

## Influence of Sharp Sand and Stone Dust Combinations on the Properties of Wood Ash Blended Cement Concrete

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### Abstract

Concrete production relies heavily on Portland limestone cement and natural sharp sand, contributing to environmental degradation and resource depletion. This study investigated stone dust as a partial or complete replacement for sharp sand in concrete containing 10% wood ash as cement replacement. Five mixes were produced at a nominal 1:2:4 proportion and water-to-binder ratio of 0.50, with stone dust replacing sharp sand at 0%, 25%, 50%, 75%, and 100%. Wood-ash chemical composition was determined by X-ray fluorescence, while aggregate particle-size distribution was evaluated in accordance with BS 812-103.1:1985. Slump and compacting factor tests followed BS EN 12350-2:2009 and BS 1881-103:1983, respectively. Compressive strength, splitting tensile strength, water absorption, and density were determined in accordance with BS EN 12390-3:2009, ASTM C496/C496M-17, and ASTM C642-13, respectively. Selected 28-day samples were examined using scanning electron microscopy. The combined  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ , and  $\text{Fe}_2\text{O}_3$  content of the wood ash was 83.91%. Slump and compacting factor values ranged from 58–75 mm and 0.78–0.92, respectively. Compressive strength ranged from 8.00–25.20 N/mm<sup>2</sup>, with 28-day values of 20.90–23.40 N/mm<sup>2</sup>. Splitting tensile strength ranged from 0.90–3.50 N/mm<sup>2</sup>, while water absorption and density ranged from 0.71–2.04% and 2387–2453 kg/m<sup>3</sup>, respectively. SEM images showed a compact microstructure in the 50% sharp sand and 50% stone dust combination samples. Material cost ranged from ₦24,000–₦25,130 per batch. These findings demonstrate that stone dust is a technically viable alternative to sharp sand in wood ash blended concrete.

**Keywords:** Wood ash; Stone dust; Sharp sand; Blended Cement Concrete; Compressive Strength; Sustainable Construction.

### Introduction

Concrete remains one of the most widely used construction materials globally because of its versatility, strength, durability and suitability for different categories of civil engineering infrastructure. It is a composite material produced from cement, water, fine aggregate and coarse aggregate, and its performance depends largely on the quality, grading and interaction of these constituent materials. The increasing demand for housing, transportation infrastructure and other civil engineering works has resulted in a corresponding rise in the consumption of cement and natural aggregates. Consequently, the cost and environmental burden associated with conventional concrete materials have continued to attract research attention. The production of cement is energy intensive and contributes significantly to greenhouse gas emissions. Flower and Sanjayan (2007) reported that about 0.8 tonne of CO<sub>2</sub> is emitted for every tonne of cement produced. Similarly, the concrete industry has been identified as one of the major contributors to carbon emissions due to the large quantity of cement consumed in construction works (Barbhuiya *et al.*, 2024). Apart from cement, the extraction of natural aggregates also raises environmental concerns. Excessive quarrying and mining of conventional aggregates can lead to natural resource depletion, environmental degradation and ecological imbalance (Blankendaal *et al.*, 2014). These challenges have encouraged the use of alternative, locally available and waste-derived materials in concrete production.

Fine aggregate is an essential component of concrete because it fills the voids between coarse aggregate particles, improves packing density, influences workability and contributes to the strength and durability of

the hardened matrix. Sharp sand has traditionally been used as fine aggregate due to its availability and favourable grading characteristics. However, the increasing demand for sand in construction has resulted in scarcity, high cost and environmental concerns related to river sand mining. Sand has been described as one of the most consumed natural resources after water, and indiscriminate extraction from rivers and coastal environments has been associated with erosion, riverbed degradation and damage to aquatic habitats (Kotla and Kumar, 2020; Rentier and Cammeraat, 2022). This has made it necessary to investigate alternative fine aggregates that can reduce dependence on natural sharp sand. Stone dust, also referred to as quarry dust, is a by-product generated during the crushing of stones in quarry operations. It is often regarded as waste and may cause disposal and environmental problems around quarry sites. However, because of its mineral composition, angular particle shape and relatively fine texture, stone dust has shown potential as partial or full replacement for natural sand in concrete. Previous studies have reported that the use of quarry dust as fine aggregate can improve compressive strength due to its filler effect and enhanced particle interlocking, although workability may reduce as quarry dust content increases because of its higher surface area and water demand (Jagadeesh *et al.*, 2016; Shyam Prakash and Hanumantha Rao, 2017). The use of stone dust in concrete therefore offers both environmental and economic benefits by converting quarry waste into a useful construction material while reducing the demand for natural sand.

In addition to aggregate replacement, reduction in cement consumption through supplementary cementitious materials has become an important strategy for sustainable concrete production. Supplementary cementitious materials are generally siliceous or aluminosiliceous materials that, in finely divided form and in the presence of moisture, react with calcium hydroxide released during cement hydration to form additional cementitious compounds (ASTM C618, 2005). Agricultural and biomass residues have received attention as supplementary cementitious materials because they are usually available at low cost and their utilisation supports waste management and environmental sustainability (Aprianti *et al.*, 2015). Raheem and Ikotun (2020) noted that agricultural residues can serve as partial substitutes for cement in concrete and mortar when properly processed and selected. Wood ash is one of the biomass residues that have been investigated as partial replacement for cement in concrete. It is obtained from the combustion of wood and wood products, including residues from domestic cooking, industrial heating and bakery operations. Wood ash contains oxides such as silica, alumina, iron oxide and calcium oxide, which may contribute to pozzolanic activity depending on its source, burning condition and fineness (Siddique, 2008; Chowdhury *et al.*, 2015). The pozzolanic reaction between reactive silica or alumina in wood ash and calcium hydroxide from cement hydration can produce additional calcium silicate hydrate, thereby improving the microstructure and later-age strength of concrete. Previous studies have shown that wood ash can be used as partial cement replacement, with optimum replacement commonly reported within moderate levels, particularly between 5% and 15% depending on the characteristics of the ash and concrete mix (Raheem and Adenuga, 2013; Sebastian *et al.*, 2016; Pranav and Malkhede, 2018).

