

CONSTRUCTION

Fragility Mapping for Hollow Blocks in Agbado/Oke-Odo Local Council Development Area, Lagos, Nigeria

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Abstract

Sandcrete hollow blocks are widely used in building construction. The quality of these blocks produced, however, differs from each manufacturer due to different methods employed in the production and the properties of the constituent materials. This research work focuses on the impact of quality control practices by manufacturers on the quality of blocks produced in Agbado/Oke-Odo Local Council Development Area, Lagos State. General survey of the entire local council development area was conducted to determine the number of block industries in the area and 67 registered block manufacturing industries were observed and were selected randomly for the studies. In total, 201 sandcrete blocks of average sizes of 450 × 225 × 225 mm were purchased from the manufacturers and tested for compressive strength, density and water absorption. Fine aggregate samples were also taken from the manufacturers and tested for grain size distribution analysis. Cement samples used for the manufacturing of these blocks were collected and tested for chemical composition. The mix ratio and method of curing were also considered. By analyzing various factors, including block properties, construction practices, and environmental conditions, a systematic mapping of their fragility levels is established for the local council development area. This mapping will assist the local authorities in identifying the areas with heightened risk and facilitate a proactive approach towards improving the overall structural strength and safety of hollow block structures within the local development area.

The research work confirmed that the highest dry compressive strength value was found to be 2.40 N/mm² and the lowest compressive strength value was 0.6 N/mm². The Nigerian Industrial Standard (NIS) specified that the lowest compressive strength of individual blocks shall not be below 2.5 N/mm² and the average of five blocks shall not be below 3.45 N/mm². The fine aggregate materials fell within zones 1 and 2 of the British Standard sieve, which are adequate for good mix. The cement consistency was found to be 30.5% which is within the BS EN 196-6:2010 requirement. The blocks produced are therefore less than the local and international standard requirements and therefore, unsuitable for use as a load bearing wall.

Keywords: sandcrete blocks; compressive strength; water absorption; sieve analysis; aggregates; reliability index; fragility mapping

1 Introduction

Sandcrete hollow block is one of the most common building materials used in most building constructions that require walling units in many countries of the world, Nigeria inclusive. Sandcrete hollow block is made from the mixture of cement, fine aggregate and water in a standard specified mix proportion. It has the following nominal standard sizes of: 450 mm × 225 mm × 100 mm, 450 mm × 225 mm × 150 mm, 450 mm × 225 mm × 225 mm. (NIS 87:2004).

Sandcrete hollow block is either produced manually or by moulding machine. The manual production suffers the problem of less compaction and therefore less strength after curing. The machine moulding when produced according to the standards, are supposed to attain a strength of not less than 3.45 N/mm^2 for mean strength and 2.59 N/mm^2 for the lowest individual strength. (NIS 87:2004).

The fragility curves give the relation between the intensity measure and the quality of blocks. Their fragility under seismic loading is a significant concern. Fragility mapping is a valuable tool for assessing the seismic vulnerability of structures. The opportunity to choose the most suitable block for buildings is more open and wider from the use of fragility map for various block industries. (Ibrahim *et al.*, 2025). This approach allows estimation of the probability of failure of blocks based on measured compressive strength data (Auyo, 2023).

2 Materials and methods

Sixty-seven block industries were randomly selected with three block samples collected from each of the block industries, that is 201 pieces of hollow block samples of size $450 \text{ mm} \times 225 \text{ mm} \times 225 \text{ mm}$ from the selected block industries for the test. Also obtained from the selected block industries are the aggregates used in each location and the Portland cement used which would all be used in carrying out compressive strength, sieve analysis, density, water absorption test and chemical composition test.

These sample blocks, aggregates and cement were subjected to laboratory tests for compressive strength, sieve analysis, water absorption and chemical composition tests. The samples of blocks used for this research were collected in January 2026 from all the selected block industries.

2.1 Tests conducted

Compressive strength: Compressive strength is a critical property of sandcrete blocks, determining their ability to withstand loads and stresses. The compressive strength of sandcrete blocks is typically determined using the compressive strength test. The compressive strength will be obtained from the ratio of maximum load to the cross-sectional area of the block, as shown in equation (1):

$$F = \frac{P}{A} \quad (1)$$

where F is the compressive strength, P is the maximum load or applied force and A is the cross-sectional area of the block.

Sieve analysis: Sieve analysis is a laboratory test used to determine the particle size distribution of a fine aggregate sample. The test involves passing the sample through a series of sieves with progressively smaller openings, allowing the particles to be separated and weighed.

The sieve analysis provides valuable information about the particle size distribution of the fine aggregate sample, which can be used to determine its suitability for various construction applications.

Water absorption: The water absorption test is a laboratory procedure used to determine the water absorption characteristics of a fine aggregate sample. This test is crucial in evaluating the suitability of the fine aggregate for use in sandcrete block production.

$$WA = \frac{W_w - W_d}{W_d} \times 100 \quad (2)$$

where WA is the water absorption, W_w is the final (wet) weight and W_d is the initial (dry) weight.

Density: The density of fine aggregate is a critical property that affects the quality and performance of sandcrete blocks. Fine aggregate density is typically determined using the water displacement method. In the water displacement method, a container is filled with water and the initial water level is recorded. The fine aggregate sample is then added slowly to the water, with gentle stirring, until it is fully submerged. The final water level is recorded and the density of the fine aggregate is calculated using equation (3):

$$D = \frac{M}{V} \quad (3)$$

where D is the density, M is the mass of fine aggregate and V is the volume of water displaced.

By determining the density of fine aggregate, manufacturers can ensure that the sandcrete block mixture is properly proportioned, resulting in a high-quality and durable product.

