SADI International Journal of Science, Engineering and Technology
ISSN: 2837-194|Impact Factor : 8.27
Volume. 12, Number 4; October-December, 2025;
Published By: Scientific and Academic Development Institute (SADI)
8933 Willis AveLos Angeles, California
https://sadijournals.org/index.php/sijset|editorial@sadijournals.org

USE OF LATERITE AS PARTIAL SAND REPLACEMENT IN SANDCRETE BLOCKS: STRENGTH AND PERMEABILITY STUDY

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DOI: https://doi.org/10.5281/zenodo.17937061

Abstract: This study examined the effect of replacing part of sand with laterite in sandcrete block production and how the permeability of fine aggregates influences block strength. First, the fine aggregates (river sand and two laterite samples) were tested to determine their physicochemical properties (moisture content, specific gravity and permeability). The sandcrete blocks were then produced using a 1:6 mix ratio with laterite replacement levels of 0%, 25%, 50% and 75%, and cured for 7, 14 and 28 days. Density and compressive strength were determined, and correlation analysis was performed between aggregate permeability and 28-day block strength. The results showed that the laterites had higher moisture content and lower permeability than the river sand. The control sample (100% sand) had the highest strength, whereas the 25% laterite mixes achieved compressive strength values above the minimum requirement for non-load-bearing sandcrete blocks. The 50% and 75% mixtures did not meet the standard. Block density and compressive strength reduced as laterite content increased. A strong positive correlation was observed between the permeability and 28-day strength of the block samples, and aggregates with higher permeability produced stronger blocks. The optimal replacement level is 25% laterite. Higher laterite contents weaken the block structure and are unsuitable for major construction.

Keywords: Sandcrete block, Laterite, Fine aggregate, Compressive strength, Permeability

1. INTRODUCTION

Sandcrete blocks are the most commonly used walling materials in Nigeria. They are simple to produce, and the materials used for production are commonly available and easy to obtain. The materials used are cement, fine aggregate, and water. River sand is the main fine aggregate material that is mostly used for sandcrete blocks. As the demand for this type of sand increases, the price of sandcrete blocks increases, which in turn affects housing. Thus, there is a need to reduce the cost of production of sandcrete blocks and ultimately reduce construction costs. There is also a need to continually improve methods of production of blocks and seek better ways to achieve quality. As such, other materials in the environment that can be used in place of sand in making hollow blocks without losing its strength and becoming or too weak for use can be considered.

Laterite is a widely available, easy, and cheap material that is the dominant soil in many rural and semi-urban areas. Laterite contains fine particles, has a high clay content, and sometimes holds much water; therefore, when mixed with cement in producing blocks, the block's behaviour changes. For instance, when micronized laterite was used to replace sand in hollow sandcrete blocks, the density and compressive strength steadily decreased as the laterite content increased, especially at higher replacement levels (Awolusi *et al*., 2021). This shows that laterite affects how cement hydrates inside the block.

Several studies have attempted to understand how much laterite can be safely used. A study on the partial replacement of sand with lateritic soil in Ogun State discovered that low replacement levels (approximately 10%–20%) still gave acceptable compressive strength, but higher percentages led to block weakness because the fine particles of laterite disrupted the packing of the mix (Joshua *et al*., 2014). Another research produced both hollow blocks and interlocking blocks using laterite in place of sand, and it also reported consistent reduction in strength when laterite content increased, although some mixes still met required strength limits at moderate replacement levels (Olopade *et al*., 2022). In a related experiment on laterite–quarry dust blocks, the combined use of laterite with other fine materials showed that the aggregate composition largely controls block strength and water absorption due to changes in pore structure (Okafor & Egbe, 2017).

More recently, improvements in the properties of laterite-based blocks were achieved through stabilization, such as using microbial treatment, which helped the laterite blocks resist water and maintain better strength (Abdullahi *et al*., 2024). Even though that study was not conducted on sandcrete, it shows that laterite can perform better depending on how it is treated and used.

