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DEVELOPMENT OF TERMITE MOUND CLAY BRICKS FOR RURAL HOUSING

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Abstract

Bricks represent one of the most used materials for the construction of buildings, but rising demand of building materials and increased construction and demolition wastes have encouraged the development of new building material. Clay bricks remain the most widely used materials in the building and construction industries, due to their good qualities, low cost and versatility compared to other materials for building purposes. In this study, bricks were developed using termite mount soil. River Sand and White Portland cement were used as a stabilizing agent. Mix proportion of termite soil to sand of 5:2 ratio are considered. White Portland cement of 20% was used as replacement for Termite mound clay soil (TMCS). Preliminary test on the materials are performed in terms of Sieve Analysis, Bulk Density, Atterberg Limit and Compaction test. Water absorption, compressive strength, and thermal resistance of bricks were also determined. The thermal resistance of the brick specimen at different temperatures of 200°C, 400°C, 600°, 800°C and 1000°C are determined in electrical muffle furnace and samples are burnt for 1 hour. The outcome indicates that the brick can withstand temperature up to 1000ºC. The water absorption results show that that the bricks resistance to water penetration is satisfactory. The average results of compressive strength value of 1.88 N/mm² obtained at 21 days is greater than 1.6 N/mm² specified by ARS 682 (1996) Standard, this shows that the bricks are good for construction.

Keywords: Termite mount soil, Bricks, Liquid limit, plasticity index, compressive strength, water absorption, Thermal resistance

1. INTRODUCTION

Conventional building materials are beyond the reach of a majority of the world population and Nigeria in particular due to their poor affordability (Ugochukwu & Chioma, 2015). In rural and urban areas, clay bricks have been identified as low cost and effective materials for dwellings and other infrastructures.

Brick is traditional building material which due to its high quality in compressive strength, moisture absorption resistance, fire resistance and insulation earn it wide acceptance in the construction and building industries. In developing countries, about 80% of the rural population still live in low quality and substandard houses as they cannot afford the high cost of new building materials that can provide better dwellings and other infrastructures. Clay bricks have been identified as low cost and effective materials for dwellings and other infrastructures.

Bricks manufactured from clay soils have environmental impacts such as land degradation due to extraction of the clay. They have led to the disfiguring of the landscape, cutting down the vegetation, water and air pollution, among the other impacts, thus affecting ecological diversity, animal habitats, drainage patterns and neighbouring local communities (Legese, Kenate, & Feyessa, 2021). According to Fuyane, Atlhopheng, and Mulale (2013), extraction of clay for brick making causes land degradation because of extensive and excessive clay removal from one place and may affect human health by creating pools and still water, which provide a suitable environment for mosquitoes and malaria.

Housing is an asset that all family aspires to acquire and own in the world to feel secure. However, in many parts of the world, particularly in the developing countries, fulfilling housing requirement of the population remains challenging (Woetzel *et al*., 2014). Therefore, majority of the population of developing countries are either homeless or live in slums and sub-standard houses.

There is a need for affordable building materials in providing adequate housing for humankind in the world. The cost of conventional building materials has continued to increased and in other hand majority of the population continues to fall below the poverty line, the cost of the conventional construction materials has become unfordable. Thus, there is a need to search for local environmentally friendly materials as alternative and low-cost building materials, without compromising the quality in both rural and urban areas (Seghir, Benaimeche, Krzywiński, & Sadowski, 2020). Nowadays, using locally available alternative construction material are one of the most common methods for combating lack of affordable construction materials for a developing countries.

The construction materials account for between 40 and 60 % of the total construction cost, and this is attributed to the fact that basic conventional building materials like cement and aggregates are becoming increasingly expensive due to high cost incurred in their processes, production and transportation (Alake and Akaninyene, 2014). This led us to the utilisation of locally available materials like termite mound clay that can either reduce or replace the conventional materials. The characteristics of termite mound soil are suitable for construction material because they have binding properties as the mound is rich in silica and alumina (Jouquet et al., 2020).

Termite clay is obtained from anti hill (or mound) which is a pile of earth made by termite from the soil in the immediate vicinity. It is a large tower of soil stuck together with termite secretion. The termite hill can be found anywhere in the world though highly populated in Africa and Australia (Nwakonobi, Anyanwu and Tyav, 2014).

