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COMPRESSIVE STRENGTH PERFORMANCE OF CEMENT STABILISED EARTH MADE BRICKS FOR LOW COST HOUSING

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ABSTRACT

Purpose: The quest for the government to provide more affordable housing for the masses has necessitated more researchers to continue to investigate alternative means of low cost Building materials. Earth made bricks have been recognized as one of the oldest building material. It is not enough to provide these low cost houses but more efforts should be geared towards durability and other mechanical properties. This research examines performance characteristic of earth made brick to determine the compressive strength and water absorption rate of earth made bricks.
Design/methodology/approach: Samples of earth made bricks were produced using cement as a binder at various percentages of 0%, 5%, 10%, and 15%, using 0% as the control. The produced earth made bricks were cured for a maximum of 28 days and the strength was determined at 7 days, 14 days, 21 days and 28 days respectively including its rate of water absorption.
Findings: The result of the dry density test indicates that the higher the cement contents and age of curing, the lower the density. The compressive strength increased as the percentage of binder increased. The result shows that the control mix (NSB) has a maximum compressive strength of 0.01N/mm^2 at 7 days of curing with steady increase to 0.50N/mm^2 at 28 days of curing. At 5% cement stabilisation (SB_1), the maximum compressive strength recorded between 0.02N/mm^2 and 0.79N/mm^2 at 7 days and 28 days of curing respectively. Similarly, 10% cement stabilisation reveals a maximum compressive strength of 1.10N/mm^2 to 1.73N/mm^2 at 7 days and 28 days of curing. While at 15% cement stabilisation, the maximum compressive strength recorded between 1.45N/mm^2 to 2.01N/mm^2 both at 7 days and 28 days of curing. However, the result shows that the compressive strength of SB_{II} increased by 54% while SB_{III} increased by 14%, indicating that the higher the cement content and curing age, the higher the strength and the lower the density. And also the maximum water absorption of 12% recommendation was not exceeded.
Originality/value: The study therefore concluded that 10% and above is recommended for cement stabilization for the production of earth made bricks in the study area and the various tests carried out showed an acceptable performance standard of the earth made bricks.

Keywords: Earth made brick; compressive strength; stabilisation; performance standard; absorption rate

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1. INTRODUCTION

The dream of the poor masses to own their own houses will remain a mirage if urgent steps are not taken by the government including private sector to participate in affordable housing delivery. This can only be possible if alternative building materials are constantly been developed and utilized. Earth made bricks has been recognized as one of the oldest building material. It is not enough to provide these low cost houses but more efforts should be geared towards durability, strength and other mechanical properties that could make its usage worthwhile.

The abundance of earth materials also known as lateritic soil deposits in Nigeria can be harnessed for brick production, unfortunately, this potential is not adequately maximized. The production of bricks using earth materials is believed to be a lot more economical, especially when compared to sandcrete blocks/bricks. This may not be unconnected with savings in the cost of cement used for mortar in plastering and elimination of cost of transporting the products as production takes place right on site. Akinrolabu in Igbokwe (2006) posited that over the years, cement-based materials and most of other imported building components have continued to add to the cost of housing. This is consequent upon the inflationary trends and scarcity of foreign exchange for the purchase of these items. Another dimension of the problem stems from over reliance on cement which happens to be the main ingredient for the provision of public infrastructure especially housing where it constitute 40% of building materials (Suleiman, 2011).

