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# Properties of Sawdust Concrete

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ABSTRACT

This work examined the structural properties of concrete obtained by partially replacing cement with sawdust ash. The sawdust ash which is a pozzolan was obtained by burning sawdust which is a waste product from processing of timber in an open air. The burnt ash was passed through a 150 µm metric sieve to obtain the ash used. Physical and chemical analysis were performed on the ash to verify its suitability as a partial substitute for cement in concrete. Chemical analysis was also carried out on the Ordinary Portland Cement (OPC) sample. Concrete mixes were produced by replacing OPC with 0%, 5%, 10%, 20% and 30% of Sawdust Ash (SDA). Both fresh and hardened properties of the concrete produced were investigated. The chemical investigation on the ash showed that it contained most of the basic compounds found in OPC making it suitable to serve as a partial substitute for OPC in concrete. Investigation on the concrete showed that both the workability and density of the concrete reduce as the SDA content increases. Analysis on the hardened concrete revealed that the compressive strength of the concrete decreases as the ash content increases for the early ages of curing. However, from 21 days curing age upwards, the compressive strength decreases as SDA increases up to 10% of SDA at which the compressive strength rose to a maximum value, and then starts reducing again as the percentage SDA increases. Thus, the SDA concrete gained rapid strength at later ages indicating its pozzolanic activity.

## 1. Introduction

Concrete is a composite inert material that is mainly made up of a binding agent (e.g. lime, ordinary Portland cement, pozzolans, etc.), mineral filler or aggregates and water. Sometimes an additional material known as admixture is added to modify certain properties of the concrete [1]. Before the advent of the portland cement, clay and lime-based materials were some of the traditional binders used by man in the production of concrete and mortar for building construction [2].

The important features of both the fresh and hardened concrete include workability, compressive strength, rate of setting and hardening, deformation under load, durability, permeability, shrinkage, etc. However, compressive strength is considered to be an important property and the

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quality of concrete is often judged by its strength.

It is a well-known fact cement is the most expensive constituent of concrete, which makes the overall cost of concrete to be too high. Shetty and Jain [3] affirmed that in 1996, the global production of cement was estimated at about 1.3 billion tons, for each ton produced, 0.87 tons of $CO_2$ was expelled, thus, 7% of the world's emission of $CO_2$ is attributed to Portland cement production.

Hence, because of the high cost of cement, its significant contribution to environmental pollution and the high consumption of natural resources such as limestone, we cannot go on producing more and more cement. This justifies the search for a more environmentally friendly and less expensive binding agent to substitute cement in concrete. In the past, such searches for alternative cement led to the discovery of pozzolans. A pozzolan is a natural or artificial material that contains silica or a combination of silica and aluminium which has little or no cementitious value but when in finely divided form and also in the presence of water, it will chemically react with lime (produced during the hydration of Portland cement) at ordinary temperatures to yield compounds that possess cementitious properties [4]. According to Neville and Brooks [5], concrete produced from a mixture of Portland cement and pozzolan will gain strength slowly and hence, needs to be cured for a comparatively long period of time, but the long-term strength is high. Pozzolan or Pozzolana needs to be in finely divided form so as to present a larger surface area to the alkali solutions for the reaction to take place [6].

In the recent times, the ash from many agricultural wastes in Nigeria have been found to possess pozzolanic characteristics and are thus used as supplementary cement in concrete [7]. The use of these wastes as concrete materials promotes sustainability in the production of structural concrete [7].

