SSR Journal of Engineering and Technology (SSRJET)
Homepage: https://ssrpublisher.com/ssrjet/
Volume 3, Issue 7, 2026 ISSN: 3049-0383
OPEN ACCESS

# Transport and Mechanical Properties of Hollow Concrete Blocks Produced Using Sharp Sand and Fine/soft Sand

**M. H. Nensok[1], M. Ibrahim[1], A. A. Bena[2] and M. Tanko[3]**

[1]Department of Building, Federal University Birnin Kebbi, P.M.B 1157, Birnin Kebbi, Kebbi State, Nigeria
[2]Department of Architecture, Federal University Birnin Kebbi, P.M.B 1157, Birnin Kebbi, Kebbi State, Nigeria
[3]Department of Civil Engineering, Waziri Umaru Federal Polytechnic, P.M.B 1034 Birnin Kebbi, Kebbi State, Nigeria

***Received:** 11.06.2026* | ***Accepted:** 22.07.2026* | ***Published:** 27.07.2026*

***Corresponding author:** M. H. Nensok

**DOI:** *10.5281/zenodo.21616938*

**Abstract** **Original Research Article**

The mechanical and durability characteristics of hollow concrete blocks are heavily dependent on the nature of mineral aggregate used. In North Western Nigeria, sharp sand (SS) is scarce and expensive; therefore, many block makers relied on locally available fine sand (FS), despite insufficient proof of its viability for structural purposes. This study evaluated the transport and mechanical performance of hollow concrete blocks produced with varying blends of SS and locally available FS. Five sand combinations—100SS:0FS, 75SS:25FS, 50SS:50FS, 25SS:75FS, and 0SS:100FS—were produced using a cement-to-sand mix ratio of 1:6 and a water–cement ratio of 0.55. Sieve analysis, fineness modulus, sedimentation, bulk density, and specific gravity tests of aggregates were conducted. Hardened blocks and cubes were then assessed for water absorption, capillary sorption, abrasion resistance, and compressive strength at 7, 14, 21, and 28 days. Results indicates that SS improved aggregate grading and mechanical behavior, due to its higher fineness modulus (3.38) and lower silt content (2.96%). Conversely, mixtures containing FS exhibited improved transport-related properties: the 25SS:75FS blend recorded the lowest water absorption and capillary sorption, attributed to improved particle packing and reduced pore connectivity. The control mix (100SS:0FS) achieved the highest 28-day compressive strength (4.64 $N/mm^2$) and best abrasion resistance, while full FS (0SS:100FS) replacement reduced compressive strength to 3.65 $N/mm^2$ However, all mixes met the Nigerian Industrial Standard minimum requirement of 3.45 $N/mm^2$ for load-bearing hollow concrete blocks. The results show that partial or total substitution of SS with FS is a realistic, cost-effective, and long-lasting alternative for producing sustainable hollow concrete blocks without sacrificing structural adequacy.

**Keywords:** Sharp sand, fine sand, transport properties, mechanical properties, abrasion resistance.



## 1 Introduction

In Nigeria and most West African countries, hollow concrete blocks are the most widely used masonry units in both building and civil engineering works (Odeyemi et al., 2019). This is due to their low cost, improved thermal and sound insulation properties, strength and durability (Owamah et al., 2024). It has been reported that over 90% of physical infrastructures in Nigeria are being constructed using hollow concrete blocks (Justus & Benedict, 2023). According to Oyetola and Abdullahi, (2006) hollow concrete blocks has been in use throughout West Africa for over 5 decades as a popular building material for preparation of building blocks and bricks.

The Nigerian Industrial Standard NIS 87: 2007, (2007) defines hollow concrete block as a composite material made up of cement, sand and water, moulded into different sizes. According to Neville and Brooks, (2010), concrete blocks are walling materials made of coarse natural sand or crushed rock dust mixed in proportion with cement and water and is compacted to shapes. In other words, concrete hollow blocks are structural walling units dimensionally larger than bricks and have one or more large holes or cavities passing through it (Owamah et al., 2024). According to Okigbo and Gana, (2017), hollow concrete blocks come in different sizes and shapes such as the 450mm × 225mm × 225mm, known as the 9 inches blocks. 450mm × 225mm × 175mm, commonly called 7 inches blocks. 450mm × 225mm × 150mm blocks, refers to as 6 inches blocks. 450mm × 225mm × 125 mm known as the 5 inches and finally 450mm × 225mm × 100mm commonly called 4 inches blocks. These concrete blocks sizes could either be produced as solid or hollow blocks. However, the hollow concrete blocks are the most locally manufactured in the Nigerian block industry market?

The quality and properties of hollow concrete blocks depend significantly on the type and nature of aggregates used in their production (Adanikin et al., 2024). Fine/Soft sand (builder's sand) (FS) and sharp sand (SS) are two commonly used aggregates in Birnin Kebbi metropolis. These sands type varies in particle size, texture, and composition that influence the mechanical and physical properties of the concrete blocks. Understanding these variations is essential for optimizing construction materials, ensuring structural integrity, and promoting sustainable construction practices.

FS, sometimes called building sand is a soft, smooth and granular material with a particle size ranging between 0.063mm to 2.00mm (ISO 14688-1 2017, 2017). Soft sand has tiny, rounded grains suitable for smooth finishing in plastering and bricklaying work. This sand type can often be sourced from river beds and river banks and is usually a light brown colour. It is important to note that most of the rivers and small lakes of Kebbi and Sokoto states are tributaries to River Niger and predominantly, the type of soils along the river basins are soft sand. In this region sharp sand are mostly very scarce and expensive to supply. However, soft sand is found everywhere (small streams, open drainage passage and rivers) and therefore most construction works are carried out with them including the manufacture of concrete blocks by most block industries in Birnin Kebbi.

However, SS sometimes called grit sand or pit sand has grains that are a lot larger, coarser, and angular than soft sand, which is why it is referred to as coarse sand. According to ISO 14688-1 2017,(2017), the particle size distribution of sharp sand ranges between 0.63mm to 5.0mm. Sharp sand is mostly used in concrete mixing because of its angular nature. Sharp sand is suitable for producing plain and reinforced concrete and structural masonry units. However, in Kebbi state sharp is very scarce to find and requires extra effort to transport it to site.

