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A comparative study of compressed earth bricks (ceb's) and sandcrete blocks for building construction

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Abstract

This study examined the production and testing of sandcrete bricks and compressed earth bricks (CEB's) with a view to comparing their strength and moisture content of materials used. Some units of sandcrete bricks and laterite bricks were made using machine vibrated sandcrete brick mould and hydraulic brick making machine respectively. The bricks were tested to determine their moisture content and compressive strength. The results obtained from the tests were compared with the specifications of Nigerian Building and Road Research Institute (2006), Nigerian Building Code (2006), and Nigerian Industrial Standards (2000). The results indicated that the compressive strength of 300×150×170 sandcrete bricks varies from 1.3 N/mm2 to 2.6 N/mm^2, as the curing age increases from 7 to 28 days. For laterite bricks, the strength varies from 1.0N/mm^2 at 7 days to 2.2N/mm^2 at 28 days. All the bricks produced satisfied the minimum requirements in terms of compressive strength, by all available codes, but the compressive strength of sandcrete bricks is higher than the CEB's. It was concluded that sandcrete bricks have better strength compare to compressed earth brick, more so compressed earth bricks (CEB's) absorb more water than sandcrete bricks, and sandcrete bricks can be use as substructure (foundation unit). It was recommended among others that sandcrete bricks should be used for foundation of a building.

Key words: Concrete, Sandcrete bricks, Laterite, Compressed Earth Bricks (CEBs), Building, Compressive strength.
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Introduction

Housing is seen as one of the best indicators of human's standard of living and of his or her place in society (United Nations Centre for Human Settlement, 2002). Housing and building conditions also reflect the living standards of society (Venkatarama Reddy, 2004). The most vulnerable in terms of lack of access to decent and affordable housing in developing countries are the low-income group. The population of this group has been on the increase due to rapid urbanization and population. This has led to various researches into development of locally available building materials and constructions techniques to enhance access to housing for all.

Walling materials constitute an essential element in housing delivery. It is estimated that it covers about 22% of the total cost of a building. The choice of walling materials is a function of cost, availability of materials, durability, aesthetics and climatic condition. Barry (2006) defines a wall as a vertical structure of bricks, stone, concrete timber or metal, thin in proportion to it length and height, which encloses and protects a building or serves to divide building into compartments or rooms.

For the purpose of this study, sandcrete bricks are walling units produced from sand, cement and water. The quality of bricks is a function of the method employed in the production and the properties of the constituent materials. Sandcrete bricks are available for construction of load bearing and non-load bearing structures. Compressed earth bricks (CEB) are one of the products that Nigerian building and road research institute (NBRRI) introduced into the construction industry due to the fact that laterite is readily available in Nigeria and that it requires a very small quality of cement. Compressed earth bricks (CEB's) are construction bricks made with laterite and a stabilizing ingredient such as lime or Portland cement. The earth mixture is poured into a hand- operated or motorized hydraulic made, compressed earth bricks are uniform in size and shapes.

This study compares compressed earth bricks and sandcrete block for building construction. Specific objectives were to sudy:

- The moisture content of materials used in Compressed Earth Bricks and sandcrete block.
- The compressive strength of Compressed Earth Bricks and sandcrete block.

Materials and Method.

The laboratory test, casting and crushing was carried out at building Technology laboratory in Federal University of Technology, Minna. Niger State Nigeria. Materials used for the production of sandcrete bricks and CEB's were obtained locally - cast steel mould (300mm × 150mm × 170mm) for the production of CEB's bricks and manually operated compression machine of mole 300mm×150mm×170mm was used. Sharp sand and laterite was used for the production of sandcrete and CEB's respectively as fine aggregates and it was made free from deleterious substances by washing and sieving. Laterite samples used were air-dried for seven days in a cool dry place. Air drying was done to enhance grinding and sieving of the laterite. After drying, grinding was carried out using a punner and hammer to break the lumps present in the soil. Sieving was then done to remove over size materials from the laterite sample using a wire mesh screen with aperture of about 4.75mm in diameter as recommended by Oshodi (2002). Fine materials passing through the sieve were collected for use while those retained were poured away. The liquid limit, plastic limit and plasticity index of the laterite sample were determined in accordance with British Standard 882 (1992). Ordinary Portland cement (dangote brand) was used as binder, the water used was that which is drinkable and free from impurities and it was obtained from tap in the laboratory.

