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Assessment of Quality and Compliance of Commercially Produced Sandcrete Blocks in Kaduna Metropolis

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Abstract

The rapid implementation of educational and administrative facility infrastructure at the Air Force Institute of Technology (AFIT), Kaduna, demands strict quality control of basic building components to mitigate risks of structural defects. This study evaluates the physical and mechanical properties of 225mm hollow sandcrete blocks supplied by five commercial block manufacturing yards (Industries A, B, C, D, and E) directly feeding structural partition works across the campus footprint. The engineering investigation comprised extensive field audits alongside laboratory characterization of aggregate particle size distribution curves, silt content percentages, dry bulk density properties, 24-hour volumetric water absorption capacity, and 28-day ultimate crushing test using a Compression Testing Machine (CTM) evaluated on both gross and net area bases. Experimental results demonstrated low compliance margin against the statutory requirements of the Nigerian Industrial Standard (NIS 87:2007), which mandates a minimum gross compressive strength threshold of 2.5N/mm² for non-load bearing units. Industry E logged the highest structural capacity with an ultimate mean compressive limit of 1.497 ± 0.112N/mm² (gross area) and 2.495 ± 0.187N/mm² (net area), dry bulk packing density of 1611.36 ± 18.42kg/m³, and a minimized water absorption value of 7.03 ± 0.35%. Conversely, Industry C established the minimum structural baseline with a gross strength profile of 0.933 ± 0.084N/mm² and density configuration of 1532.86 ± 22.15kg/m³.Low structural compliance may be traced to commercial field malpractices including weak cement batching patterns (ranging from 1:12 to 1:16 variations), erratic water-cement ratios, excessive silt content in sand supplies, and inadequate on-

site curing. Continuous quality audits and enforced standardization are critical to safeguard institutional infrastructural lifespans.

Keywords: Sandcrete Blocks, Compressive Strength, Bulk Density, Water Absorption, NIS 87:2007, Structural Deficiencies

Introduction

Shelter represents an essential baseline requirement for human security, social stabilization, and institutional advancement [1,2]. In developing countries, particularly within Sub-Saharan Africa, the construction sector relies heavily on concrete masonry blocks for the development of both housing portfolios and large-scale public facilities. According to [3,4,5,6], sandcrete masonry units continue to account for a significant proportion of residential and commercial walling materials used across major Nigerian cities. These masonry elements are engineered composites produced from an adjusted blend of Ordinary Portland Cement (OPC), fine aggregate (sand), and water [7,8,9]. When mixed in balanced proportions, these materials undergo chemical hydration, forming a durable structural matrix capable of resisting environmental and mechanical loading conditions over extended lifespans [10, 11,12].

Despite their widespread application, the contemporary building ecosystem in Nigeria is severely impacted by structural durability failures, masonry cracking patterns, and structural collapses [13,14,15,16,17,18]. Technical field investigations have systematically demonstrated that while structural design errors and soil instability play a role, the usage of poor-quality, commercial-grade masonry units serves as a primary driver of premature structural deterioration. This structural concern is highly visible across expanding educational landscapes such as the Air Force Institute of Technology (AFIT), Kaduna. The rapid infrastructure development at AFIT including lecture halls, laboratories, hostels, and administrative complexes demands an extensive supply of masonry walling materials, which are frequently outsourced to commercial producers distributed throughout the Kaduna metropolitan area [19,20]. To control material performance, the Standards Organisation of Nigeria (SON) established the Nigerian Industrial Standard for sandcrete blocks (NIS 87:2007). This standard defines strict quality baselines, requiring a minimum 28-day gross compressive strength of 2.5 N/mm² for hollow sandcrete blocks utilized in non-load-bearing partitions and 3.45 N/mm² for load-bearing options. Additionally, the standard mandates a dry bulk density of not less than 1500 kg/m³ and limits water absorption capacity to a maximum threshold of 12% to prevent moisture-induced deterioration (NIS 87:2007). However, commercial manufacturing yards within local markets often manipulate sandcrete mix formulations due to economic constraints, increasing the sand-cement ratio far past standard parameters to maximize unit yields from each cement bag [21,22,23,24].

