



UTILISATION OF SAWDUST ASH AS A PARTIAL CEMENT REPLACEMENT IN CONCRETE PRODUCTION

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ARTICLE INFORMATION	ABSTRACT
<p>Article history: Received 18th January 2025 Revised 29th January 2025 Accepted 17th February 2025 Available online 8th March 2025</p> <p>Keywords: Compressive strength Partial replacement Pozzolan Sawdust ash Waste management</p>	<p><i>The increasing demand for sustainable construction materials has led researchers to explore the use of alternative binders and supplementary cementitious materials. Industrial and agricultural by-products such as fly ash, rice husk ash, and sawdust ash (SDA) have gained attention for their potential to partially replace cement in concrete production. This study investigates the feasibility of utilizing sawdust ash derived from sawmill waste as a partial substitute for cement in concrete, focusing on its effect on workability and compressive strength. Sawdust obtained from a sawmill in Ede was air-dried and subsequently burnt in a furnace at approximately 600°C at Adeleke University, Ede, to produce sawdust ash (SDA). The ash was used to partially replace cement in concrete at varying proportions of 0%, 5%, 10%, and 20% by weight, using a standard 1:2:4 mix ratio. Batching was carried out by weight with a water–cement ratio of 0.5. Slump tests were conducted on each mix to determine workability, and the concrete cubes were cured for 28 days. Chemical analysis of the sawdust ash revealed the presence of silica (3.39%), alumina (5.67%), and ferric oxide (66.7%), with a combined composition exceeding 70%, classifying the material as a pozzolan. The compressive strength results showed a progressive increase in strength with curing age. Concrete containing up to 10% SDA exhibited higher compressive strength compared to the control mix, while strength decreased at 20% replacement. These findings indicate that sawdust ash can be effectively utilized as a partial replacement for cement in concrete production up to an optimal level of 10%, contributing to sustainable construction practices and waste material management.</i></p> <p style="text-align: right;">© 2025 JNTCE. All rights reserved</p>

1. INTRODUCTION

Cement is one of the most widely used construction materials in the world, serving as a critical component of concrete — the backbone of modern infrastructure. However, cement production is energy-intensive and contributes significantly to global carbon dioxide emissions, estimated at about 7–8% of total anthropogenic CO₂ output (Andrew, 2018). In view of increasing environmental concerns, there is a growing need to identify sustainable alternatives that can reduce the carbon footprint of cement while maintaining or enhancing concrete performance. One of the most promising approaches to sustainable cement production is the partial replacement of cement with pozzolanic materials derived from industrial and agricultural wastes. Pozzolans are siliceous or aluminous substances that, when finely divided and in the presence of moisture, react with calcium hydroxide to form compounds possessing cementitious properties (ASTM C618, 2019). Common examples include fly ash, rice husk ash, metakaolin, and sawdust ash. The use of such materials not only reduces the quantity of cement required but also promotes environmental conservation through waste management (Obilade, 2014).

Sawdust is a by-product of timber processing in sawmills and is often disposed of through open dumping or burning, leading to environmental pollution. When properly combusted under controlled conditions, sawdust can yield ash rich in oxides such as silica (SiO₂), alumina (Al₂O₃), and ferric oxide (Fe₂O₃), which are key indicators of pozzolanic activity (Ettu et al., 2013). Several studies have demonstrated the potential of sawdust ash (SDA) as a supplementary cementitious material capable of improving the mechanical properties and durability of concrete when used in suitable proportions (Udoeyo et al., 2006; Adesanya & Raheem, 2009).

Incorporating SDA in concrete production aligns with global efforts toward sustainable construction and circular economy principles. It reduces the dependence on ordinary Portland cement (OPC), minimizes waste generation, and contributes to cost-effective construction materials (Oyeleke et al., 2020). However, the performance of SDA-blended concrete depends on various factors such as the burning temperature, fineness, chemical composition, and replacement level.

This research focuses on the production and utilization of sawdust ash obtained from a sawmill at Ede, Osun State, Nigeria, as a partial replacement for cement in concrete. The study evaluates the workability and compressive strength of concrete mixtures containing varying percentages of SDA (0%, 5%, 10%, and 20%) and identifies the optimal replacement level suitable for structural applications. The findings provide valuable insights into the potential of SDA as a sustainable and eco-friendly material for concrete production.