Test Conducted.

Tests were carried out to determine the specific gravity of cement, sand and laterite, Bulk density of sand and laterite, moisture content of sand and laterite, water absorption on bricks, sieve analysis of sand and laterite and also Compressive strength of sandcrete bricks and CEBs.

Procedure for specific gravity of cement.

The cement was dried thoroughly in order to remove moist, the empty density bottle was weighed on electrical weighing machine and weight W_1 noted, the density bottle was filled with ⅓ of cement (sample) and weighed (W_2), the density bottle containing ⅓ of cement (sample) was filled with water and weighed (W_3), the density bottle was also filled with clean water only and its weight (W_4) was obtained.

The formula for specific gravity of any construction materials used for building construction can be express as ;

$$\frac{w2-w1}{(w4-w1)-(w3-w2)} = \text{specific gravity of that materials.}$$

Where;

W_1= weight of empty density bottle.

W_2= weight of density bottle with cement (sample).

W_3= weight of density bottle, cement sample and water.

W_4= weight of density bottle and clean water.

Note: the same procedure is followed to obtain the specific gravity of laterite and sand.

Procedure for bulk density of sand.

The empty cylinder was thoroughly cleaned and weighed as W_1, the cylinder base was weighed and the weight was noted W_2, the cylinder was then filled up with sand (sample), and stamped 25 times for each layers pour into the cylinder until it was fill up, then the surface of the cylinder was level, the cylinder was weighed with the sand sample and weight was noted as W_3, An empty container was weighed (W_4), the empty container was then filled with ⅓ of sand sample taken from the top sand of the cylinder and the weight was noted as W_5, another empty container with ⅓ of sand sample taken from the bottom sand of the cylinder was weighed and noted as W_6, the container filled up with the top sand sample was dried up for 24hours and weighed (W_7) and also the container filled up with the bottom sand sample was dried up for 24hours and weighed, noting the weight as W_8.

Procedure for sieve analysis of sand.

The sand was thoroughly dried to be free from moist, each of the sieve size was weighed and their weights were noted, the set of sieve were arranged in an ascending order of their sizes, e.g 4.75mm, 2.36mm, 1.18mm, 600µm, 300µm, 150µm, 75µm, and pan, 500g of dry sand that is free from moist was measured and poured right from the first sieve, then the sieve was covered and the set of the sieve was thoroughly shake to enhance passage of the sand to the respective sieve size, finally each sand sample retained in each sieve was weighed and their weights were noted.

Note: the same procedure is followed to obtain the sieve analysis of laterite.

Productions of sandcrete bricks.

Laterite sandcrete bricks were produced using vibrating bricks moulding machine with double 150mm (6inches) moulds. Cement and sand were measured in ratio 1:9 by volume bathing with the aid of head pans. The materials were then thoroughly mixed together manually until a homogeneous mix with uniform colour was obtained.

Water was then added in sufficient quantity to ensure workability of the mixture, the water used was calculated and judged to be sufficient when a quantity of the mixture pressed between the palms form caked without bringing out water. The composite mixture was then introduced into the mould in the bricks moulding machine and the pulley of the machine was compressed against composite mixture to impose vibration for one minute and to ensure adequate compaction of the bricks constituents as practiced by Raheem, Bello and Makinde (2006). The bricks on wooden pallet was removed from the bricks moulding machine and water was sprinkled on the bricks, at least twice a day for proper curing for twenty eight days (28days).

Productions of compressed earth bricks (CEB's).