Kebbi State, like many other regions in the North Western Nigeria, has an abundance of FS, which is used in all form of construction. However, SS is difficult to find and very expensive, since the suppliers have to travel longer distance to find it and requires tremendous utilisation of human resource to dig it from burrow pits. Hence, most concrete block manufacturing companies make use of the soft or builder's sand in the production of both structural load bearing and non-load bearing hollow concrete blocks. But there is limited research comparing the structural performance of hollow concrete blocks produced with soft sands. This study aims to bridge this knowledge gap by conducting a comparative assessment of the properties of hollow concrete blocks produced using fine sand and sharp sand sourced from Kebbi state. The study intends to compare the physical properties of the FS and SS. Explore, how the physical properties influence the transport and durability properties of the blocks produced using soft and sharp sand and finally compare the mechanical properties of hollow concrete blocks produced with the soft and sharp sand.

## 2 Materials and Methods

### 2.1 Materials

The materials used in this research included the two types of sand, namely, FS otherwise referred to as builder's sand and SS. The binder used in the study is the common Portland cement and finally, water serving as the solvent for mixing the concrete.

#### 2.1.1 Fine/Soft sand

The soft sand otherwise called fine sand used in this study was the common river sand purchased from local vendors and fetched directly from the Ambursa River, a suburb in Birnin Kebbi metropolis. The sand which was collected wet from the river was first allowed to dry naturally outside the laboratory. It was later collected in trays and allowed to further dry outside for 72 hours before taken inside for preliminary investigation.

#### 2.1.2 Sharp sand

An attempt was made to purchase from local vendors SS for hollow concrete blocks from the tipper garage in Birnin Kebbi metropolis. The vendors usually fetched such sand from nearby rivers, such as, Bunza, Ambursa, Basaura burrow pits. The vendor assigned to bring sand, came with wet sand from the Basaura burrow pits which was allowed to dry outside the concrete laboratory for at least 3 days. The sand after drying turns out to be soft and smooth sand. Hence, the researchers sent for real sharp sand directly from Mahuta River, along Mahuta-Zuru roads of Fakai local government area of Kebbi State. Figures 1 (a) and (b) below shows the picture of SS obtained from the Mahuta River and FS obtained from Ambursa River.

**Figure 1 (a) Sharp sand from Mahuta**

**1 (b) Fine/Soft Sand from Ambursa river**

#### 2.1.3 Ordinary Portland cement

The Bua brand of Ordinary Portland Cement (OPC) obtained from the old Sokoto Cement Factory of Northern Nigeria. The cement which was defined by the Nigerian Industrial Standard (NIS) as Grade 42.5N conforms with the cement type 1 of BS EN 197-1, (2019)

### 2.1.4 Water

Portable borehole water obtained from the laboratory was used. The water was colourless, tasteless, free of deleterious material and suitable for drinking as specified by BS EN 1008:2002, (2002). An instant digital pH tester was used to test the water pH and the reading was 7 indicating the water is neutral.

## 2.2 Methods

Several tests were conducted on the materials used for research as well as harden hollow concrete blocks and cubes. The tests on the materials which includes sieve analysis test, fineness modulus, bulk density and specific gravity test are referred to as the preliminary tests. Apart from the preliminary tests, transport property test on the harden concrete cubes was conducted, which includes; water absorption test as well as the capillary sorption tests on the materials. Abrasion resistance test of hardened concrete cubes was also conducted. For the mechanical properties of blocks, compressive strength was the test conducted on the concrete blocks. Hollow concrete blocks of sizes 450mm x 225mm x 225mm were produced and tested for compressive strength tests.

### 2.2.1 Preliminary tests on the materials

Among the preliminary tests on materials are the sieve analysis, conducted of the two types of sand. The test was undertaken in line with ASTM C 778, (2017). The test was conducted to show vividly the differences in particle size distribution between the FS and the SS. Sedimentation test was also conducted on the two sand samples. The test was conducted in accordance with BS 812-103.1:1985, (1985). Figure 2 shows the test set-up during sedimentation test. The test on the bulk density of the materials was performed in line with ASTM C 29/29M-17, (2017). The bulk density of an aggregate is described as the density of a sum of aggregates when it is packed together in bulk. The test was conducted on the soft and sharp sand as well as the cement. Specific gravity is the ratio of a given volume of that material to the weight of an equal volume of water. This test was conducted for the fine and sharp sand as well as the cement used as the binder. The test was conducted in line with BS EN 1097-3:98, (1998) standard.

**Figure 2: Set up for sedimentation tests for fine and sharp sand**

### 2.2.2 Transport property tests

Two types of transport property tests were conducted. Water absorption test and capillary sorption test. The tests were all conducted using mortar samples of sizes 100mm x 100mm x100mm. Three tests specimen were prepared for each batch and dried in a ventilated ovum at 100$^{o}$C for 72 hours for each case. Water absorption test was undertaken in line with BS 1881: Part 122:11, (2011). While the capillary sorption test was conducted in accordance with ASTM C 1403-14, (2014). Figure 3 below shows the test set-up for the capillary sorption test.


**Figure 3 (a) and (b) Test set-up for capillary sorption test**

### 2.2.3 Abrasion resistance test

Abrasion resistance test was conducted to assess the surface resistance of hollow concrete blocks to mechanical wear, particularly in applications where the blocks are exposed to frictional forces such as foot traffic. Test specimens were prepared using three number 100mm x100mm x 100mm cubes from hollow concrete block mix batches and were subjected to the manual scrubbing using an iron metal brush. The cubes were first ovum dried for 72 hours at 100$^{o}$C in a ventilated ovum to completely dry it. Then, the cubes samples were weighed to obtain the initial weight of W1, after scrubbing with 40 strokes, the samples were surface cleaned and reweighed to obtain the final weight of W2. This test was conducted following the procedure describe by ASTM C779/C779M-12, (2012)

### 2.2.4 Compressive strength test

The compressive strength test was conducted on three number 450mm x225mm x225 mm (9inch) hollow concrete blocks and their average recorded for each curing age. For each concrete batch a total of 12 hollow concrete blocks were produced using a simple block moulding machine, which was tested at the interval 4 curing ages of 7, 14, 21, and 28 days. The test was performed in accordance with method described by BS EN 772-1, (2011) for masonry unit. Figure 4 shows the test set-up for the compressive strength test.