The major characteristics of low-cost housing is that, it should be affordable, durable, comfortable and at least have some measures of considerable improvement over existing condition. Although, there is no fixed standard for low-cost housing as it varies with technology, culture and economy of a particular country concerned. The construction of walls with cement stabilized laterite bricks could be load or non-load bearing. But in any case, it also protects the interior from exterior elements and provides attractive finishes. Using cement as binder to stabilize earth bricks in buildings have the advantages of fire resistance, thermal insulation, bulletproof and do not require plastering and painting if desired, due to its high aesthetic looks. These qualities suggest cement stabilized laterite bricks, to be a better product in terms of cost and functional performance requirement. A lot of researches have been carried out in the past to arrive at the best possible way laterite can be harnessed and utilized in different ways. A study by Ahon (2008) shows that 10% by volume of cement usage increased the strength of the laterite block by 73%. In another study by Raheem, et al (2010), the use of cement and lime in stabilizing laterite interlocking blocks was investigated. The study shows that 5% volume of cement could not meet the required compressive strength specified by the code but at 10% and above the requirement was met. According to Agbede and Manasseh (2008), a study of Cement-Sand Admixture in Laterite Brick Production shows that laterite cannot be stabilized effectively for brick production within the economic cement content of 5% as the 28-day unconfined compressive strength of 1.1N/mm2 did not meet the value recommended by NBRRI. An addition of 45% sand content by dry weight enhanced its suitability for use in the production of bricks within the optimum cement content of 5% giving a 28-day UCS of 1.8 N/mm2. Since NBRRI did not specify any particle distribution curve for soil to be used in brick production, addition of 45% sand was used as a guide for the production of bricks in Makurdi metropolis (Agbede and Manasseh, 2008). Past studies shows that inclusion of fibre can help improve the performance standard of earth made bricks. Aguwa (2013), reported on the use of coconut coir as fibre in stabilizing laterite blocks. In his study it was discovered that, Coir has the potential to increase the compressive strength of laterite blocks by ten percent (10%) at 28 days curing duration and reduction in mass by two percent (2%). Oluremi, Adedokun and Osuolale (2012), investigated the effects of coconut husk ash on stabilizing poor lateritic soil. The result indicates that coconut husk ash is suitable for improving the California bearing ratio because this parameter increases with addition of coconut husk ash. In all these studies, the performance standard of stabilizing earth made brick with 5% cement was below the required percentage. Looking at the current economic price of cement in the market, this research tends to investigate the use of cement as a stabilizing agent for the production of earth made bricks and also to improve its performance characteristics.

2. MATERIALS AND METHODS

The earth sample which was gotten from Bariga, Yaba, Lagos State was extracted from a pit of not less than 4 meters below the top soil and was air–dried for seven days in a cool, dry place. This was necessary in order to enhance grinding and sieving. After drying, grinding was carried out using hammer to break the lumps present in the soil with adequate care being taken not to reduce the sizes of the individual particles, after which sieving was done to remove over size materials from the earth sample using a wire mesh screen with aperture of about 6mm in diameter as recommended by Oshodi (2004). Fine materials passing through the sieve was collected for use while those retained were discarded.

Ordinary Portland Cement (grade 32.5) with the trade mark “Dangote Cement” which comply with BS EN 197-1 and fully certified by Standard Organisation of Nigeria (SON) was used as the binder. Clean tap water, free from particles and good for drinking as specified in BS EN 1008 was used for the mixing. To be sure of the right sample of laterite used, the following laboratory tests were carried out indicating the various observations.

Table 1: Laterite sample tests

S/No	Types of Test	Observation/Result	Percentage Content (%)	
			Sand	Clay
1	Touch Test	A slight fluffy feel	-	-
2	Wash Test	Easy washing off of sand with slight deposits of clay particles	-	-
3	Cigar Test	Average laterite cigar length of 6.7cm	75.5	23.5
4	Bottle/Sedimentation Test	Sand dimension of 3.8cm out of 5cm	76	24
5	Colour	Reddish colouration observed		

2.1. Production of earth made brick

The earth made bricks were produced using a prefabricated steel mould measuring 290mm x 140mm x 100mm base. In each sample, twelve (12) no. bricks were produced giving a total of 48 brick samples. The production process consists of batching, mixing, casting and compaction of the earth bricks. For the 5% cement stabilization, the mix ratio was 0.5:10 while 1:10 and 1.5:10 was for 10% and 15% cement stabilization respectively. The materials that were used for the production of the earth made bricks were measured by weight of dry soil in accordance with the predetermined percentages of stabilization (0%, 5%, 10% and 15%) with 11kg (in weight) of water content determined.

The main approach adopted was to compare the properties and performance standard of two categories of earth made bricks, namely: Non Stabilised Bricks (NSB) and Stabilised Bricks (SB). While the later was made in a conventional way using Ordinary Portland Cement (OPC) as the stabiliser, the former was used as a control against the SB. A four litre container was used as the gauge box. One four litre container of laterite measured 6kg, making ten number of four litre container to be 60kg which is equivalent to 2.5 headpans. Table 3 shows the mass of each material used for the varying percentages of stabilisation considered.