The CEB's were produced using hand molding method with steel or wooden mould of size 300×150×170. The materials used for the production of CEB were measured by volume batching. For the 5% cement stabilization adopted, ninety five (95) parts of laterite with five (5) parts of cement i.e. ratio 19:1 (laterite: cement) was used.

A four liter plastic container was used as the gauge box, the mixing was done on an impermeable surface made free from all harmful materials which could alter the properties of the mix, by sweeping and brushing or scraping. The measured laterite sample was spread using a shovel to a reasonably large surface area, cement was then spread evenly on the laterite and the composite materials thoroughly mixed with the shovel. The dry mixed 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 of the mixture was determined by progressively wetting the soil and taking handful of the soil, compressing it firmly in the fist, then allowing it to drop on a hard flat surface from a height of 1.10m. When the soil breaks into 4 or 5parts, the water is considered right (National Building Code, 2006).

The interior of the mould were lubricated so as to prevent the laterite CEB from sticking to the side of the mould and also to give the bricks a smooth surface. The wet mixture was filled into the mould and then compacted with hydraulic press. After removing the bricks from the machine, they were first allowed to air dry under a shade made with polythene sheet for 24hours.

Thereafter, curing was continued by sprinkling water, morning and evening and covering the bricks with polythene sheet for one week to prevent rapid drying out of the bricks which could lead to shrinkage cracking. The bricks were later stacked in rows and columns with maximum of five bricks in a column until they were ready for compressive strength test.

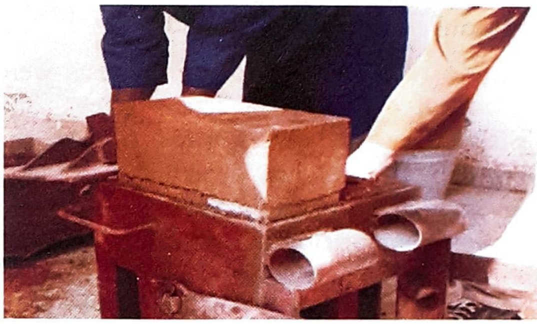

Fig. 1: Compressed Earth Brick

Fig. 2: Sandcrete Blocks

Tests on bricks.

Different tests and experiments, all of which have direct bearing with the investigation of the effects of stabilization and moulding pressure on the strength and performance of bricks, were selected and conducted. The tests include the wet and dry compressive strength tests and the water absorption test. Although the wet and dry compressive strength tests and the water absorption tests are both now standard performance tests widely described and used for stabilized soils, they were originally developed for concrete bricks and fired bricks.

Compressive strength test.

The compressive strength of the bricks is perhaps their most important property. The compressive strength values give an overall picture of the quality of the bricks and are an indication of the hardness of the hydrated cement paste that binds the various particles together. The main aim of the compressive strength tests was to determine the wet compressive strength values of the bricks. It is the wet compressive strength value, which is normally lower than the dry compressive strength, used in the structural design of buildings. The compressive strength test done is a standard test based on ASTM standards, 2004.

Procedure and apparatus used

Compressive strength and density tests were performed on both sandcrete bricks and CEB's, the test were carried out at the workshop of building department, Federal University of Technology, Minna, A manually operated compression machine was used for the compressive strength test on the bricks in accordance with *BS 1992.*

Compressive strength test was carried out to determine the load bearing capacity of the bricks. Both CEB and sandcrete bricks that have attained the ripe ages for compressive strength test of 7, 14, 21 and 28 days were taken from the curing or stacking area to the laboratory, two hours before the test was conducted, to normalize the temperature and to make the bricks relatively dry or free from moisture. The weight of each bricks was taken before being placed on the compression testing machine in between metal plates. The bricks were then crushed and the corresponding failure load recorded.

Compressive strength = load to failure
(KN/m^2) Net area of bricks

Breakdown of procedure and apparatus

Apparatus

The apparatus are compressive machine, weighing balance and two metal plates.

