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Moisture Percolation Rate and Compressive Strength of Hydraform Earth Bricks as Walling Material

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ABSTRACT
Due to climate change brought on by global warming, which causes flooding and other ecological problems, the demand for sustainable and environmentally friendly buildings must receive urgent attention in the housing and construction sector. When looking for alternatives to traditional building materials, adequate and thorough information about the characteristics of natural materials is helpful. For instance, the moisture properties and compressive strength of walling material are important for environmentally friendly and long-lasting structures. The goal of this study was to gauge the rate of moisture absorption on hydraform earth brick materials in to estimate their compressive strength when completely saturated with moisture. Hydraform earth bricks were fabricated from a composition of 40% soil, 52% coarse sand, and 9% Ordinary Portland Cement (OPL) in a mechanically operated moulding machine. The rate of moisture absorption was very significant within the first hour of immersion. The samples of hydraform earth bricks gradually and continually absorbed moisture until they became completely saturated at the 8th hour of complete immersion in water. Immersion continued with no further absorption of moisture. An average compressive strength of 6.53Mpa was deduced from three samples of dry hydraform earth bricks, while an average compressive strength of 4.97Mpa was gotten from samples of saturated wet hydraform bricks. The results of the experiment show a 23.89% reduction in compressive strength. However, the result of wet saturated compressive strength meets the minimum requirement of 4Mpa for 28 days old bricks for laterite interlocking blocks as stated by Nigerian Building and Road Research Institute for blocks produced with interlocking block making machines.
Keywords: moisture, compressive strength, percolation, walling, bricks.

I. INTRODUCTION

Earth is a universally accessible building material with a wide range of compositions. Earth is used extensively around the world and remains a key component of many buildings, particularly in underdeveloped nations. Stones and bricks in the form of granite, marble, travertine, limestone, concrete block, glass, block, and tiles make up the typical materials used in masonry buildings. Cement, concrete, and hollow blocks hold an important place in the construction and erection of modern buildings and the building industry (Jayasinghe and Mallawarachchi, 2009).

Masonry has a long-standing history and has been used extensively to build homes because of its beneficial qualities, which include durability, affordability, accessibility, efficient insulation to sound and heat, resistance to fire, appropriate weathering resistance, and its aesthetic look (Jayasinghe and Mallawarachchi, 2009). Adam and Agib (2001) posited that for a long time, earth masonry holds an illustrious record of giving durable and aesthetically pleasing buildings. Also in recent times traditional earth construction technology has witnessed significant and impactful improvements leading to enhanced performance in quality and durability of earth brick as low-cost construction material for buildings.

Hydraform bricks have been created recently as improved earth masonry. It is made of soil and coarse sand that has been dynamically rammed into moulds to produce compressed earth bricks or formed inside formwork monolithically to create solid earth walls. Portland cement is often used as a hydraulic binder (UNIDO, 2015).

Bricks are mainly produced from laterite and it serves as a suitable alternative for sandcrete blocks. Hydraform interlocking block are improved earth-stabilised brick, a class of Solid Interlocking Blocks (SIB) made primarily from cement-stabilised laterite clay with a mix ratio of (1:20) (Hodge, 2008). This is an upgrade on the normal adobe or unfired laterite blocks that were popular in the twentieth century. Research in the use and development of varieties of interlocking blocks is ongoing as reported by The Nigerian Building and Road

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Research Institute; this is geared towards providing sustainable and affordable housing for Nigerians to bridge the housing deficit in Nigeria.

For a building to act as an enclosure, it must have some basic elements or components such as external walls/masonry to be covered by a Roof. The walls in turn will need a firm and solid base or foundation to be built upon, which will transfer their weight and that of the structure to the ground beneath. In recent times heavy rainfalls and flooding have become frequent in many parts of Nigeria and other parts of the world causing heavy damage to buildings and their surroundings. Water is considered among the major source of harm to mason work and architectural estate (Franzoni, 2018). Rain penetration usually plays a major role in hazards to buildings leading to sudden or slow disasters. That is flooding on the one part, precipitations, and water incursion on the other. The rising damp phenomenon occurs if water penetrates from the ground, this can negatively impact any building element near the ground or substructure and the wall element.

