Assessment of termite mound additive on soil physical characteristics

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Abstract: This study was performed to assess termite mound inherent property as additive for improvement of soil strength of construction purpose in Nigeria. The mound on the Rhodic Acrisol was sampled from top at 0-60 cm, 60-120 cm and 120-180 cm intervals through a vertical section. For the Rhodic Acrisol, three samples were sampled from bottom at 0-60 cm, 60-120 cm and 120-180 cm intervals through a vertical section. Termite mound sample was mixed with the two soil samples separately, that is, termite mound and clayey soil in one part and termite mound and laterite soil in another part. Twenty trials experiment were conducted on the soils during compact test for soil mix ranging from 0% to 100% at interval of 5%. The optimum moisture content obtained from the compaction test was used to carry out compressive strength test. The Triaxial machine model HM -5020 was used for determination of the compressive strength. The soil samples were examined in accordance with the American Public Health Association. The data were analysed using descriptive statistics and one-way ANOVA. The findings indicated that: termite mound was classified as sandy clay loam soil while the laterite soil was sandy loam; the termite mound has the highest maximum dry density and compressive strength than other two soil samples; increases in termite mound ratio has a significant increase in maximum dry density and little effect on optimum moisture content for both soil samples; termite mound as an additive has much more effective in laterite soil than clay soil in term of compressive strength and maximum dry density; the compressive strength of the laterite almost doubled that of the clay soil at the same termite ratio. Termite is recommended as an additive for laterite soil for building construction only.

Keywords: termite mound, additive, laterite soil, clay soil, physical characteristics

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1 Introduction

The infrastructure development and food security are two major challenges in developing countries. High cost of agricultural products was being linked to high transportation cost and coupled with lack of access road in the rural areas where those commodities were being produced. The rural farmers made it clear and loud that high transportation had multiplier effect on the cost of agricultural produce. Due to economy recession in this country and high inflation made the federal Government challenged the engineers to look for local material for road construction and how to improve the strength of the laterite soil that are commonly used for local roads. This has challenged road authorities to make optimum use of naturally occurring materials which are often rejected by traditional specifications for use in the upper layers of road pavements. One of the naturally occurring material is laterite. Laterite is a type of residual soil that occurs extensively in the humid tropical and sub-tropical zones of the world, including much of central, southern and western Africa. Fortunately, research carried out in the late 1960s in a number of countries, notably in Angola, Mozambique, Brazil, Australia and Nigeria indicates that the performance of laterite has often been better than expected on the basis of traditional specifications (Adam and Agib, 2001). However, if successful use is to be made of this material, the conditions under which it can

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be successfully used must be carefully specified. To fixing our roads at avoidable cost researches have been intensified on alternative materials that can be used to replace cement partially or wholly for construction purposes (Okoli and Zubairu, 2002, Adam and Agib, 2001). The prominent material of construction in many African countries is the laterite, and often contain some reasonable amount of clay minerals that can affect its strength and stability, hence the need for its improvement. However, there are few undesirable properties such as loss of strength when saturated with water, erosion due to wind or driving rain and poor dimensional stability. These draw backs can be eliminated significantly by stabilizing the soil with a chemical agent such as cement and others additives.

Termites are called ecosystem engineers built mounds, enhancing the content of organic carbon, clay and nutrients (King, 2006). They are found mostly in savannah areas and the weight of termite soil in the savannah is greater than the weight of animals above ground (King, 2006). A termite commonly found in Nigeria is light brown (Isoptera: Termitidae). They are major agents of decomposition and play an important part in nutrient and carbon fluxes (Jouquent, 2004), redistribute organic matter, improve soil stability and its physical and chemical properties (Manuwa, 2009), and improve water absorbing and storing capacity (Holt and Lepage, 2000; Jude and Ayo, 2008).

The following were some noticed characteristics of termite mound:

It cannot be easily broken: termite mound is very strong material most especially in the dry season, this makes it very difficult to work upon; the structure of termite mound changed with climatic condition: During dry season termite mound is very dry and wet or sticky during rainy season and it possesses concrete material (Lavelle and Spain, 2001).