Procedure

The laterite and sandcrete bricks were weighed and recorded using weighing balance, the weighed bricks were placed on the compressive machine one after the other for crushing by placing two plates, one on top and the other beneath the bricks in order to have a leveled crushing surface, the dial guage meter was brought to zero with specimen (bricks) in position and the upper part of the machine trudged the metal until it crushed the bricks and the point at which the dial pointer stopped was recorded as crushing lead in Kilo Newton (KN).

Water absorption test

The aim of the water absorption test was to determine the percentage moisture absorption capacity of the bricks samples. Two (2) of each bricks samples of CEB and sandcrete bricks were weighed in the laboratory dry condition (Wd) and, immersed in water for 24 hours, removed and weighed again (Ww). An accurate electronic weighing machine was used in case, to an accuracy of 0.05g.

Procedure

The brick was dried in a ventilated oven at a temperature of 105 °C to 115°C till it attains substantially constant mass and then cooled to room temperature to obtain its dry weight (wd), the completely dried brick was immersed in clean water at a temperature of 27-29°C for 24 hours after which it was removed and traces of water was wiped out with damp cloth and the brick was weighed to obtain wet weight (ww).

Calculation

Water absorption, % by mass, after 24 hours immersion in cold water is given by the formula, The percentage moisture absorption by weight was calculated from the formula:

$$Mc = \frac{Ww - Wd}{Wd} \times 100\%$$

Where:
Mc = percentage moisture absorption (%)
Ww = mass of wetted sample (g)
Wd = mass of dry sample (g)

Through the water absorption test, it should be possible to determine the ability and extent to which bricks can absorb moisture. Knowledge of the water absorption levels of bricks could serve as useful criteria for setting limits and for investigating possible ways of reducing the same in order to improve on the durability of bricks. The apparatus consisted of an accurate weighing balance, a stop watch and a water trough with a capacity to hold up to two fully immersed bricks. The entire test took two days to complete mainly due to the overnight soaking of the bricks samples in water. This test helps to investigate the effect of water absorption of stabilized soil bricks during the rainy season. The recommended water absorption value of bricks is from 12%

to the maximum value of 20% base on British Standard 882:1992.

Data collected through the practical test carried out for the studywere analysed. A total of three (3) tests were carried out in the building laboratory of the department of building, Federal University of Technology Minna, Niger state.

Research question 1

What is the moisture content rate of materials used in CEB and sandcrete block?

In determining the moisture content of the material used, the moisture content of laterite and sand used were carried out. The result for the test is presented below;

Table. 1. Moisture content of sand and laterite.

	Sand		Laterite	
	Trial 1	Trial 2	Trial 1	Trial 2
Weight of Can, M_1 (g)	24.0	24.0	24.0	24.0
Weight of Can + Wet Sample, M_2 (g)	111	96.0	95	97.0
Weight of Can + Dry Sample, M_3 (g)	102	86.0	80	89.0
Percentage of Moisture contents	11.5%	16.1%	26.8%	12.3%
Average Percentage of Moisture Contents	13.8%		19.6%	

Key: Moisture content = $\frac{M2-M3}{M3-M1} \times 100$

The data presented in table 1 revealed that laterite have the highest moisture content of 19.6% compare to sand which is 13.8%.

Research Question 2

What is the compressive strength of CEB and sandcrete blocks?

Table 2. Compressive strength of bricks produced with sharp sand

S/No	No. of curing days	Area (mm²)	Weight of bricks (kg)	Load (N)	Average Load for each Day	Compressive Strength (N/mm²)	Average Compressive Strength (N/mm²)
1.	7days	45000	8.3	47000			
2.	7days	45000	8.7	51400	56600	1.3	
3.	7days	45000	8.5	71400			
4.	14days	45000	8.1	71800			1.92
5.	14days	45000	8.8	61100	72533	1.6	
6.	14days	45000	8.3	84700			
7.	21days	45000	8.1	98800			
8.	21days	45000	7.9	87900	98833	2.2	
9.	21days	45000	8.9	109800			
10.	28days	45000	9.0	127900			
11.	28days	45000	8.2	102600	116300	2.6	
12.	28days	45000	9.1	118400			

Compressive strength $= \frac{\text{Loadto Failure(N/mm}^2\text{)}}{\text{Net area of bricks}}$

$$compressive\ strenght = \frac{116300}{45000} = 2.6\text{N/mm}^2$$

From the result analysed in table 2, it was revealed that as curing days increase the compressive strength of the sandcrete bricks increase and the strength is greater than the minimum value stipulated by British Standard 882 and Nigeria Industrial Standard 87 (2007).