Several researchers have worked on the use of various agricultural waste in concrete. Siddique, Singh, Mehta and Belarbi [8] used varying percentages of water and sodium silicate treated sawdust to replace sand in concrete and observed that, concrete produced from 5% water and sodium silicate treated sawdust yielded compressive strength approximately of the same magnitude with that of the control concrete. In the works of Alabduljabbar, Huseien, Sam, Alyouef, Algaifi and Alaskar [9], sawdust was used to replace fine/coarse aggregate incorporating fly ash and granulated blast furnace slag to produce high-performance light weight concrete without cement. It was observed from their work that the thermal conductivity coefficient, the workability, density, setting time and compressive strength of the concrete decreases with increase in sawdust content while the general acoustic properties of the concrete was enhanced as revealed by the increase in noise reduction and sound absorption coefficients of the concrete with increase in sawdust content. Farnaz Batool, Kamrul Islam, Celal Cakiroglu, and Anjuman Shahriar [10] produced concrete in which the fine aggregate was partially replaced with untreated sawdust. In their work, they reported that the micrographs from their works showed a wider formation of cracks and interface gaps in the cement matrix, these gaps and cracks were however, found to contract after immersing the concrete in sulphate for a period of 28 days which also improved the compressive strength. Hassen and Hameed [11] studied the properties of sawdust cement mortar treated with Hypochlorite and observed that there was an improvement in the compressive strength and reduction in dry density with increase in washed and treated sawdust content in the mixture. El-Nadoury [12] investigated the properties of concrete produced by partially replacing sand and cement in concrete with sawdust and sawdust ash respectively. Ettu, Osadebe and Mbajiorgu [13] partially replaced Ordinary Portland Cement (OPC) with ash from eight different agricultural wastes such as Rice Husk, Cassava peels, Cocoanut shells, Paw-paw leaf, Plantain leaf, Corn cob, Sawdust and Oil palm bunch. In their work, they observed that the compressive strength of the concrete produced increased with increase in curing age and decreased with increase in percentage replacement of OPC with each ash. Parande, Stalin, Thangarajan, and Karthikeyan [14] used a mixture of rice husk ash, bagasse ash, fly ash and bye product from thermal waste to partially replace cement in concrete from 5% to 30%. In their work, they observed that as the percentage replacement level increased, the water absorption of the concrete increased. Patel M., Patel K., Patel A., Prajapati and Koshti [15] used sawdust as fine aggregate to partially replace sand in concrete. In their work, they increased the percentage replacement of sharp sand with sawdust gradually from 0-30%, the compressive and split tensile strength of the concrete produced decreases with increase in percentage replacement with sawdust.

Elinwa [16] used a mixture of Gum Arabic and Sawdust Ash to replace cement in concrete and discovered that with the Gum Arabic alone, the mechanical strength of the concrete increased, but with the mixture of Gum Arabic and Sawdust Ash, the mechanical strength of the concrete decreased. It was observed in the works of Elinwa and Abdukadir [17] that when SDA is used in reinforced concrete, it delays the process of corrosion of the reinforcements.

Sawdust is the loose particles of wood produced as waste products during the processes of sawing and converting timber into different sizes and shapes [18]. These particles are burnt to ashes to produced sawdust ash. Apart from reducing the cost of concrete, use of pozzolanas such as sawdust ash, an agricultural waste material promotes waste management at little cost as waste is being converted into money, and also solves the problem of environmental pollution created by these wastes.

## 2. Materials and Methods

The materials for the concrete used in this study are ordinary Portland cement (Dangote 3X Brand), aggregates (fine and coarse), Sawdust ash and water.

The ordinary Portland cement used in this study has physical and chemical properties that complies with the requirements of the British Standards [19].

The coarse aggregate used in this study was crushed granite having maximum size of 20 mm. The aggregate was sourced from a granite quarry at Ishiagu in Ebonyi State, Nigeria. It has a gray colouration, an irregular shape and a rough surface texture.

The fine aggregate used in this work was sand obtained from Otamiri River which is the major source of sharp sand for Owerri and its environs. From the grain size distribution analysis carried out on the sand, it complies with the specifications of BS.882 [20] for fine aggregates. The sand was dry and free from deleterious materials.

Sawdust Ash used in this work was obtained by burning sawdust (which is wood shavings and dust obtained as waste during the various stages of processing of timber) in an open air to ashes. The ash used in this work is the particles of the ash that passed through the 150 mm standard sieve size. The sawdust was obtained from a timber sawmill situated at the wood market at Naze in Owerri, Imo State, Nigeria. The sawdust was obtained from various local wood varieties. The local wood varieties used are Mahogany, Ubia, Gmelina, Rubber, Akwammiri, Ebelebe Udele, Udah, Imieghu and Oweh.

