ENGINEERING PROPERTIES OF TERMITE MOUND BRICKS AS A CONSTRUCTION MATERIAL FOR AGRICULTURAL BUILDINGS

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ABSTRACT

The use of termite mound soil as a construction material and as a replacement for clay in brick production was investigated. This research investigated the physical properties (Moisture Content, Specific Gravity, Dry-bulk Density, Grain Size Analysis), the Atterberg limits (liquid limit (LL), plastic limit (PL) and plasticity index (PI)) and engineering properties of *termitaria* bricks. Mound soil was sourced from two sites (Tanke, Ilorin (A) and Civil Engineering Department, University of Ilorin, Ilorin (B)). The results of the physical properties of mound soil from both sites showed that there was no significant difference in the physical properties. The Atterberg analysis revealed that soil from site A and site B had plasticity index of 40.57 % and 41.07 % respectively. The average compressive strength of 1.70N/mm^2 and 1.52 N/mm^2 was recorded after 14 days of curing for sites A and B respectively. The highest average compressive strength of 2.70 N/mm^2 and 2.50 N/mm^2 was recorded after 28 days of curing for site A and site B respectively. This indicated 58.8 % increment in compressive strength for sites A and 64.50 % increment in compressive strength for site B. These increments in compressive strengths were as a result of the strong bond between the soil particles as a result of a high percentage of clay and silt and the elimination of air and water pockets within the brick formation. As a result, soil samples from both sites are suitable for brick production for agricultural structures such as grain silos and yam barn.

KEYWORD: Termite mound, atterberg limits, compressive strength, properties, plasticity indices

1. INTRODUCTION

Termites are tropical social insects that play an important role of biodegrading fallen and dead wood in the environment. About 2,800 species of termites have been identified. Termites live in nests, which could either be on the earth's surface or below the earth's surface. Nests that are on the earth's surface are also known as Mound (*termitaria*) (Ndaliman, 2006). Nests are structures made from a combination of soil, mud, chewed wood/cellulose, saliva, and faeces and are often located near trees, stumps, wood piles and other cellulosic materials. The nest performs functions such as: protection, housing, air conditioning, control of the CO_2/O_2 balance and water collection. Termites feed on wood and wood products such as books, cardboard, boxes and wooden door and window frames and cabinets (Aguwa, 2009).

Table 1: Chemical Composition of Termite Mound

Composition	Percentages (%)
SiO	58.06
AlO_3	27.72
K_2O	2.59
Fe_2O_3	1.46
TiO_3	0.87
CaO	0.20
MgO	0.36
Na_2O	0.30

Source: Ndaliman, 2006

Termite mounds are a common occurrence in Nigeria but are unwanted on farmlands, most especially in the vicinity of wooden structures. 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. The objective of this research was to determine the Atterberg limits of mound soil and the engineering properties of termite mound bricks. The aim was to investigate the feasibility of replacing clay with mound soil as well as finding an appropriate method of disposing mound soil.

2. MATERIAL AND METHODS

2.1 Study Area

The study area is Ilorin, Kwara State. Ilorin is located at latitudes 8° 05`N to 10° 05`N and longitudes 2° 50`E to 6° 05` E. The state has an elongated shape covering an area of about 32,500 sq. km. The soils of Ilorin are loamy and clay. The climate in Kwara state is described as tropical. Kwara State experiences an annual rainfall of about 1500 mm, average temperature 33.50 ^{o}C, average relative humidity of 77.50 % and 7.1 hours of sun shines daily (Olanrewaju, 2009).

2.2 Collection of Termite Mound Soil

Termite mound soil used for the study was obtained from two sites in Ilorin South Local Government Area. The collection of the samples from the sites was done using a shovel, pickaxe and polyethylene bags.

