Performance of Laterite-Cement Blocks as Walling Units in Relation to Sandcrete Blocks

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Abstract

A study of the performance of laterite-cement blocks as walling materials in relation to those of sandcrete was conducted, for the purpose of establishing a cheaper building material in Minna, Niger state, Nigeria and surrounding towns, in the present ever increasing cost of building material. An A-2-6 laterite according to the AASHTO classification system was stabilized with 0-10% cement content by weight of the soil at a constant interval of 2% to produce 20 blocks of size 100mm × 100mm × 100mm for each mix. One hundred laterite-cement blocks were produced, cured under laboratory conditions and subjected to compressive strength test at 7, 14, 21, and 28-days of age, in five applications for each cement mix ratio. The average compressive strength was determined from five blocks crushed in each mix at every age of curing and the same procedure was repeated using sandcrete blocks. At a common cement content of 6%, the compressive strengths, densities, water absorption and the cost per square metre of wall for both types of blocks were determined. The study recommends the use of laterite-cement blocks as walling materials in Minna and environs because it has better engineering properties and more economical with a saving of 30% per square metre of wall when compared with the use of sandcrete blocks.

Keywords

Blocks; Laterite-Cement; Sandcrete; Mix; Performance; Walling-units

Introduction

The need for locally manufactured bulding materials has been emphasized in many countries of the world. There is imbalance between the expensive conventional building materials coupled with depletion of traditional building materials. To address this situation, attention has been focused on low-cost alternative building materials [1].

In Minna, the capital of Niger State of Nigeria and other surrounding towns, sandcrete blocks are the most common and popular materials for walling units for domestic, industrial or commercial buildings. The over dependence on the utilization of sandcrete blocks for buildings have kept the cost of these blocks as walling units in buildngs financially high. This hitherto, has continued to deter the underdevloped and poor nations of the world from providing houses to their rural dwellers who constitute the higher percentage of their populations and are mostly agriculturally dependent. The high cost of sandcrete blocks coupled with the low strength properties of commercially available sandcrete blocks necessitaes the need for alternative low cost walling material.

Sandcrete blocks consist of Ordinary Portland Cement (OPC) and natural clean sand mixed with water in very carefully selected proportions. Sandcrete blocks are produced in two major forms as lightweight and dense blocks. Lightweight blocks are made with either lightweight aggregates or aerated concrete. Dense blocks are made with dense aggregates as specified in [2], which include natural sand and crushed rock. Blocks made with such aggregates have densities of 1920 to 2080Kg/m^3 and may be solid or hollow. Dense solid blocks made with natural sand were used in this research work. Cement as a binder is the most expensive input into the production of sandcrete blocks and this has necessitated producers to produce blocks with low cement content, which is affordable to people [3]. In most cases, the producers of these weak sandcrete blocks and the users lack adequate engineering knowledge on the strength quality requirements of sandcrete blocks [4].

Traditionally, lateritic soils, which are reddish brown in colour, have been used as blocks for buildings without any cement content. Recently, modern builders started introducing some percentage of cement to laterite for moulding stornger blocks, because of high cost of sandcrete blocks. A major advantage of the use of laterite instead of sand in moulding building blocks is the low cost, due to small quantity of cement required to produce blocks with adequate compressive strengths as well as low cost of transporting laterite. This is

Issue 16, January-June 2010
p. 189-200

in good agreement with earlier finding by [5], which reported that small amounts of cement inhibit the weakening effect of water and increase strength. The compressive strength of laterite-cement blocks increased steadily with increase in percentage of cement content up to 20% but decreased at cement contents above 20% [6]. In Minna and surrounding towns within Niger state, abundant lateritic soil deposits exist and this can be well harnessed for the production of low-cost laterite-cement blocks.