### Methodology

After burning the sawdust to ash, the ash obtained was sieved using British standard sieve of 150 mm diameter. The sawdust ash (SDA) sample used in this work was the ash materials that passed through the 150 mm sieve. The SDA sample was characterised by taking it to the laboratory to determine its physical and chemical properties. This was done by mixing the sample with water to form a cake-like texture. The briquettes were moulded according to the prescribed test i.e. porosity test, shrinkage test, rupture and plasticity test. The briquettes were coded, dried and fired to the desired temperature. Readings were taken after drying and firing to calculate the final results for the physical analysis. The OPC sample used was equally taken to the laboratory to determine its chemical composition. Sieve analysis was carried out on both the coarse and fine aggregates using the British standard sieves to determine the grain size distribution of the aggregates. The following parameters were deducted from the results of the sieve analysis:

$$Coefficient\ of\ Uniformity,\ \mathrm{C}_u = \frac{\mathrm{D}_{60}}{\mathrm{D}_{10}}, \tag{1}$$

$$Coefficient\ of\ Curvature,\ \mathrm{C}_c = \frac{\mathrm{D}_{30}{}^2}{\mathrm{D}_{10}.\,\mathrm{D}_{60}} \tag{2}$$

Dxx is the particle size corresponding to xx percentage passing [21].

The test specimen for compressive strength is a concrete cube of size; 150 mm × 150 mm × 150 mm as recommended by BS 1881: Part 116 [22]. A concrete mix ratio of 1:2.58:3.42 and a water-cement ratio of 0.57 was used in producing concrete cube specimens. The batching of concrete was done by mass and a total of five different batches were made. For each of the five different batches, OPC was replaced with 0%, 5%, 10%, 20% and 30% by mass of SDA respectively. Slump test was carried out on each concrete mix to determine its workability. After a period of twenty-four (24) hours of casting, the concrete cubes produced were cured by totally submerging them in a water tank. For each percentage replacement of OPC with SDA, two cubes each were cast and cured for a period of 7, 14, 21 and 28 days respectively. After curing, the cube was brought out of water and left to dry after a little period of time and weighed on a weighing balance to determine its self-weight. Thereafter, the cube was taken to a universal testing machine having a maximum capacity of 1000 kN and was placed with the cast faces placed in contact with the platens of the crushing machine and the value of the load in kN at which a cube fails during crushing is recorded. The compressive strength and the density of the cube are obtained from the following equations:

$$\text{Compressive Strenrth} = \frac{\text{Failure Load}}{150 \text{ x } 150} \left( {}^{N}\!/_{mm^2} \right) \tag{3}$$

$$\text{Density} = \frac{\text{Self Weight}}{0.15\text{x}0.15 \text{ x } 0.15} \left( {}^{kg}\!/_{m^3} \right) \tag{4}$$

## 3. Results and Discussions

### 3.1 Physical and Chemical Properties of Sawdust Ash

The results of the physical and chemical properties of the SDA were presented on Tables 1 and 2 respectively. Table 3 shows a comparison between the chemical composition of the SDA and that of the OPC.

**Table 1.** Summary of the Physical Properties of SDA

| S/N | Parameter | Value |
|---|---|---|
| 1 | Porosity | 85.40% |
| 2 | Water Absorption | 74.59% |
| 3 | Apparent Density | 1.146 |
| 4 | Bulk Density | 8.03 |
| 5 | Shrinkage | 3.6% |
| 6 | Modulus of Plasticity | 3.32 |
| 7 | Making Moisture | 29.547% |
| 8 | Modulus of Rupture | 1.172 $kg/cm^2$ |
| 9 | Loss on Ignition | 61.00 |

**Table 2.** Summary of the Chemical Composition of SDA

| S/N | Oxide | Percentage by Mass (%) |
|---|---|---|
| 1 | $SiO_2$ | 20.8 |
| 2 | CaO | 3.22 |
| 3 | $Al_2O_3$ | 1.53 |
| 4 | $Fe_2O_3$ | 3.58 |
| 5 | $Na_2O$ | 0.20 |
| 6 | $K_2O$ | 0.22 |
| 7 | PbO | 0.02 |
| 8 | MgO | 5.14 |
| 9 | MnO | 0.008 |
| 10 | LOI | 61.0 |
| | Total | 95.718 |

**Table 3.** Comparisons between the Chemical Compositions of SDA and OPC

| S/N | Compound | Percentage by Mass | |
|---|---|---|---|
| | | SDA | OPC |
| 1 | $SiO_2$ | 20.80 | 21.20 |
| 2 | CaO | 3.22 | 64.73 |
| 3 | $Al_2O_3$ | 1.53 | 5.02 |
| 4 | $Fe_2O_3$ | 3.58 | 3.08 |
| 5 | $Na_2O$ | 0.20 | 0.19 |
| 6 | $K_2O$ | 0.22 | 0.42 |
| 7 | MgO | 5.14 | 1.04 |
| 8 | MnO | 0.01 | - |
| 9 | PbO | 0.02 | - |
| 10 | $SO_3$ | - | 2.01 |
| 11 | LOI | 61.00 | 1.45 |
| | Others | 4.282 | 0.66 |