One aspect that is seen as crucial is the moisture of building materials. This is because moisture has a damaging effect on how long building materials last. (Jenisch,1996; Rahn and Bonk,2008) and other aspects of their technicality, such as strength(Uncik et al. 2013). The interactions between porous building materials' structures and water are the main cause of their deterioration. The degree of water absorption and sorption mechanisms may vary depending on the properties of the material, the physical state of the water (liquid or vapor), and the environmental conditions (Pasculli and Sciarra, 2001).

This study investigates moisture percolation rate and compressive strength performance of hydraform earth bricks as walling materials. During the study, basic experiment were conducted to ascertain the pattern of moisture absorption on an hourly basis in hydraform earth bricks and to determine the moisture saturation point of hydraform earth bricks when fully immersed in water. Finally, the study examined the impact of moisture on the compressive strength of hydraform earth bricks.

1.1 Material constituents and Production of Hydraform Bricks

The soaring costs of building resources have made it essential for building stakeholders to seek ways of reducing the cost of constructing buildings while ensuring durability and safety. The utilisation of materials sourced locally such as laterite soil is a possible solution. Laterite is a red tropical earth that is enriched with iron oxide and mainly gotten from rock weathering that is subjected to strong oxidising and leaching conditions. It is formed where there is a humid climate, such as in tropical and subtropical areas (Mahalinga-Iyer and Williams, 1997). A large deposit of laterite is found in Burma, Central America, Ceylon, Central Africa, India and West Africa. Nigeria and her sister African countries have an abundant deposit of laterite, thereby making the material readily available and cheap. The prospect of laterite in brick manufacturing for building development is currently underutilised.

The main locally accessible resources that can be utilized, according to Adam and Agib (2001), include natural deposits such as stones, laterite, agricultural wastes, and industrial wastes. According to Oshodi (2004), laterite is widely available, inexpensive, and exploited in Nigeria without posing any environmental risks. The samples of laterite were air-dried for seven days in a cool, dry environment to improve the grinding and sifting of the laterite. Once the dirt had dried, the earth's lumps were broken by grinding with a punner and a hammer. Oversized materials from the laterite samples were removed by sieving the laterite with a wire mesh screen with an aperture of 6mm diameter approximately, as recommended by Oshodi (2004). The material that goes through the sieve was gathered for further usage, while the material that was held was disposed.

The process of production consists of batching, mixing, casting and compaction of the bricks. The mixing took place on an impermeable surface that had been cleared of all potentially dangerous contaminants (by sweeping, brushing, or scraping). A shovel was used to spread the measured laterite sample over a wide floor space. The cement was then poured uniformly on the laterite and properly blended with a shovel.

The dry mixture was once more to accept water, which was added slowly while mixing continued until the appropriate water constituent of the mixture was achieved. Following the removal of all impurities from the steel mould, it was gathered and lubricated to improve the ease of removal of the hydarform bricks from the mould. The wet mixture was poured into the mould in three layers, each of which was crushed with 35 blows of a 4.5 kg rammer on a level and rigid platform. The excess mixture was scraped away, and the mould was levelled with a straight edge. The mould and its contents were left for two hours before removal. The brick produced are stacked on a screed or concrete floor preferably under a shaded tent and covered with a canopy to improve their strength for curing purposes.

II. MATERIALS AND METHODS

2.1 Materials Preparation

Samples of soil-based hydraform brick specimens which were randomly selected from a stack of hydraform bricks were used to conduct the study. The production of the bricks took place in an experimentation site in line with the prescribed manufacturing techniques. The material used for the study was sourced from a borrow pit in Agbede, which is geographically situated in the Northern part of Edo State, Nigeria. The choice of Agbede is premised on its closeness to the experimentation site and the suitability of its laterite deposit as prescribed by the hydraform production manual (UNIDO, 2015). The units consist of 40% of soil, 52% of Coarse sand, and 9% of Ordinary Portland Cement. Bricks with a nominal size of 225× 210× 20mm were produced in a mechanically operated moulding machine and stacked appropriately.