Termite mounds are also common occurrence in Nigeria but are unwanted on farmlands, most especially in the vicinity of wooden structures (Akinyemi, Akpenpuun and Timothy, 2018). The activities of termites around wooden and agricultural structures is undesirable, as a result, termite mounds in close proximity to these structures must be broken down and properly disposed of in order to prevent recurrence (Adeniran, Mijinyawa, Akpenpuun and Oseni, 2014).

Nwakonobi, Anyanwu & Tyav (2014) investigated that there are two types of termites mound namely; the red termite mound (which is red clay) and the grey termite mound. According to Samad et al. (2021) red clay is composed of chemical constituent such as silica, calcium oxide and aluminum oxide. Magnesium oxide and other oxides like iron, potassium and sodium are present in little amount, however the red color is due to the presence of iron II oxide (Fe_2O_3) also the intensity of the color is depended on the percentage of the Ferric oxide.

In Nigeria, there are abundant termite mound spread across the Country almost available everywhere. Termite mound clay are usually made of clay whose plasticity has been further improved by the secretion from the termites while being used in building the mounds. Termite mound clay are not significantly different in clay mineralogy (Millogo *et al*., 2011). It is a better material than ordinary clay in terms of utilisation for moulding (Alake and Akaninyene, 2014).

Eze, Kokwe & Eze (2020) reported that termite mounds are clay-rich sites, and thecomposition of many chemical elements are greater than surrounding soils.William *et al.*, (1995) in their study reported that the termite hill samples indicate chemical composition similar to that of clay minerals. It is better material than the ordinary clay in terms of utilization for moulding lateritic bricks due to its plasticity (Odumodu, 1999, Mijinyewa et al, 2007). However there are few reports on the utilization of termite clay as material for brick production. The termite hill appear in different colours which according to Brady and Ray (2006) depend on the type of soil in its vicinity. The property of termite clay may therefore depend on thetype of soil within the immediate environment.

According to Alabadan, Adekola & Esumobi (2016), termite hill soils contain clay, which consist of inorganic material minerals and water that makes them fire-resistant and incombustible. It is made of clay whose plasticity is further improved by the secretion from the termites while being used in building a termite mound (Assam, Okafor, & Umoh, 2016). It is, therefore, a better material than ordinary clay in terms of utilisation for moulding (Assam et al., 2016) and in storage construction (Omobowale *et al.*, 2016).

2.0 Materials and Methods

2.1 White Cement and Fine aggregate

White Portland cement (WPC), Type I with strength of 42.5 MPa, conforming with ASTM C150 (2012) was obtained from commercial market.The relative density of WPC = 1.77g/cm^3. The fine aggregate (river sand) used for this study was natural and locally sourced.The physical test data of river showed that it had: specific gravity = 2.6, relative density = 1.68 g/cm^3, fineness modulus = 2.90 and water absorption rate = 3.0%. The fineness modulus is within recommended limit of 2.1 to 3.2 specified by ASTM C33 (2003).

This indicate that the sand will not demand more water that will affect the workability, hence it is suitable for making good mortar and brick making.

2.2 Termite claysoil

The termite mount clay soil (TMCS) is very hard in nature so it has to be sprayed with water to make it soft and easier for collection and transportation as shown in Fig. 1. Physical test data showed that it had: specific gravity = 2.6, bulk density = 1847kg/m^3, fineness modulus = 2.13.The results of coefficient of uniformity (C_u) =2, computed from the sieve analysis for TMCS in Fig. 2 is less than 4,this showed that the TMCS is poorly graded. The coefficient of curvature (C_c) = 0.7 is less than 1 which indicates that the material is well graded (ASTM D 2487-2000). This implies that the TMCS has poor coefficient of uniformity and good coefficient of curvature. The chemical compositions of the TMCS material were given in Table 1. The major component of TMCS is silicon dioxide SiO_2= 63%. The alumina (Al_2O_3) content is 17.6% and iron oxide (Fe_2O_3) content was 5.3%; the iron oxide (Fe_2O_3) being responsible for the reddish color could be the main colorant of TMCS. The sum of the percentage of SiO_2, Al_2O_3 and Fe_2O_3 content = 85.9%. This indicates that the chemical compositions were quite similar to those of cementitious materials and could be classified as reactive materials that have potential to take part in the pozzolanic reaction during hydration process. Toure, Sambou, Faye, and Thiam (2017) studied on the mechanical and thermal characterisation of bricks and reported that a combined percentage of SiO_2 and Al_2O_3 should be greater than 70% to be a good binder for the brick production. The combined percentage of SiO_2 and Al_2O_3 composition also meets the requirements of ASTM C 618(2010). Thus, TMCS can be considered as suitable raw materials for brick production.

