Investigating the thermal and mechanical performance of compressed earth blocks

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Abstract- Due to the rapidity with which structures are being constructed nowadays, particularly in developing nations like Nigeria, concrete blocks have become the most commonly used building material. Even though they aren't very light, concrete blocks have a high compressive strength, and the ingredients for concrete are easy to find. Some industrialized nations are shifting away from utilizing concrete blocks due to their lack of sustainability, which leads to their being environmentally unfriendly, in favor of compressed earthen blocks (CEB), which are more sustainable in terms of getting resources and more ecologically friendly. This paper investigated the thermal and mechanical performance of compressed earth blocks. The percentage of cement was investigated with 0%, 2%, 4%, and 6% cement sample. Results obtained revealed that the compressive strength was notably high at 28 days after curing, with strength of 10.30 N/mm2. After 28 days of curing, a high UPV of 8622m/s and 8660m/s for 4 and 6 percent cement replacement was reported respectively.
Index Terms- Thermal, Mechanical, Compressed earth, Blocks and Cement

I. Introduction

Compressed earth bricks are one of the most frequent earthen building methods (CEBs). They're a contemporary descendent of the molded earth block, or adobe block [1]. Earth compaction improves the quality and function of the blocks while also delivering a number of environmental, social, and economic benefits [2]. [3] In a cradle-to-gate investigation of various walls, a previous study indicated that using earthen building materials might result in a 50% reduction in possible environmental implications when compared to using conventional construction parts [4] Earthen constructions are prone to deterioration in harsh weather conditions [5]. If not built appropriately, earthen constructions are less durable and more prone to intense weather and rainfall than conventional structures. Over the course of a building's life cycle, this condition leads in higher maintenance and repair costs [6]. In recent years, there has been an increasing interest in tackling the mechanical and durability issues connected with clay bricks. Various stabilizing approaches were used to increase durability and compressive strength [7].

In addition, some study shows that adding lime to compressed earth blocks might improve their mechanical and hydrous properties [8]. When it comes to the thermal characteristics of earthen construction materials, their mass contributes to the structures' thermal inertia. This feature may have a positive influence on building thermal performance in specific areas. According to previous study, clay buildings in areas with hot summers and mild winters, such as the Mediterranean, can only provide a suitable internal temperature by passive means [9].

A compressed earth block (CEB), also known as a pressed earth block or a compressed soil block, is a type of construction material composed mostly of moist soil compacted under high pressure into blocks. Compressed earth blocks are made using a mechanical press from a mixture of relatively dry inorganic subsoil, non-expansive clay, and aggregate. Compressed stabilized earth block (CSEB) or stabilized earth block (SEB) refers to blocks that have been stabilized using a chemical binder such as Portland cement (SEB). Most of the time, pressures of about 21 MPa (3,000 psi) are used, and the initial volume of the soil is reduced by about half. Rammed earth differs from CEBs in that the latter employs a bigger formwork into which earth is poured and physically tamped down, rather than building blocks, to create larger shapes, such as a full wall or more at once. CEBs vary from mud bricks in that the latter are not compacted and solidify when they air dry due to chemical changes. CEB has a compression strength that is generally higher than that of mud brick. CEB has established its own set of building standards.

II. RESEARCH METHODOLOGY

A. Methods

i. Sample collection

The compressed earth, sand, clay, silt, and cement were brought from a market located in the city of Abuja, Nigeria.

ii. Preparation of the sample

The tested compressed earth blocks were manufactured in the city of Abuja, Nigeria, using one pail of rammed earth. In most cases, rammed earth was used to construct 50 compressed earth blocks, each measured in centimeters. Because, it is the most common block made locally or by corporations in Nigeria, 28 cm x 25 cm x 11 cm compressed earth blocks were used in this research. Furthermore, this is the most common size in Nigerian buildings. Water harvested on-site (groundwater) is also used in the mix (10% by weight), which evaporates during the drying process. The dirt removed from the construction site is used to create the bulk of earthen building parts. A mechanical tapping machine is also used to make and compact compressed earth blocks, according to statistics. The soil was utilized in the process. They were put through tests at the Laboratory of the Department of Civil Engineering at Nile University in Abuja.

iii. Mixing Process

Soil, cement, and water are among the ingredients utilized in the mixing process. Cement and water were added to the soil. A total of four compressed earth block samples were created: a 0% sample, a 2% sample, a 4% sample, and a 6% sample. A total of 12 compressed earth bricks were created in each sample. Twelve samples of compressed earth blocks were made from a 0% sample, which had 1 bucket of soil for each block, water, and zero percent cement. The mixing ratio for the 2 percent sample is 1 bucket of starchy soil for each block, water, and 2 percent of 1 bag of cement; twelve samples were also created using the mechanical tapping machine. Furthermore, the mixing ratio for 4% samples included 1 bucket of soil for each block created, 4% of a bag of cement and water, and 12 samples. Finally, the mixing ratio for 6 percent samples is 6 percent of 1 bag of cement, water, and 1 bucket of starchy soil. A mechanical tapping machine was used to create 12 samples.