Chemical composition of cement: The chemical composition of cement is crucial in determining its suitability for sandcrete block production. The primary components of cement include lime (CaO), silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3).

By determining the chemical composition of cement, manufacturers can ensure that the cement meets the required standards for sandcrete block production, resulting in a high-quality and durable product

3 Results and discussion

3.1 Compressive strength

The overall average compressive strength for all the two hundred and one blocks (201) of 450 mm × 225 mm × 225 mm sizes collected from the sixty-seven factories was 1.33 N/mm² and the standard deviation was 0.19 N/mm² (Figure 1, Figure 2 and Figure 3). These values are less than the standard compressive strength for a sandcrete block of 2.5 N/mm² (NIS 87:2004).

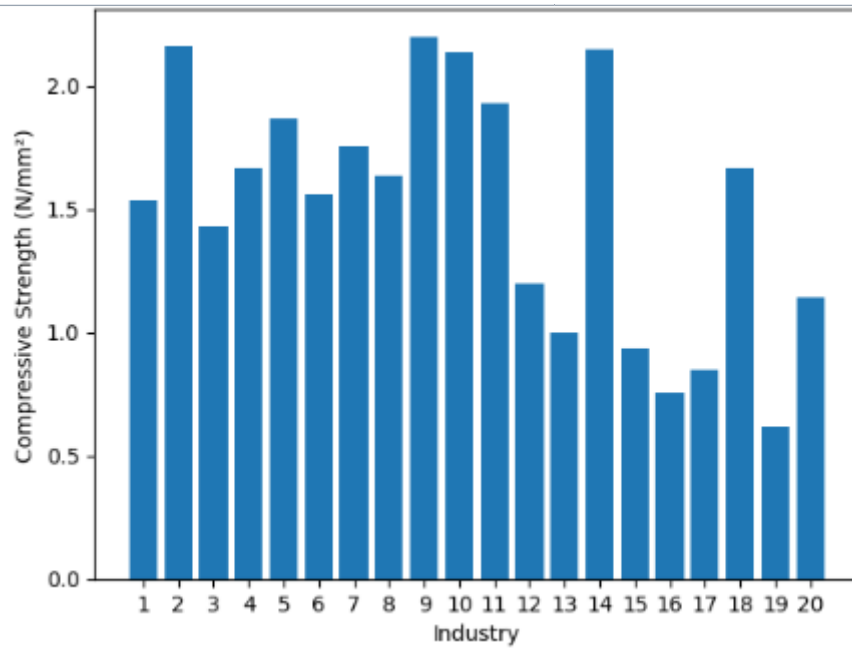


Figure 1. Compressive strength of $450 \times 225 \times 225$ mm sandcrete blocks for industries 1–20.

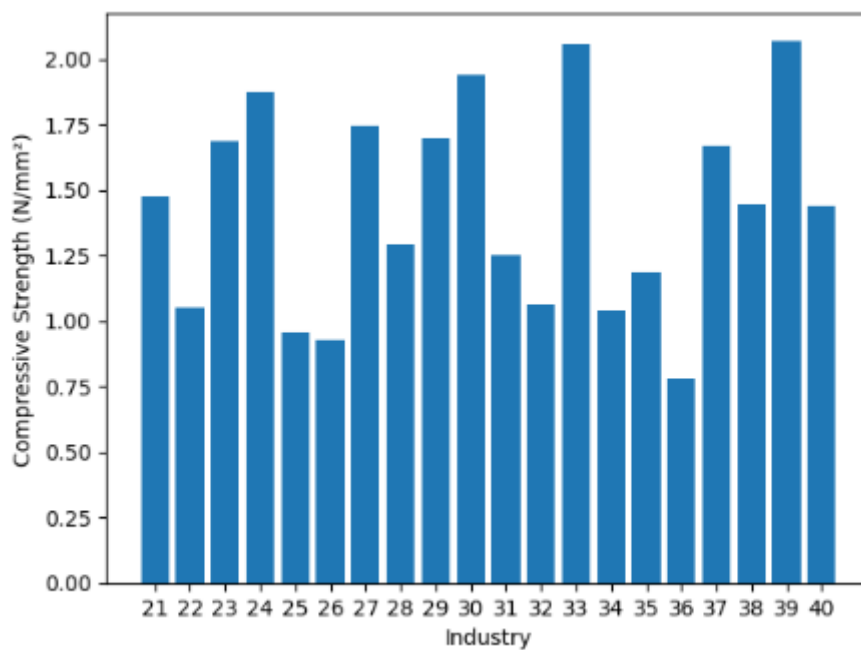


Figure 2. Compressive strength of $450 \times 225 \times 225$ mm sandcrete blocks for industries 21–40.

