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Research Paper

Analysis of Water Resistivity of Manually Produced Compressed Earth Bricks in Relation to Earth/Cement Ratios

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ABTRACT
Earth bricks which are produced by manually compressing machines are often less dense than those produced by automated compressing machines. This factor could translate to all characteristics of the earth bricks produced manually. This research seeks to analyze the level of permeability of earth bricks produced with manually operated machine when in contact with water. Eight samples of bricks were produced at different cement/sand mix ratio, and three units were randomly selected from each sample, their dry weights were taken, each brick was then soaked into a bucket of water for 60 seconds and then weighed. To analyze the brick's resistivity to water, the weight water absorbed was determined by getting the difference between the dry and the wet samples. The results show that cement additive generally improves water resistivity of manually compressed earth bricks, but it showed that an increase in cement additive may not necessarily imply higher resistance to water. It is therefore recommended that water resistant precautions should be taken during construction with the manually produced earth bricks
Keywords: *Earth, Earth bricks, Water resistivity*

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I. INTRODUCTION

One of the major indigenous building materials commonly found across Nigeria is the Red Earth. It has over the years been utilized for building construction in diversity of methods. This ranges from Adobe brick similar to 'Tubali' in Hausa communities of northern Nigeria, Wattle and daub method as predominantly visible in the Southern Region of the country, to the contemporary burnt bricks masonry works almost everywhere. The basic structural walls in most traditional architecture everywhere around the world were built of 'earth'/earth bricks in native low-cost and self-help construction method (Egenti, Khatib & Oloke, 2014). Though construction with earth has been proven to be economically viable most especially among low-income earners, it has recorded identifiable short comings paramount among which is its poor resistivity to abrasion. Yet another is the effect of water on the strength and durability of the walls. This is a major setback as it calls for regular maintenance to keep the building in shape.

Earth brick construction is seldom a common technology across the country. They are produced in different forms, sizes, shapes and in different ratios. These varieties make up the variations in construction style, technology and aesthetic appearances (Minke, 2000). The quality and durability of the bricks is dependent on factors such as choice of soil, mode of preparation and cement/sand ratio as well as the curing process. Though it is apparently clear that the state of "quality control for direct application of earth construction, hangs in critical balance with very limited tolerance for satisfactory performance in terms water resistance" (Egenti, Khatib & Oloke, 2014). However, if treated with certain additive materials, the quality and aesthetic appearances usually changed to satisfactory requirements, from its unstable character in strength and volume with reliable resistance moisture conditions to a more suitable construction material.

PROBLEM STATEMENT

Indigenous and locally molded bricks structures are confronted with challenges bothering on moisture penetration or reaction to humidity, and structural failures which is a resultant of weak compressive strength of the bricks. These anomalies are collectively a resultant of improper earth stabilization. It is based on this factor that this research intends to stabilize earth bricks using cement additive at different proportions.

II. AIM & OBJECTIVES

The study aimed to analyze the level of water resistivity of manually produced compressed earth bricks in relation to earth/cement mix ratios. While, the objectives are to:

o Produce and cure 8 samples of earth bricks
o Randomly select 3 units of each sample
o Determine their dry weights, and
o Measure their weights after immersion in water to determine quantity of water absorbed by each unit of each sample

JUSTIFICATION OF THE RESEARH

This research intends to subject earth bricks of different mix ratios to moisture content tes t in order to determine to most suitable mix that will produce a qualitative and viable output of earth bricks. This is as to forward to the academic and building sector a reliable template for additional research or implementation as the case may be.

AN OVERVIEIW OFEARTH

Earth in this context refers to the soil component materials required for the production of earth bricks (Fig. 1). In recent research done by Emmanuel Oshike on 'building with earth', he says earth' as known worldwide, "is used to mean any type of soil used for wall construction and 'earth wall' is any type of wall structure built of this material, stabilized or unstabilized, or modified in any way by the addition or subtraction of other suitable materials" (Emmanuel, 2015). Accordingly, as noted by the scholars, earth is the section of the soil that is free from fossils (Ezemerihe et al. 2022; Keefe, 2005). To this end, Emmanuel (2015), says in contemporary context earth is a construction material that has successfully brings about a return into modern construction techniques. He further expresses that even at early stage of life, man begins the act of protection against the elements of weather, or in a note shell 'shelter construction' with earth (Emmanuel, 2015). Earth can be recycled, is easy and agreeable to work (Okwu-delunzu et al. 2022). It has excellent insulating characteristics if built with adequate thermal mass more especially for hot climate regions. Scholars acknowledged the fact that the earth offers no harmful emissions (Okwu-delunzu et al. 2022; Joseph & Olugbenga, 2020). Similarly, another fact is that earth is good in terms of noise reduction as well as insulation where the need arises.