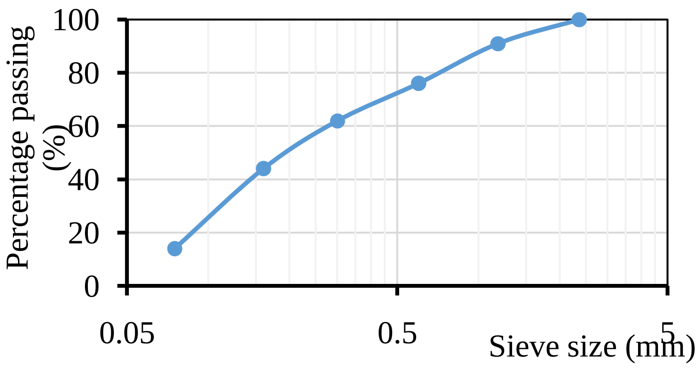

Fig. 1: Collection of Termite clay soil. Fig.2: Particle Size Distribution of Termite mound soil

Table 1: Chemical compositions of Termite mound clay soil.

Chemical composition (%)	Chemical compositions (%)												
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	TiO_2	H_2O	SO_3	LOI
TMCS	63.00	17.6	5.3	0.60	1.00	1.1	2.10	0.02	0.04	0.26	1.75	0.34	8.2

3.0 Mixture Proportion

The mixture for the brick was designed using mix ratio of 5:2 for termite clay soil and sand. Percentage of 20% white Portland cement was used to replace the TMCS in accordance with Samad et al, (2021). The water to termite soil of 0.275 was used to mix the mixture. Brick size of 215 mm x 103 mm x 80 mm were casted. Mixing of the TMCS sample with water was done manuallyand bricks were casted in batches.

4.0 Experimentation

Various experiments were performed in order to achieve the set objectives in this research work. These experiments include Atterberg limit test, compaction test, Water Absorption, Heat Resistance and Compressive Strength of brick specimens.

4.1 Atterberg Limit Test

The Atterberg limit tests were performed on the raw termite clay soil and treated stabilized with white Portland cement samples at 20%. These tests were conducted in accordance with the British Standards codes BS 1377 - 2 (1990) and BS 1377 - 4 (1990).

4.2 Compaction test

British Standard light (BSL) compaction apparatus with a mould diameter of 110 mm was used in performing the compaction test on the termite soil. The soil was mixed with varying amount of water and then compacted in three equal layers by a hammer that delivers 25 blows to each layer.

4.3 Production of Bricks

Standard bricks are produced manually with a size 215 mm × 103 mm × 80 mm with the mixture was used for the experimentations. After the bricks were casted, the samples were dried in an open air to attain good setting of the bricks produced. The TMCS bricks were kept in a shed to be dried with air for 21 days. The time of drying is dependent on the moisture content of the TMCS bricks and the humidity of the production area.

Fig. 3: Production of bricks

4.4 Compressive Strength Test

Compressive strength was determined using a compression machine with a loading capacity of 3000 kN. The loading rate applied in the compression of bricks is 2000 kN/min. The results of the compressive strength are presented in Table 3. The test was conducted in accordance toASTM C 67(2019)

4.5 Water Absorption Test

The water absorption was carried out to examine the effect of water on the heated cubes at 800°C. Three (3) samples were used to the 24 hours cold water absorption test to determine the rate at which the individual sample can absorb water in a given period of time. The samples are weighted and reweighted before and after immersing into the water for duration of 24 hours

4.6 Heat Resistance Test

The heat elevated temperature test was carried out using an auto regulated electric furnace as shown in Fig. 4. All the bricks are weighed before been placed into an electric furnace heated at different temperatures of 200, 400 ^{0}C, 600 ^{0}C, 800 ^{0}C and 1000 ^{0}C^{0}C for 1 hour period and allowed to cool to ambient temperature of 28 ^{0}C and reweighed. The essence of the test is to observe the ability of the bricks to withstand the amount of heat at required temperature and gain more strength then ambient temperature.