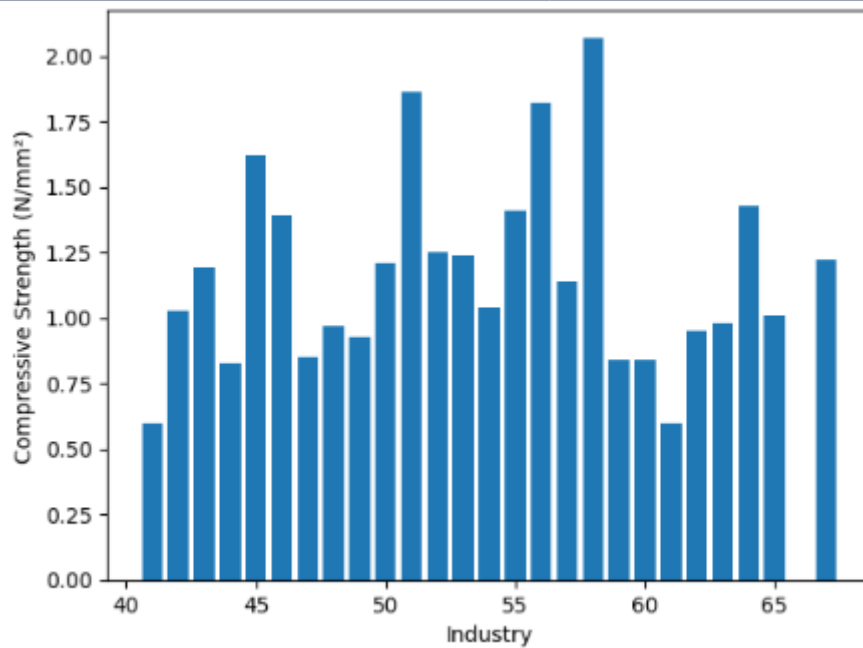


Figure 3. Compressive strength of $450 \times 225 \times 225$ mm sandcrete blocks for industries 41–67.

3.2 Density

The density results obtained from the sampled industries ranged from 1.61 g/cm^3 to 1.96 g/cm^3 , with most values falling between 1.75 g/cm^3 and 1.90 g/cm^3 . The standard density range is between 1.8 g/cm^3 to 2.2 g/cm^3 (NIS 87:2004). This indicates that the majority of the aggregates possess moderate to high bulk density suitable for sandcrete block production. Industries with higher densities above 2.2 g/cm^3 are expected to produce blocks with improved strength and reduced porosity, while industries with lower density values below 1.8 g/cm^3 may indicate the presence of lighter or more porous aggregates (Figure 4 and Figure 5).

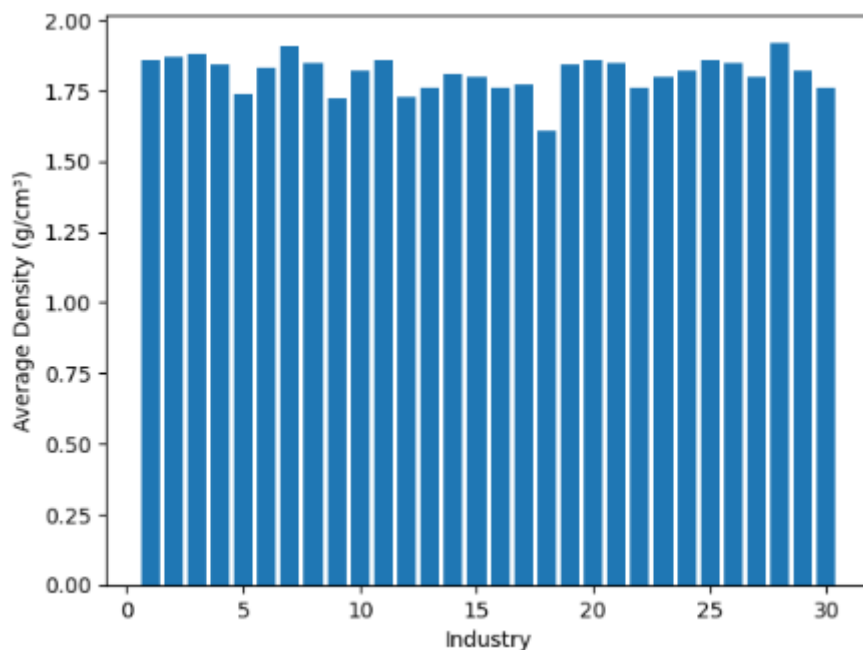


Figure 4. Density of $450 \times 225 \times 225$ mm sandcrete blocks for industries 1–30.

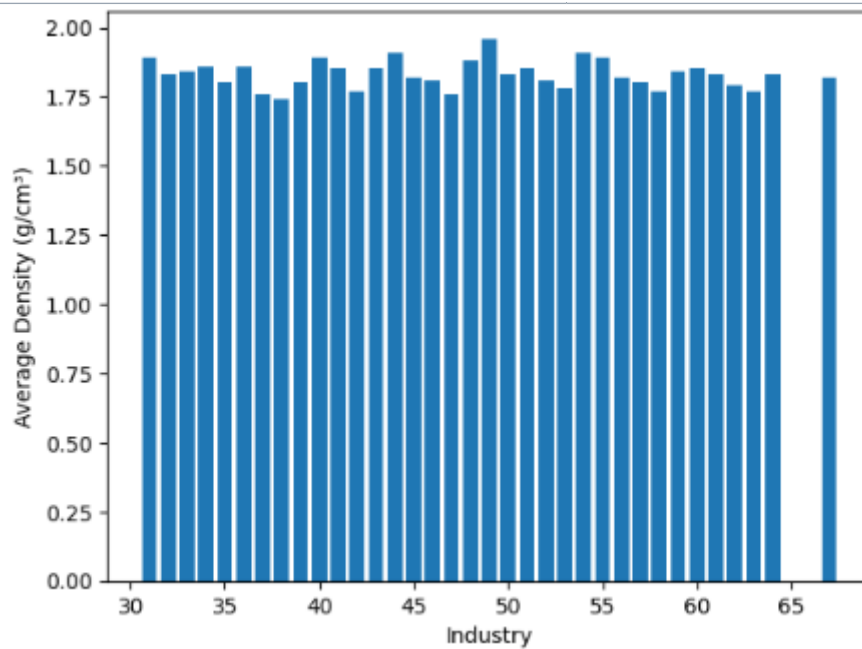


Figure 5. Density of 450 × 225 × 225 mm sandcrete blocks for industries 31–67.