Laterite bricks were made by the Nigerian Building and Road Research Institute (NBRRI) and used for the construction of a bungalow [7]. From the study, NBRRI proposed the following specifications as requirements for laterite bricks: bulk density of 1810kg/m^3, water absorption of 12.5%, compressive strength of 1.65N/mm^2 and durability of 6.9% with maximum cement content fixed at 5%. Good laterite bricks were produced from different sites in Kano, Nigeria when laterite was stabilized with 3 to 7% cement and the study showed that particle size distributiion, cement content, compactive effort and method of curing are factors, which affect the strength of bricks [8].

This study aims at comparing the weights, densities, compressive strengths and costs of laterite-cement blocks and those of sandcrete mix at specified common cement content. Accordingly, the scope includes characterization of laterite and sand as well as the determination of the densities, water absorption, compressive strengths and unit cost at Minna, Niger state, for laterite-cement and sandcrete blocks respectively.

Materials and Method

***Cement**:* The cement used was Ordinary Portland Cement (OPC) bought from a cement depot at Bosso road Minna, Nigeria and it conformed to [9] as confirmed by [10].

Sand: The sand collected from a river in Bosso village, Minna, Nigeria and used as fine aggregate was clean, sharp, free from clay and organic matter and well graded in accordance with [2].

***Water**:* Tap water was used for the mixing and it was properly examined to ensure that it was clean, free from contaminants either dissolved or in suspension and good for drinking as specified in [11].

Laterite: The lateritic soil used was obtained from an existing borrow pit in Minna, Nigeria (Latitude 9^o 37^1 N and Longitude 6^o 33^1 E) between a depth of 1.5m to 2.0m, using method of disturbed sampling. The index properties of the natural soil are summarized in Table 1.

Laboratory Tests

All laboratory tests on laterite and sharp sand for the purpose of characterization, which include natural moisture content, particle size distribution, Atterberg limits, compaction, and specific gravity were carried out in accordance with [13].

Mixing and Moulding

Mixes of laterite-cement at 2, 4, 6, 8 and 10% respectively by weight of laterite were prepared and 20 blocks of size 100mm × 100mm × 100mm were moulded for each mix. A total of 100 blocks were produced manually and cured under laboratory conditions for 7, 14, 21 and 28 days. In the same manner and under the same conditions, 100 sandcrete blocks were produced and cured. To ensure even distribution of blows in the mould, approximately 100mm square sheet of 12.5mm thick plywood was placed on the mixture in the mould and compaction was done on it in accordance with [13]. The freshly moulded blocks were carefully extruded in good shape on a clean, hard and flat surface.

Compressive Strength Test

An electrically operated Seidner compression machine was used for the compressive strength test on the blocks in accordance with [14], at the curing ages of 7, 14, 21 and 28 days. Five blocks were crushed in each day for each mix of both materials respectively and the average compressive strength was measured. During the compressive strength test, care was taken to ensure that the blocks were properly positioned and aligned with the axis of the thrust of the compression machine to ensure uniform loading on the blocks [15].

Density Test

Densities of the laterite-cement and sandcrete blocks were determined in accordance with [17] and the results are shown in Table 2.

Cost Analysis

Cost analysis at the time of this study was conducted on the basis of one square metre of wall for laterite-cement and sandcrete blocks respectively and the results are shown in Table 2.

Results and Discussion

Identification of Sand and Laterite

The index properties of the sand and laterite used for the study are summarized in Table 1 while Figure 1 shows their particle size distribution. The sand was well graded and classified in zone 1 according to [2] and it is in good agreement with the recommendation of [13] for clean quartz and flint sands. An investigation into the geotechnical and engineering properties of sample as well as study of soil maps of Nigeria after [12] showed that the sample collected belong to the group of ferruginous tropical soils derived from acid igneous and metamorphic rocks.