**Figure 4: Set-up for compressive strength test of hollow concrete blocks**

### 2.3 Mix Design and Production of Tests Samples

In this study, 9 inches, hollow concrete blocks with dimension 450mm x 225mm x225mm was produced specifically for compressive strength tests. For other tests, such as water absorption, capillary sorption test and abrasion resistance test, 100mm x100mm x 100mm cubes were produced to accomplish that. To compare the properties of the fine sand and sharp sand effectively, five batches of test samples were produced. The first batch was the control, with 100% sharp sand (100SS) and 0% fine sand (0FS), next is the batch with 75% sharp sand (75SS) and 25% fine sand (25FS), at the middle is the batch with 50% sharp sand (50SS) and 50% fine sand (50FS). This was closely followed by the batch with 25% sharp sand (25SS) and 75% fine sand (75FS) and lastly, the batch with 0% sharp sand (0SS) and 100% fine sand (100FS). The batches which were produced based on the percentage combination ratio of %SS:%FS was summarised as 100SS:0FS, 75SS:25FS, 50SS:50FS, 25SS:75FS and 0SS:100FS.

A nominal cement-sand mix ratio adopted was 1:6 for load-bearing hollow concrete blocks in line with ASTM C 90. The water/cement ratio utilised for each batch was the 0.55 to achieve adequate consistency. For each batch, a total of 12 hollow concrete blocks, for compressive strength test at the curing ages of 7, 14, 21and 28 days. 3 blocks specimen were produced and tested and their averages recorded for each curing age. In addition, each batch also concurrently produces 100mm x100mm x 100mm concrete cubes for water absorption, capillary sorption and abrasion resistance tests. Each test was carried out with 3 cubes specimens at the curing ages of 7, 14, 21 and 28 days. This sums up to 36 cubes. Table 1 below display the total number of hollow concrete blocks produced per each batch, while Table 2 also shows the total number of concrete cubes produced concurrently for each batch. This implies that for each batch, for instance, the control batch (%SS:%FS) 100SS:0FS, the total number of hollow concrete blocks produced is 12 and total number of concrete cubes is 36 summing up to 48 test specimens per each batch.

**Table 1: Quantity of hollow concrete blocks produced for compressive strength tests**

| **Batches %SS:%FS** | **Curing ages (Days)** | | | | **Total Samples** |
|---|---|---|---|---|---|
| | **7** | **14** | **21** | **28** | |
| 100:0 | 3 | 3 | 3 | 3 | **12** |
| 75:25 | 3 | 3 | 3 | 3 | **12** |
| 50:50 | 3 | 3 | 3 | 3 | **12** |
| 25:75 | 3 | 3 | 3 | 3 | **12** |
| 0:100 | 3 | 3 | 3 | 3 | **12** |
| | | | | **TOTAL** | **60** |

**Table 2: Quantity of concrete cubes produced for water absorption, capillary sorption and abrasion resistance test**

| **Batch %SS:%FS** | **Types of tests/Curing ages (days)** | | | | | | | | | | | | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Water Absorption** | | | | **Capillary Sorption** | | | | **Abrasion Resistance** | | | | |
| | **7** | **14** | **21** | **28** | **7** | **14** | **21** | **28** | **7** | **14** | **21** | **28** | |
| 100:0 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | **36** |
| 75:25 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | **36** |
| 50:50 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | **36** |
| 25:75 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | **36** |
| 0:100 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | **36** |
| | **TOTAL** | | | | | | | | | | | | **180** |

### 2.3.1 Mix Proportioning and sample production

Absolute volume method of mix proportion was adopted in determination of materials quantities by weight. As earlier stated, a nominal mix ratio of 1:6 cement/sand mix was adopted using the water to cement ratio of 0.55 in order to ensure adequate workability and hydration while minimizing bleeding and segregation. The summary of the mix proportioning is display in Table 3 below.

The production of each batch of hollow concrete blocks and cubes was undertaken at the open concrete batching bay of Federal University Birnin Kebbi. Dry constituents of cement and sand were measured using the digital weighing balance to maintain consistency and avoid error. Mixing of the materials was carried out manually on a clean, non-absorbent concrete platform using shovels. Manual mixing of cement and sand continuous until a homogenous colour was achieved. Then the measured quantity of water was gradually added while the mixing still continued until the whole mixture was completely consistent and homogenous.

The freshly mixed mortar was cast into 12 steel moulds with internal dimensions of 460 mm × 225 mm × 225 mm, for hollow concrete blocks. This was immediately taken into block making machine for proper vibration and compaction. The block was produced using block making machine at the Federal University Birnin Kebbi to achieve adequate compaction and strength in line with work. While on the hand, the remaining fresh concrete mix were manually cast into 36 number 100mm x 100mm x 100mm cubes mould compacting by vibration at least 3 cubes using the vibrating table for at least 45±5 seconds. The cast hollow concrete blocks and cubes were taking inside the concrete and masonry laboratory and covered with plastic materials to set for 24 hours. After 24 hours of setting at laboratory ambient temperature, the test samples were demoulded and cured in a water tank completely immersed in water.

**Table 3: Mix Proportion of materials for production of hollow concrete blocks and cubes**

| Batch %SS:%FS | Cement (OPC) (Kg) | Sharp Sand (SS)(Kg) | Fine/Soft Sand (FS) (Kg) | Water (Kg) |
|---|---|---|---|---|
| 100:0 | 106 | 667 | 0 | 58.1 |
| 75:25 | 106 | 500.25 | 166.75 | 58.1 |
| 50:50 | 106 | 333.5 | 333.5 | 58.1 |
| 25:75 | 106 | 166.75 | 500.75 | 58.1 |
| 0:100 | 106 | 0 | 667 | 58.1 |

## 3 Results and Discussion

### 3.1 Results of Preliminary Tests of Materials

#### 3.1.1 Result of sieve analysis of sharp sand and fine sand

The result of sieve analysis of fine and sharp sand is given in Tables 4 and 5, respectively and followed by the combined sieve analysis curve in Figure 4. From the results obtained, the SS exhibited a considerable higher fineness modulus (FM) of 3.4, whereas the FS recorded a fineness modulus (FM) of 2.25, which implies that the sharp sand is significantly coarser than the fine sand.