To better understand these material systems, recent civil engineering research has focused on applying advanced material optimization and predictive structural evaluation frameworks. For instance, predictive material evaluation models have been utilized to understand the structural performance of engineered concrete combinations, demonstrating how advanced analytics can optimize field operations [25,26,27,28]. In parallel, the investigation of supplementary cementitious components has highlighted how alternative binders modify the initial paste structure and aggregate-paste interfacial transition zone. Furthermore, environmental parameters and specific curing

frameworks have been shown to significantly dictate the mineralogical formation of calcium silicate hydrate (C-S-H) phases, directly altering the long-term density and performance of masonry systems [26,27,28].

This paper presents an empirical investigation into the mechanical and physical compliance properties of 225mm hollow sandcrete blocks supplied to active infrastructure projects at AFIT Kaduna. By conducting comprehensive laboratory testing on samples sourced from five commercial suppliers (sampled as Industries A, B, C, D, and E), this study evaluates the material quality configurations currently entering the institutional supply chain against national standard benchmarks [29,30].

The production and quality management of sandcrete blocks in Nigeria has been examined by several researchers, all pointing toward widespread non-compliance with national engineering specifications. Industry assessments underscore that sandcrete masonry blocks produced in commercial yards are often structurally deficient due to a lack of engineering monitoring and profit-driven adjustments by independent block producers. Past regional studies provide important context for evaluating this trend within North-Central and Northern Nigeria [31,32,33,34,35].

Reference [36,37,38,39] conducted an investigation focused on the quality configurations of hollow sandcrete blocks across the Kaduna South Local Government Area. Their experimental results indicated that while the fine aggregates used generally fell within acceptable particle size distribution boundaries, the commercial cement-to-sand batching configurations were extremely weak, ranging from 1:12 to 1:16 instead of the standard 1:6 ratio recommended for stable block production. Consequently, the 28-day ultimate compressive strengths of the blocks fell within a low range of 0.18 N/mm² to 0.44 N/mm², failing to meet the minimum requirements of NIS 87:2007. They concluded that poor compaction metrics and insufficient curing periods were the primary drivers of this structural weakness [40,41,42,43].

Similarly, [44] completed an assessment tracking the technical parameters of hollow blocks within the wider Kaduna metropolitan area. Their analysis of 12 commercial block factories showed that while the specific gravity of fine aggregates complied with standard specifications (ranging from 2.27 to 2.77), the mechanical performance of the resulting 6-inch hollow blocks remained below standard thresholds. The average 28-day compressive strength values ranged from 1.84 N/mm² to 1.95 N/mm², showing consistent non-compliance with national standards. They identified a lack of proper batching control and inadequate water-cement ratio monitoring as the main challenges impacting the local industry.

Furthermore, [45,46,47] evaluated the physical properties of 9-inch hollow blocks across multiple local government layers within Kaduna State. Their multi-factory audit reported compressive strengths between 0.19 N/mm² and 0.79 N/mm², alongside dry bulk density profiles varying from 1286 kg/m³ to 1537 kg/m³ [48,49,50,51]. These values sat roughly below the standard 1500 kg/m³ dry density limit. Their field assessments revealed that manual mixing practices predominated, and over 95% of commercial operations were completely unaware of the technical provisions contained within the NIS 87:2007 code framework. This highlights a persistent quality deficit within the regional material supply chain.

Although several studies have investigated commercial sandcrete blocks quality across Kaduna State, none has focused on manufacturers supplying institutional construction projects. Consequently, there is limited evidence regarding the compliance of these masonry units within AFIT's rapidly expanding infrastructure. Therefore, this study aims to investigate the specific compliance of the blocks supplied to AFIT against the NIS 87:2007.

Sample Sourcing and Experimental Control

A rigorous experimental matrix was established to collect and test standard 225mm × 225mm × 450mm hollow sandcrete block units from five primary commercial yards actively supplying construction sites at AFIT Kaduna according to the data obtained from the Directorate of Physical Planning (DPP AFIT). The designated supplier factories were coded as:

Industry A: AFIT Consult Blocks
Industry B: Chonoko Blocks
Industry C: Assu Blocks
Industry D: Habib Blocks
Industry E: Richifa Blocks

A total sample size of 45 hollow blocks (9 blocks per manufacturer) was collected under strict control parameters at 24 hours post-molding. The specimens were transported to the Civil Engineering Laboratories at AFIT Kaduna, where they underwent standard water-immersion curing in laboratory curing tanks to ensure complete hydration development up to the designated 28-day testing age.