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Fig. 4: The electric furnace for thermal resistance test

5.0 Results and Discussion

5.1 Atterberg limit tests

The results of Atterberg limit tests in terms liquid limit (LL), plastic limit (PL) and plasticity index (PI) of the termite clay soil are shown in Fig. 2. The results indicate that the Liquid Limit (LL) is a good indicator to produce the quality of clay brick. It also observed that consistency and plasticity of termite clay soil is within the limit of 25 to 35 low plasticity clay soil. Hence, this showed that the termites mound soil is classified as silty clay with traces of sand (ASTM D2487, 2006). This could be attributed to the chemical effect on structural composition of the termite clay soil. The low plasticity index might be dueto sensitivity of the soil sample to moisture and also could beattributed to the cation exchange capacity that occurs when the clay soil is stabilized (Mousavi & Karamvand, 2017). It is interesting to observe that the plastic limit of the mound soil is little high although within standard specification. Such high plastic limit may be attributed to the increase in the clay content of the mound soil and presence of enzymes.

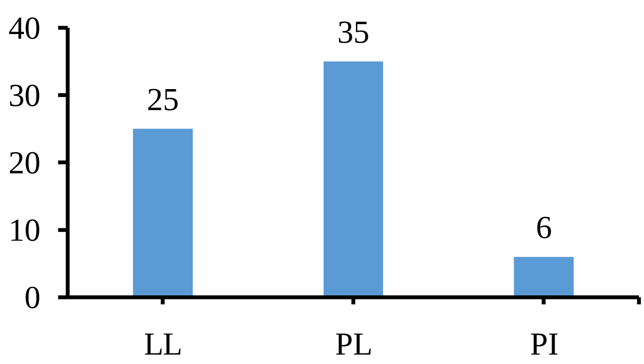

Fig. 5: Atterberg limits results of termite clay soil

5.2 Results of Compaction test

The compaction test is conducted in the soil laboratory to determine the maximum dry density (MDD) and the optimum moisture content (OMC). The results obtained are 1.68g/cm³ for maximum dry density while the optimum moisture content is 11.6%. According to Otoko, and Precious, (2014), if there is an increase in MDD it may be attributed to higher specific gravity, however increase in OMC will result a decrease in MDD, the relations are vice versa.

5.3 Compressive strength of Bricks

The results of Compressive strength for Ten (10) bricks specimens at ambient temperature (28 ^oC) are shown in Table 2. It is observed that the average compressive strength of Ten (10) bricks at 21 days is 1.88 and this value is within the Nigerian Building code which states that a compressive strength of a clay bricks should be greater than 1.6 N/mm^2 (ARS 682, 1996).

Table 2: Results of Compressive Strength of Bricks

S/N	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
1	1.90	1.88
2	2.08	
3	1.76	
4	1.85	
5	1.81	
6	1.65	
7	1.85	
8	2.12	
9	2.12	
10	1.67	

5.4 Performance of Elevated Temperature

The results of the behaviour of brick exposed to elevated temperature are presented in this section. The properties examined include; the effect of elevated temperatures on the compressive strength and weight loss. Five temperature levels of 200, 400, 600, 800 and 1000 ^oC were considered.