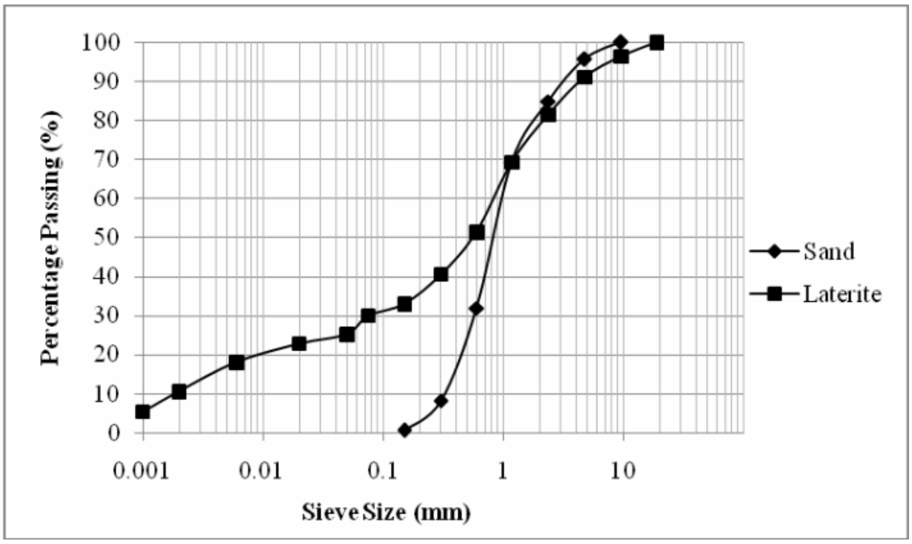

Figure 1. *Particle Size Distribution for Sand and Laterite*

Compressive Strength

The result of compressive strengths test for the two types of blocks at various cement contents are presented in Figures 2 to 5. At 0% cement content, sandcrete blocks gained no compressive strengths for all the ages of curing and this is because there is no bonding between the grains of the sand. However, the laterite-cement blocks gained small compressive strengths for all the curing ages tested and this could be attributed to the cohesiveness of the laterite soil, which bound the particles together. It is a confirmation that only laterite could be used for non-load-bearing walls.

Table 1. Properties of the Natural Laterite and Sand

Property	Laterite	Sand
Natural moisture content (%)	3.18	0.68
Percentage passing BS No 200 sieve (75μm) (%)	30	0
Liquid Limit (%)	54.34	-
Plastic Limit (%)	32.50	-
Plasticity Index (%)	21.84	-
Linear shrinkage	11	-
AASHTO classification	A-2-6	
Maximum Dry Density (Kg/m^3)	2011	-
Optimum Moisture content (%)	14.73	-
Specific Gravity	2.67	2.63
Condition of sample	Air-dried	Air-dried
Color	Brownish-red	Brown

Laterite-cement blocks consistently gained greater compressive strength values up to 10% cement content for all the curing ages of 7, 14, 21 and 28-days. Adequate compressive strength of $3.22N/mm^2$ for load-bearing walls was measured for cement content of 6% in laterite-cement blocks while sandcrete blocks had a compressive strength of $1N/mm^2$. The lowest crushing strength of individual load bearing blocks shall not be less than $2.5N/mm^2$ for machine compaction and $2.0N/mm^2$for hand compaction as recommended by [17]. This result is in good agreement with the finding of [18] who reported that for 7% cement content and$13.76N/mm^2$compactive pressure, cement stabilized laterite blocks of strength of at least $2.0N/mm^2$ at 28 days could be produced. Also [6] reported a compressive strength of $3.5N/mm^2$ for laterite-cement blocks with 6% cement content at 28-days age of curing. Suitable compressive strengths for load bearing walls can only be achieved at 6% cement content and above, for laterite-cement blocks. This is in complete agreement with the report of [1] that Ikpayongo laterite cannot be stabilized effectively for brick production within the economic cement content of 5% as the 28-day UCS of $1.1N/mm^2$ is not up to the value recommended by NBRRI.