From Table 1, the SDA has high water absorption (74.59%), this is as a result of its high porosity of 85.4%. The making moisture of the SDA is high (29.55%) and this is as a result of its high porosity. The chemical composition of SDA in Table 2 showed that the total sum of $Fe_2O_3$, $SiO_2$ and $Al_2O_3$ is 25.91%. This value is far below the required value of 70% minimum for pozolanas [4]. Table 1 shows that the Loss on Ignition of the SDA is 61.0%. This is far above the 12% maximum required for pozzolanas [4]. This shows that the ash used contained much unburnt carbon which reduces its pozzolanic activity. This shortcoming of the SDA used might have resulted from the improper method of combustion through which the ash was obtained.

Table 3 shows that there is great similarity between the chemical composition of the SDA and that of OPC and hence, SDA can to a reasonable extent serve as an alternative cement.

### 3.2 Results on Grain Size Distribution.

The sieve analysis results of the coarse and fine aggregates are presented in Table 4, Figure 1, and Table 5, Figure 2 respectively.

**Table 4.** Sieve Analysis Result for Coarse Aggregates

| Sieve Size (mm) | Mass Retained | Cummulative Mass Retained | % Cummulative Mass Retained | % Passing |
|---|---|---|---|---|
| 37.50 | 0.00 | 0.00 | 0.00 | 100.00 |
| 19.00 | 11.20 | 11.20 | 1.13 | 98.87 |
| 14.00 | 448.98 | 460.18 | 46.26 | 53.74 |
| 10.00 | 456.70 | 916.88 | 92.18 | 7.82 |
| 5.60 | 77.60 | 994.48 | 99.98 | 0.02 |
| 3.35 | 0.20 | 994.68 | 100.00 | 0.00 |
| Receiver | 285.02 | | | |

$$D_{10} = 10.1899,\ D_{30} = 11.9321, D_{60} = 14.6936 \quad (5)$$

$$C_u = 1.442\ ,\ C_c = 0.951 \quad (6)$$

**Table 5.** Sieve Analysis Result for Fine Aggregates

| Sieve Size (mm) | Mass Retained (g) | Cummulative Mass Retained (g) | % Cummulative Mass Retained | % Passing |
|---|---|---|---|---|
| 10.000 | 0.00 | 0.0 | 0.00 | 100.00 |
| 5.600 | 1.90 | 1.9 | 0.38 | 99.62 |
| 3.350 | 7.80 | 9.7 | 1.94 | 98.06 |
| 2.000 | 45.80 | 55.5 | 11.12 | 88.88 |
| 1.180 | 94.00 | 149.5 | 29.95 | 70.05 |
| 0.600 | 129.50 | 279.0 | 55.89 | 44.11 |
| 0.425 | 125.00 | 404.0 | 80.93 | 19.07 |
| 0.300 | 47.20 | 451.2 | 90.38 | 9.62 |
| 0.212 | 30.50 | 481.7 | 96.49 | 3.51 |
| 0.150 | 13.50 | 495.2 | 99.20 | 0.80 |
| 0.063 | 4.00 | 499.2 | 100.00 | 0.00 |
| Receiver | 279.80 | | | |