From Table 5 and Figure 4, the fineness modulus was calculated to be 3.38 which implies that the soil sample is very coarse since it exceeded the limit for fineness modulus specified by BS EN 12620-08, (2008) for coarse aggregate (2.92-3.2). The particle size distribution curve displayed in Figure 4 for both sharp sand and fine sand also indicates the coarseness of sharp sand.

The relatively higher FM of the sharp sand implies adequate aggregate interlocking and lower specific surface. This will consequently result to improve mechanical interlocking between the aggregate and the cementitious matrix.

Similarly, Table 5 shows the particle size distribution of the FS with total cumulative weight of sand passing summing to 225.29. And the corresponding fineness modulus from these results was 2.25. This value of 2.25 fall within the limit for fine/soft sand (2.2-2.6) as specified by BS EN 12620-08, (2008). This finding was further buttressed by the particle size distribution curve for both sharp sand and fine sand displayed in Figure 4. The relatively lower FM implies smaller and smoother particle sizes resulting to increased surface area responsible for higher water demand during mixing. On the other hand, the presence of finer particles can enhance particle packing by filling internal voids, thereby leading to improved surface finish.

**Table 4: Particle size distribution table of SS**

| **Sieve Sizes (mm)** | **Weight Retained on sieve (g)** | **Percentage of weight Retained (%)** | **Cumulative Percentage of sand weight passing (%)** | **Percentage passing (%)** |
|---|---|---|---|---|
| 4.75 | 25.75 | 5.15 | 5.15 | 94.85 |
| 2.36 | 89.75 | 17.95 | 23.10 | 76.90 |
| 1.18 | 95.70 | 19.14 | 42.24 | 57.76 |
| 0.600 | 144.75 | 28.95 | 71.19 | 28.81 |
| 0.300 | 130.90 | 26.18 | 97.00 | 3.00 |
| 0.150 | 29.90 | 2.08 | 99.37 | 0.63 |
| pan | 2.00 | 0.40 | 99.77 | 0.23 |
| **Total** | | | **338.05** | |

Fineness Modulus = Summation of cumulative % passing – pan / 100 = 3.38

**Table 5: Particle size distribution table for fine sand (FS)**

| **Sieve Sizes (mm)** | **Weight Retained on sieve (g)** | **Percentage of weight Retained (%)** | **Cumulative Percentage of sand weight passing (%)** | **Percentage passing (%)** |
|---|---|---|---|---|
| 4.75 | 2.95 | 0.59 | 0.59 | 99.41 |
| 2.36 | 9.95 | 1.99 | 2.58 | 97.42 |
| 1.18 | 26.20 | 5.24 | 7.82 | 92.18 |
| 0.600 | 101.05 | 20.21 | 28.03 | 71.97 |
| 0.300 | 303.45 | 60.69 | 88.72 | 11.28 |
| 0.150 | 44.15 | 8.83 | 97.55 | 2.45 |

| | | | | |
|---|---|---|---|---|
| pan | 13.00 | 2.40 | 100 | 0.00 |
| **Total** | | | **225.29** | |

Fineness Modulus = Summation of the cumulative % passing – pan / 100 = 2.25

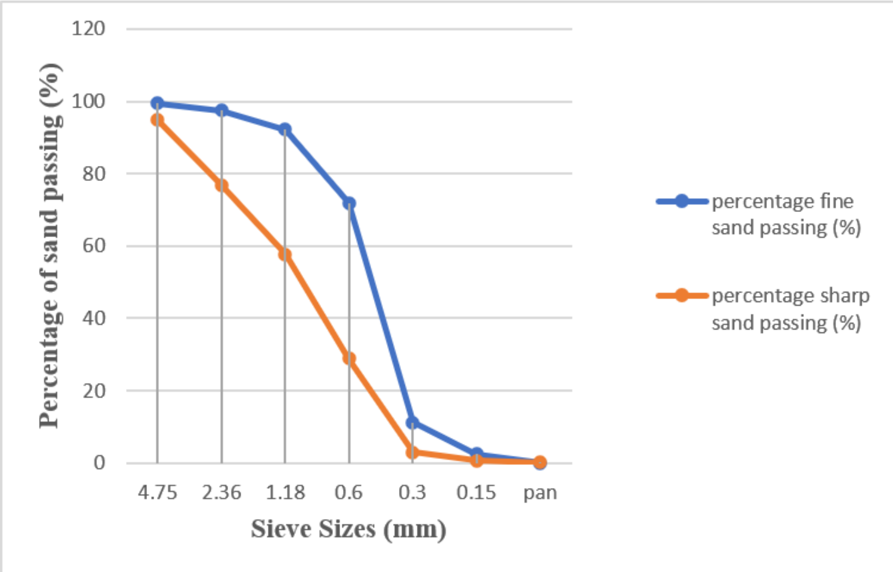


**Figure 5: Sieve analysis curves of sharp sand and fine/soft sand**

### 3.1.2 Result of sedimentation or silt content of fine and sharp sand

The sedimentation test was basically undertaking to ascertain the silt or clayey content of the two types of sand. The results from Table 6 clearly indicates that the SS has lower value of the silt content recording 2.96% while the FS demonstrated a higher silt content of 6.04% which is slightly twice the silt content of the SS. The relatively lower silt content of the SS indicates that it is cleaner devoid of much clayey and silty impurities. This is expected to promote stronger interfacial bond between the aggregate and the cement paste. On the other hand, the higher silt content found in the FS demonstrate the presence of a greater proportion of fine clay or dusty particles. These impurities may be responsible for increased specific surface area of aggregate thereby resulting in higher water demand. Excessive silt content may also interfere with cement hydration, weakening the aggregate cement bonds leading to reduced strength.

Overall, the sedimentation test confirm that sharp sand is better quality than the fine sand in terms of cleanliness. However, the result obtained for silt content of SS (2.96%) and FS (6.04% all falls within limits (3% - 8%) for fine aggregates suitable for concrete production as specified by BS 812-101:89., (1989). The findings collaborate with result of sieves analysis to suggest that incorporating an appropriate proportion of sharp sand with fine sand can improve aggregate quality, reduce adverse effects of excessive fines, and improve the transport and mechanical properties of the resulting hollow concrete.