Issue 16, January-June 2010
p. 189-200

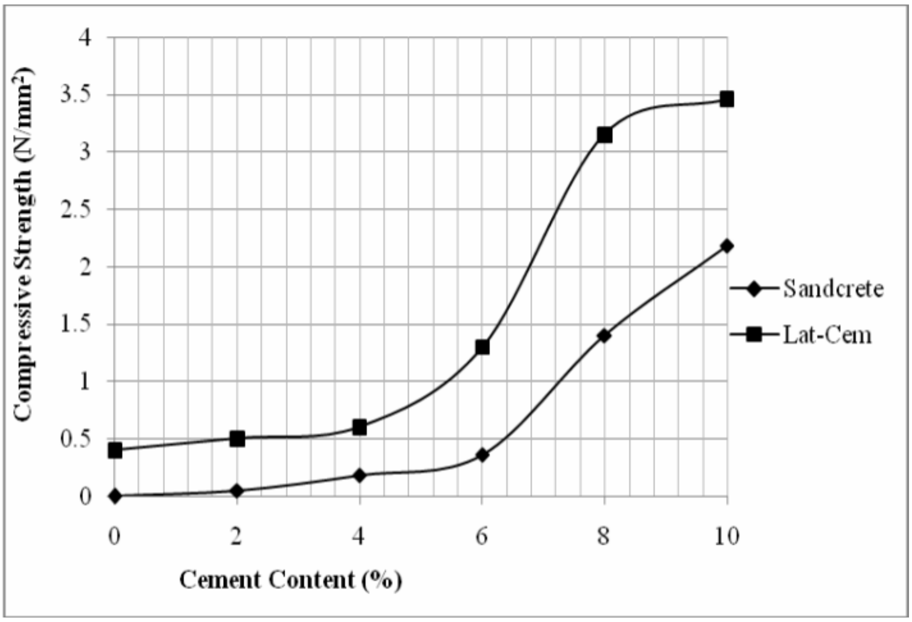

Figure 2. *7-Days Compressive Strengths for Sandcrete and Laterite-Cement Blocks*

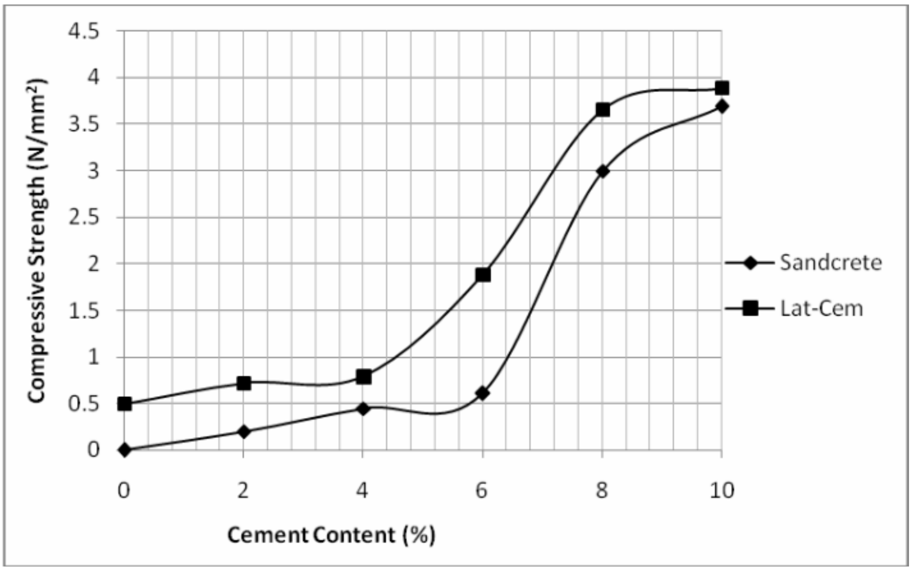

Figure 3. *14-Days Compressive Strengths for Sandcrete and Laterite-Cement Blocks*

The increase in compressive strength with increase in cement content could be due to increased bonding within the aggregates of the blocks which could as well increase the density. This trend was noted by [5] that in general, the strength increases is in direct proportion to cement content, but at different rates for different soils. However, higher cement contents result in prohibitive cost of blocks which places the sand-cement blocks at a disadvantage.