Fig 1. Pictorial view of soil sample & manually compressed earth bricks. Source: Joseph & Olugbenga, (2020).

As such, earth has been the major dominant and as well more important wall constructing material in addition to timber, reeds and bamboo. However, Minke (2000) cited in "conceptualization and pilot study of compressed earth" written by Egenti, Khatib & Oloke, (2014) and acknowledged that earth is an unstandardized building material with known characteristics in terms of limitations, as well is being identified as surface erosion particularly when exposed to weather. Several attempts have been made at different levels to find a suitable solution to the characteristics of earth with regard to weather resistivity particularly moisture. Consequently, many researchers confirmed the compressive quality with improved results of earth stability in strength with low resistance to moisture (Pacheco-Torgal & Jalali, 2012).

Okwu-delunzu et al. (2022) says "earth doesn't burn, so rammed earth walls are fire proof materials". And also, is a load bearing material that reduces the need for structural elements. Subsequently, the "monolithic rammed earth was used with no effect for the walls of the Eden Project entrance building in Cornwall" (UNCHS Habitat, 1986). Earth as building material has the plasticity quality to be molded into varieties of shapes usually called earth brick. Unfired earth bricks are different unprocessed earth products that can also be assessed in lieu of the energy concentration capacities (UNCHS Habitat, 1986). As such, scholars such as Ezemerihe et al. (2022) acknowledged that "moist earth (typically comprising of less clay than sand) is formed into a brick shape using one of three processes described below, prior to drying through a natural or unfired means".

- Molding: Where the earth mixture has a high enough water content (up to 20%) to allow it to be poured into a brick-shaped mold.
- Extrusion: Where the earth mixture has a mid-range water content (up to 14%) so that it is firm enough to retain its shape and also able to be forced through a die. The mixture is extruded as one long length and then a wire cutter divides it into individual bricks.
- Compression: Where the driest of the earth mixtures (a maximum water content of 10%) is subjected to relatively high pressures to produce dense individual bricks.

EARTH BRICKS

Earth Bricks, or compressed earth bricks (CEBs) as popularly known are adobes made from machines, that's a modern technique on a long-inherited building material (Minke, 2000). Similarly, Egenti, Khatib & Oloke (2014) opine that "laterite or lateritic soil remains one of the best natural materials to be used in compressed earth bricks, because, it is generally well graded soil that combines both cohesive (silt and clay) and the cohesionless (sands and gravels) parts of a soil". The methods differ in both concept and processes with little variations in the technical approach. Egenti, Khatib & Oloke (2014) further characterized compressed earth bricks as components of soil materials with the ability to bind due principally to the substance fraction present in both damp and dry conditions. Accordingly, "the compressed earth blocks method is formed by compressed earth in mold by means of a small pestle or ramming energetically with a heavy lid to the mold" (Ezemerihe, 2022; Egenti, Khatib & Negim, 2013).

Similarly, production of compressed earth bricks for building constructions depend on several factors like site/topographical circumstances, atmospheric conditions, proficiency in skill work and formwork/nature of the molding system (Oyelami & Van-Rooy, 2016). Today there are considerably large number of earth brick mechanical devices in markets that produces different varieties of shapes and sizes with unimaginable qualities (Fig. 2). Subsequently, in many parts of the world, including the super nations that are advanced in constructions, building with earth bricks is essentially revived due to the increase in energy costs that changed effectively on building materials notably lime, cement and red burnt bricks. To this end, the earth quality, its characteristics strength and the cohesion ability can however, be improved by the addition of stabilizers (Oyelami & Van-Rooy, 2016). This approach to some extent require few other materials for stability like bitumen, sand aggregates or cohesive and chemical additives to improve the quality properties.