Lavelle and Spain (2001) and Frederic (2003) highlighted some application uses of termite mound in different form which includes the following:

For plastering and for brick making purposes; it was used for brick stoves; for repair of Wood boats; it is used as soil amendment; for making pit latrines construction; it is used as water proof liner; for making footpath and driveway; to reduce losses in crop; in paint making and additive is a substance added to the soil to make it stabilized.

The economic importance of additive on the soil are as follows: to prevent excessive settlement of soil; it enhances soil stiffness; shear strength and soil bearing capacity (Lavelle and Spain, 2001).

Researchers like Mijinyawa et al. (2007) and Yohanna et al. (2003) reported that termite clay power has higher values of clay, liquid limit, plastic limit and maximum dry density than laterite soil. They are better material than the ordinary clay in terms of utilization for moulding lateritic bricks (Odumodu, 1999; Mijinyawa et al., 2007) and this type of clay has been reported to perform better than ordinary clay in dam construction (Yohanna et al., 2003). Previous study by the Nigerian Building and Road Research Institute (NBRRI) involved the production of laterite bricks which was used for the construction of a bungalow (Madedor, 1992). From the study, NBRRI proposed the following minimum specification as requirements for laterite bricks: bulk density of 1810 kg m^{-3}, water absorption of 12.5%, compressive strength of 1.65 N mm^{-2} and durability of 6.9% with maximum cement content fixed at 5%. Brick selection is made according to the specific application in which the brick will be used. Standards for brick cover specific uses of brick and classify the brick by performance characteristics such as minimum compressive strength, maximum water absorption and maximum. ASTM International publishes the most widely accepted standards on brick is presented in Table 1.

The physical and chemical properties such as particle size distribution, bulk density, compaction properties [optimum moisture content (OMC), maximum dry density (MDD)], Compressive strength (CS) and ultimate compressive strength (UCS) are important in construction project including earth dams, road and railway embankments, landfill liners and backfills of retaining structure. It is well known that the quantity of termite mound cannot be enough for meaningful usage, it is good to be used as additive for other local materials that are available in large quantities, therefore, this study is to assess the effect of termite mound additive on soil physical characteristics. The physical characteristics to be assessed are optimum moisture content, maximum dry density, and compressive strength of the soil.

Table 1 Physical Properties in Brick Standard Specifications

Grade/ Class	Minimum compressive strength, MPa	Maximum absorption, %	Maximum saturation coefficient, %
C52	SW: 17.2-20.7	17.0-20.0	0.78-0.80
	MW: 15.2-17.2	22-25	0.88-0.90
	NW: 8.6-10.3	No limit	No limit
C62	SW: 17.2-20.7	17.0-20.0	0.78-0.80
	MW: 15.2-17.2	22-25	0.88-0.90
	NW: 68.6-10.3	No limit	No limit
C216	SW: 17.2-20.7	17.0-20.0	0.78-0.80
	MW: 15.2-17.2	22-25	0.88-0.90
C652	SW: 17.2-20.7	17.0-20.0	0.78-0.80
	MW: 15.2-17.2	22-25	0.88-0.90
C902	SX: 24.1-27.6	8-11	0.8-0.80
	MX: 17.2-20.7	14-17	No limit
	NX: 17.2 20.7	No limit	
C1272	SX: 60.7-69.0	6.0-7.0	
	MX: 4.3-55.2	6.0-7.0	

Source: *Annual Book of ASTM Standards*, ASTM International, West Conshohocken (2006).

2 Materials and methods

2.1 Site selection

The study site made of the Rhodic Acrisol type of soil, in which laterite served as control because it was about 150 m afar from termite mound. In each location, replications of three termite mounds were selected on a uniform slope. In order to evaluate some soil physicochemical properties of termite mounds in relation to the surrounding soils, a total of three adjacent soils (control), three in each location were sampled for this study.