Despite the individual potential of stone dust as fine aggregate replacement and wood ash as supplementary cementitious material, limited studies have considered their combined effect in concrete. Most previous investigations have focused either on replacing cement with wood ash or replacing natural sand with quarry dust separately. This leaves a knowledge gap on how varying combinations of sharp sand and stone dust affect the properties of concrete in which part of the cement has already been replaced with wood ash. Understanding this combined effect is important because the simultaneous use of wood ash and stone dust can address two sustainability concerns in concrete production: reduction in cement consumption and reduction in dependence on natural sharp sand. Furthermore, the economic implication of replacing sharp sand with stone dust in wood ash blended cement concrete deserves attention. In the study area, sharp sand is relatively more expensive than stone dust. The indicative market prices were obtained through a direct price enquiry from Teaa Ventures Ltd., Ogbomoso, Nigeria, on 12<sup>th</sup> of February, 2026. At the time of enquiry, a 10-tonne tipper load of sharp sand and stone dust cost ₦65,000 and ₦45,000, respectively. These

prices were used solely for the study's comparative material-cost assessment and may vary with location, haulage distance, supplier, and market conditions.

This cost difference suggests that the use of stone dust may reduce the material cost of concrete, especially in large-scale construction. However, such cost reduction must be considered alongside strength, durability-related properties and microstructural performance to determine the practical suitability of the material. Therefore, this study investigates the influence of sharp sand and stone dust combinations on the properties of wood ash blended cement concrete. Portland Limestone Cement was partially replaced with 10% wood ash, while the fine aggregate fraction was varied using 100% sharp sand, 75% sharp sand + 25% stone dust, 50% sharp sand + 50% stone dust, 25% sharp sand + 75% stone dust, and 100% stone dust. The study evaluates the chemical composition of wood ash, particle size distribution of aggregates, workability, compressive strength, splitting tensile strength, water absorption, density, microstructure and cost effectiveness of the concrete mixes. The outcome is expected to provide useful information on the technical and economic suitability of stone dust as an alternative fine aggregate in wood ash blended cement concrete.

## **Materials and Methods**

### **Materials Used**

The materials used for this study were Portland Limestone Cement, wood ash, sharp sand, stone dust, coarse aggregate and water. These materials were selected to produce wood ash blended cement concrete in which sharp sand was partially and fully replaced with stone dust. The purpose was to assess the effect of fine aggregate variation on the fresh, mechanical, durability-related, microstructural and cost properties of concrete. Dangote brand Portland Limestone Cement was used as the main cementitious material. The cement was kept in a dry environment before use to prevent moisture absorption and premature hydration. Wood ash was used as partial replacement for cement at a constant replacement level of 10% by weight. This replacement level was adopted because previous studies reported that moderate replacement of cement with wood ash can produce satisfactory performance in concrete (Sebastian *et al.*, 2016; Raheem and Adenuga, 2013).

The wood ash was obtained from LAUTECH Bakery, Ogbomoso, Nigeria. It was collected from the combustion chamber and carefully handled to avoid contamination with soil and other impurities. The collected ash was air-dried and sieved through a 150  $\mu\text{m}$  sieve to remove unburnt particles and obtain a fine material suitable for blending with cement. Sharp sand was used as the conventional fine aggregate, while stone dust was used as partial and full replacement for sharp sand. Both materials were obtained from Teaa Ventures Ltd., Ogbomoso, Nigeria. The sharp sand was clean and free from visible deleterious materials, while the stone dust was air-dried and sieved before use to remove oversized particles. Crushed granite with a maximum aggregate size of 20 mm was used as coarse aggregate. Potable water, free from harmful impurities, was used for mixing and curing of concrete specimens in accordance with BS EN 1008:2002.

### **Testing of Materials**

The constituent materials were tested to determine their suitability for concrete production. The wood ash was subjected to chemical composition analysis using X-ray fluorescence analysis. This was done to determine the oxide composition of the ash and assess its pozzolanic suitability. The combined percentage of silica, alumina and iron oxide was used as an important indicator of pozzolanic potential, based on the requirement for pozzolanic materials (ASTM C618, 2005). Particle size distribution tests were carried out on sharp sand, stone dust and coarse aggregate using the sieve analysis method. This was done to determine the grading characteristics of the aggregates and their suitability for concrete production. The test was conducted in accordance with BS 812-103.1:1985.

Fresh concrete was tested for workability using slump and compacting factor tests. The slump test was conducted in accordance with BS EN 12350-2:2009, while the compacting factor test was carried out in

accordance with BS 1881: Part 103:1983. These tests were used to assess the consistency and ease of compaction of the concrete mixes. Hardened concrete properties were evaluated through compressive strength, splitting tensile strength, water absorption and density tests. The compressive strength test was conducted on cube specimens in accordance with BS EN 12390-3:2009. The splitting tensile strength test was carried out on cylindrical specimens in accordance with ASTM C496/C496M-17. Water absorption was determined in accordance with ASTM C642-13 using the 24-hour immersion procedure. The specimens were oven-dried to constant mass, immersed in water for 24 hours, surface-dried, and weighed. Absorption was calculated as the percentage increase from the oven-dry mass, and the mean of three specimens was reported for each mix. Scanning Electron Microscopy was also carried out on selected hardened concrete samples at 28 days to observe the microstructural characteristics of the concrete matrix. The SEM analysis was used to examine pore structure, particle packing, hydration products and bonding within the concrete matrix.

### Concrete Mix Proportion

The concrete mix proportion used in this study was based on a nominal 1:2:4 ratio of binder, fine aggregate, and coarse aggregate, respectively. The 1:2:4 mix proportion was adopted as a nominal concrete mix intended to achieve a 28-day compressive strength of approximately 20 N/mm<sup>2</sup>, corresponding to a normal-strength concrete grade suitable for general structural applications. A constant water-to-binder ratio of 0.50 was maintained for all concrete mixes. In this study, the binder comprised Portland Limestone Cement and wood ash. Portland Limestone Cement was partially replaced with wood ash at 10% by mass of the total binder in all mixes. Thus, each mix contained 90% cement and 10% wood ash as binder. The use of the term water-to-binder ratio is appropriate because the 25 L of mixing water was proportioned relative to the total binder content of 50 kg, comprising 45 kg of cement and 5 kg of wood ash.

The fine aggregate portion was varied using different combinations of sharp sand and stone dust, while the total fine aggregate content, coarse aggregate content, and water content were kept constant. This approach enabled evaluation of the effect of sharp-sand replacement with stone dust without altering the overall mix proportion. Five concrete mixes were produced. The first mix contained 100% sharp sand as fine aggregate and served as the reference mix. The second, third, and fourth mixes contained 75% sharp sand + 25% stone dust, 50% sharp sand + 50% stone dust, and 25% sharp sand + 75% stone dust, respectively. The fifth mix contained 100% stone dust as fine aggregate. The concrete mix proportions are presented in Table 1.