**Table 6: Sedimentation or silt content of sharp sand and fine sand**

| Description | Sharp Sand | | | Fine/Soft Sand | | |
|---|---|---|---|---|---|---|
| | S1 | S2 | S3 | S1 | S2 | S3 |
| Volume of sample V1(ml) | 85 | 83 | 85 | 80 | 68 | 75 |
| Volume of Silt V2(ml) | 3 | 2 | 2.5 | 5 | 4 | 4.5 |
| Percentage Silt by vol. V1/V2 x 100% | 3.53 | 2.41 | 2.94 | 6.25 | 5.88 | 6.0 |
| **Average Percentage Silt** | | **2.96%** | | | **6.04%** | |

### 3.1.3 Result of physical properties of the materials

The result of the physical properties of SS and FS is shown in Table 7. The compacted and uncompacted bulk density was obtained as 1669Kg/m$^3$ and 1516Kg/m$^3$ for the SS, while that of the FS was gotten as 1659 Kg/m$^3$ and 1483Kg/m$^3$, respectively. This indicates that the SS is slightly denser than the FS. The values obtained for the compacted and the loose bulk density falls within standard range for fine aggregate (1200-1700 Kg/m$^3$) as suggested by Neville and Brooks, (2010). The values of bulk density reported for SS and FS tallies with values of bulk densities of 1430 loose and 1568 compacted reported by Oyetola and Abdullahi, (2006). Similarly, the specific gravity values recorded for SS and FS was respectively 2.50 and 2.59 which slightly falls below the range of 2.6-2.7 for natural sand aggregates.

**Table 7: Physical properties of sharp sand, fine sand and ordinary Portland cement**

| Materials | Bulk density (Kg/m3) Loose | Compacted | Specific Gravity | Texture | Colour |
|---|---|---|---|---|---|
| **Sharp sand** | 1516 | 1669 | 2.50 | Rough, irregular and big | Dark brown |
| **Fine sand** | 1483 | 1659 | 2.59 | Smooth, round and small | Light brown |
| **Ordinary Portland Cement** | | | | Very fine and smooth | Light Ash |
| **Water** | 1000 | 1000 | 1.0 | Liquid | Colourless |

## 3.2 Transport Properties of sharp and fine sand concretes

### 3.2.1 Result of Water Absorption Test

The result of water absorption as displayed in Figure 6 shows that irrespective of mix proportion, water absorption decreases with increase curing age. This indicates the effect of continuous cement hydration and the gradual densification of concrete mixture (Odeyemi et al., 2019; Salman et al., 2022). Results from the Table also indicates that the control mix containing 100% SS (100SS:0FS) recorded the highest water absorption, throughout the curing ages. This is attributed to higher grading of the sharp sand which created larger interparticle voids and more porous internal structure, leading to higher water penetration.

The incorporation of finer, smaller particle of sand progressively reduced the water absorption progressively up to mixture that demonstrated the lowest water absorption when percentage fine sand was at 75% and sharp sand was 25% (25SS:75FS). For this mixture, the water absorption reduces from 10.38% at 7days to 8.92% at 28days. This indicates an 18.8% reduction compared with the control mixture at 28days. This improved grading results is due to the optimum packing, reduced capillary porosity and thereby restrict the movement of water. However, the last batch with 100% fine sand (0%SS:100FS) demonstrated a much higher water absorption compared to preceding batch (25%:75%). This means that while FS effectively improves concrete density, the exclusive usage may result to increase specific surface of the aggregate thereby increasing water demand during mixing. If the additional water is not fully use for hydration, residual capillary pores may result within the hardened concrete. In all, the values of water absorption obtained for the SS and FS falls below the maximum limit of 12% as specified by the NIS 87: 2007, (2007). Which implies that water absorption is not detrimental to SS and FS aggregates blocks and concretes.