2.2 Experimental Method

A Series of experiments were carried out to ascertain the hourly water incursion rate and final saturation point of the selected samples of hydraform earth bricks in line with BS 3921: 1985. Also, the compressive strength of samples of dry and wet (moisture-saturated) hydraform bricks was determined using a compression testing machine (BS 3921: 1985) at ages 28 days. This was conducted under a controlled environment to give the best result.

2.2.1 Procedure for Hydraform Bricks Water Absorption Test

Wet/dry hydraform brick tests were carried out to mimic the effects of the elements of rising water and static erosion on a wall structure. With no correlation between experimental field data and reality, somewhat test should be needed. In the course of the study, the following procedures were observed when conducting a water absorption test for hydraform bricks as illustrated in Figure 1.

i) Three bricks were randomly selected from the brick stake and labeled (A, B, and C)
ii) The dry weights of the bricks were taken and recorded
iii) The bricks were completely immersed in water
iv) The weights of the bricks were taken with a measuring scale and recorded at hourly intervals (by removing the bricks from the water and returning it immediately the weight is recorded)
v) Continue with step iv until the bricks stop gaining weight (moisture saturation point).

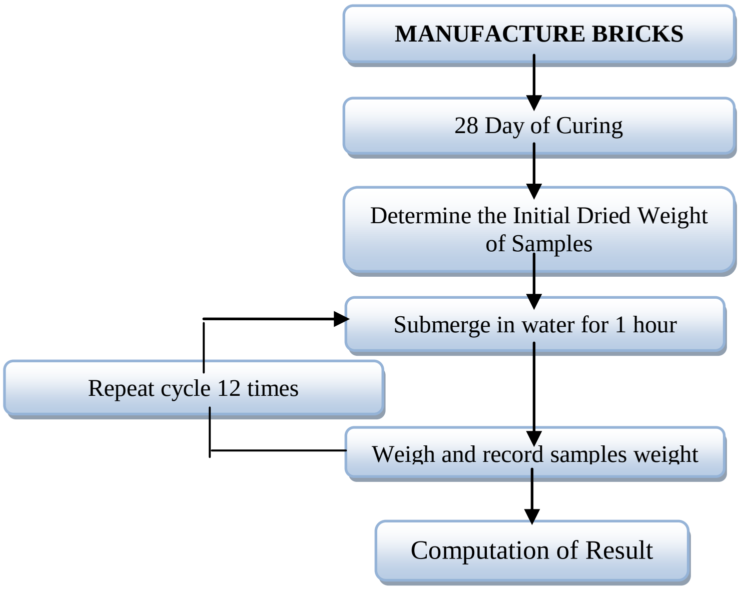

Fig. 1 Procedure of moisture absorption test for hydraform bricks

2.2.2 Procedure for Hydraform Bricks Compressive Test

In the course of the study, the following procedures were observed when conducting a dry and wet compressive test of hydraform bricks:

i) Three bricks were randomly selected from the brick stake and labeled (A, B and C)
ii) The compressive strengths of bricks were taken with a compressive test machine and recorded
iii) Retrieve the wet bricks (see 2.2.1; v) after 24 hours, take the compressive strength test and record the readings.