$$D_{10} = 0.305,\ D_{30} = 0.5014, D_{60} = 0.9553 \quad (7)$$

$$C_u = 3.1321\ ,\ C_c = 0.8628 \quad (8)$$

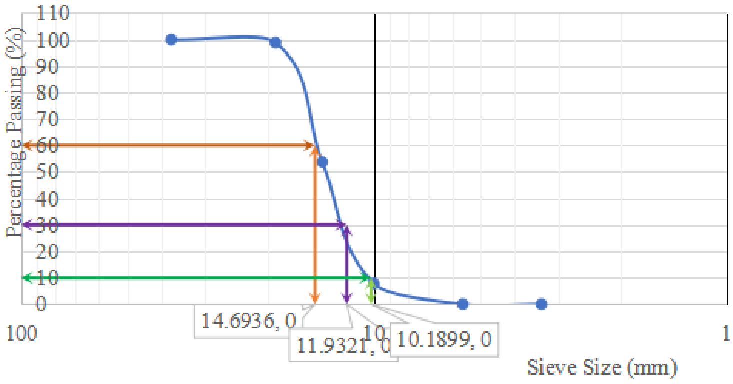


**Figure 1.** Sieve Analysis for Coarse Aggregates

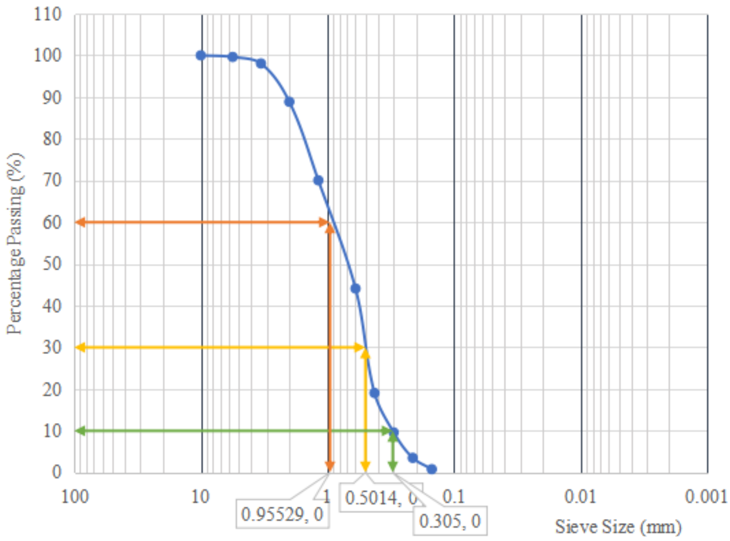


**Figure 2.** Sieve Analysis for Fine Aggregates

From Tables 4 and 5 and Figures 1 and 2, using the Unified Soil Classification System (USCS), since for the fine aggregate, $C_u < 6$ *and* $C_c < 1$, the fine aggregate is classified as "Poorly Graded Sand". Also, for the coarse aggregates, $C_u < 4$ *and* $C_c < 1$, the coarse aggregate is classified as "Poorly Graded Gravel".

### 3.3 Workability of Fresh Concrete

The results of the slump tests on the fresh concrete mixes are presented in Table 6 and Figure 3.

**Table 6.** Workability of concrete with SDA

| SDA % | Slump (mm) |
|---|---|
| 0 | 80 |
| 5 | 75 |
| 10 | 70 |
| 20 | 25 |
| 30 | 20 |

The slump test results of the SDA/OPC concrete mixes given in Table 6 and Figure 3, show a decrease in the workability of the concrete as the SDA content increases.

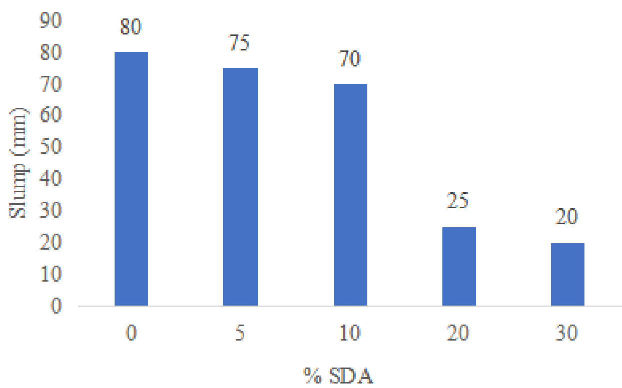


**Figure 3.** Slump Test Result

### 3.4 Compressive Strength of the Concrete

The compressive strength results of Equation (3) and dry density results of Equation (4) for the various mixes at different curing ages are presented on Tables 7, 8, 9, 10 and 11. The variation of the compressive strength of the concrete mixes with different SDA content at various curing ages is presented in Figures 4 and 5.

