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Study on the Impact of Sand Quality on the Mechanical Properties of Sandcrete Blocks

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Abstract

This research was carried out to establish the suitability of white laterite in sandcrete blocks production. White laterite "white sand" was collected from six major sand dredging sites in Isoko district of Nigeria. Physical characteristics (porosity and particle size grading) of the sand were measured in accordance with American Society for Testing and Materials (ASTM) procedures. Two batches of sandcrete blocks were made using distinct cement-to-sand mix proportions: labeled as formula 1 (with a ratio of 1:8) and formula 2 (with a ratio of 1:10). The sand physical tests results revealed that the sand has a lot of fine-grained particles, while and their porosity varied from 34.9% to 41.1%. Regarding the strength characteristics of the blocks, the results revealed that blocks produced using "formula 1" exhibited compressive strengths ranging from 1.37 MPa to 2.23 MPa. Conversely, blocks made with "formula 2" demonstrated compressive strengths ranging from 1.17 MPa to 1.96 MPa. Significantly, neither of the sandcrete blocks, irrespective of the cement-sand mix ratio, met the approved Nigeria Industrial Standard (NIS) recommended compressive strengths for sandcrete blocks. The standard specifies 3.45 MPa for load-bearing walls and 2.5 MPa for non-load-bearing walls. The inadequate mechanical strength of sandcrete blocks manufactured from "white sand" presents a significant challenge to the building industry. Addressing this issue is crucial for preventing building collapses in the region.

1. Introduction

Sand is a granular inorganic material containing some organic impurities, extensively utilized for various engineering applications. Sand possesses numerous engineering properties, which are influenced by factors such as grain particle size, moisture content, and the presence of contaminants. Sand containing a higher proportion of coarse particles generally demonstrates superior mechanical strength in comparison to sand with a lower proportion of coarse particles [1, 2]. The mechanical characteristics of the sand utilized in construction significantly influence the integrity and longevity of engineering structures. This is because sand is a crucial constituent in a variety of construction materials, thus playing a pivotal role in ensuring the robustness and durability of the final structures [3, 4]. Many instances of structural failures have been linked to the use of substandard sand in construction. Poor quality sand can significantly diminish the mechanical strength and integrity of structures built from it [5, 6].

Sandcrete block is a common wall construction material, manufactured by combining sand, cement, and water. Sandcrete blocks are designed to serve in both load-bearing and non-load-bearing walls, necessitating that their strength properties meet the desired requirements [7]. Structural elements used for the construction of load bearing walls should have the capacity (adequate compressive strength) to support vertical loads of farm buildings [8, 9]. The Nigerian Industrial Standards (NIS) recommended that compressive strength of load-bearing and non-load-bearing wall elements, used for farm structures and residential buildings construction, should not fall below 2.5 MPa and 3.45 MPa, respectively [10]. Sandcrete block compressive strength is a major parameter used to evaluate the ability of the block to withstand compressive loads without failure. Therefore, a block with higher compressive strength tends to absorb (support) greater compressive load - one of the forces buildings are naturally subjected to, leading to stability and durability of the building [11]. The compressive characteristics of sandcrete blocks rely on the quality of cement and fine aggregates, the methods employed during production and curing, as well as the environmental conditions at the time of production [12- 14]

In Africa, there has been a notable increase in the demand for sandcrete blocks, especially within the construction sector [14]. Most blocks produced by blocks producing industries are of poor grade, partially due to the poor quality sand they used for the blocks production [4, 15-16]. This is a serious challenge in the building industry, since substandard building materials can easily compromise the standard and durability of the structure [17]. Findings from previous studies have indicated significant variations in the geotechnical properties of sand across different locations, directly impacting the mechanical quality of sandcrete blocks produced from them [18 – 20]. While numerous studies have examined the geotechnical properties of soils in various regions and their impact on concrete and sandcrete, there is still knowledge gap on the mechanical strength of sandcrete produced with white laterite obtained from Isoko region of Nigeria. The objective of this research is to assess the mechanical properties of sandcrete blocks manufactured using white sand sourced from the Isoko municipal region of Delta State. The outcomes of this study will provide valuable insights for structural engineers involved in the construction of industrial buildings, with the ultimate goal of minimizing the occurrence of building failures.