**Table 1: Mix Proportions for Concrete Samples**

| MIX ID | FINE AGGREGATE COMPOSITION | CEMENT (KG) | WOOD ASH (KG) | FINE AGGREGATE (KG)       | COARSE AGGREGATE (KG) | WATER (LITRES) |
|--------|----------------------------|-------------|---------------|---------------------------|-----------------------|----------------|
| M1     | 100% Sharp Sand (SS)       | 45.0        | 5.0           | 100.0 (SS only)           | 200.0                 | 25.0           |
| M2     | 75% SS + 25% SD            | 45.0        | 5.0           | 100.0 (75.0 SS + 25.0 SD) | 200.0                 | 25.0           |
| M3     | 50% SS + 50% SD            | 45.0        | 5.0           | 100.0 (50.0 SS + 50.0 SD) | 200.0                 | 25.0           |
| M4     | 25% SS + 75% SD            | 45.0        | 5.0           | 100.0 (25.0 SS + 75.0 SD) | 200.0                 | 25.0           |
| M5     | 100% Stone Dust (SD)       | 45.0        | 5.0           | 100.0 (SD only)           | 200.0                 | 25.0           |

Source: Author's research

The use of a constant binder content, total fine aggregate content and coarse aggregate content ensured that the observed differences in concrete performance could be attributed mainly to the variation in sharp sand and stone dust combinations. The mix design therefore provided a basis for comparing workability, compressive strength, splitting tensile strength, water absorption, density, microstructure and cost effectiveness of the concrete samples.

### **Specimen Preparation**

The concrete specimens were prepared by batching the materials by weight. For each mix, the required quantities of cement, wood ash, sharp sand and/or stone dust were first dry-mixed until a uniform colour was obtained. The coarse aggregate was then added and thoroughly mixed with the dry constituents. Water was gradually introduced while mixing continued until a homogeneous concrete mix was obtained.

Immediately after mixing, the fresh concrete was tested for slump and compacting factor. Thereafter, the concrete was placed in clean and lightly oiled moulds. Cube specimens of 150 mm × 150 mm × 150 mm were prepared for compressive strength and density tests, while cylindrical specimens were prepared for splitting tensile strength test. The concrete was placed in layers and compacted properly to remove entrapped air and ensure uniform consolidation.

The specimens were covered and left undisturbed for 24 hours. After demoulding, they were transferred into a curing tank containing clean water. The specimens were cured for 3, 7, 28, 56 and 90 days, depending on the test requirement. At each curing age, the specimens were removed from the curing tank, surface-dried and tested. For each concrete mix and curing age, three 150 mm cube specimens were tested for compressive strength, while three cylindrical specimens were tested for splitting tensile strength. The reported values represent the arithmetic mean of the three replicate test results. For the water absorption test, specimens cured for 28 days were dried to constant mass and later immersed in water for 24 hours. The increase in mass after immersion was used to determine the percentage water absorption. For microstructural examination, representative hardened concrete samples were taken at 28 days and prepared for Scanning Electron Microscopy analysis. The SEM observations were used to relate the internal structure of the concrete to the strength and durability-related behaviour of the mixes.

## **Results and Discussion**

### **Characterisation of Materials**

The chemical composition of the wood ash used in this study is presented in Table 2. The wood ash contained silica, alumina, and iron oxide as its major reactive oxides. The contents of SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, and Fe<sub>2</sub>O<sub>3</sub> were 45.23%, 14.43%, and 24.25%, respectively. Their combined content was 83.91%, exceeding the 70% minimum commonly associated with pozzolanic materials. This indicates that the wood ash has potential for use as a supplementary cementitious material in concrete.

The relatively high SiO<sub>2</sub> content suggests that the ash may participate in pozzolanic reactions with calcium hydroxide released during cement hydration, contributing to the formation of additional calcium silicate hydrate and improving the cementitious matrix. Similar observations on the use of wood ash in blended concrete have been reported by Sebastian *et al.* (2016) and Raheem and Adenuga (2013).

The CaO content of the wood ash was 2.30%, while MgO and K<sub>2</sub>O contents were 0.45% and 1.90%, respectively. The relatively low CaO and high Fe<sub>2</sub>O<sub>3</sub> contents differ from those of many wood ashes reported in the literature. This variation may be attributed to differences in wood source, combustion conditions, ash collection methods, and possible impurities. Therefore, the ash is expected to exhibit mainly pozzolanic rather than self-cementing behaviour. The loss on ignition was 9.70%, indicating the presence of some unburnt carbon or volatile matter.

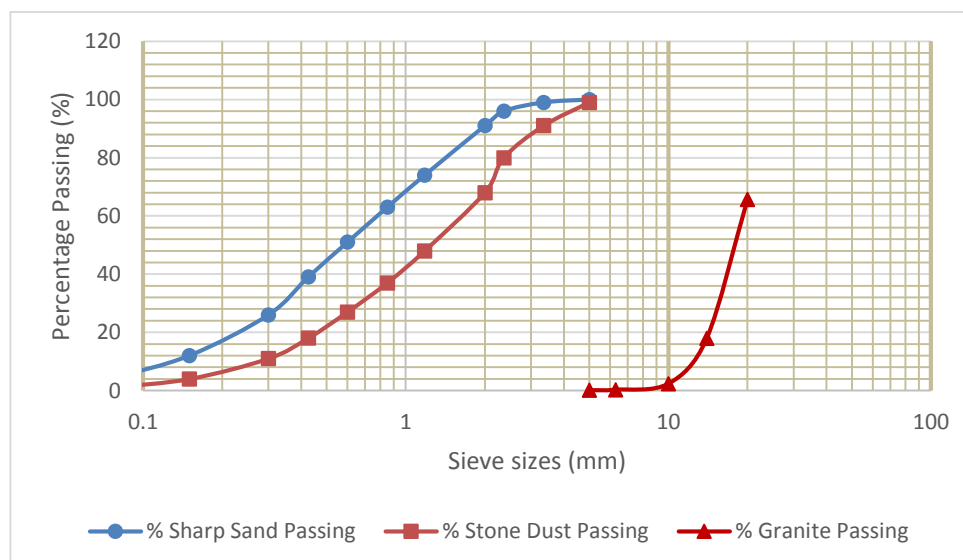
**Table 2:** Chemical composition of wood ash

| Chemical Composition           | Percentage Composition (%) |
|--------------------------------|----------------------------|
| SiO <sub>2</sub>               | 45.23                      |
| Al <sub>2</sub> O <sub>3</sub> | 14.43                      |
| Fe <sub>2</sub> O <sub>3</sub> | 24.25                      |
| CaO                            | 2.30                       |
| MgO                            | 0.45                       |
| Na <sub>2</sub> O              | 0.17                       |
| K <sub>2</sub> O               | 1.90                       |
| P <sub>2</sub> O <sub>5</sub>  | 0.32                       |
| MnO                            | 0.02                       |
| LOI                            | 9.70                       |