The mixing was performed on an impermeable surface made free (by sweeping and brushing/ scraping) from all harmful materials that could alter the properties of the mix. The measured laterite sample was spread using a shovel to a reasonably large surface area. Cement was then spread evenly on the laterite and mixed thoroughly with the shovel. The dry mixture was spread again to receive water, which was added gradually while mixing until the optimum moisture content of the mixture was attained. The optimum moisture content (OMC) of the mixture was determined by progressively wetting the soil, collecting handfuls of the soil, compressing it firmly in the first, then allowing it to drop on a hard and flat surface from a height of approximately 1.10 m. When the soil breaks into four or five parts, the water content is considered adequate (National Building Code, 2006). After the steel mould was rid of all impurities, it was coupled together and oiled to enhance the demoulding of the blocks. The wet mixture was filled into the mould in 3 layers, with each layer being compacted with 35 blows of 4.5 kg rammer on a level and rigid platform. The excess mixture was scraped off, and the mould was leveled using a straight edge. The mould and its contents were left for two hours before the removal of the mould. Identification marks were inscribed on the bricks to allow easy referencing. The bricks were first allowed to air dry for 24 hours under a shade constructed from a polythene sheet. Thereafter, water was sprinkled on the bricks in the morning and evening, and the bricks were covered with a polythene sheet for one week to continue the curing process and prevent rapid drying of the bricks, which could lead to shrinkage cracking. The earth made bricks were later stacked in rows and columns with a maximum of four bricks in a column until they were ready for strength and durability tests

Table 2: Sample classification

Sample Type	Composition
NSB	0% Cement Stabilisation
SB_1	5% Cement Stabilisation
SB_{II}	10% of Cement Stabilisation
SB_{III}	15% of Cement Stabilisation

Table 3: Sample batching by weight

Percentage of Cement Stabilisation	Laterite (Kg)	Cement (Kg)	Water (Kg)
0	60	0	13
5	60	3	11
10	60	6	11
15	60	9	11

2.2. Testing of earth made bricks

2.2.1 Water absorption test

This test was performed on the earth made bricks after 28 days of curing. Two bricks were randomly selected from each group of the specified age and were weighed on a balance. These bricks were then immersed completely in water for 24 hours, after which they were removed, excess moisture was mopped from the surface of the brick and then weighed again. The percentages of water absorbed by the bricks were estimated using the following formulae:

$$W_a = \frac{W_s - W_d}{W_d} X\ 100$$

Where:
Wa = percentage moisture absorption
Ws = weight of soaked brick
W_d = weight of dry brick

2.2.2 Strength Test

Compressive strength tests were performed to determine the load-bearing capacities of the earth made bricks. In this test, the bricks aged 7, 14, 21 and 28 days were transported from the curing or stacking area to the laboratory two hours prior to the test to normalise the temperature and to ensure that the bricks was relatively dry. The weight of each brick was measured before it was placed onto the compression testing machine such that the top and bottom, as moulded, lied horizontally on a flat metal plate; the recesses were filled with a metal plate of the exact size to prevent sheaving of the brick during testing. The brick was then crushed, and the corresponding failure load was recorded. The crushing force was divided by the sectional area of the brick to arrive at the compressive strength.

3. RESULTS AND DISCUSSION

3.1. Water absorption test

The results of the water absorption tests is presented in Table 4. In general, the results indicate that water absorption decreases with increased percentages of cement stabilisation. This result was expected because the cement binds the laterite particles together and thereby reduces the sizes of the pores through which water could flow into the bricks. No measurement was obtained for the control (0% stabilisation) because the control bricks dissolved in the surrounding water. The maximum water absorption of 12% recommended in the Nigerian Industrial Standard (NIS, 2004) was satisfied by the bricks produced.

Table 4: Water absorption at 28 day of curing

Sample Types	Composition (Mix)	Water Absorption (%) After 28 Days
NSB	0% Cement Stabilisation	-
SB_1	5% Cement Stabilisation	10.4
SB_{II}	10% Cement Stabilisation	10.2
SB_{III}	15% Cement Stabilisation	8.4