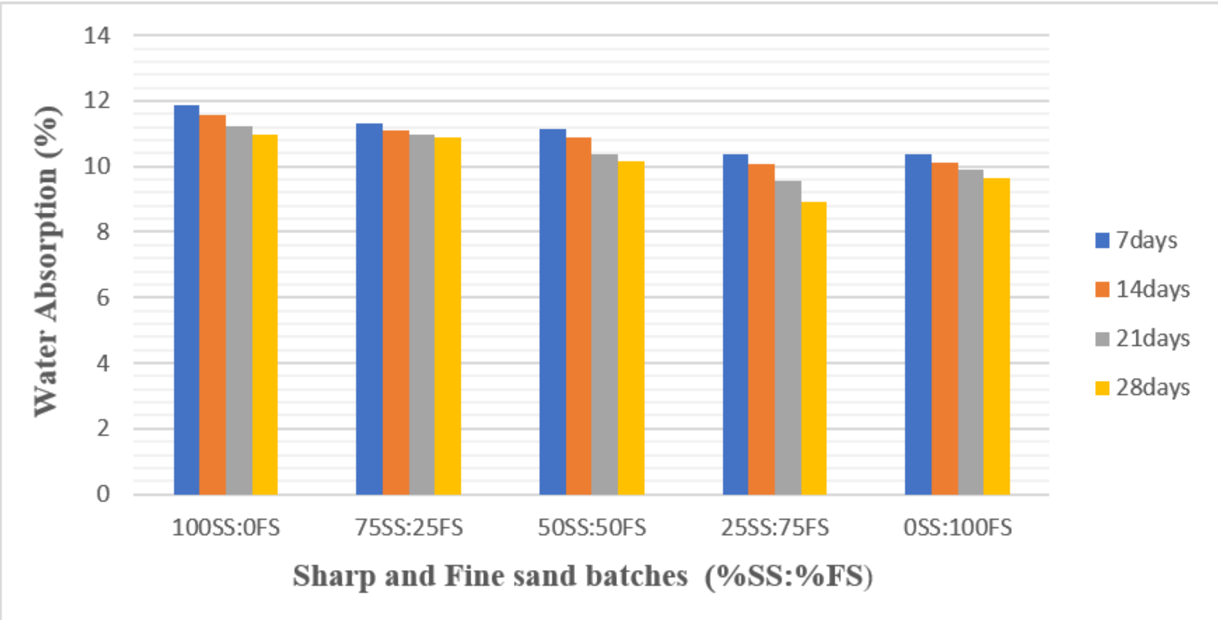


**Figure 6: Variation of water absorption of SS and FS concrete cubes**

### 3.2.3 Result of capillary sorption of sharp sand and fine sand concretes

Results from Figure 7 for capillary sorption demonstrate an increase in capillary sorption with time for all batches of the concretes. This is in consistent with expected behaviour of all cementitious materials as water continuously penetrate the interconnected pore structure rapidly at the early first hour (60 minutes) due to the strong capillary suction of unsaturated pores. And later slowed down, towards the last 4 to 24 hours (240-1440 minutes), when pore system became fully saturated (Al-Shwaiter et al., 2022; Nambiar & Ramamurthy, 2007).

The result from Figure 7, also indicates that the concrete cubes with 100% sharp sand (100SS:0FS) display the highest capillary sorption throughout the test period, increasing from 52.0 grams/100cm$^2$ at 1 minute to 226.5 grams/100cm$^2$ after 24 hours. This could be attributed to the coarser particle of the sharp sand which resulted to less efficient particle packing, larger inter particle voids and hence more porous internal microstructure. Conversely, the concrete batch containing 100% fine sand (0SS:100FS) display lower capillary sorption compared to the control batch but capillary value compared to some of optimised batches. Although the abundance of fine sand contributed to reducing some of lager voids, the exclusive used of fine sand might have increased the specific surface area, resulting into a higher water demand during mixing. This could result to a less dense hardened matrix with large capillary pores to permit considerable water absorption.

The optimised mixture with the lowest capillary sorption is the 25% sharp sand and 75% fine sand batch (25SS:75FS). For this batch, the capillary sorption increased from 29.1 grams/100cm$^2$ at 1 minute to 105.2 grams/100cm$^2$ at 1440 minutes, representing the lowest capillary sorption of the all mixtures. This implies that this mixture produced the densest concrete mix with the list interconnected capillary pores. Fine sand improves the particle packing, by filling in the interfacial capillary pores of the sharp sand present in the matrix resulting to reduced voids between particles, promoting a compact cement paste-aggregate interface. Consequently, the water suction through capillary pore was significant reduced. This result was in agreement with the findings reported by Osuji and Egbon, (2015) where porosity and permeability of hollow concrete blocks decreased with increase in the percentage replacement of granite quarry dust since it is finer that river sand used in their study.

From this result, it is clear that the blended sand batch, containing fine sand and sharp sand all substantially improved the capillary transport properties. The incorporation of fine sand improved aggregate packing, reduced capillary pore connectivity and reduced resistance to water penetration. With the optimum performance obtained with 25% sharp sand and 75% fine sand batch, exhibiting the lowest capillary sorption. This seriously improve the concrete durability by limiting the ingress of water and potentially harmful substances such as chloride and sulphates in concrete blocks.

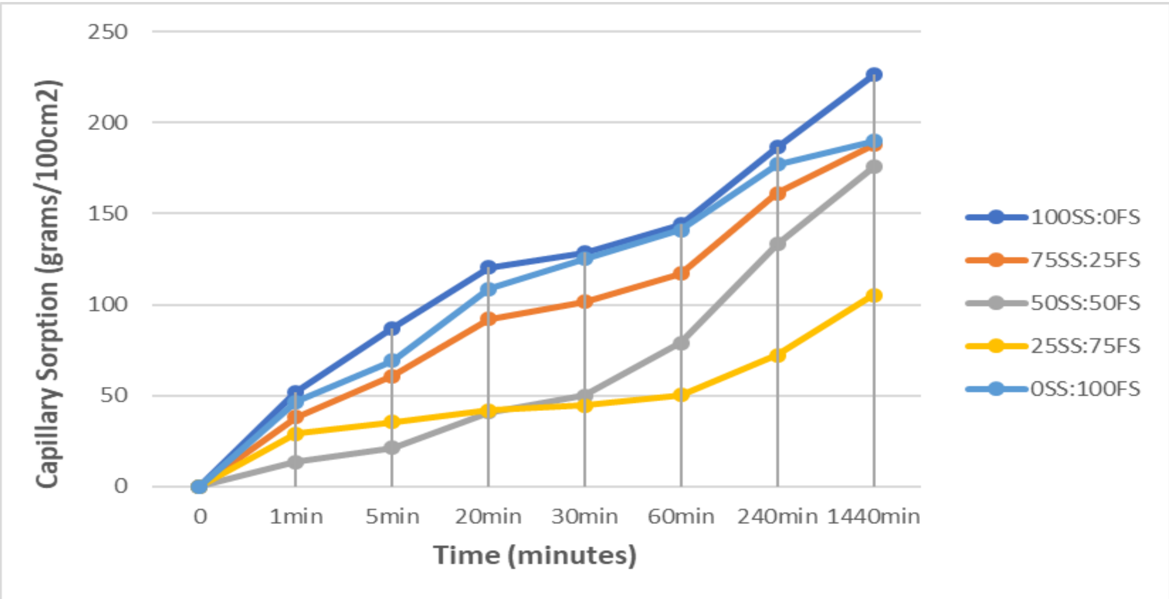


**Figure 7: Variation of capillary sorption of SS and FS concretes cubes with time**

### 3.3 Abrasion resistance properties of sharp and fine sand concretes

#### 3.3.1 Results of abrasion resistance of sharp and fine sand concretes

The results from Figure 8 demonstrate that the resistance of all concrete cube batches to surface wear improved significantly with increase in the curing ages. The percentage abrasion lost reduces continuously from 7 to 28 days for all batches, indicating that prolong curing enhanced the hardness and integrity of the concrete surface. This is attributed to the continuous hydration of cement which resulted to additional calcium silicate hydrate (C-S-H) gel that filled the capillary pores, strengthening the interfacial transition zone (ITZ) and resulted in denser and more durable concrete (Nensok et al., 2021; Owamah et al., 2024).