3.3 Sieve analysis

The results indicated that most samples fall within the medium to coarse sand category, which is generally acceptable for construction applications such as sandcrete block production. However, samples with very high fineness modulus values (above 4.6) may require blending with finer aggregates to improve grading, workability, and bonding with cement (Figure 6).

A typical sieve analysis result is given in Table 1.

Table 1. Sieve analysis of aggregate samples.

Sieve size (mm)	Weight retained (g)	Cumulative weight retained (g)	Cumulative retained (%)	Passing (%)
9.5	2.31	2.31	0.15	99.85
4.75	431.18	433.49	28.79	71.21
3.0	143.06	576.55	38.30	61.71
2.0	235.17	811.72	53.92	46.09
1.18	75.70	887.42	58.94	41.06
0.600	272.49	1159.91	77.04	22.96
0.425	37.69	1197.60	79.55	20.46
0.300	79.02	1276.62	84.80	15.21
0.212	62.41	1339.03	88.94	11.06
0.150	63.24	1402.27	93.14	6.86
0.075	68.80	1471.07	97.71	2.29
< 0.075	34.47	1505.54	100	0

Source: field work.

Fineness modulus = sum of cumulative % retained/100 = 396.78/100 = 3.97.

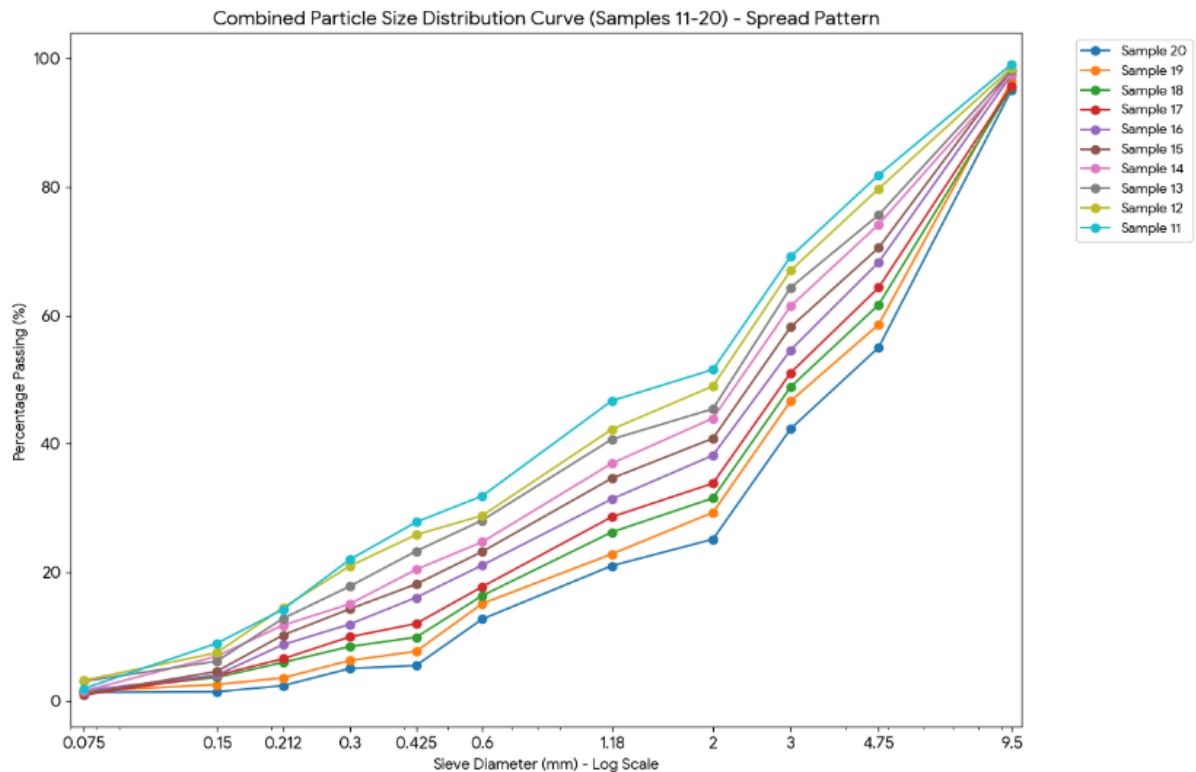


Figure 6. Particle size distributions.

Based on the sieve analysis conducted on the sixty-seven aggregate samples from the selected industries, the computed average fineness modulus was 4.51. This value significantly exceeds the recommended range of 2.0 to 3.5 for fine aggregates used in sandcrete block production. Consequently, the majority of the samples fall outside the standard grading zone classifications for fine sand and are more accurately described as very coarse sand or fine gravel. This deviation has direct implications for workability, compaction, and compressive strength of the resulting blocks.

3.4 Chemical composition of cement

The test results indicated that the cement sample complied with ASTM C150/C150M specifications for Portland cement across all measured parameters. Overall, the cement is of good quality and suitable for construction purposes, meeting all required chemical composition standards (Table 2).

Table 2. Cement composition.

S/N	Parameter	ASTM C150/C150M (specification for Portland cement)	Result
1	Appearance	Grey powdery substance	Conforms
2	Loss on ignition (%)	0.01–0.1	0.05
3	Insoluble residue (%)	0.5–2.0	0.64
4	Chloride content (Cl^-) (%)	0.01–0.1	0.03
5	Calcium oxide (CaO) (%)	60–67	66.2
6	Aluminium oxide (Al_2O_3) (%)	3–8	4.8
7	Iron oxide (Fe_2O_3) (%)	0.5–6	1.5
8	Magnesium oxide (MgO) (%)	0.5–4	0.82

3.5 Water absorption

The majority of factories produced blocks within acceptable and good quality absorption standard limits ($\leq 12\%$). However, some factories recorded values above 15%, with a maximum of 27.91%, indicating excessive porosity, poor quality and weak durability (Figure 7 and Figure 8).