2. MATERIALS AND METHODS

2.1 Sieve Analysis

A representative sample (sand) was first air-dried to remove moisture and then weighed. The sieves (of size ranging from 4.75 mm to 0.75 mm) were arranged in order of decreasing mesh size, and the dried sample was poured into the top sieve. Each set was shaken with the aid of electric shaker for five minutes. The material retained on each sieve was weighed, and the percentage retained and passing are calculated to determine the grading of the aggregates. The procedure above was repeated for sample of coarse aggregates (granite) with the sieves' size ranging from 28.00 mm to 2.36 mm.

2.2 Preparation of Sawdust Ash

The sawdust was obtained from the sawing of a mahogany planks at a sawmill at Ede Osun State Nigeria. The sawdust was first air-dried and burnt in a furnace at Adeleke University Ede at temperature of about 600 °C. The ash obtained from it was allowed to cool and sieved through sieve 150 mm.

2.3 XRF Analysis of the Sawdust Ash

Sample of the sawdust ash (SDA) was crushed with an electric crusher and then pulverised for 60 seconds using Herzog Gyro-mill (Simatic C7-621). Pellets were prepared from the pulverised sample, first by grinding 20 g of each sample with 0.4 g of stearic acid for 60 seconds. After each grinding, the Gyro-mill was cleansed to avoid contamination. 1 g of stearic acid was weighed into an aluminium cup to act as binding agent and the cup was subsequently filled with the sample to the level point. The cup was then taken to Herzog pelletizing equipment when it was passed at a pressure of 200 kN for 60 seconds. The 2 mm pellets were added into a sample holder of the x-ray equipment (Phillips PW-1800) for analysis.

2.4 Batching and Mixing of Concrete

Batching of materials for the production of concrete was done by weight, and 1:2:4 concrete mix was adopted. The materials were batched as shown in Table 1. The water-cement ratio adopted was 0.5 and the mixing of the constituent materials was done manually.

Table 1: Batching of Concrete Materials

% SDA	Cement Content (kg)	SDA Content (kg)	Sand (kg)	Granite (kg)
0	4.11	0	8.28	16.46
5	3.90	0.21	8.28	16.46
10	3.70	0.41	8.28	16.46
20	2.29	0.82	8.28	16.46

2.5 Slump Test

The slump cone was first oiled and later placed on a smooth surface after the mixing of the concrete. The concrete was poured into the slump cone in three layers and each layer was tamped with 25 strokes using tamping rod. Afterward, the cone was raised from the concrete immediately and slowly in a vertical direction. The difference between the height of the cone and the concrete specimen was measured and recorded.

2.6 Casting and Curing of Concrete

The concrete moulds (150 mm X 150 mm X 150 mm) were oiled so as to ensure seamless removal of formwork from the concrete cubes. The thoroughly mixed concrete was then cast into the concrete moulds with the aid of trowel. The casting was done in three layers, with each layer being tamped with 25 blows of tamping rod. After 24 hours of casting, the concrete was removed from the mould and curing was done by immersing the concrete cubes in the curing tank filled with water for a period of 7, 14, 21 and 28 days.

2.7 Compressive Strength Test

The concrete cubes were removed from the curing tank after a specified curing period. The cubes were placed in the compressive strength test machine and a load of 140kg/m²/minute was applied gradually without shock till the concrete cube failed, then the maximum load was noted. The compressive strength was determined with the aid of Equation 1.

$$\text{Compressive Strength} = \frac{\text{Maximum Load Applied (N)}}{\text{Area of Cube (mm}^2\text{)}} \quad (1)$$

3. RESULTS AND DISCUSSION

3.1 Sieve Analysis of Sand and Granite Used for the Study

The results of the sieve analysis are shown in Table 2. The sieve analysis indicated that the fine aggregate (sand) was well graded, with a coefficient of uniformity (Cu) of 3.38 and coefficient of curvature (Cc) of 0.92. The coarse aggregate (granite) showed Cu = 1.55 and Cc = 0.90, indicating uniform particle distribution suitable for concrete production. These values suggest good gradation that promotes strong bonding and reduced voids in the concrete matrix.