Table 3. Compressive strength of bricks produced with laterite

S/No	No. of curing days	Area (mm²)	Weight of bricks (kg)	Load (N)	Average load for each day	Compressive strength (N/mm²)	Average Compressive strength (N/mm²)
1.	7days	45000	10.3	47000			
2.	7days	45000	10.3	51400	45233	1.0	
3.	7days	45000	10.0	71400			
4.	14days	45000	10.3	71800			
5.	14days	45000	10.2	61100	55500	1.2	
6.	14days	45000	10.0	84700			
7.	21days	45000	9.9	98800			
8.	21days	45000	7.8	87900	67500	2.0	
9.	21days	45000	9.2	109800			
10.	28days	45000	10.1	127900			
11.	28days	45000	9.5	102600	98867	2.2	1.6
12.	28days	45000	9.4	118400			

Compressive strength = <u>Load to failure(N/mm^2)</u>
Net area of bricks.

$$Compressive\ strenght = \frac{98867}{45000} = 2.2\text{N/mm}^2$$

The result presented in table 3 shows that at 28days the compressive strength of laterite bricks is 2.2N/mm^2.

Table 4. Standard deviation for the compressive strength of sandcrete bricks.

s/no	Curing days	Area (mm^2)	Mass (kg)	Load (N)	Compressive strength (N/mm^2)	x-$\bar{x}$	$(x-\bar{x})^2$
1	7th Day	300x150	8.3	47000	1.04	-0.86	0.7396
2	7th Day	45000	8.7	51400	1.14	-0.76	0.5776
3	7th Day	45000	8.5	71400	1.59	-0.31	0.0961
4	14th Day	45000	8.1	71800	1.60	-0.3	0.09
5	14th Day	45000	8.8	61100	1.36	-0.54	0.2916
6	14th Day	45000	8.3	84700	1.88	-0.02	0.0004
7	21st Day	45000	8.1	98800	2.19	0.29	0.0841
8	21st Day	45000	7.9	87900	1.82	-0.08	0.064
9	21st Day	45000	8.9	109800	2.44	0.54	0.2916
10	28th Day	45000	9.0	127900	2.84	0.94	0.8836
11	28th Day	45000	8.2	102600	2.28	0.38	0.1444
12	28th Day	45000	9.1	118400	2.63	0.73	0.5329
					Total – 22.81		Total – 2.92

$$\text{Mean} = \frac{22.81}{12} = 1.90$$

$$\text{Variance} = \frac{\Sigma(x-\bar{x})2}{n} = \frac{2.92}{12} = 0.24$$

$$\text{S.D} = \sqrt{0.24} = 0.49.$$

The analysis of the data presented in table 4 revealed that compressive strength of sandcrete bricks is high and the materials has required strength to withstand the load of a building.

Table 5. Standard deviation for the compressive strength of compressed earth bricks (CEB's).

s/n	Curing Days	Area (mm^2)	Mass(kg)	Load(N)	Compressive Strength (N/mm^2)	x-$\bar{x}$	(x-$\bar{x}$)^2
1	7th Day	300x150	10.3	48000	1.07	-0.41	-0.1681
2	7th Day	45000	10.3	48900	1.09	-0.39	-0.1521
3	7th Day	45000	10.0	38800	0.86	-0.62	-0.3844
4	14th Day	45000	10.3	58500	1.30	-0.18	-0.0324
5	14th Day	45000	10.2	58500	1.30	-0.18	-0.0324
6	14th Day	45000	10.0	49500	1.1	-0.38	-0.1444
7	21st Day	45000	9.9	64200	1.43	-0.05	-0.025
8	21st Day	45000	7.8	75300	1.67	0.19	0.0361
9	21st Day	45000	9.2	63000	1.4	-0.08	0.064
10	28th Day	45000	10.1	89000	1.98	0.5	0.25
11	28th Day	45000	9.5	106400	2.36	0.88	0.7744
12	28th Day	45000	9.4	101200	2.25	0.77	0.5929
					Total=17.81		Total=3.24