Hence, using laterite to partly replace sand may be a reasonable way to reduce over-dependence on river sand and support sustainable housing. Although the physical properties of laterite vary by location and are not always predictable, its performance in sandcrete cannot be assumed. Laterite can reduce strength when used in high proportions (Joshua *et al*., 2014), and block quality depends heavily on the mix design and aggregate characteristics. Because of this variability, more research using local laterite sources is needed to identify replacement levels that maintain acceptable block performance. This study addresses this gap by checking the strength and how the permeability of the aggregates influences the cement bonding effectiveness.

1.1 Aim and Objectives:

This study aimed to evaluate the strength performance of sandcrete blocks produced using laterite as partial sand replacement and the influence of fine aggregate permeability on block performance.

The specific objectives were as follows:

i. Evaluate the physicochemical properties of the sand and laterite samples;
ii. determine the density and compressive strength of sandcrete block samples produced with different replacement levels of sand with laterite; and
iii. analysed the correlation between the permeability of the fine aggregates and the compressive strength of the sandcrete blocks.

2. MATERIALS AND METHODS

This study was conducted at Federal Polytechnic, Ile-Oluji, Ondo State, situated at km 13, Ondo/Ipetu Ijesa expressway, Ile-Oluji, Ondo State, Nigeria. The research involved laboratory testing of various samples required for the production and evaluation of sandcrete blocks.

2.1 Materials

The primary materials used in this study, namely: Cement – ordinary portland cement (Dangote), sourced from a local vendor within the Ile-Oluji community; Sand – sharp river sand obtained from a river along Aaye Quarters along Ile-Oluji – Ondo road, within Ile-Oluji, Ondo State; Laterites (from two different locations), obtained from borrowed pits within the Ile-Oluji community at latitudes 07°14’21”N and 07°13’09”N and longitudes 04°52’16”E and 04°51’46”E for samples 1 and 2, respectively; and Water – obtained within the study area.

2.2 Methods

Preliminary tests (moisture content, specific gravity and permeability) were conducted on the fine aggregates (sand and laterites) to determine their physicochemical properties. For the permeability test, the falling head method was used on each fine aggregate, including the samples from the mix between the sand and laterites.

The sandcrete blocks were produced in a prefabricated steel mould of 450 mm × 225 mm × 150mm, using a 1:6 cement-to-aggregate mix ratio and a water-cement ratio of 0.5. Different mix proportions were prepared: the control sample, consisting of only cement and sand (0% laterite replacement), and six experimental samples, where the 2 laterites both replaced sand at 25%, 50%, and 75% by weight (Table 1). Nine (9) blocks were produced for each mix variation of aggregates with cement and water.

Following production, the blocks were demoulded after 24 h and water-cured for 7, 14, and 28 days. The density (by weight of the block and volume of mould) was determined for each curing age, and the compressive strength of the blocks was determined in accordance with BS EN 772-1:2011 using a compression testing machine (Plate 1).

The results of these tests were then analysed to compare the density and compressive strength of the sandcrete blocks across different laterite replacement levels. Additionally, the correlation between the permeability of the fine aggregate sample mixes and the compressive strength of the sandcrete block samples was evaluated to assess the influence of pore structure on structural performance.

Table 1: Variations in the mix for block production

Mix Proportion (%)	Cement (kg)	River Sand (kg)	Laterite (kg)
0	35.4	212.4	0
25	35.4	159.3	53.1
50	35.4	106.2	106.2
75	35.4	53.1	159.3

Plate 1: Crushing of the block samples using a compression machine

3. RESULTS AND DISCUSSION

3.1 Moisture content (MC) and specific gravity (SG)

The results of the physicochemical properties tests on the fine aggregates show that the river sand has a moisture content of 9.17% and a specific gravity of 2.68, while laterite sample 1 has 13.2% moisture content and 2.63 specific gravity of 2.63, and laterite sample 2 has 16.61% moisture content and 2.56 specific gravity of 2.56. This means that laterite generally contains finer particles and iron–aluminium oxide compounds that hold water more easily, which explains why the higher moisture content and lower specific gravity of laterite means its particles are lighter than river sand, and this usually affects density of blocks made from those materials (Ewa *et al*., 2022).