2.2 Field investigations and sampling

One modal profile and a nearby termite mound on each of the two soil series were selected for characterization and sampling. For each soil, a profile pit was dug after which disturbed and undisturbed samples were collected from each genetic horizon. Three representative samples were taken from each mound after the surface had been carefully scrapped. The mound on the Rhodic Acrisol was sampled from top at 0-60 cm, 60-120 cm and 120-180 cm intervals through a vertical section. For the Rhodic Acrisol, three samples were sampled from bottom at 0-60 cm, 60-120 cm and 120-180 cm intervals through a vertical section.

2.3 Laboratory investigations

The disturbed soil samples were air dried and ground gently to pass through a 2 mm sieve for analyses of selected physical and chemical properties. Laboratory analyses were carried out on the samples collected from the termite mounds, laterite and clay profiles. Physical properties determined included bulk density (on the undisturbed soil cores), particle size distribution, (OMC), (MDD), (CS) and (UCS).

2.3.1 Optimum moisture content (%)

Three soil samples were randomly taken with soil auger at various depths and intervals. Soil samples were weighed, oven dried at 105°C for 24 h and weighed again to determine the gravimetric moisture content. The result is presented in Table 1.

Optimum moisture Content (Dry basis, %) =

$$\frac{\text{Weight of moist soil} - \text{Weight of dry soil (g)}}{\text{Weight of dry soil (g)}} \times 100 \quad (1)$$

2.3.2 Bulk density (kg m^{-3})

Bulk density was determined by gravimetric method. The samples box was weighed empty, and later weighed with the soil. The sample box was placed in an oven at a temperature of 105°C for 24 h and allowed to cool in a desiccator. The bulk density was determined using the formula given by FAO/IIASA (2008).

$$\text{Bulk density of soil (kg m}^{-3}\text{)} = \frac{\text{Mass of over dry soil (kg)}}{\text{Volume of core (m}^3\text{)}} \quad (2)$$

2.3.3 Soil texture:

100 grammes of air-dried finely powered soil were put in a 500mL of conical flask and 15 mL of 0.5 N sodium oxalate (Na_2SiO_3) was added. 200 mL of distilled water was added to the mixture and shake for 20 min. The content was transferred to one litre capacity measuring cylinder and make it up to one litre by adding enough water. Stir the suspension thoroughly, then stop stirring and note the time. Hydrometer was dipped into the suspension after 5 min. given direct reading of the percentage of Clay + Silt. Hydrometer reading after 5 h of sedimentation gives percentage of Clay directly. Hydrometer given the reading in g L^{-1}. Percentage of sand was determined by deducting the percentage of Clay +

Silt from 100 %. Similarly percentage of silt was determined by subtracting the hydrometer reading from clay + silt (APHA, 2005).

2.3.4 Maximum dry density (kg m^{-3})

.Optimum moisture content was used to determined maximum dry density using Practor model ASTMD 698-78 (Standard). The experiment was repeated 5 times and then dry density of soil was calculated (FAO/IIASA, 2008).

2.3.5 Sample preparation and compressive strength test

6 kg of clayey soil and laterite soil were kept in respective labelled two metal bays. 6 kg of the respective air dried sample was mixed with 5% of water in a metal bay and their weight of the respective sample was recorded. 12 kg of anthill mounds was also kept in a labelled metal bay and mixed with 5% of water and it's recorded.

Samples of termite mound and clayey soil were mixed in the percent ratio of 5:95; 10:90; 15:85; 20;80; 25:75; 30:70; 35:65; 40:60; 45:55; 50:50; 55:45; 60:40; 65:35; 65:35; 70:30; 75:25; 80:20; 85:15; 90:10; 95:5; 100:0.

Similarly, termite mound and laterite soil of the ratios as presented in the same as anthill and clayey soil (OMC) from the compaction test was used to compacted soil for determination of the compressive test. The samples were taken to triaxial machine model HM-5020 to determine its failure load.