III. Data Analysis and Discussion of Findings

3.1 Moisture absorption rate of hydraform bricks

Table I Moisture absorption rate of hydraform bricks

Immersion duration (Hour)	Hydraform Bricks Weight (kg)				**Water Absorption (%) $WA_b = \frac{W_s - W_d}{W_d} \times 100$**
	Sample "A"	Sample "B"	Sample "C"	Average Weight of Samples	
0 (dry weight)	9.7	10.00	10.05	9.92 (W_d)	0
1	10.10	10.50	10.85	10.48	5,71
2	10.20	10.70	11.00	10.63	7,23
3	10.35	10.85	11.10	10.77	8,57
4	10.45	10.90	11.20	10.85	9,41
5	10.50	10.95	11.30	10.92	10,08
6	10.55	11.00	11.35	10.97	10,59
7	10.60	11.05	11.35	11.00	10,92
8	10.65	11.10	11.40	11.05	11,43
9	10.65	11.10	11.40	11.05	11,43
10	10.65	11.10	11.40	11.05	11,43
11	10.65	11.10	11.40	11.05	11,43
12	10.65	11.10	11.40	11.05	11,43

From the data in Table I the hourly rate of water absorption was derived from Equation (1) as shown below:

$$WA_b = \frac{W_s - W_d}{W_d} \times 100 \qquad \text{………………………. Eq. (1)}$$

Where W_d is the weight of the dried specimen while W_s is the weight of the specimen at an hourly rate. The fully saturated condition was determined at the point of constant wet brick weight. Water absorption was calculated by factoring the average weights of the specimens in the equation.

Table I show that the average dry weight and the moisture-saturated weight of hydraform bricks are 9.92kg and 11.05kg respectively. The water absorption test conducted shows that fully saturated hydraform bricks absorb 11.43 percent of water. The result of the finding is in line with (Watile, Deshmukh and Gawatre, 2013) who state that the water absorption of interlocking bricks range from 6.42 to 12.4 percent.

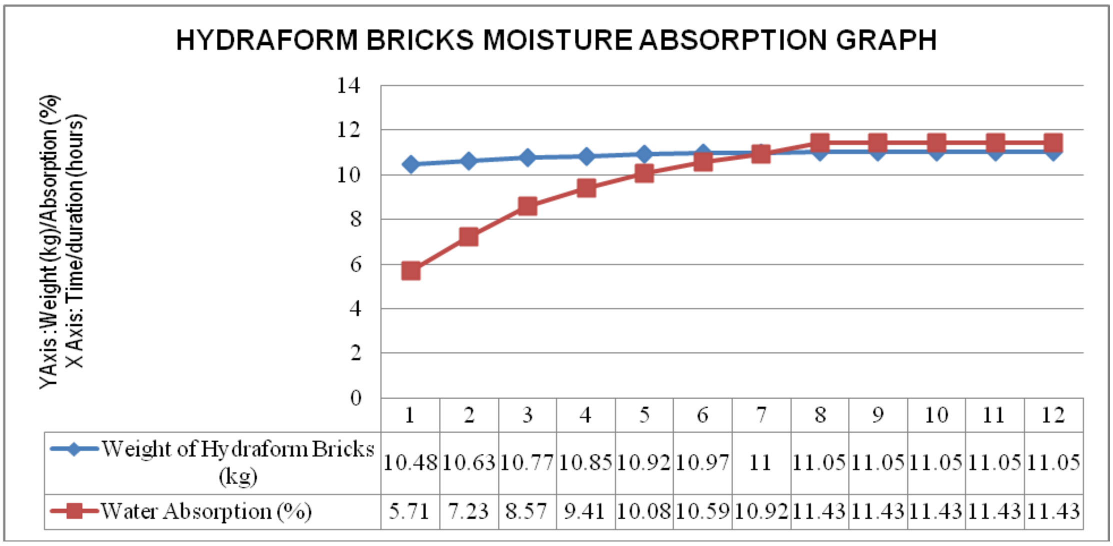

Fig. 2 Moisture absorption rate of hydraform bricks

It can also be deduced (as seen in Table I and Fig 2) that hydraform bricks take an average of eight (8) hours to attain their moisture saturation point when fully immersed in water, after which the weight of the hydraform bricks remain constant and cease to absorb more moisture.

