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Evaluating the Suitability and Mechanical Properties of Sandcrete Blocks Produced from Borrow Pits Sands in some Communities in Isoko, Delta State, Nigeria

Umukoro[a*] L.O, Owamah[b] H.I., Atikpo E[c], Ikpeseni[d] S.C.

[a,b,c]Department of Civil Engineering, Delta State University, Abraka, Nigeria
[d]Department of Mechanical Engineering, Delta State University, Abraka, Nigeria
*Corresponding author osiwime.lous@yahoo.com

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ABSTRACT

This research was conducted to establish the suitability of dredged (borrow) pits "white sand" in sandcrete block production. White sand was collected from six major sand dredging sites in the Isoko district of Nigeria. Some geotechnical properties (porosity and particle size grading) were done on the sand following American Society for Testing and Materials (ASTM) approved methods. Also, the sand particle size compressive strength was determined through sandcrete blocks produced according to ASTM standards. Two sets of sandcrete blocks were produced with different cement–sand mix ratios; which were mix ratio 1 (mix ratio of 1:8) and mix ratio 2 (mix ratio of 1: 10). Results from the geotechnical test revealed that the majority (66.7%) of the sand were poorly graded sand, while their porosity varied from 34.9% to 41.1%. Additionally, blocks produced through mix ratio 1 had compressive strength that varied from 1.34 MPa - 2.21MPa; while the mix ratio 2 blocks compressive strength ranged between 1.12 MPa and 1.85 MPa. Remarkably, none of the sandcrete blocks regardless of the cement-sand mix ratio met the approved Nigeria Industrial Standard (NIS) recommended compressive strength for sandcrete blocks - load-bearing walls of 3.45MPa and non-load-bearing walls of 2.5 MPa. Hence, the low compressive strength of the sandcrete blocks produced from the studied region white sand should be of major concern to stakeholders, to prevent the occurrence of building collapses in the region

1. Introduction

Soil is a complex compound that consists of organic and inorganic materials, with grain particle size playing an essential role in its internal deformation behaviour [1]. The organic content of the soil greatly influences the soil's engineering properties. Soil is a vital civil engineering construction material, and its mechanical properties are dependent on the particle grain size, moisture level and pollution level. Detailed knowledge of the geotechnical properties helps in the design of civil engineering structures - bridges, concrete, pavements, sandcrete blocks and retaining walls [2].

Sandcrete block is one of the vital building materials in Nigeria, used for the construction of load and non-load-bearing walls. It is produced basically from cement, fine aggregates (sand) and water [3]. Research had shown that the majority of the sandcrete blocks used for building construction are of poor quality – low compressive strength; thus, they failed to meet the Nigeria Industrial Standard (NIS) specifications [4, 5]. According to NIS, the compressive strength of non-load-bearing and load-bearing walls should not be lower than 2.5MPa and 3.45MPa respectively [6]. The compressive properties of sandcrete block are dependent on the quality of cement and fine aggregates, the production and curing methods used, and the prevailing environmental conditions [7, 8].

Isoko region (district) is experiencing rapid structural development due to the presence of primary and secondary industries, educational centres and tourist centres. Therefore, the demand for sandcrete blocks has increased dramatically within the last five years, and most of these sandcrete blocks are sold to the public to use for load-bearing and non-load-bearing walls and foundation. Though some studies have been carried out on the geotechnical properties of other regions borrow pits sand [9-11], literature search yields few reports on the geotechnical properties of Isoko borrow pits white sands. Therefore, it has become paramount to determine the geotechnical properties of the Isoko region borrow pits sand and establish their suitability for sandcrete production. Information obtained from this research will aid structural engineers during buildings construction, to minimize the occurrence of building failures.

2. Materials and methods

2.1 Materials

Study area
This study was conducted within the Isoko region of Delta State, Nigeria. This region is located in the tropical rainforest of Nigeria, and the topsoil is mainly alluvial with underlying highly leached lateritic soil. The region experiences high annual rainfall (about 1,800 mm) and a temperature of approximately 26±5oC. The rainwater is slightly acidic due to pollution from oil exploration activities, vehicular activities and other anthropogenic actions [12].