**Table 7.** Compressive Strength Result at 7 days of Curing

| %SDA | | Wt. of cube (kg) | Density (kg/m$^3$) | Average Density (kg/m$^3$) | Crushing Load (kN) | Strength (N/mm$^2$) | Average Length (N/mm$^2$) |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 8.30 | 2459 | 2489 | 490.00 | 21.8 | 24.0 |
| | 2 | 8.50 | 2519 | | 590.00 | 26.2 | |
| 5 | 1 | 8.20 | 2430 | 2415 | 511.00 | 22.7 | 20.7 |
| | 2 | 8.10 | 2400 | | 420.00 | 18.7 | |
| 10 | 1 | 8.10 | 2400 | 2408 | 349.00 | 15.5 | 16.3 |
| | 2 | 8.1`5 | 2415 | | 382.00 | 17.0 | |
| 20 | 1 | 8.20 | 2430 | 2400 | 284.00 | 12.6 | 12.6 |
| | 2 | 8.00 | 2370 | | 282.00 | 12.5 | |
| 30 | 1 | 8.10 | 2400 | 2378 | 192.00 | 8.5 | 9.2 |
| | 2 | 7.95 | 2356 | | 222.00 | 9.9 | |

**Table 8.** Compressive Strength Result at 14 days of Curing

| %SDA | | Wt. of cube (kg) | Density (kg/m$^3$) | Average Density (kg/m$^3$) | Crushing Load (kN) | Strength (N/mm$^2$) | Average Length (N/mm$^2$) |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 8.40 | 2489 | 2460 | 590.00 | 26.2 | 26.0 |
| | 2 | 8.20 | 2430 | | 580.00 | 25.8 | |
| 5 | 1 | 8.30 | 2459 | 2430 | 563.00 | 25.0 | 24.6 |
| | 2 | 8.10 | 2400 | | 545.00 | 24.2 | |
| 10 | 1 | 8.30 | 2459 | 2408 | 653.00 | 29.0 | 25.0 |
| | 2 | 7.95 | 2356 | | 470.00 | 20.9 | |
| 20 | 1 | 8.05 | 2385 | 2393 | 462.00 | 20.5 | 21.0 |
| | 2 | 8.10 | 2400 | | 482.00 | 21.4 | |
| 30 | 1 | 8.00 | 2370 | 2385 | 442.00 | 19.6 | 19.6 |
| | 2 | 8.10 | 2400 | | 440.00 | 19.6 | |

**Table 9.** Compressive Strength Result at 21 days of Curing

| %SDA | | Wt. of cube (kg) | Density (kg/m$^3$) | Average Density (kg/m$^3$) | Crushing Load (kN) | Strength (N/mm$^2$) | Average Length (N/mm$^2$) |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 8.35 | 2474 | 2437 | 594.00 | 26.4 | 26.3 |
| | 2 | 8.10 | 2400 | | 590.00 | 26.2 | |
| 5 | 1 | 8.40 | 2489 | 2430 | 592.00 | 26.3 | 25.7 |
| | 2 | 8.00 | 2370 | | 565.00 | 25.1 | |
| 10 | 1 | 8.25 | 2444 | 2422 | 646.00 | 28.7 | 28.6 |
| | 2 | 8.10 | 2400 | | 640.00 | 28.4 | |
| 20 | 1 | 8.05 | 2385 | 2378 | 620.00 | 27.6 | 25.2 |
| | 2 | 8.00 | 2370 | | 514.00 | 22.8 | |
| 30 | 1 | 7.94 | 2353 | 2377 | 490.00 | 21.8 | 21.7 |
| | 2 | 8.10 | 2400 | | 485.00 | 21.6 | |

**Table 10.** Compressive Strength Result at 28 days of Curing

| %SDA | | Wt. of cube (kg) | Density (kg/m$^3$) | Average Density (kg/m$^3$) | Crushing Load (kN) | Strength (N/mm$^2$) | Average Length (N/mm$^2$) |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 8.40 | 2489 | 2467 | 596.00 | 26.5 | 26.9 |
| | 2 | 8.25 | 2444 | | 614.00 | 27.3 | |
| 5 | 1 | 8.30 | 2459 | 2459 | 592.00 | 26.3 | 26.6 |
| | 2 | 8.30 | 2459 | | 605.00 | 26.9 | |
| 10 | 1 | 8.25 | 2444 | 2437 | 650.00 | 28.9 | 29.4 |
| | 2 | 8.20 | 2430 | | 670.00 | 29.8 | |
| 20 | 1 | 8.15 | 2415 | 2421 | 572.00 | 25.4 | 25.3 |
| | 2 | 8.19 | 2427 | | 564.00 | 25.1 | |
| 30 | 1 | 8.18 | 2424 | 2408 | 470.00 | 20.9 | 22.9 |
| | 2 | 8.07 | 2391 | | 558.00 | 24.8 | |