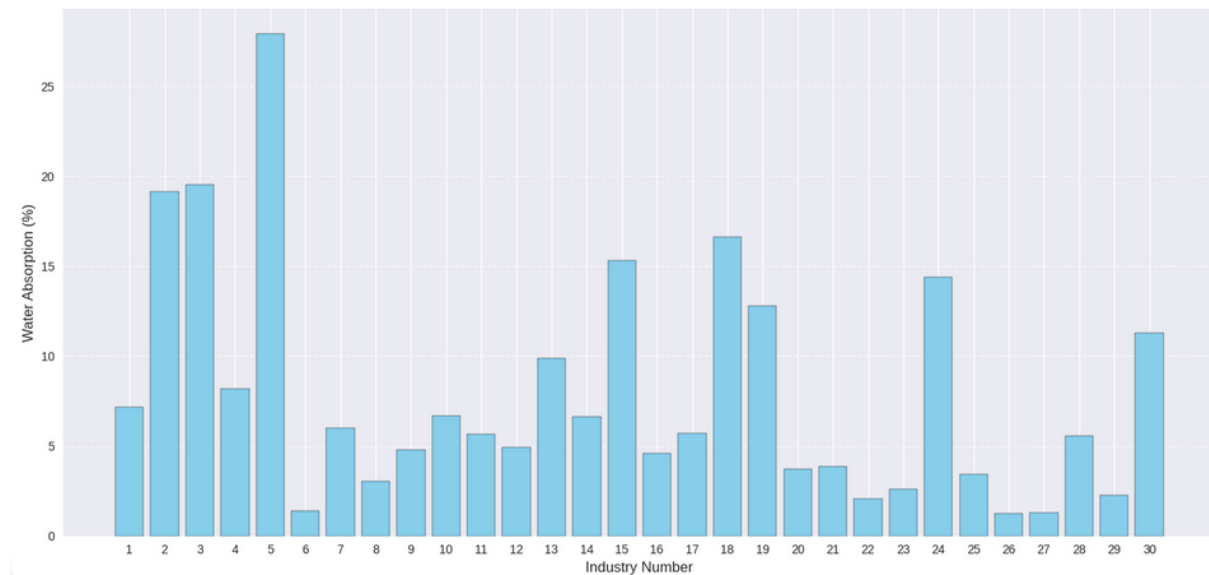


Figure 7. Water absorption of samples for industries 1–30.

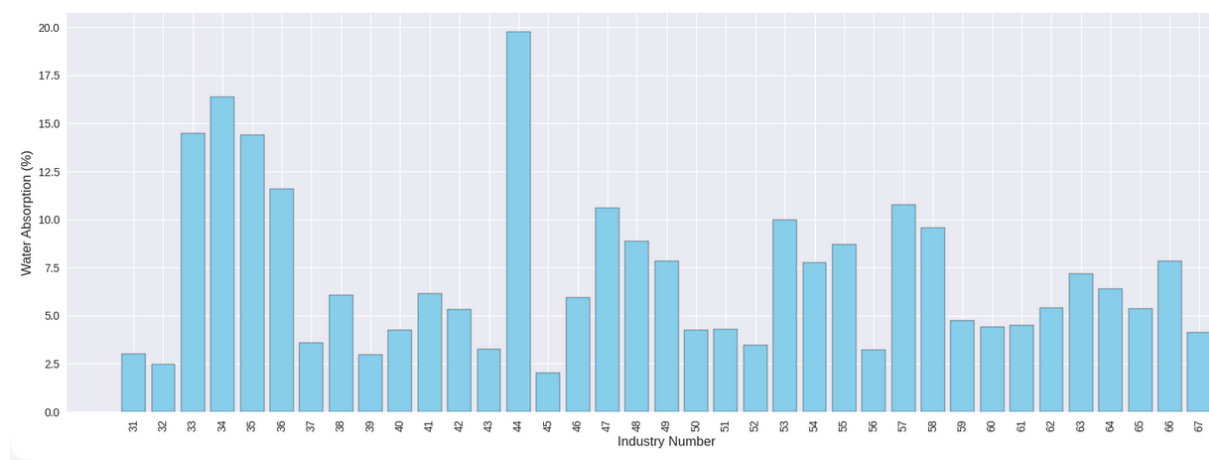


Figure 8. Water absorption of samples for industries 31–67.

3.6 Reliability assessment

Table 3 presents a comprehensive reliability analysis of 67 block production industries based on the reliability index (β), probability of failure (P_f), and their corresponding geographical coordinates. This dataset provides insight into both the structural performance of the blocks produced and the spatial variation in quality across the study area.

A general observation from the table is that all reliability indices are negative, indicating that most of the sampled industries fall within the failure domain. In reliability engineering, a negative β -value signifies that the resistance of the system is lower than the applied load or demand, suggesting a high likelihood of failure. This is further supported by the relatively high values of P_f recorded for many industries (Table 3).

Table 3. Reliability index and probability of failure distribution with geographical coordinates.