Table 1. Compressed Earth Block Produced

S/no	Samples	Number of blocks produced
1.	0% sample	12
2.	2% sample	12
3.	4% sample	12
4.	6% sample	12
Total		48

iii. Compressed Earth Block Produced

Total of fifty compressed earth blocks were produced, each sample include 0%, 2%, 4% and 6% of cement ratio.

Fig. 1. Fifty Compressed Earth Block Produced.

B. Testing of compressed Earth Block

i. Ultrasonic Pulse Velocity

The Ultrasonic Pulse Velocity (UPV) test assesses material qualities such as elasticity modulus, homogeneity, mechanical resistance, and cracking. The propagation velocity can also be calculated. The time it takes for a particular sound pulse to travel through a known area of a material is measured in UPV tests. This is based on the wave propagation hypothesis, which states that a sound pulse travels quicker in dense materials than in porous materials. So, the propagation speed can be calculated, and this test can be used in a roundabout way to find out what a specific sample is made of. There is practically no literature on the use of this test on compacted earth blocks. Nonetheless, certain investigations into rammed earth have revealed a link between the UPV and the compressive strength of earthen products. In two ways, the UPV measurement was developed (direct and indirect). The transmitter and receiver transducers were placed on opposing sides to measure UPV in the direct position. The indirect measurements were carried out by putting the transmitter on one side and the receiver on the opposite side. To avoid voids in the contact region, a suitable coupling gel was put between the transducers and the sample. For each sample, three separate readings must be recorded. Equation 1 is used to figure out the UPV. It is the ratio of the distance (L) between the emitter and receiver to the time (t) it takes for the signal to travel.

$$UPV\ (m/s) = L/t \quad (1)$$

ii. Compressive Strength

According to the British Standard, the compressive strength test was performed using a hydraulic press machine with a capacity of 3000 kN (Figure 2) and a hydraulic control system. Two transducers were employed in the test, one from the press and the other from the outside (LVSTs). The test employed displacement control with a regular load velocity of 0.5 kN/s. The experiment consisted of increasing the compressive load until it reached 40 percent to 50 percent of the failure value after the highest load peak was recorded. Six samples were examined to determine the compressive strength of CEBs.

Fig. 2. Testing of compressed earth blocks

ii. Total Water Absorption

The total water absorption of a block must be determined since it may be utilized for routine quality checks, categorization based on needed durability and structural usage, and estimation of void volume. The higher the structural performance and longevity of a block, the less water it absorbs and retains. Reducing a block's overall water absorption capacity has long been thought to be one approach to improving its quality. Immersing a block in water until no further rise in apparent mass is noticed is the complete water absorption test. When two successive mass measurements differ by less than 0.1 percent, it is assumed that no apparent mass increase occurred. Three samples were submerged in water for 1, 2, 3, 4, and 5 hours at atmospheric pressure for the test. The surface of the specimen was cleaned with a towel after each interval to remove any adsorbed water. The samples were then weighed. Initially, the test was carried out for 24 hours, as per the norm and previous research. The CEBs, on the other hand, decomposed after 72 hours in water, making it impossible to determine their wet weight. An equation was used to compute the proportion of water absorbed (A).

Where Wh represents the weight of the specimen after each immersion, and Ws represents the weight of the dry block.

A (percentage) = (WhWs) /Wst..(1)

III. RESULTS AND DISCUSSIONS

The findings of the cement used in this investigation are displayed in Table 2. The cement test complies with the British Standard Institution's (BSI) (2011) guideline for block manufacturing cement. The results of the water absorption, compressive strength, and ultrasonic pulse velocity tests were obtained.

Table 2. Properties of cement

S/No	Properties	Value
1.	Standard Consistency	31 %
2.	Initial setting time	166 min
3.	Final setting time	340 min
4.	Specific Gravity	3.13
5.	Fineness	1.58