2.3 Preparation of Bricks

Wooden forms of dimension (100 × 100 × 100) mm were fabricated. The termite mound soil was sieved using 0.4 mm sieve in order to remove organic debris, which might interfere with bond formation. Fifteen bricks were moulded for each of the soil samples using the forms and tempered properly so as not to have any voids. The forms were lubricated with oil in order to ease demoulding after 24 hours. The bricks were air-dried under a shed to avoid cracking that could have occurred under direct sun drying.

2.4 Determination of Physical Properties

2.4.1 Natural Moisture Content

Equipment used for this test were, moisture cans, gloves, crucibles, electric oven and weighing balance. Oven drying method was used to evaluate the moisture content of soil samples. The moisture content is the basis on which the Atterberg limits of a soil sample are established. The natural moisture content was determined using equation (1) below:

$$\text{Moisture Content, W (\%)} = \frac{Weight\ of\ Water}{Weight\ of\ Oven\ dry\ soil} = \frac{W_1 - W_2}{W_2 - W_3} \qquad 1$$

Where, W_1 = Weight of can and wet soil, g; W_2 = Weight of can and Oven dry soil, g; W_3 = Weight of can, g

2.4.2 Specific Gravity

Equipment used included: Pycnometer, weighing balance, Vacuum pump, Funnel and spoon. The specific gravity was evaluated using the equation (2) stated below:

$$G.S = \frac{Weight\ of\ oven\ dry\ soil}{Weight\ of\ Water} = \frac{W_2 - W_1}{W_3 - W_2} = \frac{W_2 - W_1}{W_4 - W_1} \qquad 2$$

Where, W_1 = weight of empty bottle; W_2 = weight of empty bottle + dry soil; W_3 = weight of empty bottle + dry soil + water; W_4 = weight of empty bottle + water only

2.4.3 Bulk Density

It is the ratio of the mass of the dry soil to the volume of the soil sample. Equipment used to carry out this experiment were straight edge, weighing balance, moisture can, Measuring cylinder, drying oven and Vernier calliper. The dry-bulk density was evaluated using the equation (3) below:

$$\text{Bulk density}\left(\frac{g}{cm^3}\right) = \frac{\text{Weight of Oven dry Soil}}{\text{Total Volume of Soil}} = \frac{W_2 - W_1}{V} \qquad 3$$

Where, W_1 = Weight of empty cylinder; W_2 = Weight of empty cylinder + dry soil; V= Volume of Soil = Volume of Cylinder = $\pi r^2 h$; R = radius of cylinder, cm; h = height of soil in cylinder

2.4.4 Sieve Analysis of Mound Soil

Sieve analysis was conducted on the mound soils in the Material Laboratory of Civil Engineering Department, University of Ilorin, Ilorin, Nigeria. The apparatus and materials used were set of sieve (0.15, 0.3, 0.6, 1.18, 2.36, 4.75), weighing balance (accuracy of 0.01 g), brush, mechanical shaker, large pan and timing device.

$$C_U = \frac{D60}{D10} \qquad 4$$

$$C_C = \frac{(D30)^2}{D10 \times D60} \qquad 5$$

Where C_u = coefficient of Uniformity and C_c = Coefficient of Curvature

2.4.5 Atterberg Limits Analysis

Atterberg limits analysis (liquid limit, plastic limit and plasticity index tests) was performed on the fraction of the soil sample that passed through the 0.4 mm sieve based on ASTM D 4318 standard.

Liquid Limit:

Liquid Limit (LL) is the moisture content at which soil begins to behave as a liquid material and begins to flow. Equipment used included: porcelain evaporating dishes, pulverizing apparatus (mortar and pestle), 0.4 mm sieve, Spatula, Weighing balance (accuracy of 0.01 g), Watering bottle, Drying tares, Manually operated Liquid Limit Device(s) and Grooving Tool and Gauge, Oven and Desiccator. The water content in this state is determined using equation above (1), while the Liquid Limit was determined using equation 6 below:

$$\text{Liquid Limit, LL} = W\left[\frac{N}{25}\right]^{0.12} \qquad 6$$

Geotechnical Engineering Bureau, 2007.