Industry	Reliability index (β)	P_f	$(1 - P_f) \times 100$ (%)	Location (latitude, longitude)
1	-1.22	0.89	11	6.620399, 3.256866
2	-2.85	0.64	36	6.650059, 3.252777
3	-1.60	0.054	95	6.587808, 3.257739
4	-1.21	0.89	11	6.649335, 3.271281
5	-0.78	0.78	22	6.620399, 3.256866
6	-1.40	0.92	8	6.643738, 3.244672
7	-0.94	0.83	17	6.624951, 3.258378
8	-1.26	0.90	10	6.650167, 3.252850
9	-0.29	0.61	39	6.620752, 3.285435
10	-0.39	0.65	35	6.622449, 3.292670
11	-0.69	0.76	24	6.655831, 3.271098
12	-1.90	0.029	97.1	6.643823, 3.251654
13	-1.58	0.057	94.3	6.619692, 3.291533
14	-0.36	0.64	36	6.627542, 3.293762
15	-2.79	0.0026	99.7	6.624916, 3.287415
16	-2.05	0.020	98	6.638611, 3.252181
17	-2.89	0.002	99.8	6.646557, 3.245572
18	-1.18	0.88	12	6.654459, 3.245208
19	-4.60	2.15×10^{-6}	99.9	6.661265, 3.246431
20	-2.19	0.014	98.6	6.669382, 3.266513
21	-1.64	0.051	94.9	6.667870, 3.262697
22	-2.35	0.0093	99.1	6.665850, 3.255988
23	-1.13	0.87	13	6.657501, 3.254525
24	-0.83	0.79	21	6.655507, 3.271700
25	-2.95	0.0016	99.8	6.641881, 3.270476
26	-2.22	0.0013	98.7	6.649811, 3.282063
27	-1.07	0.86	14	6.647630, 3.284439
28	-1.76	0.039	96.1	6.645252, 3.287707
29	-1.16	0.88	12	6.645379, 3.290523
30	-0.70	0.76	24	6.645024, 3.287756
31	-1.91	0.028	97.2	6.631402, 3.281317
32	-2.56	0.0052	99.5	6.629886, 3.276756
33	-0.51	0.69	31	6.620430, 3.277252
34	-2.40	0.0081	99.2	6.643119, 3.285803
35	-2.17	0.014	98.6	6.650390, 3.290510

Industry	Reliability index (β)	P_f	$(1 - P_f) \times 100$ (%)	Location (latitude, longitude)
36	-3.82	0.000067	99	6.637470, 3.282840
37	-1.18	0.88	12	6.667661, 3.263918
38	-1.70	0.004	96	6.669467, 3.266562
39	-0.49	0.69	31	6.654840, 3.271991
40	-1.72	0.004	96	6.641848, 3.270840
41	-4.65	0.0000016	99.9	6.635813, 3.252031
42	-2.74	0.003	99	6.637900, 3.250536
43	-2.35	0.009	99	6.650140, 3.252927
44	-2.17	0.015	98	6.635600, 3.250300
45	-1.28	0.90	90.1	6.648728, 3.252601
46	-1.85	0.03	97	6.657449, 3.255325
47	-2.75	0.0029	99.7	6.661237, 3.254096
48	-2.62	0.004	99.7	6.667046, 3.252472
49	-2.31	0.011	99	6.650950, 3.252951
50	-1.77	0.038	96.2	6.661983, 3.255524
51	-0.81	0.79	21	6.644703, 3.290189
52	-1.80	0.036	96.4	6.649107, 3.271102
53	-1.93	0.027	97.3	6.650189, 3.271778
54	-2.37	0.008	99.2	6.663147, 3.286403
55	-1.62	0.05	95	6.648458, 3.299295
56	-0.93	0.82	17.73	6.643843, 3.244689
57	-2.05	0.020	98	6.638070, 3.293675
58	-0.48	0.69	31.5	6.675488, 3.266789
59	-3.29	0.00051	99.9	6.661295, 3.281012
60	-3.20	0.00049	99.9	6.657442, 3.255486
61	-3.92	0.000054	99.9	6.668232, 3.249152
62	-2.89	0.019	98.1	6.673932, 3.262213
63	-2.56	0.005	99	6.615705, 3.297189
64	-1.71	0.04	96	6.636479, 3.283602
65	-2.50	0.006	99.4	6.648723, 3.300210
66	-2.03	0.02	98	6.627139, 3.289795
67	-1.90	0.028	97	6.652378, 3.260845

3.7 Fragility map

The map (Figure 9) illustrates the spatial variation of the reliability index (β) of block industries across the study area using contour colours. Each colour represents different reliability levels, with

red/orange indicating relatively higher reliability (lower failure risk) and blue/purple indicating very low reliability (high failure risk). The results show that reliability is not uniformly distributed. High-reliability zones are limited and mainly found in parts of the southern and eastern areas, while low-reliability zones dominate the northern and some western regions. The presence of closely spaced contours suggests significant variability in block quality even between nearby industries.

Overall, the map reveals that most industries fall within low-reliability zones, indicating a high probability of failure and inconsistent production quality. This highlights the need for improved quality control, better production practices, and stricter regulatory oversight to ensure safer construction materials.