Table 2: Sieve Analysis of Sand and Granite Used for the Concrete

Aggregate Type	Sieve Size (mm)	Mass of Sieve (g)	Mass of Sieve and Soil Retained (g)	Mass of Soil Retained (g)	Percentage Soil Retained (%)	Cumulative Percentage Soil Retained (%)	Percentage Soil Passing (%)
Sand	4.75	385	385	0.0	0.0	0.0	100.00
	2.36	380	483.5	103.5	17.26	17.26	82.74
	1.18	365	479.3	114.3	19.06	36.32	63.68
	0.600	340	534.5	194.5	32.43	68.75	31.25
	0.425	325	404.2	79.2	13.2	81.95	18.05
	0.300	320	379.4	59.4	9.9	91.85	8.15
	0.21	315	336.3	21.3	3.55	95.4	4.60
	0.15	300	310.2	10.2	1.7	97.1	2.90
	0.075	290	299.6	9.6	1.6	98.7	1.30
	Pan	250	257.8	7.8	1.3	100.00	0.00
Total				599.8	100.00		
Granite	28.00	385	385	0.0	0.00	0.00	100.00
	20.00	380	497.6	117.6	4.20	4.20	95.80
	14.00	365	1694.9	1329.9	47.50	51.70	48.30
	10.00	340	1457.1	1117.1	39.90	91.60	8.40
	6.30	325	515.4	190.4	6.80	98.40	1.60
	5.00	320	339.6	19.6	0.70	99.10	0.90
	2.36	315	329	14.0	0.50	99.60	0.40
	Pan	250	261.2	11.2	0.40	100.00	0.00
	Total				2799.8	100.00	

$$\text{For sand, Coefficient of Uniformity (C}_u\text{)} = \frac{D_{60}}{D_{10}} = \frac{0.0015}{0.0000034} = 3.38$$

$$\text{Coefficient of Curvature (C}_c\text{)} = \frac{D_{10} \times D_{30}^2}{D_{60}^2} = \frac{0.0000034 \times 0.006^2}{0.0015^2} = 0.92$$

$$\text{For granite, Coefficient of Uniformity (C}_u\text{)} = \frac{D_{60}}{D_{10}} = \frac{0.0017}{0.0011} = 1.55$$

$$\text{Coefficient of Curvature (C}_c\text{)} = \frac{D_{10} \times D_{30}^2}{D_{60}^2} = \frac{0.0011 \times 0.0013^2}{0.0017^2} = 0.90$$

3.2 Chemical Composition of the Ordinary Portland Cement and Sawdust Ash

The X-ray Fluorescence (XRF) analysis of the Ordinary Portland Cement and Sawdust Ash (SDA) is as shown in Table 3. The XRF analysis showed that the sawdust ash (SDA) contained 66.74% SiO₂, 5.67% Al₂O₃, and 3.39% Fe₂O₃. The combined oxide content exceeded 70%, which classifies SDA as a pozzolan according to ASTM C618 standards. The high silica content suggests good pozzolanic reactivity, while the low CaO (1.85%) and moderate MgO values indicate stable behavior suitable for cement replacement applications.

Table 3: XRF Analysis of OPC and SDA

Major Oxides	Concentration (Wt %)	
	OPC (%)	SDA (%)
SiO ₂	21.55	66.74
Al ₂ O ₃	5.28	5.67
Fe ₂ O ₃	3.95	3.39
SO ₃	1.50	2.54
CaO	64.45	1.85
P ₂ O ₅	-	0.17
K ₂ O	-	12.67
MnO	-	0.04
MgO	1.85	3.72
Na ₂ O	-	0.92
LOI	1.44	0.52

3.3 Slump Test Result

The slump test result is shown in Table 4. The slump values decreased with increasing SDA content, from 32 mm at 0% replacement to 20 mm at 20% replacement. This decline in workability was due to the fine texture and high surface area of SDA particles, which increased water absorption. However, all mixes exhibited medium workability, acceptable for standard concrete construction.

Table 4: Slump Test Result

Sample Identification	Height of Cone (mm)	Height of Concrete (mm)	Slump Value (mm)
0% SDA + 100% OPC	300	268	32
5% SDA + 95% OPC	300	272	28
10% SDA + 90% OPC	300	275	25
20% SDA + 80% OPC	300	280	20

3.4 Compressive Strength of the Concrete

The compressive strength values of the concrete are as shown in Figure 1. Compressive strength increased progressively with curing age for all samples. Concrete with 10% SDA replacement recorded the highest compressive strength, outperforming the control sample. This improvement is attributed to the pozzolanic reaction that produces additional calcium silicate hydrate (C-S-H), enhancing strength and durability. At 20% replacement, strength decreased, showing that excessive SDA reduces available cementitious material.