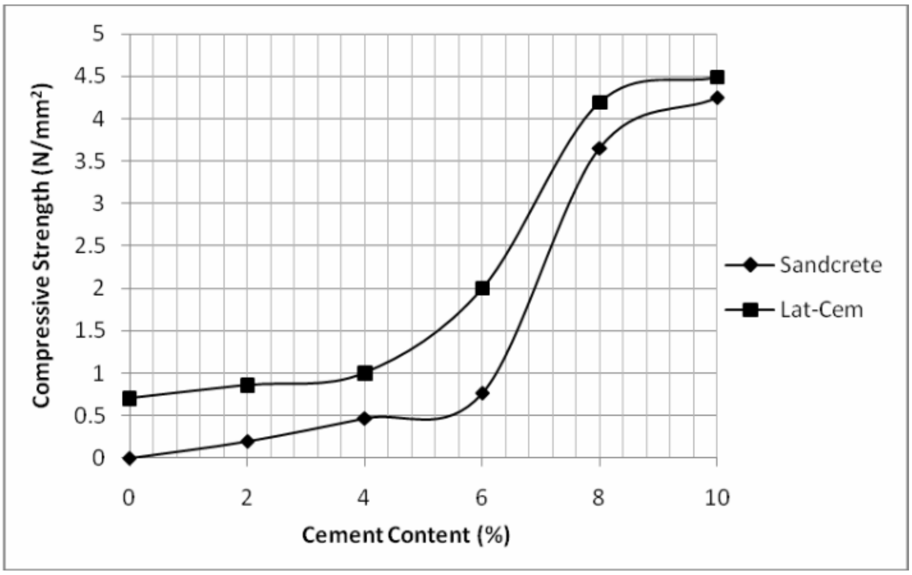

Figure 4. *21-Days Compressive Strengths for Sandcrete and Laterite-Cement Blocks*

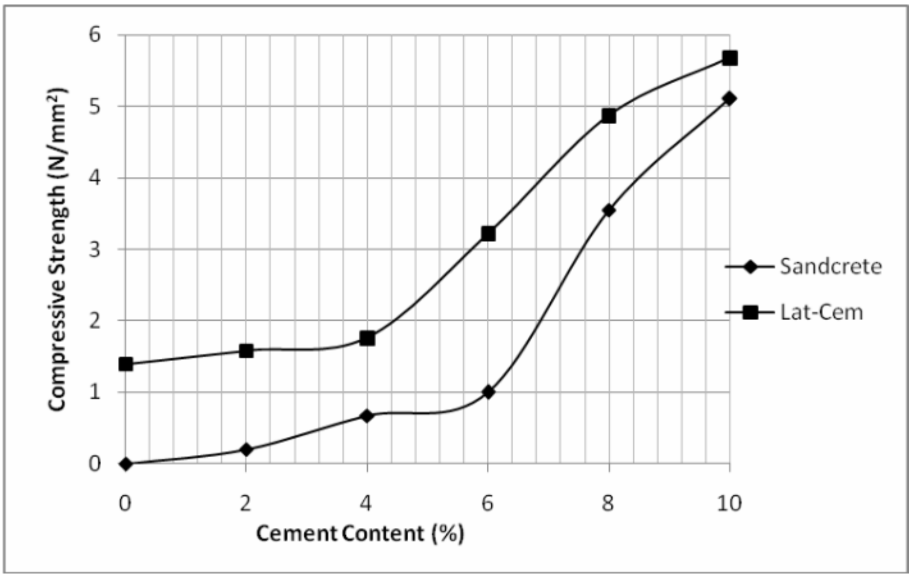

Figure 5. *28-Days Compressive Strengths for Sandcrete and Laterite-Cement Blocks*

Figure 6 shows the relationship between the compressive strengths and age of curing for the two types of blocks. The laterite-cement blocks consistently showed a definite pyramidal pattern type of failure. The conical shape was found to be the same as that of concrete cubes subjected to compression test [15]. This is an indication that walls constructed with laterite-cement blocks will likely withstand considerable deformation before total failure. In contrast to the laterite-cement blocks, the sandcrete blocks consistently showed fragments at failure which indicated that they cannot withstand considerable deformation before total failure.