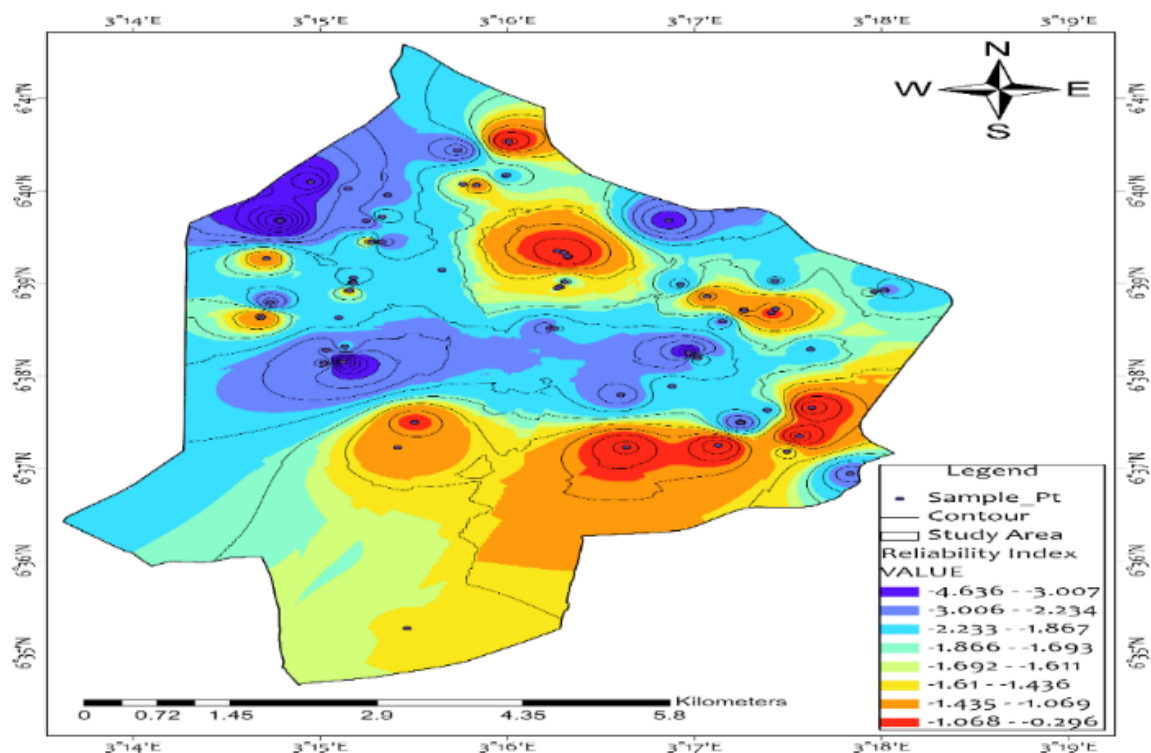


Figure 9. Fragility map for hollow blocks.

The 3D reliability map provides a visual representation of how the reliability index (β) varies across the study area in three dimensions, where height and color both indicate reliability levels (Figure 10).

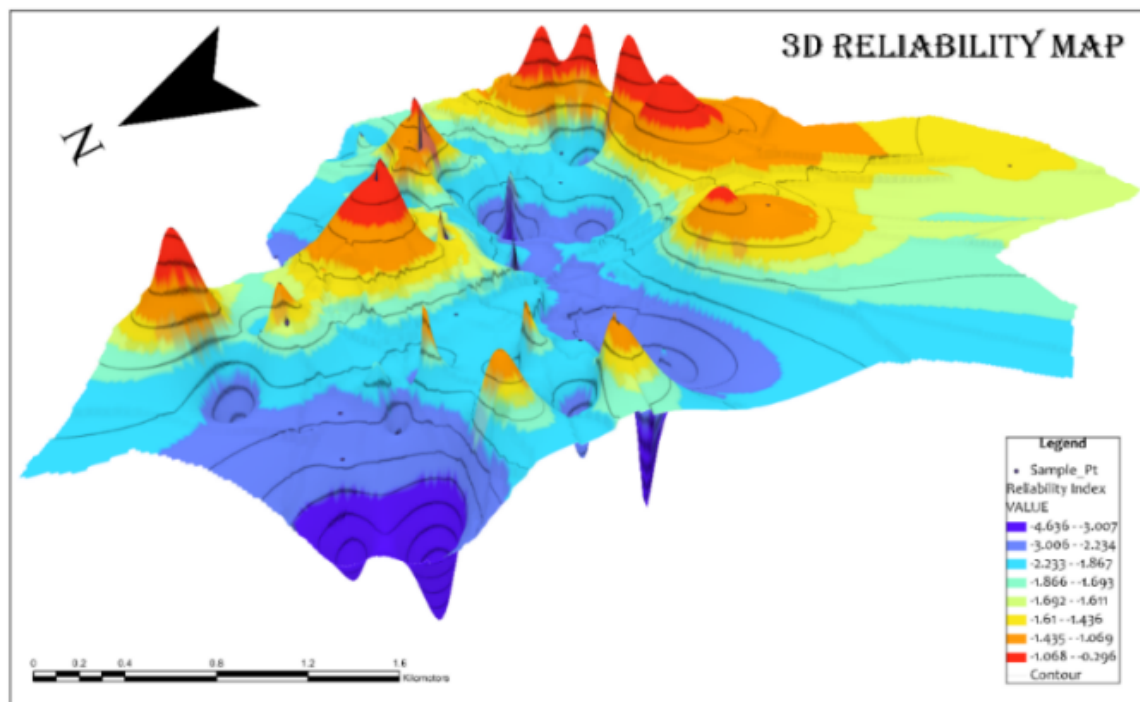


Figure 10. Three-dimensional view of the fragility map of hollow blocks.

- Peaks (red/orange areas) represent zones of higher reliability (lower probability of failure).
- Depressions (blue/purple areas) indicate low reliability and high failure risk.

The map shows that high-reliability zones are scattered and localized, while low-reliability zones are more widespread, especially in certain regions. The sharp peaks and deep valleys indicate significant variability in block quality between nearby industries.