Source: Author's research

### Physical Properties of Materials

The particle size distribution test was carried out on sharp sand, stone dust and coarse aggregate to determine their grading characteristics and suitability for concrete production. The grading curves of the materials are presented in Figure 1. The curves show the relationship between sieve size and percentage passing for the aggregates. From Figure 1, sharp sand and stone dust fall within the fine aggregate particle size range, while the coarse aggregate occupies the larger particle size range. The sharp sand showed a wider and smoother particle size distribution, indicating better grading characteristics. The coefficient of uniformity and coefficient of curvature obtained for sharp sand were 6.19 and 1.18, respectively. These values indicate that the sharp sand was well graded and suitable for concrete production. The stone dust had a coefficient of uniformity of 6.01 and coefficient of curvature of 0.96. Although the coefficient of curvature was slightly below the range usually associated with well-graded sand, the coefficient of uniformity showed that the stone dust contained a fairly wide range of particle sizes. Therefore, the stone dust was considered suitable for use as partial or full replacement for sharp sand in concrete. Its finer particles were expected to contribute to void filling, improved particle packing and better density of the hardened concrete.



**Figure 1:** Particle size distribution of sharp sand, stone dust and coarse aggregate.

Source: Author's research

For the coarse aggregate, the coefficient of uniformity and coefficient of curvature were 1.61 and 1.08, respectively. The coefficient of uniformity indicates that the coarse aggregate was more uniformly graded, with particles concentrated within a narrower size range. However, when combined with the fine

aggregates, the coarse aggregate was considered suitable for concrete production. Overall, the grading characteristics showed that sharp sand, stone dust and coarse aggregate were suitable for producing wood ash blended cement concrete.

### Workability of Fresh Concrete

The workability of fresh concrete was evaluated using slump and compacting factor tests. The results are presented in Table 3. The slump values decreased from 75 mm for the concrete containing 100% sharp sand to 58 mm for the concrete containing 100% stone dust. This shows that the workability of the concrete reduced as the proportion of stone dust increased. The concrete containing 100% sharp sand recorded the highest slump value of 75 mm, followed by 70 mm for 75% sharp sand + 25% stone dust, 65 mm for 50% sharp sand + 50% stone dust, 60 mm for 25% sharp sand + 75% stone dust, and 58 mm for 100% stone dust. The reduction in slump with increasing stone dust content can be attributed to the finer particles and higher surface area of stone dust. These characteristics increase the water demand of the mix, thereby reducing the amount of free water available for lubrication and movement of particles in the fresh concrete. Similar reductions in workability have been reported when quarry dust was used as a partial replacement for natural sand in concrete because of its fine particles, angular shape, and higher water demand (Jagadeesh *et al.*, 2016; Shyam Prakash and Hanumantha Rao, 2017).

The compacting factor results followed the same trend as the slump results. The compacting factor decreased from 0.92 for 100% sharp sand to 0.78 for 100% stone dust. This confirms that the ease of compaction reduced as the stone dust content increased. The highest compacting factor value was recorded for the 100% sharp sand mix, while the lowest value was recorded for the 100% stone dust mix.

Although the workability reduced with increasing stone dust content, all the concrete mixes remained workable and could be cast and compacted. The results indicate that stone dust can be incorporated into wood ash blended cement concrete, provided adequate compaction is applied during placement.

**Table 3:** Slump and compacting factor test results

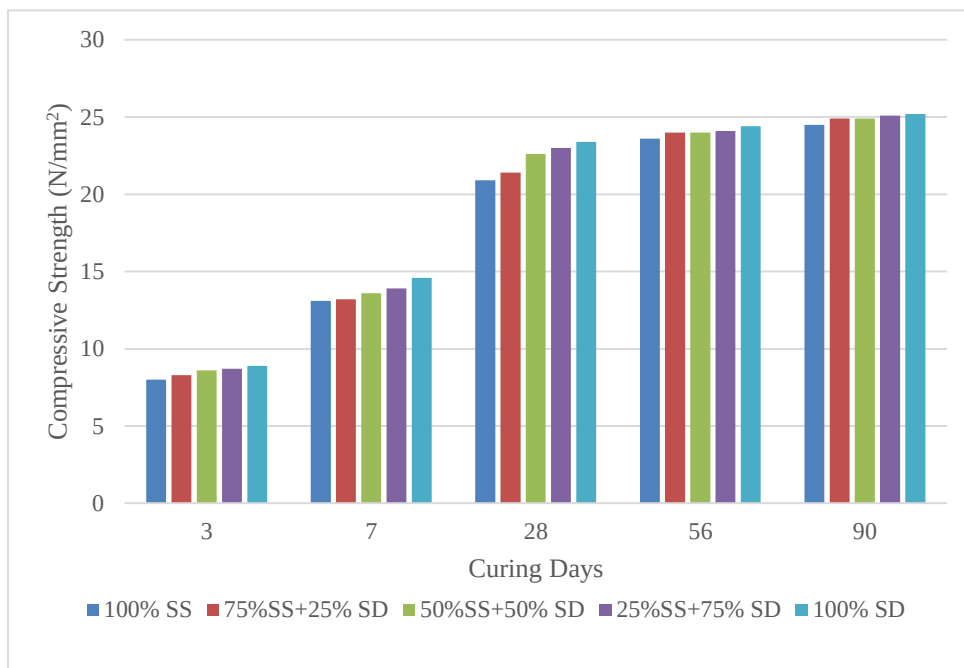
| MIX PROPORTION | SLUMP (mm) | COMPACTING FACTOR |
|----------------|------------|-------------------|
| 100% SS        | 75         | 0.92              |
| 75% SS + 25%SD | 70         | 0.88              |
| 50% SS + 50%SD | 65         | 0.85              |
| 25% SS + 75%SD | 60         | 0.84              |
| 100% SD        | 58         | 0.78              |

Source: Author's research

### Hardened Concrete Tests

#### Compressive Strength

The compressive strength results of the concrete mixes at 3, 7, 28, 56, and 90 days are presented in Figure 2. The compressive strength of all mixes increased with curing age due to continued cement hydration and the pozzolanic reaction of the wood ash, which contributed to the formation of additional cementitious products. At 3 days, the compressive strength values ranged from 8.00 N/mm<sup>2</sup> to 8.90 N/mm<sup>2</sup>. The 100% sharp sand mix recorded the lowest strength of 8.00 N/mm<sup>2</sup>, while the 100% stone dust mix recorded the highest strength of 8.90 N/mm<sup>2</sup>. At 7 days, the strength increased across all mixes, ranging from 13.10 N/mm<sup>2</sup> for 100% sharp sand to 14.60 N/mm<sup>2</sup> for 100% stone dust.