2.0 Materials and methods

2.1. Study area

This study was carried out in the Isoko region of Delta State, Nigeria, situated within the country's Tropical rainforest zone. The subsoil consists mainly of white and red lateritic soil, prone to crude oil pollution from oil production facilities. The area experiences significant rainfall of approximately 1,800 mm per annual. The rainwater in the region tends to be slightly acidic, attributed to pollution from activities such as oil exploration, vehicular traffic, and other human actions [21]. There are numerous sand mining sites in the regions, mining white and red lateritic soils for constructional purposes.

2.2. Sample collection

Samples of white lateritic soil, commonly referred to as "white sand," were collected randomly from six spatial locations within the Isoko region of Delta State, Nigeria. The sand were taken to the laboratory and dried at room temperature of 31±5^{o}C, to reduce its moisture content. Soil natural moisture content usually interferes with cement-sand composites compressive strength. Excess moisture in the soil can lead to higher water-cement ratios in the mixture, affecting its workability and potentially weakening the resulting structure [13, 22].

2.3. Water
Clean borehole water devoid of oil contamination and any other foreign substances was used to make the blocks. Contaminants in water can adversely affect the hydration process of cement, leading to weakened bonds between particles and reduced compressive strength of the blocks [23].

2.4. Cement
The blocks were produced using Grade 42.5 Limestone Portland cement.

2.5 Sandcrete block production
Mix ratio
In this study, two mix ratios "formulae" were employed for the cement-fine aggregates (sand) combination. Formula 1 has a mix ratio of 1:8, and formula 2 has a mix ratio of 1:10. Additionally, a water-to-cement ratio (w/c) of 0.5 was utilized for both sandcrete batches.

Mixing method
The mechanical mixing technique was used to mix the sandcrete constituents.

Blocks production
The well-blended components were poured into a vibrating (mechanical) molding machine, which was employed to mould the blocks. For the purpose of this study, 9-inch (228.6 mm) sandcrete blocks were produced for every mix ratio considered.

Curing
The sandcrete blocks underwent a dual curing process—morning and evening—using the irrigation method over a 28-day period.

2.6 Laboratory Tests

Sieve analysis
The sieve analysis of the white sand followed the ASTM D422 procedures [24], as outlined by Eboibi [25]. Subsequently, the key coefficients, including the coefficient of uniformity (Cu) and the coefficient of gradation (Cc), were determined using Equations 1 and 2.

$$C_U = \frac{D_{60}}{D_{10}} \quad (1)$$

$$C_C = \frac{{D_{30}}^2}{D_{60} \times D_{10}} \quad (2)$$

Where: D_{60}, D_{30} and D_{10} are the 60%, 30% and 10% finer sand respectively [26].

Porosity
The sand porosity was determined in agreement with ASTM D4404 [27] approved guidelines.

The block compressive strength
The compressive strength of the sandcrete block was determined at the 28th curing day, in harmony with NIS-87:2000 procedures [10], by using the block crushing machine (Figure 1). At the end of each block crushing operation, the compressive strength of each block was calculated through Equation 3 [16]. Each mix ratio underwent testing using four blocks, and the resulting average value was recorded.

Figure 1: A block undergoing compression testing

$$\text{Compress strength} = \frac{\text{Failure force (N)}}{\text{Net surafce area of block } (mm^2)} \quad (3)$$

3.0 Results and Discussion

3.1 Sieve analysis

The results regarding the particle grain size distribution are detailed in Table 1 and illustrated in Figure 2. According to the Unified Soil Classification System (USCS), the analysis indicated that sand from borrow pits 1, 2, 3, and 4 contained fines exceeding 5% and Cu values below 6.0, thus classified as Poorly Graded sand. Conversely, sand from borrow pits 5 and 6 exhibited fines percentages below 5% and Cu values greater than or equal to (≥) 6.0, qualifying them as Well Graded sand [16]. Poorly graded sand is generally unsuitable for sandcrete and concrete production due to its tendency to result in sandcrete blocks with lower compressive and tensile strengths. Conversely, Well Graded sand has the potential to yield sandcrete blocks with higher compressive and tensile strengths [28].