Results from Figure 8 also shows that concrete cubes produced with 100% SS (100SS:0FS) exhibited the highest abrasion resistance value, at all curing ages. The 100% sharp sand concrete recorded lowest abrasion losses of 0.69%, 0.56%, 0.37%, and 0.15% at 7, 14, 21, and 28 days, respectively. This could be attributed to the angular and rough textures of sharp sand particles, which is responsible for a stronger mechanical interlocking with the cement paste. The improved aggregate-paste bond increases the hardness of the concrete surfaces and its ability to resist wear under abrasive scrubbing.

Finding depicts that as (FS) proportion increases, abrasion lost also increases, implying a gradual reduction in abrasion resistance. The 75% sharp sand and 25% fine sand batch produced the second-best performance in terms abrasion resistance. This is followed by the 50% sharp sand and 50% fine sand batch. This trend of increasing abrasion lost due increase in FS percentage continuous up to the highest abrasion lost experience by batch with exclusively 100% fine sand (0%SS:100FS). This concrete batch exhibited the highest abrasion lost at all curing ages, with values decreasing from 1.93% at 7 days to 0.71% at 28days. The comparatively poor performance in terms of abrasion resistance of this batch could be linked to the smoother and finer particle characteristics of fine sand, the larger specific surface area which resulted increased water demand mixing. This subsequently led to more porous hardened matrix if the water content is not adjusted. Consequently, the concrete surface becomes more susceptible to material removal under abrasive action.

Overall, it is clear that the proportion of SS highly influence the wear resistance of concrete blocks material. Concrete cubes with higher percentages of sharp sand display a lower abrasion loss owing to stronger aggregate paste bonding and greater surface hardness, whereas increasing the fine sand percentage generally reduced abrasion resistance despite improving particle packing. Hence, while higher fine sand content may enhance certain durability properties such as reduced capillary water absorption and reduced water absorption in general, a higher proportion of sharp sand is beneficial expecially where resistance to mechanical wear and surface abrasion is important.

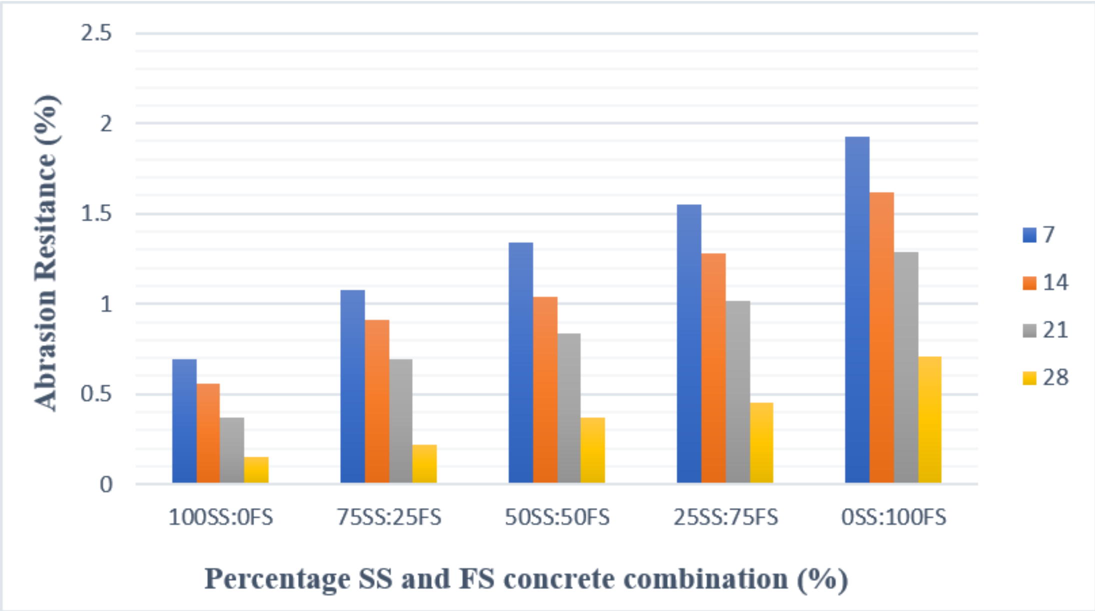


**Figure 8: Variation of abrasion resistance with the percentage SS and FS concrete combination**

### 3.4 Mechanical property of sharp and fine sand aggregate concretes

#### 3.4.1 Results of compressive strength of sharp and fine sand aggregate concrete

Figure 9 shows the result of the compressive strength of hollow concrete blocks produced using varying proportions of SS and FS as aggregates. The results depict that compressive strength increases as the curing age increases for all batches of concrete block (Al-Tarbi et al., 2022). Confirming the continuous hydration of cement and gradual development of stronger and denser microstructure with age.

The control batch (100SS:0FS) demonstrated the highest compressive strength throughout the curing period, increasing from 2.89 N/mm$^2$ at 7days to 4.64 N/mm$^2$ at 28 days. This superior performance of the 100% sharp sand batch is attributed to angular particle shape, rough surface texture, lower silt content, and better grading characteristics of SS which resulted to stronger mechanical interlocking with cement paste and enhanced aggregate-paste bond. This behaviour improved the load transfer within concrete matrix, leading to higher compressive strength. This improvement in compressive strength decreases with the gradual increase in the FS percentage content. As the percentage FS content increases from 0% to 25% (75SS:25FS) the compressive strength reduced to 4.21N/mm$^2$ representing about 9% reduction in strength. Further increase in the percentage content of FS to 50% and 75% (SS50:FS50) and (SS50:FS50) resulted to additional decreased in compressive strength at 28 days. The 50SS:50FS batch recorded 3.90 N/mm$^2$ at 28 days, while the 25SS:75FS batch reached 3.84 N/mm$^2$, respectively.

This trend of decreased compressive strength with increased in the FS percentage content continued up to the last batch with 100% FS content. This batch with 100% Fine sand (0%SS:100FS) produced the lowest 28-days compressive strength of 3.39 N/mm$^2$, representing 21% decreased in compressive strength compared to the control. This result implies that the completes replacement of SS with FS is detrimental to mechanical strength because of the poorer aggregate interlock and reduced structural stability of the hardened concrete blocks matrix.