3.2 Compressive Strength test of Hydraform Bricks

Three dry identical specimens of Hydraform bricks Samples, at the age of 28 days having the size of 225mm×115mm×65mm, were tested under axial loading. Also three Hydraform bricks Samples, at the age of 28 days having the size of 225mm×115mm×65mm, were immersed in water for 24 hours and tested under axial loading. The mean compressive strength, of the dry samples, was ascertained by adding up the compressive strength (Mpa) of the three samples and dividing the result by three. A similar procedure was adopted in the calculation of the mean corresponding strength moisture saturated bricks as shown in Table II.

Table II Dry and wet compressive strength of hyraform earth bricks compared

Dry Compressive Strength (MPa)				Wet Compressive Strength (MPa)				% of mean strength reduction
"A"	"B"	"C"	Mean Compressive Strength	"A"	"B"	"C"	Mean Compressive Strength	
6.68	6.73	6.20	6.53	5.07	4.87	4.97	4.97	23.89

The percentage reduction in the mean compressive strength of dry and wet hydraform bricks (CS_r) was calculated by Eq. (2) as shown in Table 2.

$$CS_r = \frac{CS_d - CS_w}{CS_d} \times 100 \qquad \text{Eq. (2)}$$

Table II reveals the dry and wet mean compressive strength of three dry and three moisture-saturated hydraform bricks as 6.53Mpa and 4.97Mpa respectively. This indicates that the compressive strength of hydraform bricks is reduced by 23.89% when it is fully saturated by moisture. This finding is in line with Amed, Martin and Colville (2004) who state that stabilised earth bricks decrease in strength when it absorbs water continuously for some time.

Table III Saturated/Dry strength (Mpa) ratio and Saturated/Dry Absorption (kg) Ratio compared

Time (Day)	Cement Content (%)	Samples	Sand (%)	Coarse sand (%)	Strength (Mpa) Saturated	Strength (Mpa) Dry	Saturated/Dry Ratio	Absorption (Kg) Saturated	Absorption (Kg) Dry	Saturated/Dry Ratio
28	9	A	40	52	5.07	6.68	0.76	10.65	9.70	1.10
		B			4.87	6.73	0.73	11.10	10.00	1.11
		C			4.97	6.20	0.80	11.40	10.05	1.13
		Average			4.97	6.53	0.76	11.05	9.92	1.11

The result of analysis as shown in Table III indicate that there is consistency in the samples analysed as the highest Saturated/Dry Ratio of Strength (Mpa) is 0.80 while the lowest Saturated/Dry Ratio of Strength (Mpa) is 0.73 with a ratio difference of 0.07. Similarly, the highest Saturated/Dry Ratio of Absorption (kg) is 1.13 while the lowest Saturated/Dry Ratio of Absorption (kg) is 1.10 with a ratio difference of 0.03 indicating a close consistency in the samples analysed.

IV. CONCLUSIONS

The average saturated water absorption of hydraform bricks is 11.43%, and the average immersion duration of 8 hours, after which the bricks stop absorbing more water. Also, the result of the experiment reveals that the average weight of hyfraform bricks increases from its dry weight of 9.92kg to a saturated wet weight of 11.05kg. Moreover, (Ashour, Korjenic, & Korjenic, 2015) examined recent works and affirmed that the unsafe moisture content of bricks is from 15% upward. So, the moisture absorption experimental results of hydraforn brick showed significant improvement over the minimum requirement in the percolation of moisture in bricks and therefore possessed enhanced durability.

The average dry compressive strength for hydraform bricks is recorded as 6.53Mpa, while the average wet compressive strength of hydraform bricks is recorded as 4.97Mpa. This indicates that the wet compressive strength of Hydraform bricks meets the minimum requirement of 4Mpa for 28days old bricks for laterite interlocking blocks as stipulated by the Nigerian Building and Road Research Institute (NBRRI, 2006) for blocks produced with interlocking block-making machines.

Furthermore, it can be concluded that hydraform earth bricks have good moisture and compressive strength properties. Hence, it could be recommended as an alternative to the conventional walling material for building in flood-prone areas and for buildings where the compressive strength of walls is considered important.

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