3.8 Implications for sandcrete block quality in the study area

The spatial pattern observed in Figures 9 and 10, characterised by universally negative reliability index values with marked local variability, reflects the broader picture of sandcrete block quality in Nigeria's urban construction sector. The average compressive strength of sandcrete blocks from different production sites does not meet the minimum requirement stipulated by NIS 87:2004 and ISO 8484:1994, with the study further revealing that block quality is affected not only by aggregate quality but also by poor quality control and improper curing practices (Ogunbayo *et al.*, 2021). The spatial concentration of the most severely negative reliability index zones in specific sub-areas of the study territory suggests that localised factors such as proximity to low-quality sand sources, informal production clusters operating without regulatory oversight, or high factory density with shared substandard practices may be contributing disproportionately to the reliability deficit in those zones.

Only 3% of block industries complied with the required mix ratio, and less than 10% carried out quality assurance checks such as weekly inspection of mould conditions or dimensional measurements to ensure conformity with standard specifications (Wilson *et al.*, 2024). The reliability index maps therefore serve not merely as academic outputs but as practical spatial planning tools for directing quality enforcement interventions by the Standard Organisation of Nigeria and other regulatory bodies toward the most critically deficient production zones.

4 Conclusion and recommendations

4.1 Key findings

This study evaluated the quality of 201 sandcrete hollow blocks (450 mm × 225 mm × 225 mm) collected from 67 block manufacturing industries in Agbado/Oke-Odo Local Council Development Area, Lagos State. The major findings are as follows:

- The overall average compressive strength was 1.33 N/mm² (standard deviation 0.19 N/mm²), which is significantly below the NIS 87:2004 minimum requirements of 2.50 N/mm² for individual blocks and 3.45 N/mm² for the average of five blocks.
- Only a few industries produced blocks approaching the standard, with average strengths of 2.16–2.20 N/mm². The majority recorded strengths between 0.60 and 1.90 N/mm².
- Aggregate grading was predominantly coarse, with fineness modulus (FM) values ranging from 3.15 to 4.68 (average 4.51), far exceeding the recommended range of 2.30–3.50.
- Density ranged from 1.61 to 1.96 g/cm³, indicating inconsistent compaction.
- Water absorption was generally acceptable, but some industries recorded very high values (up to 27.91%), suggesting high porosity.
- All factories used volumetric batching and lean mix ratios (up to 1:18), while the cement quality was satisfactory.

These results confirm widespread non-compliance with NIS 87:2004 and are consistent with similar studies across Nigeria ([Ibrahim et al., 2025](#)).

4.2 Conclusion

The study concludes that the quality of sandcrete hollow blocks produced in Agbado/Oke-Odo LCDA is generally poor and unsuitable for load-bearing applications. The low compressive strength is primarily caused by excessively coarse aggregates, non-standard lean mix ratios, volumetric batching without compensation for bulking, inadequate compaction, and inconsistent curing practices. Although the cement used met standard specifications, deficiencies in production processes remain the main contributors to the substandard performance. This situation poses significant risks to structural safety in the study area.

4.3 Recommendations

To improve the quality of sandcrete block production in the study area, the following practical recommendations are proposed:

- *Aggregate Improvement:* Blend coarse sand with finer Zone 4 sand to bring the fineness modulus within the recommended range of 2.30–3.50.
- *Standard Mix Ratios:* Strictly adopt the 1:6 (cement:sand) ratio as specified by NIS 87:2004 and discontinue the use of leaner mixes (1:14–1:18).
- *Batching Method:* Transition from volumetric batching to weight batching for greater accuracy and consistency.
- *Compaction and Curing:* Use well-maintained vibrating machines and implement proper 28-day curing under controlled moist conditions.
- *Water Absorption Control:* Review production processes in factories showing absorption values above 12%.

- **Regulatory Enforcement:** SON and local building control agencies should intensify monitoring, make NIS 87:2004 compliance a licensing condition, and conduct regular independent testing.
- **Training:** Provide technical training for block manufacturers and operators on best practices in mix design, compaction, and curing.
- **Further Research:** Investigate the use of supplementary cementitious materials (e.g., rice husk ash, metakaolin) and the performance of blended aggregates under controlled conditions.

Implementation of these recommendations will significantly enhance block quality, improve structural safety, and support sustainable construction practices in Agbado/Oke-Odo LCDA and similar areas across Nigeria.

References

- [1] ASTM C150/C150M (2022). Standard Specification for Portland Cement. *ASTM International*, West Conshohocken, PA.
- [2] ASTM C33/C33M-18 (2018). Standard Specification for Concrete Aggregates. *ASTM International*, West Conshohocken, PA.
- [3] Auyo HA (2023). Effect of mix ratio and curing on compressive strength of sandcrete hollow blocks. *Nigerian Journal of Engineering*, 30(3), 43–47.
- [4] Ibrahim M, Yerima MA, Danbuba Z, Masud AY, Ibrahim MA (2025). Quality assessment of commercial sandcrete hollow blocks produced in Kaura District, Abuja. *Arid Zone Journal of Engineering, Technology and Environment*, 21(1), 157–167.
- [5] Nigerian Industrial Standard (NIS) 87:2004. Hollow Concrete Blocks. Standards Organisation of Nigeria (SON).
- [6] Ogunbayo BF, Ajao AM, Alagbe OT, Ogundipe KE, Tunji-Olayeni PF, Ogunde A (2021). Quality assessment of sandcrete blocks produced with river sand in Ogun State, Nigeria. In *Sustainable Education and Development*, Springer, 723–733.
- [7] Wilson UN, Adediji O, Odeyemi SO, Aliyu HI, Durosinlorun AO, Abubakar P (2024). Quality evaluation of sandcrete blocks produced in selected local government areas of Kaduna State, Nigeria. *Nigerian Journal of Technology*, 43(4).