3.2 Permeability of the fine aggregate mixes

As presented in Table 1, river sand has the highest permeability value at 6.56×10^{-3} cm/s. Both laterite samples were less permeable, with sample 1 at 7.85×10^{-5} and sample 2 at 3.24×10^{-5}. The mixed proportions followed a steady reduction in the permeability of the sand as the laterite content increased, especially at 50% and 75% replacement, where the permeability values dropped into the 10^{-5} range. This behaviour reflects the fine and clayey texture of lateritic soils, which tends to clog pore spaces in the aggregate mass, reduce flow paths, and influence pore behaviour (Oghenerukewve & Omotor, 2024).

3.3 Density of the sandcrete block samples

The density results in Table 2 show that the control sandcrete block has the highest densities ranging from 1654 to 1708 kg/m³ across curing days. For mixes with laterite content, the density dropped gradually, with mixes containing 75% laterite recording values as low as 1224–1266 kg/m³. Mixes containing higher laterite contents tend to show lower mass per unit volume (Olopade *et al*., 2022).

3.4 Compressive strength of the sandcrete blocks

The control sample's compressive strength reached 4.13 N/mm² at 28 days, as presented in Table 3, which is well above the Nigeria Industrial Standard (NIS 87: 2004) minimum standard requirement (2.5 N/mm^2) for compressive strength of non-load bearing blocks. The 25% laterite mixes (L_{1A} and L_{2A}) exhibited good strengths of 3.06 N/mm² and 2.89 N/mm² at 28 days, respectively, which still exceed the acceptable standard for non-load-bearing block categories. The 50% replacement mixes fell below the structural requirements with strengths of approximately 1.74 to 1.88 N/mm² while the weakest mixes were the 75% laterite blocks (1.32 – 1.59 N/mm²). These reductions might be due to the high clay content of the samples.

This same trend was also observed in some studies where an increase in laterite content produced consistent losses in compressive strength (Ewa *et al*., 2022; Faluyi *et al*., 2023).
Thus, the optimal replacement level for the mix proportions considered in this study appears to be 25% laterite, providing the best balance between strength and material substitution. A higher lateritic content decreases the compressive strength of the blocks.

Table 1: Permeability properties of the sand and laterite samples

Sample Type	Permeability (cm/sec)
River Sand (RS)	6.56×10^{-3}
Laterite sample 1 (L1)	7.85×10^{-5}
75% sand and 25% laterite sample 1 (L_{1A})	3.81×10^{-3}
50% sand and 50% laterite sample 1 (L_{1B})	1.09×10^{-3}
25% sand and 75% laterite sample 1 (L_{1C})	9.72×10^{-5}
Laterite sample 2 (L_2)	3.24×10^{-5}
75% sand and 25% laterite sample 1 (L_{2A})	1.18×10^{-3}
50% sand and 50% laterite sample 1 (L_{2B})	6.90×10^{-4}
25% sand and 75% laterite sample 1 (L_{2C})	7.53×10^{-5}

Table 2: Density of the sandcrete block samples

Sample Type	Density (kg/m^3)		
	7 days	14 days	28 days
RS	1654	1662	1708
L_{1A}	1523	1570	1542
L_{1B}	1451	1485	1519
L_{1C}	1358	1350	1376
L_{2A}	1488	1427	1464
L_{2B}	1377	1341	1352
L_{2C}	1235	1224	1266

Table 3: Compressive strength of the sandcrete block samples

Sample Type	Compressive strength (N/mm^2)		
	7 days	14 days	28 days
RS	1.42	2.67	4.13
L_{1A}	1.08	1.94	3.06
L_{1B}	0.93	1.15	1.88
L_{1C}	0.72	1.21	1.59
L_{2A}	1.14	1.71	2.89
L_{2B}	0.60	1.22	1.74
L_{2C}	0.65	1.04	1.32

3.5 Correlation between the compressive strength and permeability

The regression analysis between the permeability of the fine aggregate mix samples and the 28-day compressive strength yielded a strong correlation value of 0.87 (Figure 1). This indicates that more permeable aggregates tend to produce higher strength, whereas low-permeability aggregates produce blocks with weaker strength. This suggests that permeability influences how well the cement paste penetrates the aggregate structure and hydrates as laterite restricts pore movement, making it harder for cement hydration to proceed uniformly, which then reduces compressive strength (Lewechi A. 2021; Mama & Osadebea, 2011).