In all, the results demonstrated that while partial replacement of SS with FS is feasible, increasing the FS content beyond 25% results in progressive reduction of compressive strength. Nonetheless, all batches displayed continuous strength development with increase curing period, indicating that cement hydration was not affected by aggregate substitution. The 28-days compressive strength of all batches exceeded the limits of 2.70N/mm$^2$ - 3.45N/mm$^2$ specified by NIS 87: 2007, (2007) for non-load bearing and load bearing hollow concrete blocks, respectively. Thus, the predominantly available FS obtained from Birnin Kebbi and the surrounding environs if utilised to produce hollow concrete blocks under standard procedures and properly cured using curing tank results in a hollow concrete blocks with adequate compressive strength and durability performance.

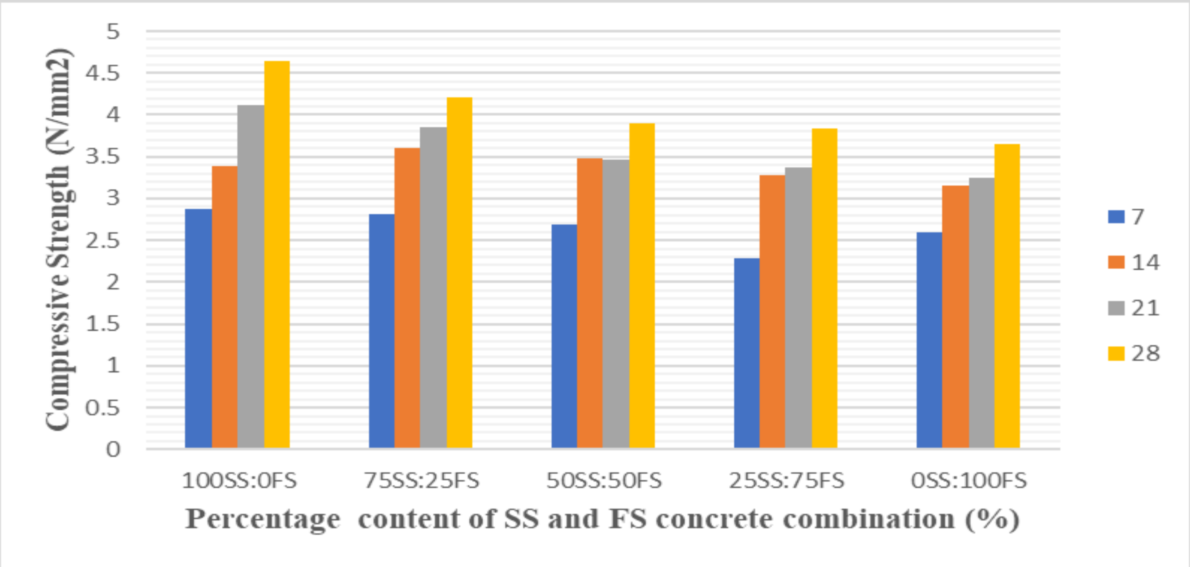


**Figure 9: Variation of compressive strength of SS and FS aggregate concretes**

### 4.1 Conclusion

This study investigated the influence of replacing SS with locally available FS on the transport and mechanical properties of hollow concrete blocks. The results demonstrated that the physical characteristics of the aggregates significantly affected the performance of the hardened concrete blocks.

1. SS displayed a higher fineness modulus, lower silt content, and coarser particle grading than FS, resulting in superior aggregate interlocking and stronger aggregate–cement bonding.
2. The transport property tests revealed that incorporating FS progressively reduced water absorption and capillary sorption, with the optimum performance obtained from the mixture containing 25% sharp sand and 75% fine sand. However, complete replacement of SS with FS resulted in a slight increase in water transport properties compared with the optimum blend, indicating that excessive fine particles may increase water demand and residual porosity.
3. Conversely, mechanical performance was improved by increasing the proportion of SS. Concrete blocks produced with 100% SS exhibited the highest abrasion resistance and compressive strength throughout the curing period owing to the angular particle shape, rough surface texture, lower silt content, and improved mechanical interlocking. Although compressive strength gradually decreased with increasing fine sand content, however, the strength for concrete cubes at 28 days exceeded the

minimum compressive strength requirement of 3.45N/mm$^2$ specified by NIS 87: 07, (2007) for load-bearing hollow concrete blocks.

4. Overall, the study establishes that locally available FS can be successfully utilized in the production hollow concrete blocks, fully and when appropriately blended with sharp sand to produced load bearing hollow concrete blocks.
5. While 100% sharp sand remains the most suitable aggregate where maximum strength and abrasion resistance are required, a blend containing 25% sharp sand and 75% fine sand provides the most favourable balance between durability performance, structural adequacy, material availability, and production economy.
6. The findings therefore provide a practical basis for optimizing aggregate selection in hollow concrete block production, particularly in Kebbi State and North Western Nigeria where sharp sand is scarce and expensive.

### 6.2 Recommendations

Based on the findings of this study, the following recommendations are made

1. A blended aggregate containing 25% sharp sand and 75% fine/soft sand is recommended where improved durability characteristics, particularly reduced water absorption and capillary sorption, are required without compromising the structural adequacy of hollow concrete blocks.
2. Where maximum compressive strength and abrasion resistance are the primary design requirements, 100% sharp sand should be adopted for the production of load-bearing hollow concrete blocks.
3. FS intended for block production should be properly washed and screened to minimize silt and clay impurities, thereby improving aggregate quality and reducing water demand during mixing.
4. Hollow concrete block manufacturers should adopt proper mix proportioning, quality control procedures, and adequate water curing practices to ensure consistent strength development and compliance with the NIS 87: 07, (2007) requirements.
5. Future research should also evaluate other engineering properties, including drying shrinkage, creep, thermal conductivity, flexural strength, and microstructural characteristics using scanning electron microscopy (SEM) and X-ray diffraction (XRD), to provide a more comprehensive understanding of the behaviour of hollow concrete blocks produced with blended aggregates.
6. Further studies should investigate the harden properties of SS and FS hollow concrete blocks produced and cured in the open (exposed to the actual field curing by blocks industries) to ascertain the performance of the aggregates in hollow concrete blocks production by local block industries in the country.

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