Sample collection
The sand was collected randomly for six (6) major borrow pits within Isoko North and Isoko South local government areas of Delta State, Nigeria. A sample of the borrow pit leached white sand is shown in Figure 1. The sand was taken to the laboratory and dried under an ambient room temperature of 28±4oC. This is because soil moisture content usually interferes with sandcrete block's compressive strength, as high moisture content reduces the compressive strength of sandcrete blocks [8, 13].

Figure 1. A heap of a borrow pit white sand

Water

Fresh borehole water free from oil contamination and other foreign materials was used to produce the sandcrete blocks.

Cement

Limestone Portland cement with grade number 42.5 was used to produce the sandcrete blocks, which were used to determine the particle strength of the borrow pits sands.

2.2 Sandcrete block production

Mix ratio

Cement–fine aggregates (sand) mix ratios of 1:8 and 1: 10 were adopted. Therefore, two mix ratios were used to produce two sets of blocks in this study. Water to cement ratio (w/c) of 0.5 was also adopted in this study.

Mixing method

The manual mixing method was used to mix the constituents (cement and sand) of the sandcrete block.

Blocks production

The thoroughly mixed constituents were poured into standard moulds, and the vibrating (mechanical) moulding machine was used to mould (produce) the blocks.

Curing

The sandcrete blocks were cured twice – morning and evening through the irrigation method for 28 days.

2.3 Laboratory Tests

The laboratory tests were done at the Delta State University of Science and Technology, Ozoro, Nigeria, using the laboratories in the Department of Civil and Water Resources Engineering. All the tests were carried out following the American Society for Testing and Materials (ASTM) and Nigeria Industrial Standards (NIS) procedures.

Sieve analysis

The sieve analysis of the borrow pits was done following ASTM D422 procedures, as described by Eboibi *et al*. [14]. Then the key coefficients - coefficient of uniformity (Cu) and Coefficient of Gradation (Cc) – were calculated through 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 [15].

Porosity

The soil's porosity was determined following ASTM D4404 [16] approved guidelines.

Compressive strength

The compressive strength of the sandcrete block produced from the borrow pits sands was determined following NIS-87:2000 procedures [6]. The compressive strength was done on the two sets of blocks produced on the 28th curing day. From the failure point obtained from the machine, the compressive strength of each block was calculated through Equation 3 [17].

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

3. Results and discussion

3.1 Sieve analysis

The results of the particle grain size distribution are presented in Table 1 and Figure 2. Using the USCS, the results showed that borrow pits 1 to 4 sand have fines more than 5% and Cu values lower than 6.0, and can be classified as Poorly Graded sand; while borrow pits 5 and 6 sand are classified as Well Graded sand, since the fines percentage is less than 5% and the Cu value greater than or equal (≥) to 6.0 [17]. Poorly graded sand may not be suitable for the production of sandcrete blocks and concrete, as they tend to produce sandcrete with poor (lower) compressive and tensile strengths; while the Well Graded sand counterparts tend producing sandcrete blocks with higher compressive and tensile strengths [18]

Table 1: Key coefficients values of the borrow pits sand

Location	Fines (%)	Coefficient of uniformity	Coefficient of Gradation
Location 1	10	4.67	0.64
Location 2	6.0	4.17	1.12
Location 3	7.6	4.18	1.12
Location 4	7.4	5.58	0.62
Location 5	3.4	7.09	1.45
Location 6	4.6	6.5	1.23