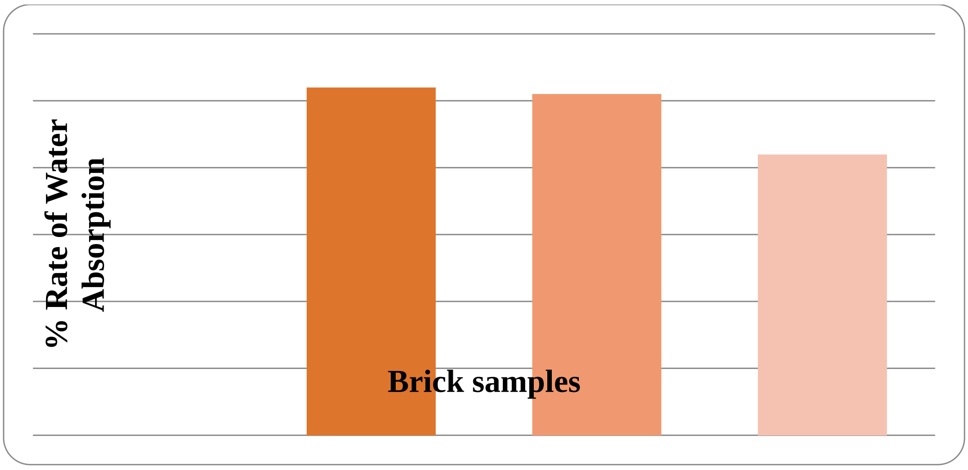

Figure 2: Water absorption of the earth made bricks

3.2. Compressive strength test

The results of the compressive strength tests performed on the various cement stabilized earth made bricks samples were tabulated in table 5. The compressive strength at 0% cement stabilisation (NSB) increases progressively as the age of curing increases from 0.01 N/mm^2 at 7 days to 0.50N/mm^2 at 28 days. At 5% stabilization (SB_1), it recorded 0.02N/mm^2 to 0.79N/mm^2. While at 10% stabilization (SB_{II}), the earth made bricks recorded 1.10N/mm^2 to 1.73N/mm^2 and lastly, at 15% cement stabilization (SB_{III}) the brick samples recorded between 1.45N/mm^2 to 2.01N/mm^2. It was observed that the compressive strength of the earth made bricks at 10% stabilization (SB_{II}) increased by 54% and at 15% (SB_{III}), the compressive strength increased by 14%.

The results indicate that the higher the cement content, the higher the compressive strength, as the results corresponds with that of Raheem, et al (2010). The twenty-one-day compressive strength recorded by 10% cement stabilization was able to meet the minimum requirement of 1.60N/mm^2 by the National Building Code (2006), whereas at fourteen-days of curing, 15% cement stabilisation met the same requirement.

Table 5: Compressive strength at various curing age with the densities

Sample Type	Composition (Mix)	Compressive Strength (N/mm^2)			
		7 DAYS	14 DAYS	21 DAYS	28 DAYS
NSB	0% Cement Stabilisation	**0.01**	**0.1**	**0.33**	**0.5**
SB_1	5% Cement Stabilisation	**0.02**	**0.40**	**0.60**	**0.79**
SB_{II}	10% Cement Stabilisation	**1.10**	**1.43**	**1.60**	**1.73**
SB_{III}	15% Cement Stabilisation	**1.45**	**1.67**	**1.80**	**2.01**

It can be seen that from the four different samples produced, only two samples (SB_{II} and SB_{III}) satisfy the 28 days minimum of 1.0 N/mm^2 compressive strength recommendation by Nigerian Building Road Research Institute (NBRRI) but failed to satisfy the 1.60N/mm^2 at 7 days compressive strength requirement of the National Building Code.

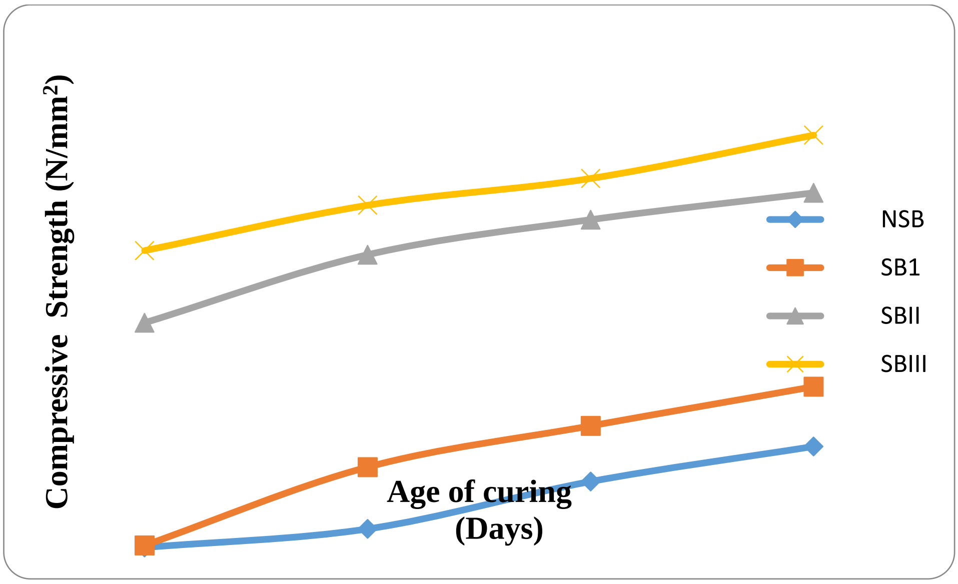

Figure 3: Compressive strength of the earth made bricks

3.3. Density of bricks

The results of the dry density of the bricks produced are shown in table 5 above. The density of the bricks from each of the mix ratios after 7 and 28 days of curing were estimated from the weight and volume of each of the bricks samples and recorded. It shows that the unsterilized bricks varied from 1810kg/m^3 to 1710 kg/m^3 at the end of seven and twenty-eight days of curing respectively, whereas that of the stabilised bricks ranges between 1950kg/m^3 to 1750kg/m^3, which clearly indicates that the higher the cement contents and age of curing, the lower the density. These values are similar to those obtained by Madedor (1992). Furthermore, the results indicate that the stabilised bricks are denser than the unstabilised bricks.