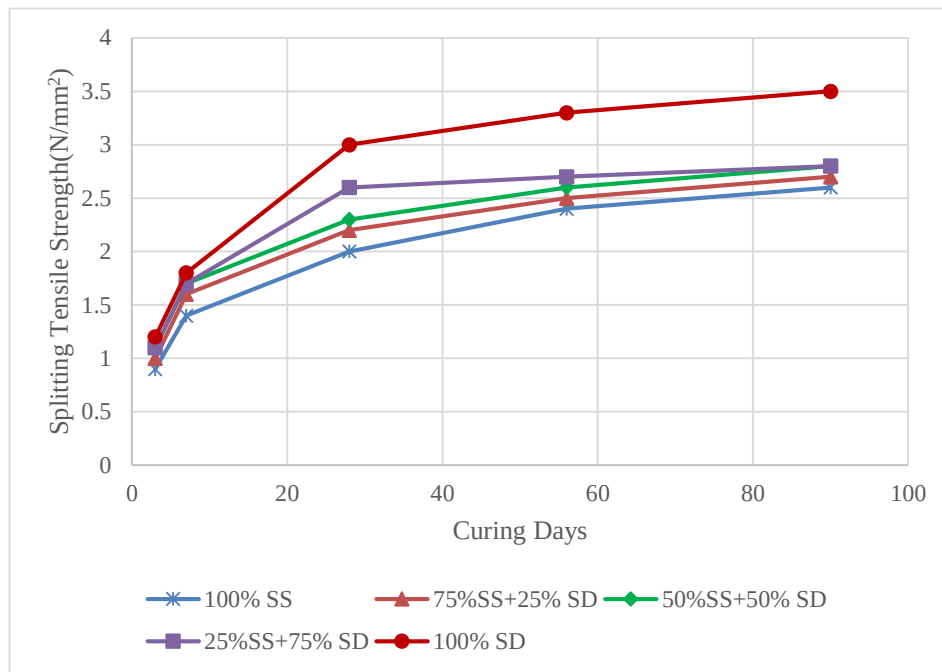
**Figure 2:** Compressive strength of concrete mixes at different curing ages.  
Source: Author's research

At 28 days, which is commonly used as the reference age for concrete strength evaluation, the compressive strength increased from 20.90 N/mm<sup>2</sup> for the 100% sharp sand mix to 23.40 N/mm<sup>2</sup> for the 100% stone dust mix. The mixes containing 75% sharp sand + 25% stone dust, 50% sharp sand + 50% stone dust, and 25% sharp sand + 75% stone dust recorded 21.40 N/mm<sup>2</sup>, 22.60 N/mm<sup>2</sup>, and 23.00 N/mm<sup>2</sup>, respectively. The adopted 1:2:4 nominal mix was intended to attain an approximately 20 N/mm<sup>2</sup> 28-day compressive strength. Therefore, all mixes achieved the target strength, with the stone-dust mixes showing improved performance above this benchmark. This confirms that replacing sharp sand with stone dust improved the 28-day compressive strength.

At 56 days, the compressive strength values ranged from 23.60 N/mm<sup>2</sup> to 24.40 N/mm<sup>2</sup>, while at 90 days, they ranged from 24.50 N/mm<sup>2</sup> to 25.20 N/mm<sup>2</sup>. The 100% stone dust mix consistently recorded the highest compressive strength at all curing ages. The strength improvement with increasing stone dust content can be attributed to the filler effect of the finer stone-dust particles, which filled voids within the concrete matrix and improved particle packing. This produced a denser matrix and enhanced strength development. Overall, stone dust can be used as a partial or full replacement for sharp sand in wood-ash-blended cement concrete without reducing compressive strength. Instead, its inclusion improved compressive strength, particularly at 28 days and beyond.

### Splitting Tensile Strength

The splitting tensile strength results are presented in Figure 3. The results show that splitting tensile strength increased with curing age for all concrete mixes. The increase with age is associated with continued hydration, pozzolanic reaction and improved bond between the cement paste and aggregate particles.