A. Determination of ultrasonic pulse velocity, compressive strength and water absorption

i. Ultrasonic Pulse velocity test after 7days curing

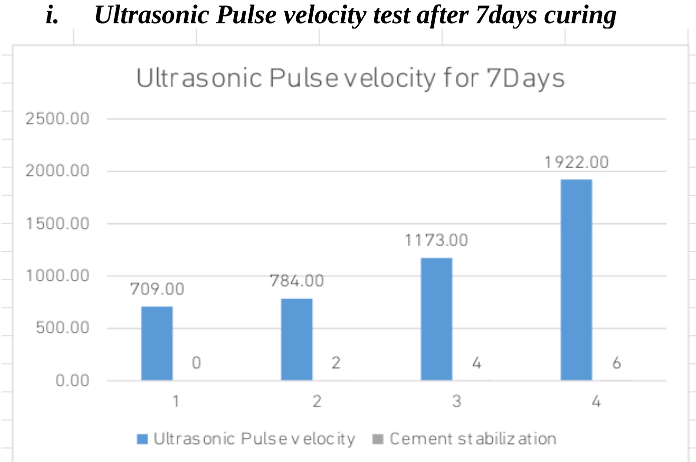

Fig. 3. Ultrasonic pulse velocity at 7 days curing

The UPV results for each sample are shown in Figure 3. Every sample was subjected to three measurements, and the values provided are the average of the data obtained for each sample. After 7 days of curing, the outcome yield a high UPV of 1922m/s with 4% cement replacement and a lower UPV of 784m/s at 2% cement replacement. As a consequence of the examination of the data, it is reasonable to deduce that sample 2 had a somewhat lower UPV, which could indicate a bigger number of voids.

ii. Ultrasonic pulse velocity test after 28 days curing

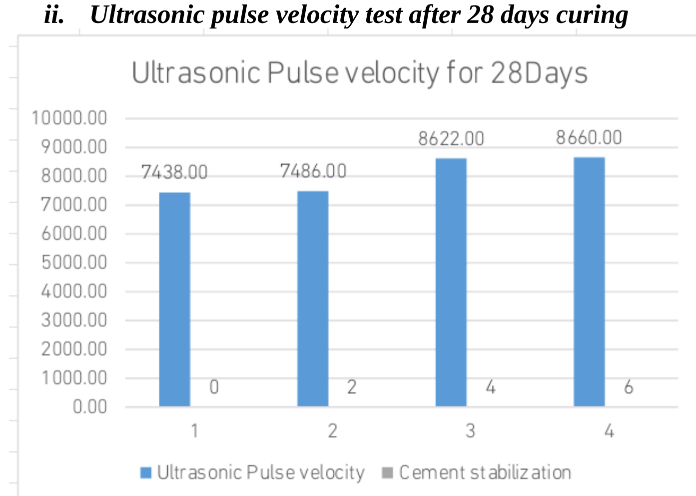

Fig. 4. Ultrasonic pulse velocity test after 28 days curing
Figure 4 shows the UPV findings for each sample. Every sample was measured three times. A high UPV of 8622m/s for 4 percent cement replacement and slightly higher for 6 percent (8660m/s) after 28 days of cure was obtained. A lower UPV of 7486m/s was found with 2% cement replacement.

iii. Water absorption after 7 days curing

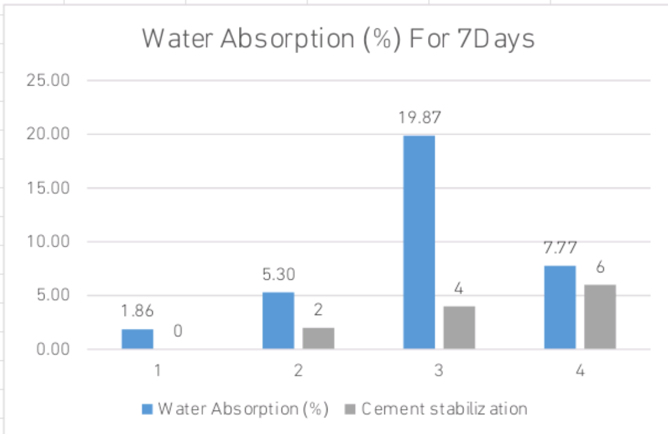

Fig. 5. Water absorption after 7 days curing

The maximal water absorption values for samples 1, 2, 3, and 4 were 1.86 percent, 5.3 percent, 19.87 percent, and 7.77 percent, respectively, according to Figure 5. Water absorption ranged between 1.86 and 19.87 percent when compared to clay bricks (0–30 percent), concrete blocks (4–25 percent), and calcium silicate bricks (6–16 percent). Although this looks to be a beneficial outcome, the quick absorption and desegregation of blocks might compromise the durability. Water absorption is influenced by soil granularity and compaction pressure.