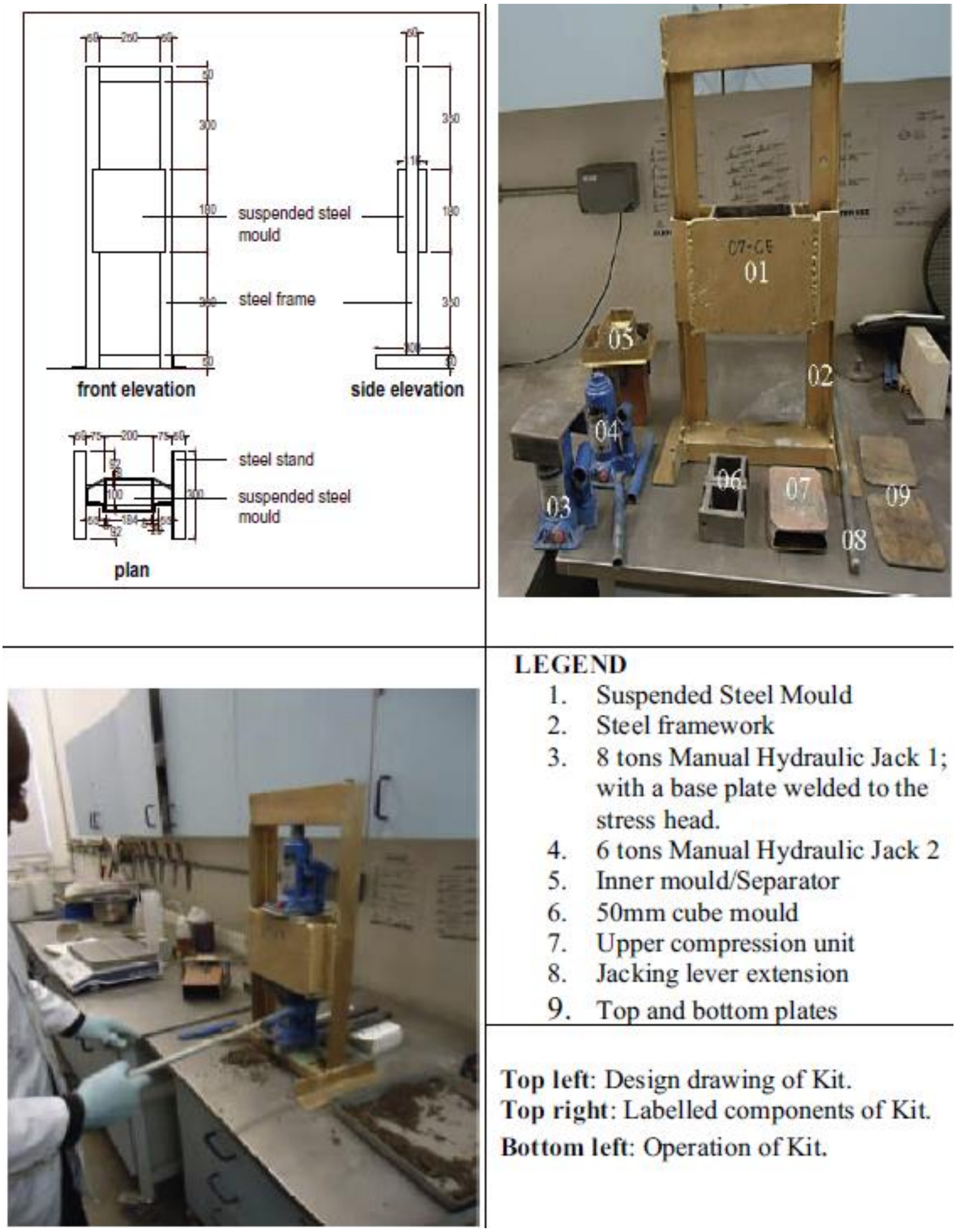

Fig 2. Pictorial view of mechanical device for the production of compressed earth bricks CEB. (Laboratory sample). Source: Egenti, Khatib & Oloke, (2014).

III. METHODOLOGY

The major components of this research are red earth and cement. However, if the red earth is noticed to be of high loam content, sea sand will be added to reduce the loam content. To carry out this research, cement which is the additive in the mix will be added to the laterite at different ratios ranging from 5%, 6%, 7%, 8%, 9%, 10%, 11% and 12%. Each mix ratio will be molded and cured to provide sufficient samples among which 3 units will be selected randomly from each set of bricks and subjected to the water resistivity test. This involves taking the specimens of cured bricks will be weighed as detailed in Table 2. Three units were selected from each of the 8 samples. Their weights at cured state were taken with the use of the weighing scale. The same units will further be immersed in water for 60 seconds and reweighed as shown in Table 3. The difference in weight will inform the quantity of water absorbed by the samples and this will further give an inference of the extent of water resistivity of each of the samples as will be shown in Table 4.