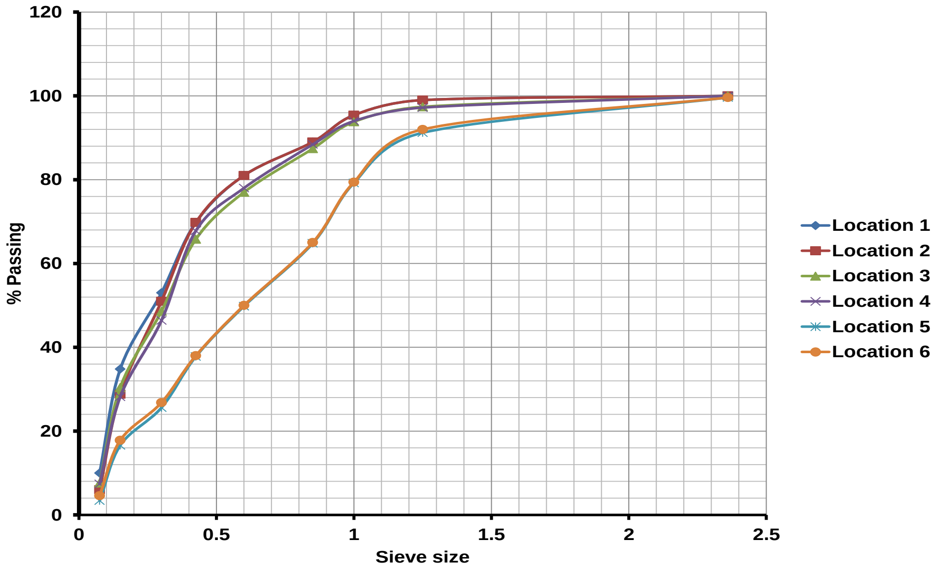

Figure 2. The plots of the soil's sieve analysis

3.2 Porosity

The results of the borrow pit's porosity values are presented in Figure 3. It can be seen that the porosity of the soil samples ranged between 34.9% and 41.1%. The fairly high porosity values are an indication that the soil contains a considerable number of fines, which will affect the compressive strength of sandcrete blocks produced from them. According to Peng *et al.* [19], porosity is one of the factors that govern the compressive strength of concrete and sandcrete blocks, and increasing porosity results in a decrease in the peak compressive strength. Additionally, Chen *et al.* [20] reported that there is a strong correlation between cement mortar compressive strength and the porosity of the fine aggregates, and experimental data revealed that the mortar compressive strength declines with an increase in the porosity values.