Table 6: Dry densities of the earth made bricks produced

Sample Type	Composition (Mix)	Density (kg/m^3)	
		7 Days	28 Days
NSB	0% Cement Stabilisation	1810	1710
SB_1	5% Cement Stabilisation	1950	1870
SB_{II}	10% Cement Stabilisation	1920	1820
SB_{III}	15% Cement Stabilisation	1830	1750

4. Conclusion and Recommendations

To provide housing for the greater majority of Nigeria, the use of laterite bricks should be encouraged as it is cheaper, more readily available and the production process is environmentally friendly. This study was able to prove beyond reasonable doubt that cement stabilized laterite bricks has greater compressive strength compared to unstabilised laterite bricks thus, enhancing its durability. Only two samples SBII and SBIII were able to meet the minimum requirements by the various codes. Therefore, 10% and above is recommended for cement stabilisation in producing earth made bricks from the study area. The earth made bricks should be cured for a minimum of 14 days before being used in buildings. Also, the strength and performance evaluation through various tests carried out proved an acceptable performance standard of the earth made bricks. It therefore shows that, it can be used without rendering thereby saving cost. However, it is not advisable to use these bricks for the base of the wall (the first two to three courses on top of the foundation slab).

References

Agbede, I. O. and Manasseh, J. (2008). Use of cement-sand admixture in Laterite bricks production for low cost housing. *Leonardo Electronic Journal of Practices and Technologies*, 12(1), 163-174

Aguwa, J. I. (2013). Study of coir reinforced laterite blocks for buildings. *Journal of Civil Engineering and Construction Technology,* 4(4), 110-115.

Ahon, J. M. (2012). Housing rural populace and urban poor, using cement stabilized laterite blocks. *Conference proceedings by International Institute for Policy Review and Development Strategies*, Ibadan, Nigeria, 1-13

BS EN 1008 (2002). *Mixing water for concrete. Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete.* British Standard Institute, London.

BS EN 197-1 (2011). *Cement, composition, specifications and conformity criteria for common cements*. British Standard Institute, London.

Igbokwe, S. (2006). "*Akinrolabu uses laterite in his building projects. He recommends it to whoever wants to save cost in building his own house*": THE PUNCH, Monday, July 31, 2006 pp 4.

Madedor, A. O. (1992*), The impact of building materials research on low cost housing development in Nigeria*. Engineering Focus. April - June, 1992. Publication of the Nigerian Society of Engineers, vol. 4, no. 2, p. 37-41.

National Building Code of Nigeria (2006). Building regulations. LexisNexis: Butterworths, Ireland, Dublin.

NBRRI (2006). *Nigerian Building Road Research Institute Newsletter.* 1(1), 15-17

Nigerian Industrial Standard (2004). Standard for sandcrete blocks, ICS 91.100.20. NIS, Abuja.

Oluremi, J. R., Adedokun, S. I. and Osuolale, O.M. (2012). Stabilization of poor lateritic soils with coconut husk ash. *International Journal of Engineering Research and Technology,* 1(8), 1-9.

Oshodi, O.R. (2004). *Techniques of producing and dry stacking interlocking block.* Paper presented at the Nigerian Building and Road Research Institute (NBRRI) workshop on local building materials, Ota, Ogun State, Nigeria.

Raheem, A. A., Bello, O. A. and Makinde, O.A. (2010). A comparative study of cement and lime stabilized lateritic interlocking blocks. *The Pacific Journal of Science and Technology*, 11(2), 31-32.

Raheem, A. A., Falola, O. O. and Adeyeye, K. J. (2012). Production and testing of laterite interlocking blocks. *Journal of Construction in Developing Countries*, 17(1), 33- 48.

SON (2003).Nigerian Industrial Standard for Cement Composition, Specification and Conformity Criteria for common cements. *Designation NIS* 444-1: 2003. Standard Organization of Nigeria.

Suleiman, M. (2011). Challenges to affordable housing in Nigeria. Cooljoe News January, 26.