Fine Aggregate Sieve Analysis and Silt Content Evaluation

Sieve analysis was performed on aggregate samples extracted from each manufacturer's yard to establish particle size distribution curves following BS 812-103.1:1985 guidelines. Sieve sizes utilized for the laboratory evaluations ranged from 4.75mm down to 75µm, mounted on an automatic mechanical sieve shaker. A 500g air-dried sand sample from each yard was placed into the stack and shaken for 5 minutes. The mass retained on each sieve layer was measured using a high-precision electronic balance to calculate cumulative passing percentages, fineness modulus (FM), and silt content percentages.

Density and Water Absorption Determination

Dry bulk density and volumetric water absorption capacity were measured following NIS 74:1976 and NIS 87:2007 protocols. Blocks were oven-dried at 105°C ± 5°C until a constant oven-dry mass (denoted M) was attained. Linear dimensions were verified with digital callipers to compute the total gross external volume (V), allowing the calculation of dry bulk density (ρ):

$$\rho = \frac{M}{V} \qquad (1)$$

To measure water absorption, the oven-dried blocks were weighed to obtain the dry mass (denoted M1) then completely submerged in a clean water tank at room temperature (23°C ± 2°C) for 24 hours. The specimens were then removed, wiped to a saturated surface-dry state, and weighed immediately to record the saturated wet mass (denoted M2). The volumetric water absorption rate was determined using Equation 2:

$$Absorption\ Rate\ (\%) = \frac{M2-M1}{M1}\ X\ 100 \qquad (2)$$

Ultimate Compressive Strength Testing Execution

The ultimate crushing resistance of full-sized hollow blocks was evaluated at the 28-day curing threshold using a calibrated 2000kN capacity Compression Testing Machine (CTM). Before loading, external dimensions and core void cavities were measured. The gross cross-sectional area (Agross = 225mm × 450mm = 101,250 mm²) and net solid area (Anet = Agross - Acores = 60,750 mm², based on a 40% core void ratio) were determined. The block specimen was positioned centrally between the

hardened steel bearing platens to ensure uniform axial load distribution. Plywood packing strips were placed at contact faces to prevent localized stress concentration. The axial loading rate was maintained at a continuous speed of 0.05 N/mm² per second until crack failure occurred. Peak failure load (P) was recorded to determine compressive strength on both gross and net area bases:

Compressive Strength: $(Gross\ Area) = \frac{P}{A(gross)}$ ***(3)***

Compressive Strength: $(Net\ Area) = \frac{P}{A(net)}$ ***(4)***

Quantitative Experimental Presentation

The quantitative data gathered from laboratory tests across fine aggregate sieve analysis, silt content evaluation, dry density, water absorption, and compressive strength properties are summarized in Tables 4.1 and 4.2.

Table 4.1: Sieve Analysis Metrics and Masses Retained Across Sourced Sand Supplies

Sieve Size	Industry A (g)	Industry B (g)	Industry C (g)	Industry D (g)	Industry E (g)
4.75 mm	4.67	15.33	13.67	3.00	4.00
2.36 mm	14.67	44.67	24.67	14.33	14.00
1.70 mm	14.33	39.00	21.00	17.67	18.00
1.40 mm	28.00	59.67	26.67	25.67	23.33
300 µm	408.33	319.67	364.67	423.67	423.67
75 µm	24.00	17.00	44.33	14.00	15.67
Silt Content (%)	**3.40%**	**2.80%**	**8.87%**	**3.60%**	**3.80%**