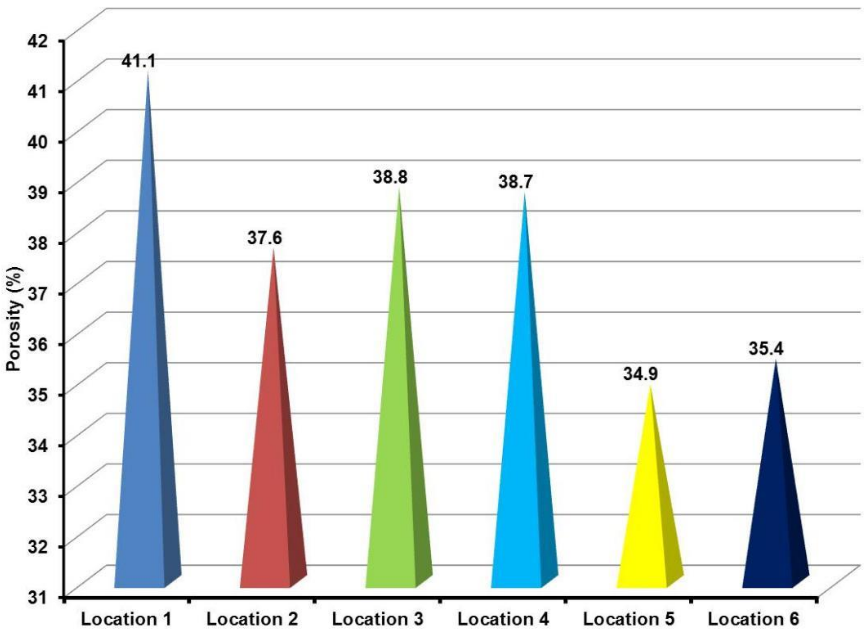

Figure 3. The soil's porosity values

3.3 Compressive strength

The results of the compressive strength of the sandcrete blocks produced from the mix ratio are presented in Figure 4. It can be seen from the results that the compressive strength of the concrete produced through mix ratio 1 (1:8), was considerably higher when compared to the compressive strength of the concrete produced through mix ratio 2 (1:10). The sandcrete blocks produced with mix ratio 1 led to compressive strength between 1.34MPa and 2.21MPa, while 1.12MPa to 1.85MPa was obtained for blocks produced from mix ratio 2. Remarkably, none of the sandcrete blocks produced either through mix ratio 1 or mix ratio 2 met the approved NIS recommendation for sandcrete blocks. According to NIS recommendations, sandcrete block required for the construction of load and non-load-bearing walls must have a compressive strength greater than 3.45 and 2.5MPa respectively [6]. The poor compressive strength observed in blocks produced from borrow pits 5 and 6 and even though they are well graded according to USCS, could be attributed to some external factors such as prevailing environmental conditions, water quality, soil mineral and organic content, and other human factors.

These results are similar to those obtained by Aiyewalehinmi and Akande [21] for compressive strength (1.03MPa) of sandcrete blocks produced with sand collected from another geographical region. Results obtained in this study were lower than those recorded by Akpokodje and Uguru [8] for sandcrete blocks produced with well-graded sand. The differences in the compressive strength observed in the sandcrete blocks produced by different researchers could be attributed to the different mix ratios, mixing techniques, block production methods and curing procedures adopted by the various researchers [3, 22].

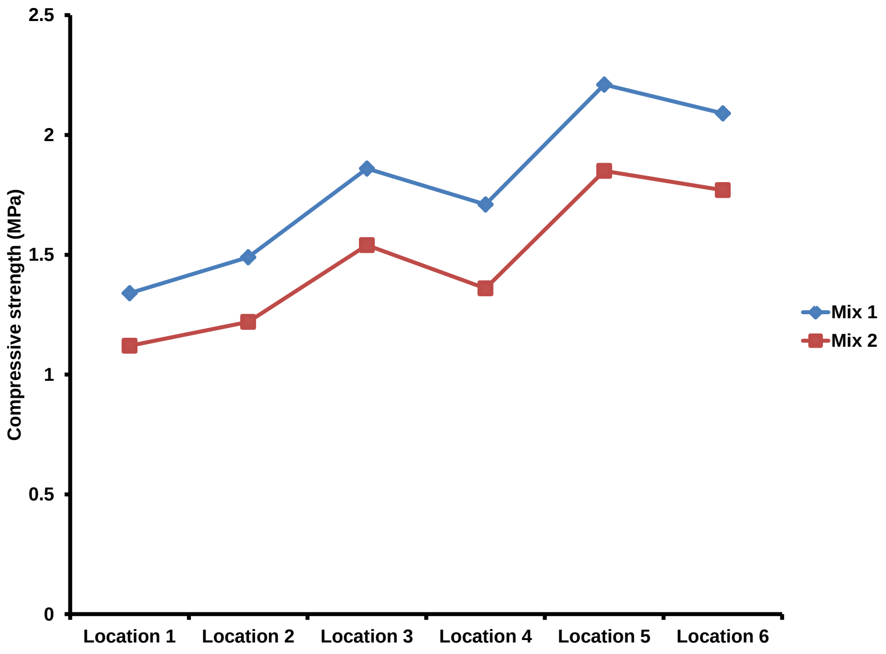

Figure 4. The compressive strength of the sandcrete blocks

4. Conclusion

This study was embarked upon to establish the suitability of borrow pit (dredged) white sand for sandcrete block production. Sand randomly collected from six borrow pits were subjected to geotechnical and mechanical properties analyses, by American Society for Testing and Materials (ASTM) guidelines. The findings depicted that most sand obtained from the borrow pits was poorly graded sand, and the sandcrete blocks produced from all the borrow pits sand failed to meet Nigeria

Industrial Standard (NIS) guidelines. This finding will be important to policy makers and players in the Nigerian construction industry.

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