2.3.5 Data analysis

Physical and chemical properties of soil samples were determined in accordance with the American Public Health Association Standards (APHA, 2005). Data were analyzed using descriptive statistics. Means of each parameter was compared using Duncan`s multiple range test. The statistical inference was made at 0.05 (5%) level of significance.

$$CS = \frac{Failure \times PRC}{Area} \text{ KN mm}^{-2} \tag{3}$$

where, CS = Compressive strength. KN mm^{-2}; PRC = providing ring constant, is given as 0.025; A = area of sample $= \frac{\pi d^2}{2}$; (d = 38 mm)

$$\text{UCS} = \frac{CS}{2}\text{, KN mm}^{-2} \tag{4}$$

where, UCS=Unconfined compressive strength, KN mm^{-2}.

3 Results and discussion

The particle size distribution and physical properties of soil samples are presented in Table 2.

Table 2 The particle size distribution and physical properties of the soil samples

Parameters	Termite mound height, cm			Laterite Soil Depth (cm)			Clay soil
	0-60	60-120	120-180	0-60	60-120	120 - 180	
Sand, %	68.5±4.1a	67.7±3.7a	67.8±3.8a	82.2±4.3b	82.1±4.1b	83.1±3.6b	
Silt, %	14.3±1.2a	14.5±1.1a	15.0±1.1a	11.1±1.4b	11.3±1.2b	10.6±1.2b	
Clay, %	17.2±3.2a	17.8±3.1a	17.2±3.1a	6.7±3.6b	6.6±3.3b	8.3±3.1b	
Texture	SCL	SCL	SCL	SL	SL	SL	
BD, g cm^{-3}		1.46±0.1a			1.54±0.1b		1.34±0.1c
OMC, %		19.2±0.2a			18.5±0.3b		21.1±0.1c
MDD, g cm^{-3}		1.85±0.2a			1.39±0.3b		1.01±0.02c
CS, kPa		6.26×10^{-4}			2.99×10^{-4}		$1.24\times x10^{-4}$
UCS, kPa		3.13×10^{-4}			1.49×10^{-4}		0.62×10^{-4}

The compaction test was carried out for determination of the soil (OMC) and (MDD). The results of compaction test for (OMC) and (MDD) for the mixed ratio of termite mound and clayey soil for compaction test and also for optimum moisture content and maximum dry density for the mixed ratio of anthill and laterite soil are detained in the Table 3.

The results of compressive test results for Dial gauge reading, compressive strength (CS) and unconfined compressive strength (UCS) for the mixed ratio of termite mound and clayey soil and also for dial gauge reading, compressive and unconfined compressive strength for the mixed ratio of termite mound and laterite are presented in the Figures 1 and 2 respectively.

Values are means of four replicates (n=4) in all treatment results, they were presented as means values of each determination ± standard error means (SEM) Means indicated by the same letter did not differ ($P \geq 0.05$) as assessed by Duncan's multiple range test (horizontal comparisons only)

Key:

SCL = Sandy Clay Loam

SL = Sandy Loam

Table 3 Comparisons between the mixed ratios of termite mound + clayey soil and termite mound + laterite soil on (MDD), (CS) and (UCS)

Parameters	Termite mound+Clayey soil		Termite mound+Laterite soil	
	MIN. VALUE	MAX. VALUE	MIN. VALUE	MAX. VALUE
OMC, %	13.00	24.00	12.50	27.50
MDD, kg m^{-3}	1087	1848	1420	1885
CS, KN mm^{-2}	1.43×10^{-4}	6.71×10^{-4}	3.13×10^{-4}	1.07×10^{-3}
UCS, KN mm^{-2}	7.15×10^{-5}	3.43×10^{-4}	1.55×10^{-4}	5.35×10^{-4}