iv. Water absorption after 28 days curing

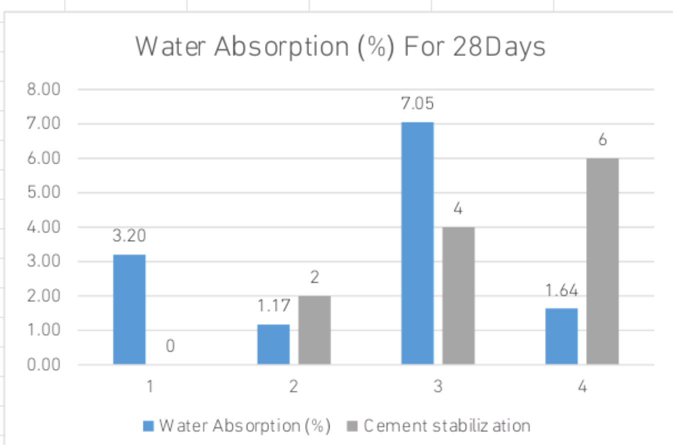

Fig. 6. Water absorption after 28 days curing

According to Figure 6, the maximum values for water absorption for samples 1, 2, 3, and 4 were 3.20 percent, 1.17 percent, 7.05 percent, and 1.64 percent, respectively. When compared to clay bricks (0–30%), concrete blocks (4–25%), or calcium silicate bricks (6–16%), it is possible to deduce that water absorption varied between 1.17 and 7.77 percent. Although this appears to be a positive result, the rapid absorption and desegregation of blocks may have a negative impact on the durability.

A. Compressive Strength

i. Compressive strength after 7 days curing

After 7 and 28 days of curing, the blocks were crushed to assess compressive strength. On the sides, a variable load was applied, and the failure load was recorded.

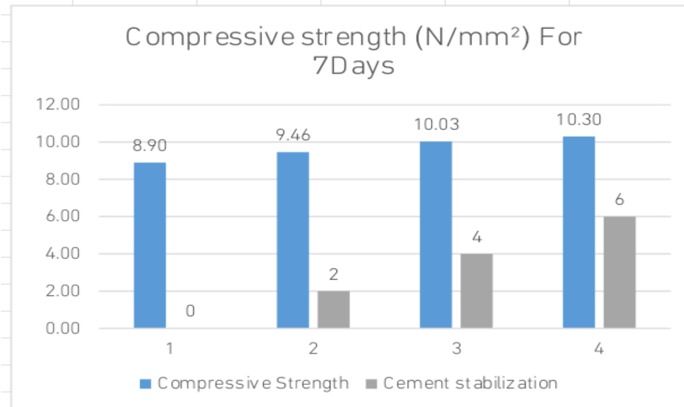

Fig. 7. Compressive strength after 7 days curing

The compressive strength was notably high at 7 days after curing, with strength of 10.30 N/mm2. As shown in Figure 7, the control with 0% sand replacement has a compressive strength of 8.90 N/mm2, with a modest rise from when the sand was partially replaced by Cement in 2% and a slight increase from 4% replacement onward.

ii. Compressive strength after 28 days curing

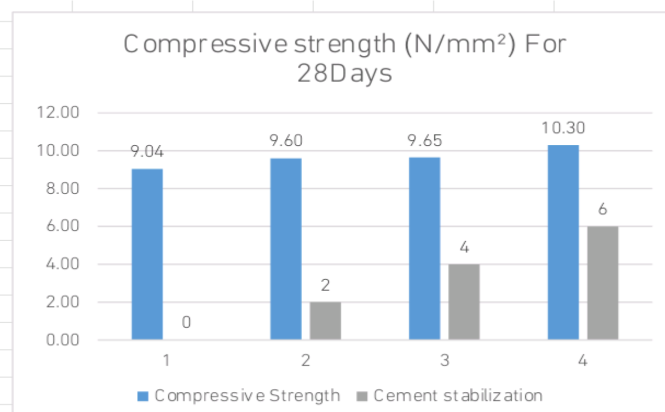

Fig. 7. Compressive strength after 28 days curing

Water absorption maximum values for samples 1, 2, 3, and 4 were 3.20 percent, 1.17 percent, 7.05 percent, and 1.64 percent, respectively, according to Figure 8. Water absorption ranged between 1.17 and 7.77 percent as compared to clay bricks (0–30 percent), concrete blocks (4–25 percent), and calcium silicate bricks (6–16 percent). Although this looks to be a beneficial outcome, the quick absorption and desegregation of blocks might compromise the durability.

IV. CONCLUSION

The compressive strength and the water absorption were determined. The compressive strength was notably high at 28 days after curing, with strength of above 10.30 N/mm2. The control, which has no cement replacing any of the sand, has a compressive strength of 9.04 N/mm2. When 2 percent of the sand is replaced by cement, the strength increases and from 4 percent replacement it increases more, to 9.65 N/mm2. These indicates that increase in the cement, increases the strength of the block. In general, the compressed earth blocks have been examined as suitable for use in the building of partition walls. Furthermore, it was discovered that the compressed earth blocks had a number of environmental benefits. Taking this into account, changing the size distribution of the soil particles in the mixture before making compressed earth blocks could be a way to solve these problems (mostly in terms of thermal performance) while keeping the blocks' strong mechanical resistance.

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