$$\text{Mean} = \frac{17.81}{12} = 1.48$$

$$\text{Variance} = \frac{\Sigma(x-\bar{x})2}{n} = \frac{3.24}{12} = 0.27$$

$$\text{S.D} = \sqrt{0.27} = 0.52$$

The analysis of the data presented in table 5 revealed that compressive strength of CEB's is high and the materials have the required strength to withstand the load of a building which is inline with BS and NIS.

Discussion

The result obtained from table 1 revealed that the moisture content in laterite used to produced compressed earth bricks is more than the moisture content in sharp sand used to produced sandcrete bricks, moisture content of the laterite and sharp sand is 19.6% and 13.8% respectively. This finding is supported by the finding of Adeyeye (2013) as highlighted that the water absorption capacities for all the sandcrete blocks were lower than the maximum limit recommended by America Standard of Testing Materials (ASTM, 2004). Thus, the tested sandcrete blocks were satisfactory for standard recommendation.

The result obtained in table 2 and 3 shows that the compressive strength of individual bricks range between 1.0N/mm^2 to 2.6N/mm^2, the average compressive strength of the twenty four bricks ranges between 1.6N/mm^2 to 1.92N/mm^2, revealed that the average comprehensive strength of bricks produced with sharp sand had a higher comprehensive strength with values of 1.3, 1.6, 2.2 and 2.6 N/mm^2 for 7, 14, 21 and 28 days respectively.

While bricks produced with laterite had the lower comprehensive strength values of 1.0, 1.2, 2.0 and 2.2 N/mm^2 for 7, 14, 21 and 28 days respectively which according to Neville and Brooks (2008) is in line with American Society of Testing of Materials (ASTM) C 330-89. This implies that the compressive strength of block produced with sharp sand is within the standard while the compressive strength of brick produced with laterite is below the standard prescribed for load bearing blocks by Nigerian Industrial Standard 87 (2007). The range of minimum strength specified by Nigerian Industrial Standard 87 (2007) is between 2.5N/mm^2 to 3.45N/mm^2 at 28days. This is inline with the findings of Anthony, Olabosipo, Adewuyi and Musibau (2015) that the aggregate grading of sandcrete blocks are within the limit specified by BS 882: 1992 and are therefore suitable for block making.

The result obtained in table 4 and 5 revealed that both Sandcrete and CEB blocks have standard deviations of 0.49 and 0.52 respectively, which is an indication that Sandcrete and CEB blocks can withstand heavy load of building. This is inline with Anwar *et. al.* (2000) who highlighted that Sandcrete walls have adequate strength and stability, provide good resistance to weather and ground moisture, durable and easy to maintain.

Conclusion and Recommendation

The study established that sandcrete brick is better than compressed earth bricks (CEBs) because bricks produced with sand (sandcrete blocks) had comprehensive strength of 2.6N/mm^2 which is higher than the strength of compressed earth bricks (CEBs). Moreso, the bricks produced with laterite (CEBs) is of higher moisture content of about 19.6% while Sandcrete blocks had a moisture content of 13.8%. This is an indication that sandcrete brick is better in building construction because it contains lesser moisture content.

Based on the findings, the following recommendations are made:
Government should intensify policy to boost production sector of national economy for the production of building materials, especially cement for production of sandcrete blocks due to the fact that it has a higher comprehensive strength.

Builders should be encouraged to use sandcrete block for the foundation of a building because it is made up of little moisture content. However, compressed earth brick is also good for the low income housing construction.

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