Where, W = moisture content, %; N = Number of blows

Plate 1: Casagrande Liquid Limit Device

Plastic Limit (PL):

Plastic Limit is the moisture content at which soil begins to behave as a plastic material and was determined using equation (2) stated above.

Plasticity Index (PI):

It is a measure of the plasticity of a soil. The plasticity index is the water content level at which soil exhibits plastic properties. It is the difference between the liquid limit and the plastic limit (PI = LL - PL). Soils with a high PI tend to be clayey while those with lower PI tend to be silty and sandy.

3. RESULTS AND DISCUSSION

3.1 Texture and Consistency Limits

The results of the physical properties of the soil samples from the two sites are presented in Table 2 below. Hydraulic conductivity of soil is affected by the size and distribution of soil particles, mineral composition, texture, characteristics of wetting fluid, void ratio and the degree of saturation (Kasali, 2014). Plasticity index recorded for soil samples from sites A and B was 40.57 % and 41.07 % respectively. These values indicate that clay and silt contents are high in both soil samples and this increases the workability of the soil in terms of cohesion. Plasticity index is inversely proportional to voids within the soil. That is, the higher the plasticity index the fewer are voids within the soil structure. Likewise, the higher the plasticity index the lower the hydraulic conductivity (seepage rate) vice-versa. This implies that the rate of moisture absorption by the bricks will be low as a result the bricks are suitable for agricultural structures such as grain silos and yam barns.

Table 2: Physical and Index Properties of Termite Mounds from both Sites

Physical Properties		**Sample A**	**Sample B**
LL Moisture Content		39.70	40.50
PL Moisture Content		16.03	19.80
No. of Blows		30.00	28.00
Liquid Limit, LL, %		26.65	24.03
Plastic Limit, PL, %		16.03	14.26
Plasticity Index, PI = LL – PL, %		40.57	41.07
Specific Gravity		2.55	2.80
Bulk Density, g/cm^3		1.46	1.54
Particles Size Analysis	Coefficient of Uniformity, C_u	8.97	10
	Coefficient of Curvature, C_c	0.67	0.64

AASHTO Classification	A-2-7	A-2-7
USCS Classification	SW-SM	SP-SC

These values indicate that the soil from both sites can be classified as inorganic clays of medium plasticity according to the Casarande Plasticity Chart in Fig. 2 shown below. His classification is based on the Unified Soil Classification System (USCS) following the ASTM 2487 - 00 Standard. This shows that termite mound is workable and capable of carrying considerable loads.