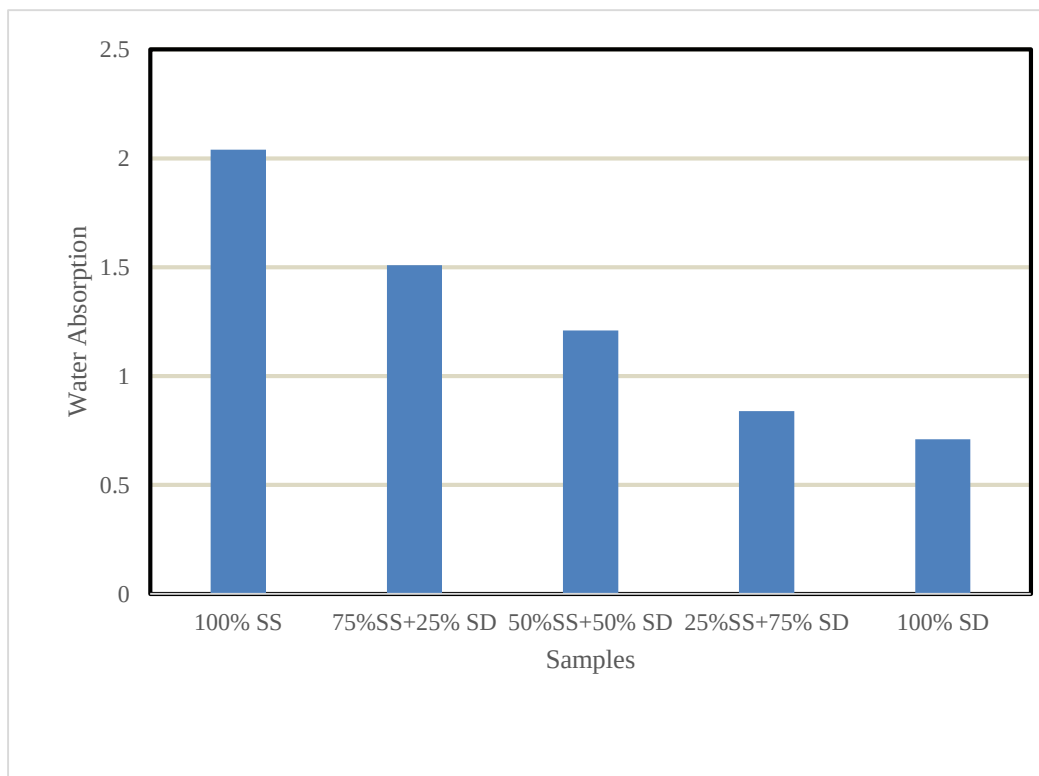


**Figure 3:** Splitting tensile strength of concrete mixes at different curing ages.  
Source: Author's research

At 3 days, the splitting tensile strength ranged from  $0.90 \text{ N/mm}^2$  for 100% sharp sand to  $1.20 \text{ N/mm}^2$  for 100% stone dust. At 7 days, the values increased from  $1.40 \text{ N/mm}^2$  for 100% sharp sand to  $1.80 \text{ N/mm}^2$  for 100% stone dust. This indicates that stone dust improved early-age tensile strength. At 28 days, the 100% sharp sand mix recorded a splitting tensile strength of  $2.00 \text{ N/mm}^2$ , while the 100% stone dust mix recorded  $3.00 \text{ N/mm}^2$ . The mixes containing 75% sharp sand + 25% stone dust, 50% sharp sand + 50% stone dust, and 25% sharp sand + 75% stone dust recorded  $2.20 \text{ N/mm}^2$ ,  $2.30 \text{ N/mm}^2$  and  $2.60 \text{ N/mm}^2$ , respectively. The increase in tensile strength with stone dust content indicates improved internal bonding and compactness of the concrete matrix. At 56 days, the splitting tensile strength ranged from  $2.40 \text{ N/mm}^2$  to  $3.30 \text{ N/mm}^2$ , while at 90 days, it ranged from  $2.60 \text{ N/mm}^2$  to  $3.50 \text{ N/mm}^2$ . The 100% stone dust mix produced the highest tensile strength at all curing ages. This improvement may be attributed to the angular texture and finer particles of stone dust, which enhanced interlocking and improved the interfacial transition zone between the paste and aggregate. Generally, the splitting tensile strength results followed a similar trend to the compressive strength results. This confirms that the inclusion of stone dust contributed positively to the mechanical performance of wood ash blended cement concrete.

### Water Absorption

The water absorption results of the concrete samples at 28 days are presented in Figure 4. The results show that water absorption decreased as the percentage of stone dust increased. The 100% sharp sand mix recorded the highest water absorption value of 2.04%, while the 100% stone dust mix recorded the lowest value of 0.71%.

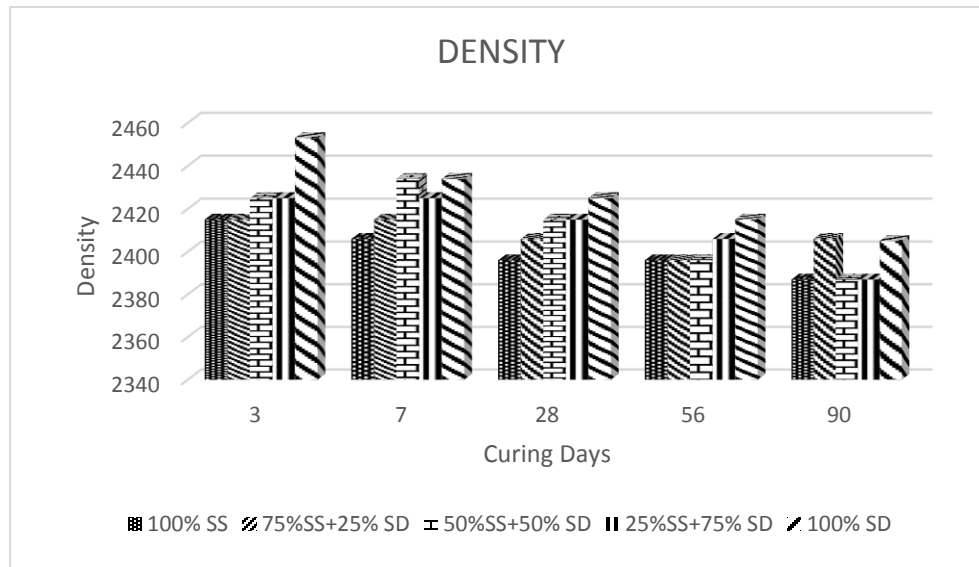


**Figure 4:** Water absorption of concrete samples at 28 days.  
Source: Author's research

The mixes containing 75% sharp sand + 25% stone dust, 50% sharp sand + 50% stone dust, and 25% sharp sand + 75% stone dust recorded water absorption values of 1.51%, 1.21% and 0.84%, respectively. The gradual reduction in water absorption suggests that the inclusion of stone dust improved the compactness of the concrete matrix. The lower absorption values observed in mixes containing higher stone dust content can be linked to the filler effect of stone dust. The finer particles of stone dust filled internal voids and reduced pore spaces within the hardened concrete. As a result, the concrete became less permeable and more resistant to water ingress. This indicates that replacing sharp sand with stone dust improved the durability-related behaviour of the wood ash blended cement concrete.