Table 1: Sieve analysis parameters

Spatial Points	Fine-grained particles (%)	Cu	Cc
1	10.0	4.67	0.64
2	6.0	4.17	1.12
3	7.6	4.18	1.12
4	7.4	5.58	0.62
5	3.4	7.09	1.45
6	4.6	6.5	1.23

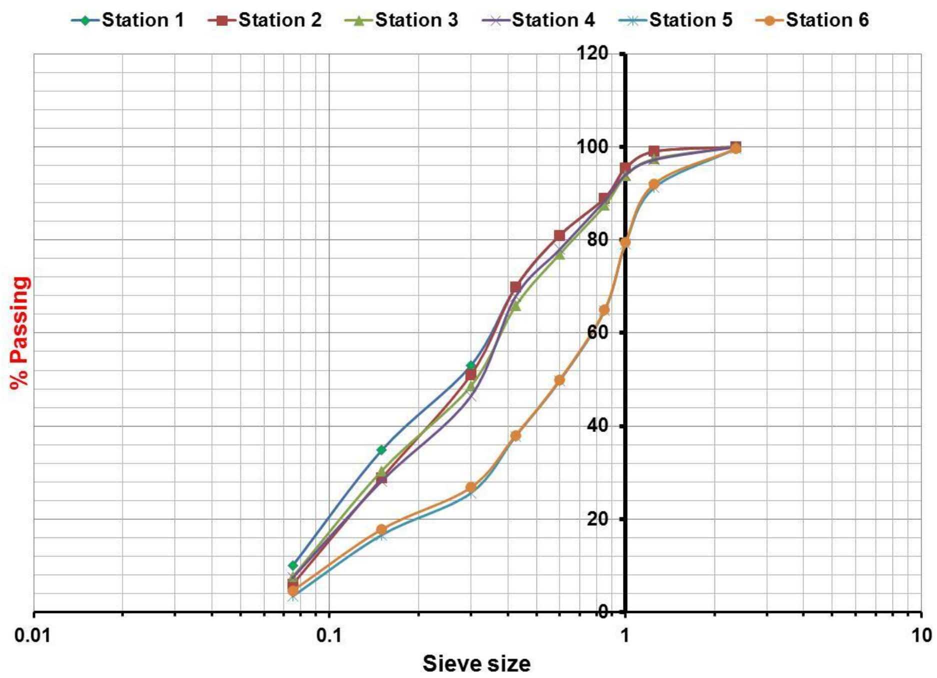

Figure 2: The sieve analysis plots

3.2 Porosity

The porosity results of the soil samples are presented in Figure 3. As depicted in Figure 3, the porosity ranged from 33.7% to 42.5%. These relatively high porosity values suggest the presence of a significant amount of fines in the soil, which can adversely affect the strength of sandcrete composites produced from them. Furthermore, according to Chen [29] and Peng [30], there exists a robust correlation between the compressive strength of cement mortar and the porosity of fine aggregates. Their experimental data showed a decrease in mortar compressive strength with an increase in porosity values.