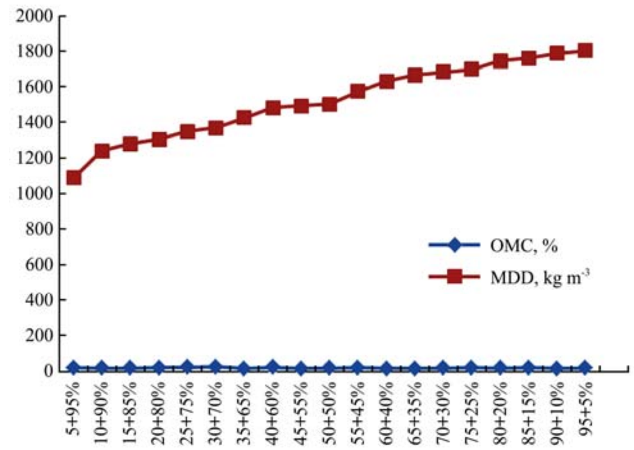

Figure 1 The graph shows the mixed ratios of termite mound and clay soil

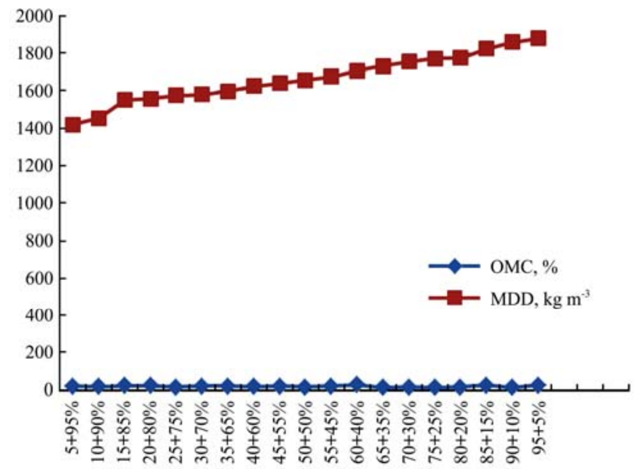

Figure 2 The graph shows the mixed ratios of termite mound and laterite soil

3.1 Particle size distribution

The textural class of the termite mound was sandy clay loam, while surrounding soil (Laterite soil) was sandy loam. There are no significant different ($p\geq0.05$) within the soil profiles for the soil samples (Table 2).

3.2 Physical properties of the soil samples in the study area

The (BD) of the laterite soil has the highest values of 1.54 g cm^{-3} (1540 kg m^{-3}) follow by termite mound of 1.46 g cm^{-3} (1460 kg m^{-3}) and clay with the least value of 1.34 g cm^{-3} (1340 kg m^{-3}). Clay soil has the highest (OMC) of 21.1%, follow by termite mound of 19.2% and laterite have the least value of 18.5%. The termite mound has the highest values in terms of (MDD) and (CS), followed by laterite soil and least values was clay (Table 2). The OMC of a soil at the time of compaction significantly affects the dry density which in turns affects at least the strength of the samples. The OMC serves as a guide for the preparation and mixing of the block units. Moisture contents affect strength development and durability of the material and have a significant influence on the long term performance of stabilized soil material especially on bonding with mortars at the time of construction. The compressive strength is the most universally accepted criterion or determining the quality of material for construction.

3.3 Optimum moisture content and maximum dry density

For termite mound and clayey soil, the minimum value of optimum moisture content was 13.00% and it occurred at mixed ratio of 40% and 60%, while the maximum value was 24.00% and it occurred at mixed ratio of 30% and 70%. And also the maximum dry density minimum value was 1087 kg m^{-3} and it occurred at mixed ratio of 5% and 95%, while the maximum value was 1848 kg m^{-3} and it occurred at mixed ratio of 100% and 0% (Figure 1). Increasing the termite mound content in the mixed ratio led to increasing in maximum dry density with no significant effect on the optimum moisture content as shown in Figure 1. For termite mound and laterite soil, the minimum value of optimum moisture content was 12.50% and it occurred at mixed ratio of 75% and 25%, while the maximum value was 27.50% and it is occurred at mixed ratio of 60% and 40%. And also the maximum dry density minimum value was 1420 kg m^{-3} and it occurred at mixed ratio of 5% and 95%, while the maximum value was 1885 kg m^{-3} and it occurred at mixed ratio of 100% and 0% (Figure 2). The