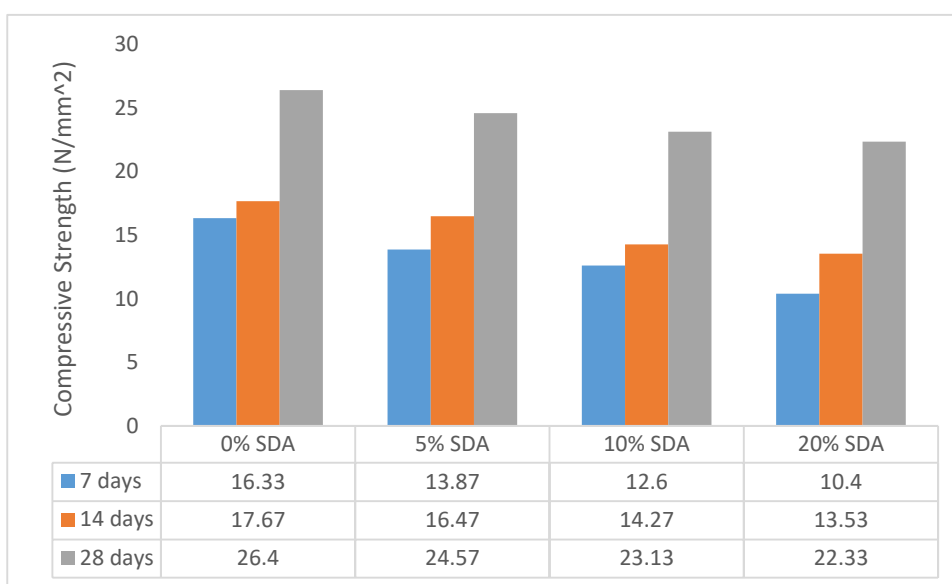


Figure 1: Compressive Strength –Time Characteristics of SDA-Blended Concrete

4. CONCLUSION

This study demonstrates that sawdust ash (SDA) can effectively replace a portion of cement in concrete production up to an optimal level of 10%. SDA exhibited excellent pozzolanic properties, contributing to improved compressive strength and sustainable material utilization. Although higher replacement levels led to reduced workability and strength, moderate inclusion enhanced performance while supporting environmental conservation. Therefore, SDA is recommended as an eco-friendly, cost-effective cement substitute for concrete works. Further studies should explore its long-term durability and performance under different environmental conditions.

REFERENCES

Adesanya, D. A., & Raheem, A. A. (2009). Development of corn cob ash blended cement. *Construction and Building Materials*, 23(1), 347–352. <https://doi.org/10.1016/j.conbuildmat.2007.12.013>

Andrew, R. M. (2018). Global CO₂ emissions from cement production. *Earth System Science Data*, 10(1), 195–217. <https://doi.org/10.5194/essd-10-195-2018>

ASTM C618 (2019). Standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete. ASTM International.

Ettu, L. O., Njoku, F. I., Awodiji, C. T., & Opara, H. N. (2013). Strength of ternary blended cement concrete containing corncob ash and sawdust ash. *American Journal of Engineering Research*, 2(6), 75–80.

Obilade, I. O. (2014). Use of sawdust ash as partial replacement for cement in concrete. *International Journal of Engineering and Technology*, 4(1), 47–50.

Oyeleke, T. D., Olatunji, S. O., & Lawal, A. A. (2020). Effect of sawdust ash on the properties of lateritic soil stabilized with cement. *Journal of Building Performance*, 11(1), 67–74.

Udoeyo, F. F., Inyang, H., Young, D. T., & Oparadu, E. E. (2006). Potential of wood waste ash as an additive in concrete. *Journal of Materials in Civil Engineering*, 18(4), 605–611. [https://doi.org/10.1061/\(ASCE\)0899-1561\(2006\)18:4\(605\)](https://doi.org/10.1061/(ASCE)0899-1561(2006)18:4(605))