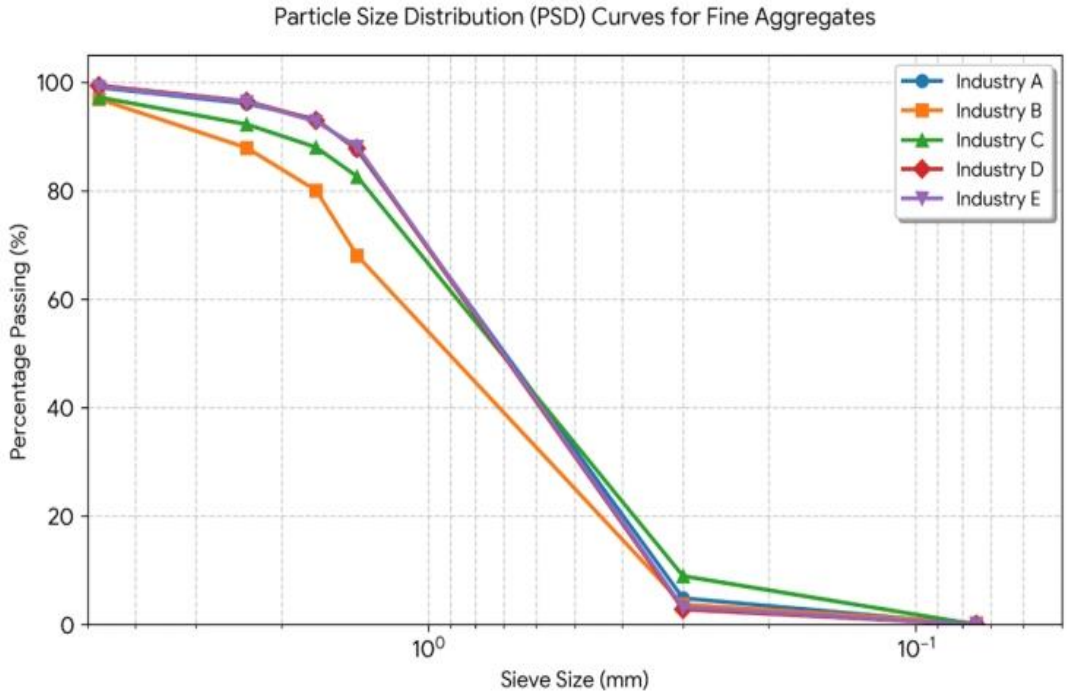


Figure 4.1: PSD Curves for Fine Aggregates

Table 4.2: Consolidated Physical and Mechanical Property Configurations at 28-Day Curing Age (Mean ± SD, n =9)

Manufacturer Sourced	Average Bulk Density (kg/m^3)	Gross Compressive Strength (N/mm^2)	Net Compressive Strength (N/mm^2)	Average Water Absorption (%)
Industry A	1580.51 ± 21.34	1.191 ± 0.095	1.985 ± 0.158	10.61 ± 0.42
Industry B	1549.28 ± 25.10	0.947 ± 0.078	1.578 ± 0.130	11.17 ± 0.51
Industry C	1532.86 ± 22.15	0.933 ± 0.084	1.555 ± 0.140	10.90 ± 0.48
Industry D	1593.03 ± 19.80	0.943 ± 0.071	1.572 ± 0.118	10.51 ± 0.39
Industry E	1611.36 ± 18.42	1.497 ± 0.112	2.495 ± 0.187	7.03 ± 0.35

Comparative Evaluation and Mechanical Discussions

The sieve analysis test results recorded in Table 4.1 show noticeable variations in aggregate grading across the block yards. Fine aggregate grading directly influences microstructural packing density as already outlined by [12]. Industry E utilized a well-graded fine aggregate that tracked closely within standard grading boundaries. This optimized particle distribution allows smaller aggregate grains to fill inter-particle voids, producing a dense structural skeleton. This configuration minimizes the required paste volume while enhancing interfacial bonding. Conversely, Industry B exhibited high retention on the 2.36mm and 1.70mm sieves combined with a rapid reduction at finer fractions, indicating a gap-graded aggregate profile. This gap leaves unfilled micro-voids in the sandcrete matrix, severely reducing mechanical performance under compressive stresses.