(OMC) for both mixed ratios were not affected by the inherent properties of the mixtures, similarly, the trend showed that increasing of termite mound content, (MDD) was increased (Figure 2). The trend exhibit time and environment dependant, while the maximum dry density for both the mixed ratios were depend upon the inherent property of termite mound only. Hence, MDD is direct proportional to termite mound content and inversely proportional to clayey and laterite soil contents (Mijinyawa et al., 2007, Yohanna et al., 2003). The Figure 1, shown the different values for both minimum and maximum for MDD recorded between the mixed ratios and they were not significant different (P≥0.05). Both mixed ratios, the maximum dry density was below the minimum specified value of 2000 kg m^{-3} (2.0 g cm^{-3}) for road construction in Nigeria (Briges, 2007). But the maximum dry density of laterite and termite additive started from 85%-95% mixed ratios (1825-1880 kg m^{-3}) have values greater than 1810 kg m^{-3} recommended for building construction in Nigeria (Madedor, 1992; Oshodi, 2004). Hence, Termite mound additive can be used for building construction.

3.4 Compressive strength and unconfined compressive strength

For termite mound and clayey mixture, the compressive strength ranging between (1.43×10^{-4} and 6.71×10^{-4}) KN mm^{-2}, the results of the ration of termite mound 5% mixed with 95% clayey soil gave the minimum compressive strength at which the soil failed in stress to be 1.43×10^{-4} KN mm^{-2}, while maximum compressive strength occurred at 95% termite mound mixed with 5% of clayey soil. Similarly, unconfined compressive strength ranging between (7.15×10^{-5} and 3.36×10^{-4}) KN mm^{-2} and formed the same pattern with the compressive strength. For termite mound and laterite soil mixed ratio, the compressive strength ranging between (3.09×10^{-4} and 1.07×10^{-3}) KN mm^{-2}, the results of termite mound 5% mixed with 95% clayey soil gave the minimum compressive strength at which the soil failed in stress to be 3.09×10^{-4} KN mm^{-2}, while maximum compressive strength was 1.07×10^{-3} KN mm^{-2} and it is occurred at 100% anthill mixed with 0% of clayey soil. Similarly, unconfined compressive strength ranging between (1.55×10^{-4} and 5.35×10^{-4}) KN mm^{-2} and formed the same pattern with the compressive strength. The compressive strength of termite mound only is higher than the values of the termite mound mixture. The relationship between compressive strength of clay and laterite soils at the same termite ration is presented in Figure 3.

Compressive strength values of the termite mound and laterite was almost double the values of termite mound and clayey soil (Table 3). This difference may be attributed to:

i. Allotropic nature of clay soil
ii. Impurity in the clayey soil
iii. Difference composition of clay and laterite
iv. Difference retention of moisture content.

Despite, difference values of for both minimum and maximum for compressive strength and unconfined compressive strength recorded between the mixed ratios and they were not significant different (P≥0.05).

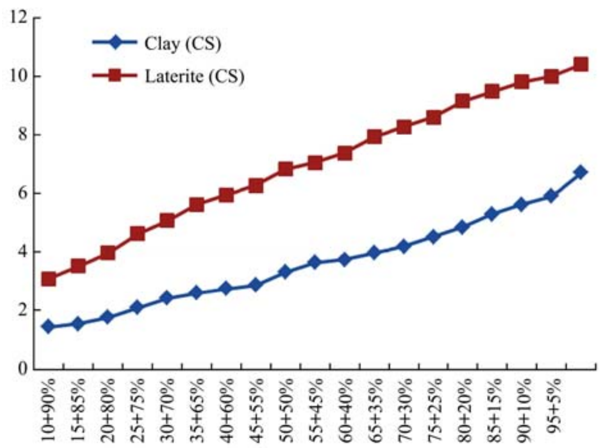

Figure 3 The relationship between compressive strength of clay and laterite soils at given termite mound ratios