Samples	Cement Additive (%)	Cement/Red Earth Mix Ratio
1	5	1:20
2	6	1:16.6
3	7	1:14.2
4	8	1:12.5
5	9	1:11.1
6	10	1:10
7	11	1:9
8	12	1:8.3

Table 1: Mixing Ratios of Bricks Samples

DATA COLLECTION

Three units I, II, & III of each samples are taken from a weighing scale as shown in Table 2 and subjected to water resistance test as shown in Table 3.

SAMPLES	ADDITIVE	I (kg)	II (Kg)	III (kg)	AVERAGE WEIGHT
1.	5%	7.55	7.95	8.10	7.86
2.	6%	8.50	7.75	7.90	8.05
3.	7%	7.75	7.75	8.25	7.91
4.	8%	8.20	8.00	8.55	8.25
5.	9%	7.90	8.40	8.38	8.23
6.	10%	8.00	7.05	7.20	7.42
7.	11%	7.30	7.45	7.70	7.48
8.	12%	7.95	8.15	7.80	7.97

Table 2: Weight of Samples at Dry State

WATER RESISTANCE TEST

This will involve the measurement of the weights of each specimen of earth bricks as presented in the Table 2before subjecting them to moisture for 60sec.Each unit of every sample will be immersed in a bucket filled with water and then measured again to ascertain the water content absorbed.

SAMPLES	ADDITIVE	I (kg)	II (Kg)	III (kg)	AVERAGE WEIGHT
1	5%	7.80	8.10	8.25	8.05
2	6%	8.60	7.85	8.00	8.15
3	7%	7.80	7.85	8.40	8.02
4	8%	8.35	8.10	8.65	8.37
5	9%	8.10	8.55	8.40	8.35
6	10%	8,10	7.30	7.85	7.75
7	11%	7.60	7.70	7.85	7.72
8	12%	8.10	8.20	7.80	8.03

Table 3: Water Resistance Test

IV. RESULTS

The table below shows an evaluation of the average weights of the samples and the amount of water absorbed by each sample.

SAMPLES	ADDITIVE	WEIGHT (kg) DRY	WEIGHT (KG) WET	WEIGHT OF WATER (kg)	QUANTITY OF WATER (cm^3)
1	5%	7.86	8.05	0.19	0.00019
2	6%	8.05	8.15	0.10	0.00010
3	7%	7.91	8.02	0.11	0.00011
4	8%	8.25	8.37	0.12	0.00012
5	9%	8.23	8.35	0.12	0.00012
6	10%	7.42	7.75	0.33	0.00033
7	11%	7.48	7.72	0.24	0.00024
8	12%	7.97	8.03	0.06	0.00006

Table 4: Water Absorption Values

V. DISCUSSION

The results show that earth mix with 5% cement additive absorb 0.00019cm³, the mix with 6% only absorbed 0,00010cm³ of water. Contrastingly, at samples 3, 4& 5 with cement additives 7%, 8% and 9%, the absorption increased steadily to 0.00011, 0.00012 and 0.00012 respectively. Sample 6 with 10% cement additive showed to exhibit the highest degree of absorption with a value of 0.00033cm³. Samples 7 and 8 on the other hand show water absorption 0.00024 and 0.00006 respectively. The implication of this results is that the higher the permeability of a sample, the lower the water resistivity.

VI. CONCLUSION & RECOMMENDATIONS

Earth bricks have been subjected to several tests in order to ascertain their durability, resistivity and strength. The results are more often than not incoherent because of the diverse characteristics and composition of the earth samples subjected to the series of research. However, manually produced earth bricks with cement additives have been observed to exhibit increased density, increased resistivity to abrasion, smoother surfaces, and better precision in size and shapes.

This research in an attempt to evaluate the rate of water absorption by compressed earth bricks subjected samples with varying ratios of cement additives to moisture test, whose results are tabulated in Table 4.Having evaluated the results from Table 4, it shows that an increase in cement additive may not necessarily imply higher resistance to water absorption. Though cement additive generally increases the strength of manually compressed earth bricks, increasing the additive may not guarantee and increased resistance to water or moisture.

It is therefore recommended that water resistant precautions should be taken during construction with the manually produced earth bricks especially when such areas are prone to dampness or flooding. This may include the use of water seal cement or the water proofing membrane to protect bricks against contact with water.

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