**Table 11.** Compressive Strength Result for concrete mixes with SDA.

| % SDA | Compressive Strength (N/mm$^2$) | | | |
|---|---|---|---|---|
| | 7 Days | 14 Days | 21 Days | 28 Days |
| 0 | 24.0 | 26.0 | 26.3 | 26.9 |
| 5 | 20.7 | 24.6 | 25.7 | 26.6 |
| 10 | 16.3 | 25.0 | 28.6 | 29.4 |
| 20 | 12.6 | 21.0 | 25.2 | 25.3 |
| 30 | 9.2 | 19.6 | 21.7 | 22.9 |

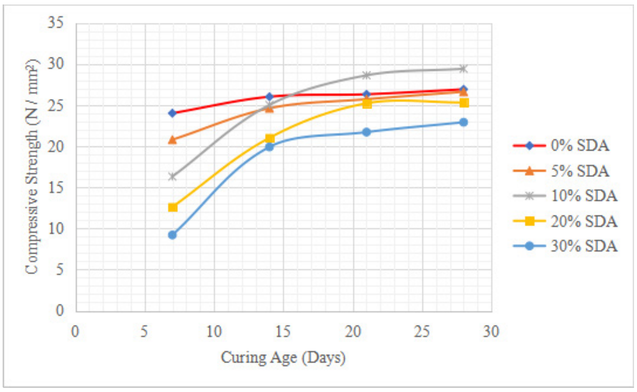


**Figure 4.** Variation of the Compressive Strength of Concrete mixes at various curing ages.

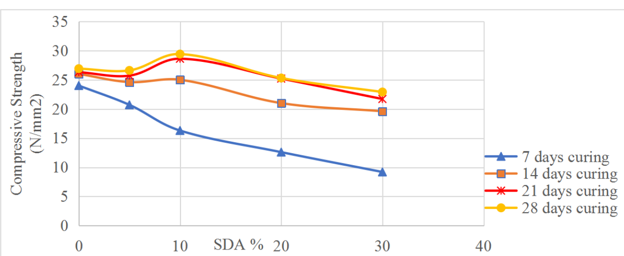


**Figure 5.** Variation of the Compressive Strength of Concrete mixes at different percentages of SDA.

Figures 4 and 5, and Table 11 show that for all the percentages of SDA content in the concrete, the compressive strength of the concrete increases as the curing age increases. Also Figure 4 shows that, from 16 days of curing upwards, the compressive strength of the concrete with 10% SDA became higher than that of the 0%, 5%, 20% and 30% SDA content in concrete. Figure 5 showed that at 10% SDA content in concrete and 28 days curing age, the compressive strength of the concrete assumed the highest value of 29.4 N/mm$^2$ which is higher than that of the control mix (the mix with 0% SDA or 100% cement) whose value is 26.9 N/mm$^2$. Also after 10% SDA content, the compressive strength decreases as the percentage SDA in the concrete increases. Tables 7, 8, 9 and 10 show that the dry density of the SDA/OPC concrete decreases as the percentage replacement of SDA increases. This indicates that the SDA is of lighter weight than the OPC.

## 4. Conclusions

The Sawdust ash under study has similar chemical compounds that are found in OPC but in varied quantities. SDA has a high water absorption, low plasticity and a high porosity.

The SDA/OPC concrete assumes higher strength at longer age of curing. At 10% replacement of cement with SDA, the highest compressive strength of 29.4 N/mm$^2$ was achieved at 28 days of curing, thus, 10% SDA in concrete yields optimum result. Above this percentage

(10%), the compressive strength of the concrete decreases.

Though there are some similarities between the physical and chemical properties of SDA and that of OPC, however, SDA has high porosity, high shrinkage, low modulus of rupture, low $SiO_2$, $Al_2O_3$ and CaO content and hence, is not suitable for total replacement but rather, partial replacement of cement in concrete.

By using SDA to partially replace cement which is the most expensive constituent of concrete in Nigeria, the entire cost of concrete construction is thus, reduced.

### Recommendations

Concrete construction industries should incorporate SDA in their mix so as to save cost and reduce the environmental pollution otherwise caused by sawdust.

Partial replacement of cement with 10% SDA in concrete is recommended for structural concrete while higher percentage up to 30% of SDA in concrete is recommended for light load bearing structures.

It is recommended that incinerators be used in burning sawdust so as to ensure complete combustion to ash to enhance its pozzolanic capacity.

## Author Contributions

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## Conflict of Interest

There is no conflict of interest.

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