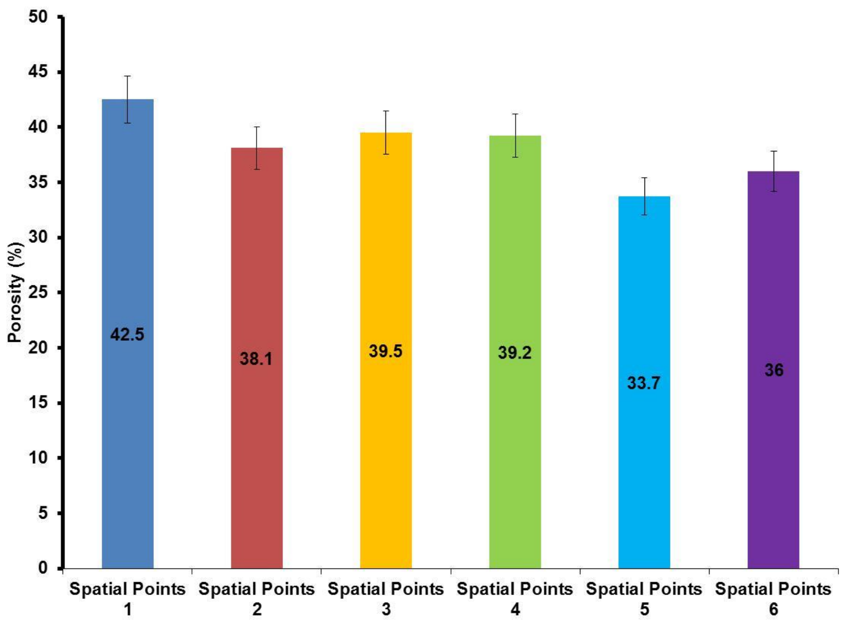

Figure 3: The porosity values

3.3 Compressive strength

The compressive strength results of the sandcrete blocks produced from the two mix ratios are displayed in Table 2. It is evident from the findings that the compressive strength of the concrete produced with mix ratio of 1:8 (formula 1) was significantly higher compared to that of the concrete produced with mix ratio of 1:10 (formula 2). It was noted that the compressive strength of the sandcrete blocks produced through mix ratio 1 ranged between 1.37 MPa and 2.23 MPa; while in the compressive strength of the blocks produced through mix ratio 2 varied from 1.17 MPa to 1.96 MPa. Remarkably, none of the sandcrete blocks produced using either formula met the approved recommendations set by the Nigerian Industrial Standard (NIS) for sandcrete blocks. According to NIS guidelines, sandcrete blocks intended for the construction of load-bearing walls must possess a compressive strength exceeding 3.45 MPa, while those used for non-load-bearing walls should have a compressive strength greater than 2.5 MPa [10]. The low mechanical strength developed by blocks made from borrow pits 5 and 6 sand, despite their classification well-graded nature, could be attributed to various factors, which include: water quality, soil mineral and organic content, and other anthropogenic actions [13].

These findings closely align with those reported by Aiyewalehinmi [31] and Olonade [32], who also observed a compressive strength for sandcrete blocks manufactured using sand sourced from a different geographical region. The variations in compressive strength observed among sandcrete blocks produced by different researchers may be attributed to differences in mix ratios, mixing techniques, block production methods, and curing procedures adopted by each researcher [6, 8, 33].

Table 2: Blocks compressive strength (MPa)

Spatial Location	Mix ratio 1	Mix ratio 2
1	1.37±0.04	1.17±0.02
2	1.61±0.05	1.28±0.03
3	1.89±0.07	1.52±0.05
4	1.74±0.05	1.49±0.02
5	2.23±0.03	1.96±0.02
6	2.16±0.04	1.92±0.03

4.0 Conclusion

This study aimed to assess the suitability of white lateritic soil for sandcrete block production. Sandcrete blocks created from sand specimens collected from six sand dredging sites were analyzed for mechanical properties following American Society for Testing and Materials (ASTM) guidelines. The results indicated that most of the white sand from was poorly graded. Furthermore, the study found that the mechanical properties of the sandcrete blocks manufactured from this white sand did not meet the standards outlined by the Nigerian Industrial Standard (NIS) for blocks intended for building construction. The low compressive strength exhibited by the sandcrete blocks produced from the dredged white sand in the Isoko region underscores a critical concern for structural engineers. This emphasizes the imperative to address this issue effectively to mitigate the risk of building failures in the area.

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