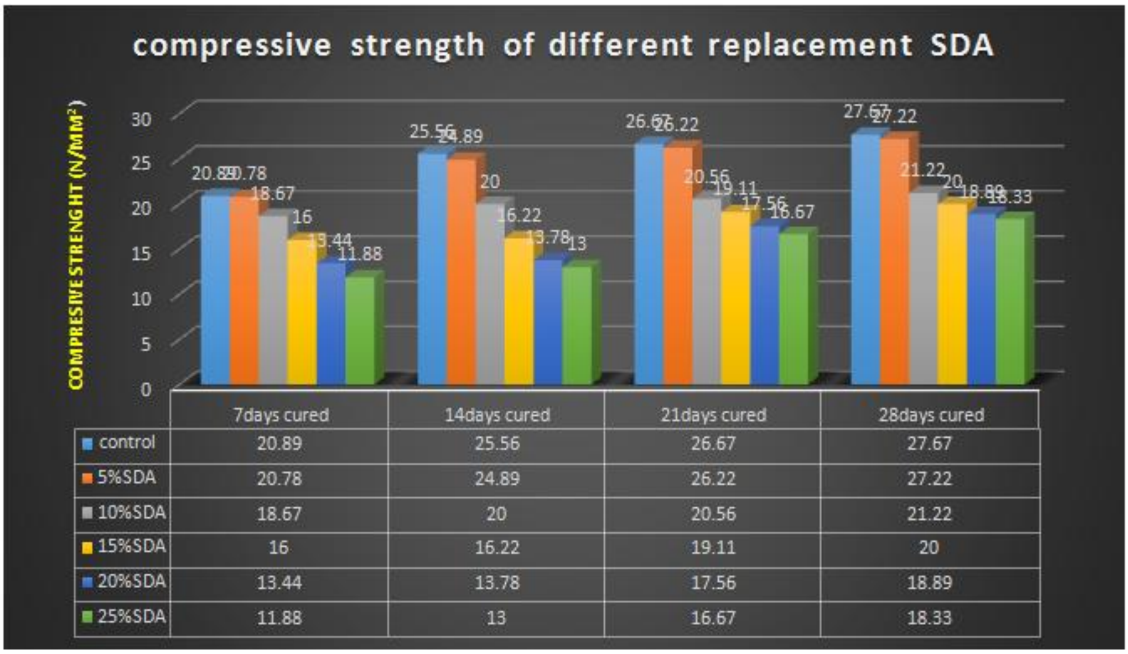
3.7 Compressive Strength of Hardened Concrete after 7, 14, 21, and 28 days Curing

The various results obtained from the concrete for 24 hours of setting as plotted are to be analysis individually. The cubes and cylinder of 150x150x150 were tested for strength using a compressive machine of 2000kN capacity. The different crushing and splitting load was obtained as tabulated below.

Fcu= for the mean crushing load.
Sample uses 0% at 7days Fcu= 20.89.

From figure 5 the various compressive strength has a constant and progressive strength, growth since 7 days - 28days. At 7days the control had the highest value, followed by the 5% concrete and down from 10% strength with 25%, but at 14 days the strength of control and 10% SDA matched with the remaining having a progressive decrease down to 50%SDA this which also occurred in the 21 and 28 days with 5%SDA having the highest strength. At 28 days curing the control exceeded the target mix design of 25N/mm^2 thus notifying that the mix at 0.5% water cement ration was adequate. Also in this 28days control and 5% exceeds stipulated designed strength, but the remaining concrete from 10%, 15%, 20% and 25%, respectively meet up with the stipulated strength for light weight concrete, which is 17N/mm^2 as given in ASTM C330-89.Y J Kim, (2010), Neville (2008).



	7days cured	14days cured	21days cured	28days cured
control	20.89	25.56	26.67	27.67
5%SDA	20.78	24.89	26.22	27.22
10%SDA	18.67	20	20.56	21.22
15%SDA	16	16.22	19.11	20
20%SDA	13.44	13.78	17.56	18.89
25%SDA	11.88	13	16.67	18.33

Figure 1: Compressive Strength of Concrete cubes (150x150mm) at 7-28 Days Curing (N/mm^2)

IV. CONCLUSION AND RECOMMENDATION

This research "Application of industrial waste (sawdust ash) in the manufacturing of self-compacting concrete" has proved that:

i. The cost of the Sawdust was found to be very low, as in the saw mill they are seen as waste and the only cost to encounter is in the transportation and the increase cost of labour require for its burning and sieving process. Therefore, the replacement of ordinary Portland cement with sawdust ash would be beneficial to low income areas which may not afford to keep up with the rising costs of and difficulty in getting cement with a total reduction on the average load on structures making other parameters like foundation work to reduce.

ii. The utilization of this wood material will in turn reduce its effect as environmental pollutants and emission of gases which causes global warming when they are being burned or allowed to decay.

iii. The absorption capacity varies due to the differences in sawdust ash replacement. The higher the sawdust ash replacement the higher the absorption capacity, which is to say that various percentages of sawdust ash replacement have different absorption capacity.

iv. The workability of each percentage of sawdust ash replacement also differs. Example the 25% sawdust

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ash replacement, the concrete was affected by segregation. Segregation is the separation of the constituents of a homogeneous mixture so that their distribution will no longer be uniform.

It is recommended that:

i. From the foregoing, the compressive strength of concrete produced from 5%, 10%, and 15% sawdust ash perform satisfactory when use as to replace cement in Portland cement concrete, although their compressive strength varies considerably but they can be used as a construction material.
ii. The 5% and 10% sawdust ash replacements should be used in casting slabs, beams and columns due to its strength and surface texture.
iii. Due to the additional water retention in its core matrix I recommend its use in areas prone to concrete shrinkage resulting from excess heat like the Northern part of Nigeria.
iv. Owing to the rate of water absorption of the concrete made with 20% and 25% sawdust ash replacements, I recommend that it should not be used for foundation or any water retaining structure rather to be used for structure and superstructure with a mild condition of exposure.

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