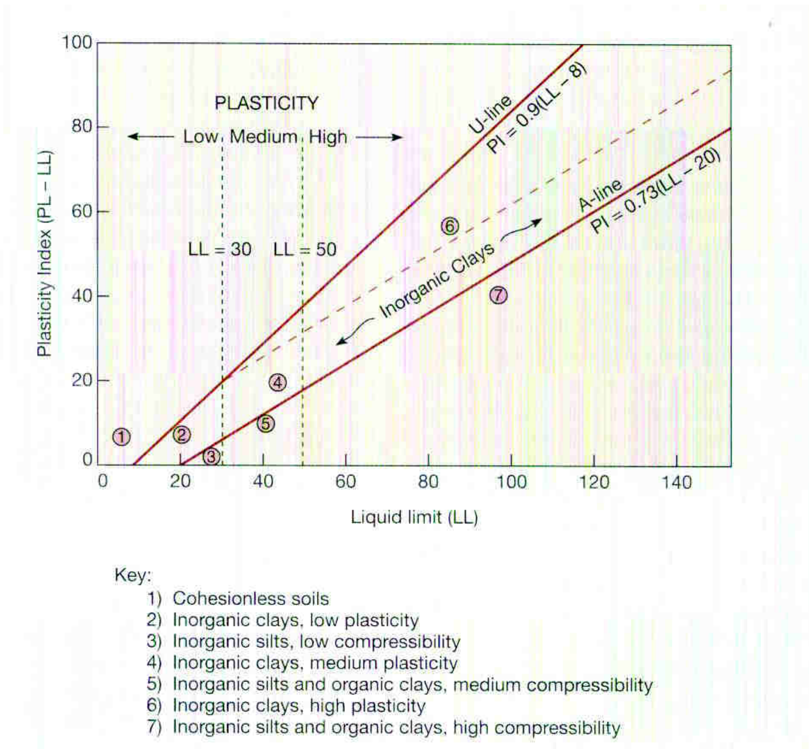

Fig. 1: Casagrande's Plasticity Chart
(**Source:** Geotechnical Engineering Bureau, 2007)

The specific gravity of soil samples from site A was determined to be 2.6, while soil from site B was determined to be 2.8. These values are within the range of the specific gravity of clay (2.79). This implies that mound soil can serve as a replacement for clay soil.

Table 3 below presents the textural and organic properties of the soil samples. It is clear from the table that the clay and silt contents of the samples decrease as the sand content increases.

Table 3: Textural and Organic Properties of Samples

Components, %	**Sample A**	**Sample B**
Organic Carbon	0.51	0.45
Organic Matter	0.87	0.75
Sand	39.52	37.81
Silt	40.00	42.74
Clay	20.48	19.45
Texture (USDAstd)	SL	SL

3.2 Compressive Strength of the Mound Bricks

A total number of thirty bricks of dimension 100 mm x 100 mm x 100 mm were made from the two soil samples; fifteen brick for each soil sample. These specimens were tested by a compression testing machine (Testometric, Model M500-100 AT) after 14, 21, and 28 days curing. At each measurement, the load was applied gradually at the rate of 25 mm/Sec until the specimen failed (Fig. 2, 3). Load at failure divided by area of specimen gives the compressive strength of the mound bricks.

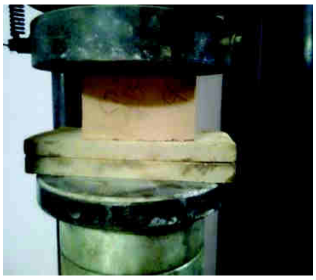

Figure 2: Specimen under Load

Figure 3: Failure at Maximum Load

Tables 4, 5, 6, 7, 8 and 9 below present the respective compressive strength of the mound bricks at their various periods of curing.

Table 4: Compressive Strength of Sample A at 14 Days Curing Age

Replicates	Weight Brick, (g)	Crushing Load, (KN)	Compressive Strength (N/mm^2)
A1	922	17	1.70
A2	956	23	2.30
A3	969	27	2.70
A4	945	20	2.00
A5	938	18	1.80

Table 5: Compressive Strength of Sample A at 21 Days Curing Age

Replicates	Weight Brick (g)	Crushing Load, (KN)	Compressive Strength (N/mm^2)
A6	950	18	1.80
A7	1003	28	2.80
A8	976	24	2.40
A9	990	26	2.60
A10	975	21	2.10

Table 6: Compressive Strength of Sample A at 28 Days Curing Age

Replicates	Weight Brick, (g)	Crushing Load, (KN)	Compressive Strength (N/mm^2)
A11	1017	20	2.00
A12	1040	25	2.50
A13	1062	28	2.80
A14	1085	32	3.20
A15	995	18	1.80

Table 7: Compressive Strength of Sample B at 14 Days Curing Age

Replicates	Weight Brick, (g)	Crushing Load, (KN)	Compressive Strength (N/mm^2)
B1	1044.5	18	1.80
B2	1062	21	2.10
B3	1047	20	2.00
B4	995	10	1.00
B5	1002	12	1.20