### Hardened Density

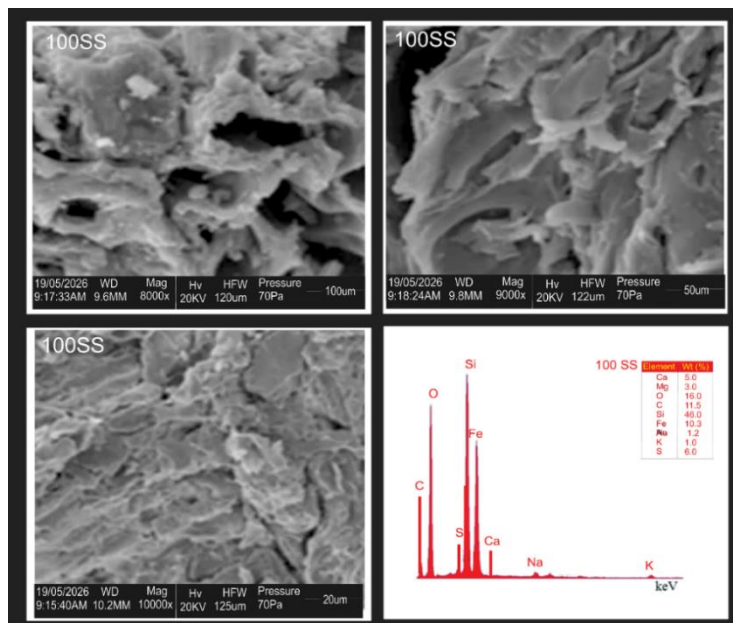
The density results of the concrete samples at different curing ages are presented in Figure 5. The density values ranged from 2387 kg/m<sup>3</sup> to 2453 kg/m<sup>3</sup>, confirming that all mixes produced normal-weight concrete. At 3 days, density values ranged from 2415 kg/m<sup>3</sup> to 2453 kg/m<sup>3</sup>, with the 100% stone dust mix recording the highest value. At 7 days, the values ranged from 2406 kg/m<sup>3</sup> to 2434 kg/m<sup>3</sup>. At 28 days, the density values ranged from 2396 kg/m<sup>3</sup> for 100% sharp sand to 2425 kg/m<sup>3</sup> for 100% stone dust. Similar trends were observed at 56 and 90 days. The mixes containing higher proportions of stone dust generally showed higher density values. This can be attributed to the finer nature of stone dust, which improved particle packing and reduced internal voids in the concrete matrix. Although slight variations occurred with curing age, all density values remained within the range of normal-weight concrete. Therefore, replacing sharp sand with stone dust did not negatively affect the density classification of the concrete.



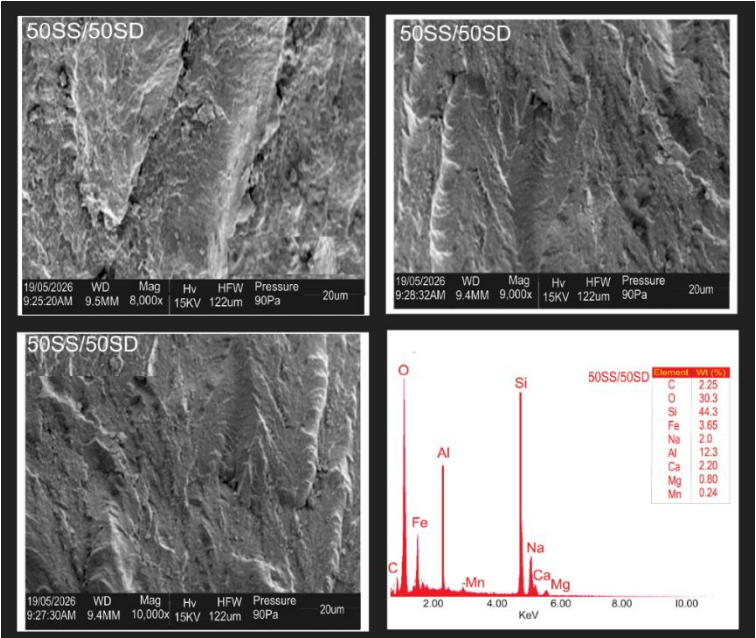
**Figure 5:** Density of concrete samples at different curing ages.  
Source: Author's research

### Microstructural Analysis

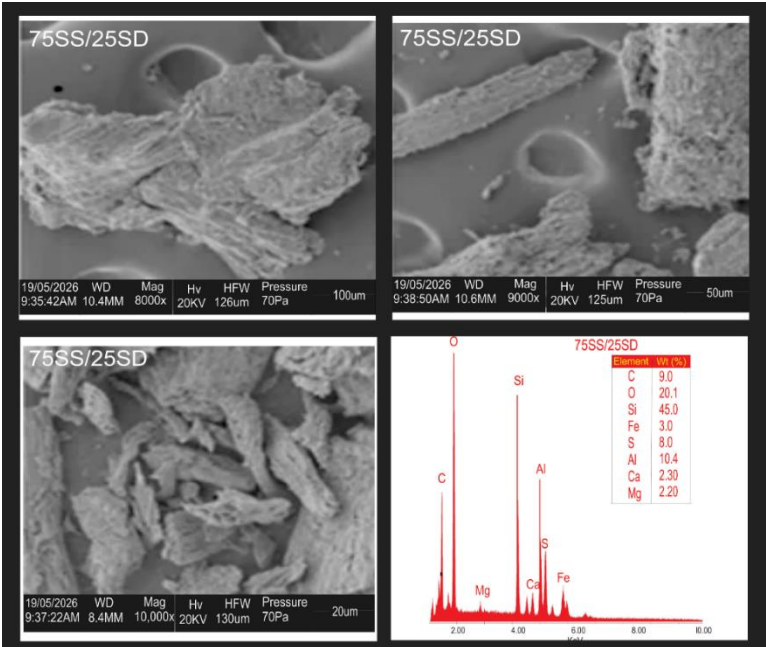
The Scanning Electron Microscopy analysis was carried out on selected concrete samples at 28 days to examine the internal morphology of the hardened concrete matrix. The SEM images are presented in Figure 6 to Figure 10.



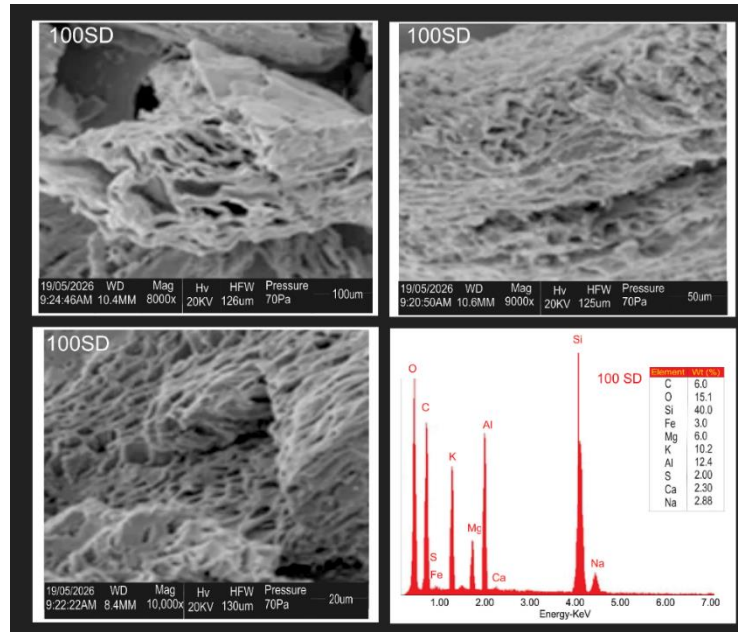
**Figure 6:** SEM analysis for 100% sharp sand.  
Source: Author's research