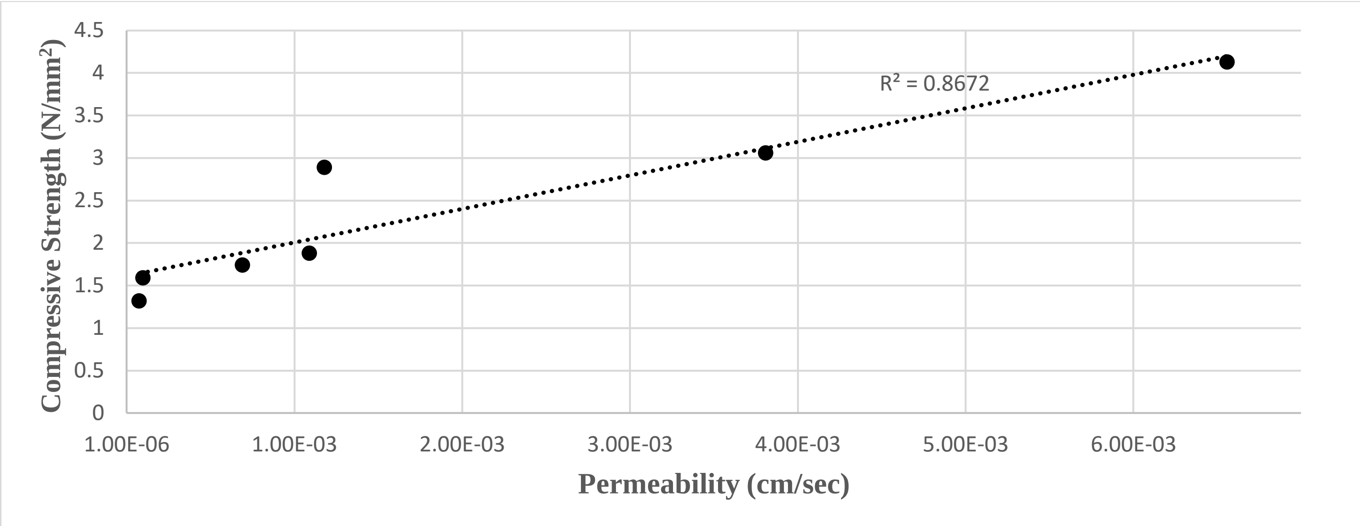

Figure 1: Correlation between the compressive strength of the sandcrete block and the permeability of the fine aggregate samples

4. CONCLUSION AND RECOMMENDATIONS

This study evaluated the usage of laterite in partially replacing sharp sand in sandcrete block production and to determine how the fine aggregate permeability affects the block strength. The fine aggregates exhibited different physicochemical properties. The laterites had higher moisture content, lower specific gravity, and much lower permeability than the sharp sand.

In terms of the compressive strength, the control sample (100% river sand) gave the highest strength, while the mixes with 25% laterite and 75% sand still produced blocks with good compressive strength values that are above the acceptable standard for compressive strength of non-load bearing blocks as required by Nigeria Industrial Standard (NIS 87: 2004). The blocks with 50% and 75% laterite replacement levels did not meet the standard sandcrete strength requirement. There was also a noticeable decrease in the density and compressive strength of the block samples when the laterite quantity increased.

Based on the results obtained in this study, the optimal replacement level is 25% laterite as it provides the best balance between material strength and substitution. The correlation between permeability and strength also showed a strong relationship. Aggregates with higher permeability produced stronger blocks, whereas laterites with low permeability produced weaker results. This implies that permeability plays a major role in cement penetration and hydration inside the blocks.

Overall, it is recommended that laterite be used for sand replacement only at low levels, and anything beyond the recommended optimum replacement level will reduce the block strength and render it ineffective for practical construction use.

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