Table 8: Compressive Strength of Sample B at 21 Days Curing Age

Replicates	Weight Brick, (g)	Crushing Load, (KN)	Compressive Strength (N/mm^2)
B6	1059	22	2.2
B7	1068	20	2.0
B8	1082	24	2.4
B9	1000	15	1.5
B10	1010	17	1.7

Table 9: Compressive Strength of Sample B at 28 Days Curing Age

Replicates	Weight Brick, (g)	Crushing Load, (KN)	Compressive Strength (N/mm^2)
B11	1061	24	2.40
B12	1083	27	2.70
B13	1112	36	3.60
B14	1101	28	2.80
B15	1009	20	2.00

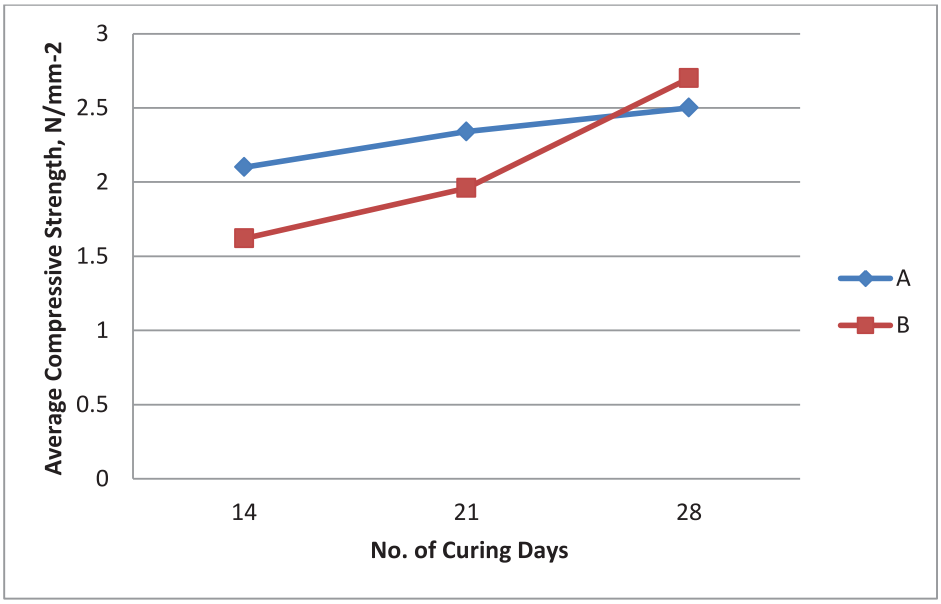

Fig. 4: Average Compressive Strength of Samples

Fig. 4 shows that the compressive strength of all the bricks increased with increasing days of curing. This is expected because as the days of curing increased, the voids within the brick formation continued to reduce due to moisture loss and increased compaction, which eventually leads to loss in weight and increased hardness.

The compressive strength of 2.70 N/mm^2 was recorded as the highest for sample A after 28 days of curing. The values of the compressive strength of the samples were indicative of the stiffness of the bricks and resilience to crack that might lead to seepage and subsequent failure. The high compressive strength could be attributed to the absence of organic content in the mound soil. Ata *et al.*, 2007, observed a decrease in compressive strength of sandcrete blocks as the percentage of laterite content and was increased.

5. CONCLUSION

From the result of the compressive strength, the strength of Sample A increases with an increase in the number of days used in curing while the strength of Sample B increased from 14 days of curing until 28 days of curing. It can thus be concluded that the *termitaria* soils are suitable for agricultural structures.

The Atterberg tests revealed that soils from both sites have 45.74 % and 43.47 % of plasticity indices while the textural and organic properties test revealed that the soil samples had 40 % and 42.75 % of silt and 20.48 % and 19.45 % of clay. These values directly have effects on the plasticity indices of the soils and hydraulic conductivity of the bricks formed. The higher the plasticity indices the lower the hydraulic conductivity which implies low absorption of moisture by the bricks.

From the results, it is recommended that the absorption rate and the shrinkage properties of the mound bricks be investigated.

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