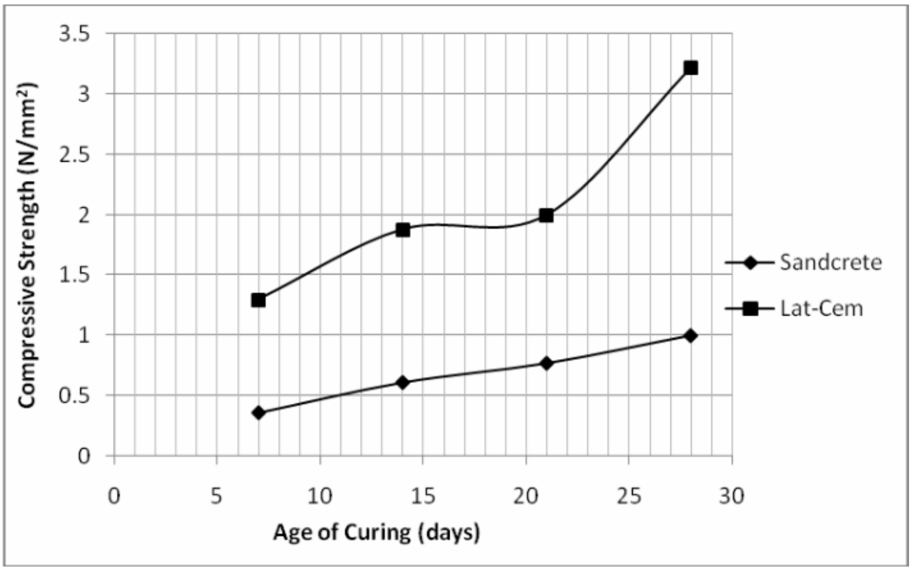

Figure 6. *Compressive Strength-Age of Curing Relation for Sandcrete and Laterite-Cement Blocks*

Properties of Laterite-Cement and Sandcrete Blocks

Table 2. Properties of Sandcrete and Laterite-Cement Blocks at 6% Cement Content

Property	Sandcrete	Laterite-Cement
Density (kg/m^3)	1325	1935
Water Absorption (%)	11.85	9.78
Compressive Strength at 28-days (N/mm^2)	1.00	3.22
Cost per unit area of wall (₦)	2650	2040

The densities for the two types of blocks are at 6% cement contents are shown in Table 2 and it can be seen that density of laterite-cement block is higher than that of sandcrete by 46.04%. This could be attributed to the texture of the laterite with wide spread of all particle sizes, which allows the particles to be closely packed thereby reducing the voids in the blocks.

Sandcrete blocks are more porous than their laterite-cement counterparts and this could be as a result of higher value of density recorded by the laterite-cement blocks. The strength of concrete is low and the durability is reduced drastically when the porosity of blocks is high.

Cost analysis for production, transportation and labour for building 1m^2 of wall in Minna, Nigeria was carried out for both sandcrete and laterite-cement blocks respectively. It was found that laterite-cement block wall is cheaper than that of sandcrete by 29.9%.

Conclusion

From this study, the following conclusions can be drawn:

- Gravelly lateritic soils classified as A-2-6 under AASHTO classification system are good materials for production of laterite-cement blocks for walling units in buildings.
- Laterite-cement blocks have densities that are generally more than their sandcrete counterparts and they may likely provide more solid and durable walls in buildings.
- The compressive strengths of laterite-cement blocks are usually greater than those of sandcrete blocks at percentage of cement contents below 10% and a minimum of 6% cement content is required in order to achieve adequate compressive strength for load bearing walls.
- Laterite-cement blocks are more economical building materials for walling units within Minna and surrounding towns in Niger state, Nigeria than the sandcrete blocks.
- In order to provide adequate housing for the ever increasing population of people in Minna and environs, the use of laterite-cement blocks should be encouraged by individual and government at all levels.

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