4 Conclusion

The results from this study indicated that: the texture class for the termite mound and laterite soil were sandy clay loam and sandy loam respectively. The termite mound has the highest maximum dry density and compressive strength than other two soil samples. Increasing of termite mound ratio has a significant increase in maximum dry density for both the soil samples and also has little effect on moisture content for both soil samples. Termite mound as additive can increase the strength of the soil samples. Termite mound as an additive has much more effective in laterite soil than in clay soil in term of compressive strength and maximum dry density. The compressive strength of the laterite almost doubled that of the clay soil at the same termite ratio.

References

Adam, E. A., and A. R. A. Agib. 2001. *Compressed Stabilized Earth Block Manufactured in Sudan,* France, Paris: Graph print for United Nation Education, Scientific and Cultural Organization

American Public Health Association (APHA). 2005. *Standard Methods for the Examination of Water and Wastewater,* 16th and 17th Eds. Washington, DC; American Water Works Association, Water Control Federation.

Briges, T. ed. 2007. *Nigeria Highway Code.* Concept Publisher, Lagos, Nigeria.

FAO/IIASA. 2008. *Harmonized World Soil Database,* Version 1.0, FAO, Rome, Italy and Laxenburg, Austria, ASA.

Frederic, B. B. 2003. *Engineering Treatment of Soil Encyclopaedia of Soil Science*. Dordrecht: Kluiver Academy Publisher

Holt, J. A., and M. Lepage. 2000. *Termites and Soil Properties: In Termites: Evolution, Sociality, Symbioses, Ecolog,* eds. T. Abe, D. E. Bignell, and M. Higashi, 389-408. Dordrecht: Kluwer Academic Publishers.

Jouquet, P., D. Tessier, and M. Lepage. 2004. The soil structural stability of termite nests role of clays in Macrotermes bellicosus (Isoptera, Macrotermitinae) mound soils. *European Journal of Soil Biology,* 40: 23–29.

Jude, C. C., and O. O. Ayo. 2008. Influence of termite infestation on the spatial variability in the guinea savanna region of Nigeria. *Geoderma,* 148: 357–363

King, T. 2006. The value of ant-hill in grassland Bristish wildlife. *Journal of Soil Ecology*, 17(B): 392–397.

Lavelle, P., and A. Spain. 2001. *Soil Ecology*. Dordrecht: Kluiver Academy Publishers.

Madedor, A. O. 1992. The impact of building materials research on low cost housing development in Nigeria*. Engineering Focus*, 4(2): 37–41.

Manuwa, S. I. Physico-chemical and dynamic properties of termite mound soil relevant in sustainable food production. In *9th African Crop Science, Conference Proceedings*, 365-369. Cape Town, South Africa, 28th September-2nd October, 2009.

Minjinyawa, Y., E. B. Lucas, and F. O. Adegunioye. 2007. Termite mound clay as material for grain silos construction. *Agricultural Engineering International, CIGR E-Journal:* 43–51.

Odumodu, R. C. 1999. Clay bricks industry in Nigeria problem and prospects. *Engineering Focus*, 3(6): 37–40.

Okoli, O. G., and I. K. Zubairu. 2002. Preliminary study of properties of compressed building blocks stabilized with Rice Husk Ash. In *Proceedings of the Millennium Conference Building in the 21st Century,* ed A. T. Lawal, 64–74. Zaria: Building of Department, Ahmadu Bello University.

Oshodi, O. R. 2004. Techniques of producing and dry stacking interlocking blocks. In *Nigerian Building and Road Research Institute (N.B.R.R.I) Workshop on Local Building Materials*, 234–238. Ota, Ogun State, Nigeria, 19-20 July.

Yohanna, J. K., U. Fulani, E. D. Azagaku, and A. D. Anda. 2003. Prosect of using anthill materials for the control of seepage in earthdam. *Proceeding of the Nigerian Institution of Agricultural Engineering*, 135–143. 5-6 August.