Furthermore, aggregate quality evaluation revealed that Industry C exhibited an excessively high fine fraction passing the 300 µm sieve and retained on the 75 µm sieve (44.33g), resulting in a calculated silt content of 8.87%. This exceeds the maximum 3.0% to 5.0% threshold mandated by standard engineering codes. Excessive silt content increases aggregate surface area, elevates water demand, coats aggregate particles to prevent cementitious adhesion, and forms porous micro-void networks that severely compromise strength.

The mechanical testing results in Table 4.2 demonstrate a quality deficit across all sampled commercial block yards supplying AFIT construction sites. None of the evaluated suppliers achieved the minimum 28-day gross compressive strength requirement of 2.5 N/mm^2 mandated by NIS 87:2007 for non-load bearing walling units. Industry E recorded the highest performance with a mean gross compressive capacity of 1.497 ± 0.112 N/mm^2 (net area strength of 2.495 ± 0.187 N/mm^2), which still represents a 40.12% deficit relative to the national code baseline. Industry A reached a mean gross strength of 1.191 ± 0.095 N/mm^2, while Industries B, C, and D failed to cross 1.0 N/mm^2, clustering between 0.933 ± 0.084 N/mm^2 and 0.947 ± 0.078 N/mm^2. This places them over 62% below statutory safety limits. Installing these under-strength units creates extreme structural vulnerability, predisposing partition walls to cracking, shear displacement, and progressive structural failure [34].

The experimental data demonstrates a clear engineering relationship between dry bulk density, water absorption capacity, and ultimate compressive strength confirm with other studies. Industry E achieved the highest bulk density (1611.36 ± 18.42 kg/m^3) alongside the lowest water absorption capacity (7.03

± 0.35%), which directly correlates with its superior gross compressive strength (1.497 ± 0.112 N/mm²). A dense sandcrete structure limits internal void volume, restricting moisture penetration and increasing resistance to mechanical crushing. In contrast, Industry C recorded the lowest average dry bulk density (1532.86 ± 22.15 kg/m³) and the minimum compressive strength profile (0.933 ± 0.084 N/mm²). This lower density indicates a highly porous internal structure, which allows rapid water migration and leads to early micro-fracturing along void boundaries under compressive loading.

The widespread failure to meet national standards across commercial operations is driven by systemic field production defects. First, field observations confirmed that all yards rely on manual volume batching using lean sand-to-cement ratios ranging from 1:12 to 1:16, far exceeding the standard 1:6 mix ratio required for structural block production. Second, commercial block makers add uncontrolled excess water during manual mixing to increase workability and speed up demolding, producing high water-cement ratios that compromise paste strength. Third, mechanical compaction tables lack sufficient vibrational force to achieve full consolidation. Finally, commercial operators prematurely terminate or completely omit wet-curing protocols, halting cement hydration prematurely and preventing the formation of calcium silicate hydrate (C-S-H) gel required for matrix strength development.

Conclusions

1. A low compliance margin against NIS 87:2007 requirements was established across the material supply chain at AFIT Kaduna, as all five commercial suppliers failed to achieve the 2.5 N/mm² minimum gross compressive strength threshold.

2. Industry E recorded the highest mechanical performance, achieving a mean gross compressive strength of 1.497 ± 0.112 N/mm² (net area strength of 2.495 ± 0.187 N/mm²), dry bulk density of 1611.36 ± 18.42 kg/m³, and water absorption rate of 7.03 ± 0.35%, driven by well-graded aggregate particle distribution.

3. The primary drivers of structural low compliance may include weak mix batching (1:12 to 1:16 volume ratios), uncontrolled water-cement ratios, inadequate mechanical compaction energy, high sand silt content, and absence of standardized wet-curing regimes.

Recommendations

1. The Directorate of Physical Planning at AFIT should establish mandatory batch-testing quality assurance protocols for all sandcrete block deliveries prior to structural integration.

2. Commercial block manufacturers supplying institutional projects must transition from volume batching to standardized mass batching, enforcing a maximum sand-to-cement ratio of 1:6 for non-load bearing units.

3. Commercial producers must enforce strict sand quality screening to ensure silt content remains below 3.0%, alongside implementing high-energy vibrating tables to reduce internal porosity.

4. Institutional project managers must mandate a minimum 7-day shaded wet-curing period to guarantee calcium silicate hydrate (C-S-H) hydration development and full-strength achievement.

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