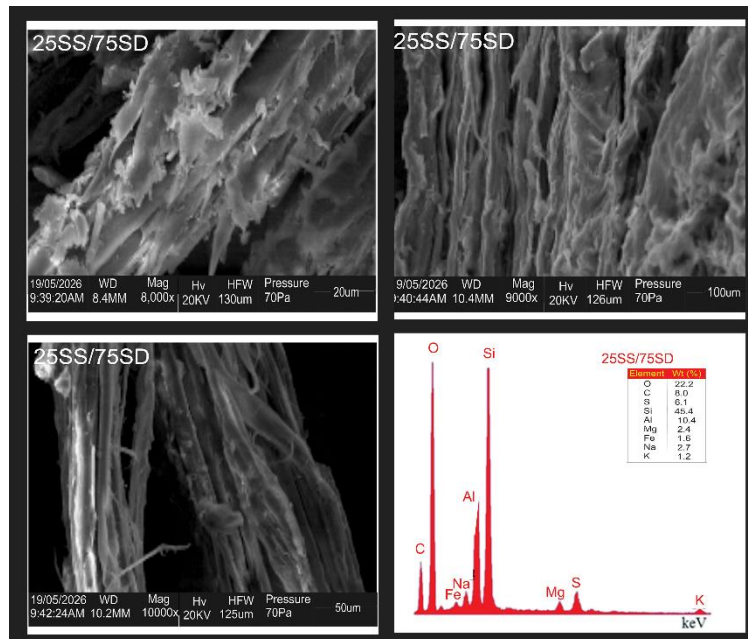
**Figure 7:** SEM analysis for 75% sharp sand + 25% stone dust.  
Source: Author’s research



**Figure 8:** SEM analysis for 50% sharp sand + 50% stone dust.  
Source: Author’s research



**Figure 9:** SEM analysis for 25% sharp sand + 75% stone dust.  
Source: Author's research



**Figure 10:** SEM analysis for 100% stone dust.  
Source: Author's research

The SEM images showed that the 100% sharp sand concrete (Figure 6) had a heterogeneous cementitious matrix with gel-like hydration products, pores, dark regions, and microvoids, indicating incomplete densification. The 75% sharp sand + 25% stone dust mix (Figure 7) showed slight improvement in particle packing, although pores and discontinuities remained. The 50% sharp sand + 50% stone dust mix (Figure 8) exhibited the densest and most continuous microstructure, with fewer pores and better distribution of hydration products. This indicates that the equal combination of sharp sand and stone dust improved the filler effect and particle packing. The 25% sharp sand + 75% stone dust mix (Figure 9) showed layered

formations, voids, and discontinuities, suggesting that excessive stone dust increased paste demand. The 100% stone dust mix (Figure 10) showed good particle interlocking and gel-like hydration products but retained some pores and dark regions. Overall, stone dust improved the microstructure of wood ash blended concrete. The 50% sharp sand + 50% stone dust mix had the best microstructural arrangement, while the 100% stone dust mix achieved the best strength and water-absorption performance.

### Cost Analysis

Table 4 presents the cost analysis of the concrete mixes produced with varying proportions of sharp sand (SS) and stone dust (SD). The analysis compares the total material cost of each mix and the savings achieved relative to the control mix containing 100% sharp sand. Since the quantities of cement, wood ash, coarse aggregate, and water were constant for all mixes, the observed variation in cost was mainly due to the replacement of sharp sand with stone dust. The 100% sharp-sand mix recorded the highest total material cost of ₦25,130. As the percentage of stone dust increased, the material cost reduced progressively. The 75%SS + 25%SD, 50%SS + 50%SD, and 25%SS + 75%SD mixes recorded costs of ₦24,900, ₦24,600, and ₦24,300, representing savings of ₦230 (0.92%), ₦530 (2.11%), and ₦830 (3.30%), respectively. The 100% stone-dust mix recorded the lowest material cost of ₦24,000 and the highest saving of ₦1,130, equivalent to 4.50%, compared with the 100% sharp-sand control mix. The result confirms that stone dust is a more economical fine aggregate than sharp sand under the prevailing market prices. Therefore, its use can reduce the material cost of wood ash blended cement concrete, particularly in large-scale construction projects.

**Table 4:** Cost analysis of concrete samples

| Mix Description | Total Cost of Materials (₦) | Savings Compared with 100% SS (₦) | Savings (%) |
|-----------------|-----------------------------|-----------------------------------|-------------|
| 100% SS         | 25,130                      | -                                 | -           |
| 75% SS + 25%SD  | 24,900                      | 230                               | 0.92        |
| 50% SS + 50%SD  | 24,600                      | 530                               | 2.11        |
| 25% SS + 75%SD  | 24,300                      | 830                               | 3.30        |
| 100% SD         | 24,000                      | 1,130                             | 4.50        |

Source: Author's research

### Conclusion

The following conclusions were drawn from the study:

- The wood ash used in this study showed good pozzolanic potential, with a combined  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$  and  $\text{Fe}_2\text{O}_3$  content of 83.91%. The aggregate grading results also confirmed that sharp sand, stone dust and coarse aggregate were suitable for concrete production.
- Increasing the stone dust content reduced the workability of the concrete, as slump decreased from 75 mm to 58 mm and compacting factor decreased from 0.92 to 0.78. However, stone dust improved the hardened properties, with the 28-day compressive strength increasing from 20.90  $\text{N/mm}^2$  to 23.40  $\text{N/mm}^2$ , splitting tensile strength increasing from 2.00  $\text{N/mm}^2$  to 3.00  $\text{N/mm}^2$ , and water absorption reducing from 2.04% to 0.71%.
- The 50% sharp sand + 50% stone dust mix exhibited the most compact microstructure, while the 100% stone-dust mix recorded the lowest material cost of ₦24,000 and the highest saving of ₦1,130 (4.50%). Therefore, stone dust can be used as partial or full replacement for sharp sand in wood ash blended cement concrete, especially where improved strength, reduced water absorption and lower material cost are desired.

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