5.4.1 Compressive strength of bricks at elevated temperatures

The compressive strength of bricks exposed to different temperatures is presented in Table 3. The compressive strength of brick was remarkably improved by firing at higher temperatures. At 200 ^0C the compressive strength increased to 13.52 MPa compared to 1.88 MPa average compressive strength of ambient temperature (28 ^oC). However, with the increased in temperature from 200 to 600^0C, it was obseved that the compressive strength decreased from 13.52 to 12.80 MPa. These decreased in compressive strength with temperature attributed to the white cement dehydration of the calcium hydroxide producing CaO and H_2O. It was also observed that the compressive strength increased to 13.65 MPa as the temperature increased to 800. This increase might be due to the decrease in porosity and increase in bulk density as the exposure temperature increased (Dos Reis et al., 2020; Tsega, Mosisa, & Fufa, 2017). The increase in compressive strength could also be due to vitrification phenomenon. Similar observation was reported by Tsega et al. (2017). TMCS possess pozzolanic material, an additional C-S-H gel was formed as a result of the pozzolanic reaction of $Ca(OH)_2$ with reactive silica in the brick specimen. Similar findings were reported by Savva, Manita, and Sideris (2005) on the influence of elevated temperatures on the mechanical properties of concretes prepared with limestone and siliceous aggregates. As the exposure temperature increased from 800 to 1,000^{0}C, the compressive strength of the brick decreased. This decrease was mainly caused by calcium carbonate dissociation and subsequent CO_2 escape from $CaCO_3$.

Table 3: Residual compressive strength of the bricks

Temperature (^{O}C)	**Compressive Strength (N/mm²)**
200	13.52
400	13.40
600	12.80
800	13.65
1000	13.25

5.4.1 Influence of temperature rise on weight loss

The influence of elevated temperature on the weight loss of brick is shown in Figure 6. The weight loss increased with temperature increase and is expressed as a percentage of the original weight (weight before heating) between room temperature (28 ^{o}C) and weight after exposure to a targeted temperature. The weight loss within this temperature range is primarily attributed to moisture movement from concrete surface to the surrounding environment (Ismail et al., 2011).

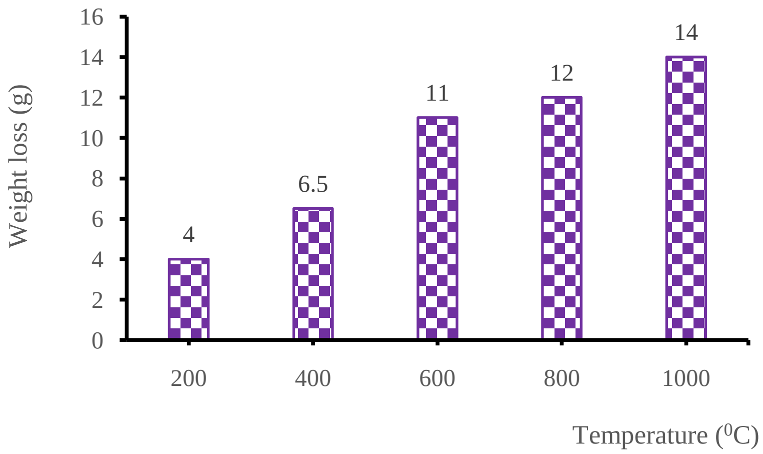

Figure 6: Influence of temperature rise on weight loss

5.3 Water Absorption

The results of water absorption test conducted is presented in Table 4. From the Table, it could be seen that specimen absorb less water (9.8%) as compared to permissible limits of 18% recommended by ASTM C67-94 for clay bricks. Therefore, based on these standards, TMCS bricks have met the requirement. This might be attributed to the continuous hydration of the white Portland cement which reduced the water absorption of the bricks.

Table 4: Result of Water Absorption

Sample no	**Water absorption**	**Average water absorption (%)**
A	10.48	**9.80**
B	8.79	
C	10.13	

6.0 Conclusion

Based on the experimental investigation, the following conclusions were highlighted:

1. The consistency and plasticity of termite clay soil is within the standard limit of 25 to 35, which indicates that it has low plasticity. The liquid limit result may be ascribed to the presence of organic content and higher percentage of enzymes in the termite mound soil.

2. The results obtained for maximum dry density optimum moisture content 1.68g/cm^3 and 11.6%, respectively are within the acceptable limit.

3. Water absorption rate of the mortar brick is low which indicates that the bricks are water resistant that cannot be easily washed away due to rain water flooding.

4. The results of thermal resistance show that the bricks sustained temperature up to 1000^{0}C which match the refractory requirements.

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