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Properties and Shear Strength of *Insitu* and Compacted Termite Mound Soil (TMS) in Akure South-western Nigeria

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Abstract: Insects have been recognised as an important factor that regulates soil processes and consequently the development of soil profile and its characteristics. Termites are common insects that abound in Nigerian soils and the mounds they form are common features of agricultural landscape. The purpose of this paper is to investigate the physical, chemical and strength properties of termite mounds in Akure, south-western Nigeria. It was found that the texture of a termite mound could vary from top to bottom and from that of the surrounding soil 3.0 m away and that clay fraction was more prominent than silt and sand. Consistently, there was less organic matter, organic carbon, and nitrogen in the termite mound than in the surrounding soil. Also, the liquid limits and the plasticity index of the termite mounds were higher than that of the surrounding soil. Similarly, it was observed that the insitu mean shear strength (cohesion) of the mounds was higher than that of the surrounding soil. For the mounds, it ranged between 63.11 to 120.11 kPa while for the surrounding soil 40.52 to 72.46 kPa. The shear strength of the compacted soils was also determined in the laboratory having subjected them to 5, 10 and 15 Proctor's hammer blows. The highest shear strength about 194 kPa corresponding to 15 blows occurred at about 11.7 % (db) moisture content.
Key words: termite mound, properties, shear strength, Nigeria

INTRODUCTION

Termites have been identified as common biological agents that produce significant physical and chemical modifications to tropical and subtropical soils (Semhi *et al.*, 2008, Pomeroy, 1976; Briese, 1982; Akamigbo, 1984; Lobry de Bruyn and Conacha, 1990 and 1995; Mando *et al.*, 1996; Heikens *et al.*, 2001; Semhi *et al.*, 2008).

It has been reported that termites go through a sequence of actions, from fetching, carrying, to cementing mineral particles into mounds by using their salivary secretion (Howse, 1970; Wood, 1988; Donovan *et al.*, 2001; Ndiaye *et al.*, 2004; Vandecasteele *et al.*, 2004; Lopez-Hernandez *et al.*, 2006). Also, it has been shown that termite activity increases the content of organic matter in the soils that they use for the construction of their nests and also modifies the clay mineral composition of these soil materials (Mahaney *et al.*, 1999; Jouquet *et al.*, 2002; Roose Amsaleg *et al.*, 2004).

Termites process considerable quantities of material in their building their nests and consequently greatly influence the soil properties, as compared to the surrounding soils (Lee and Wood, 1971 and Lobry de Bruyn & Cornacher, 1990). Many studies emphasized the role of termite on soil texture and chemical properties (Pomeroy, 1983; Wood *et al.*, 1983), soil nutrient cycling and soil metabolism (Arshad *et al.*, 1982; Menaut *et al.*, 1985; Abbadie and Lepage, 1989). But the strength properties of termite mound soil are very scarce in literature.

This work was embarked upon to understand the physical, chemical and strength properties of *insitu* and compacted TMS in Akure south western Nigeria.

Literature shows that termite mound soils generally have high clay content, enhancing water storage capacity.

It was reported (Rupela et al. 2006) that African, farmers collect termite-mound soil and apply to cropped fields (Watson 1977) as it can be rich in available nitrogen (by about 20%), total P (by 2.25 times) and organic carbon (by 9.3%) than adjacent soil (Lopez-Hernandez 2001)

It was reported that in the Southern Province of Zambia soils with low water retention capacity are common, so when termite mound soil is spread on these soils it results in higher soil moisture content and improved crop growth. Literature also shows that termite mound soils have high levels of calcium, phosphorus and organic matter, which also contribute to better crop development, especially on the poor soils in the area. Plants also take up nutrients very easily from termite mound soil and that TMS is proving a viable option to local farmers who can not afford to buy expensive inorganic fertilizers (Siame, 2005).

It was reported (Nottidge *et al.*, 2007) that the use of chemical fertilizers alone to sustain high crop yield has not been successful due to the prevailing acidic conditions, nutrient leaching and degradation in soilphysical properties. Also, high cost, unavailability of commercial lime necessitated studies in to locally available and adoptable sources of lime and fertilizer materials to stabilize and improve physical and chemical properties and productivity of soil.

The objectives of this project are: to determine the physical and chemical properties of TMS; to determine the shear strength of TMS and compare with surrounding soil of about 3 metres away from the mound; to determining the influence of moisture content on the shear strength at different levels of compaction.

MATERIALS AND METHODS

Study site

The study was carried out within the campus of The Federal University of Technology, Akure, Nigeria (7^0 15^1N, 5^0 15^1E). The annual precipitations in the area ranged from 130 to 150 cm with average relative humidity (80%). The climate consists a long wet season from mid March to July, short dry season (August break) July to August, short wet season September to October and long dry or harmattan season from November to Mid March. The vegetation is high forest (forest regrowth).

Soil description and sampling

Soil samples were collected from three different termite mounds and soil from 3.0 m away from each mound was also collected (as control) at different location within the study area. Two soil samples were taken from each mound, that is, top (T) and base (B) and the third sample, control, that is , soil from surrounding (S) at 3.0 m away from the base of the mound. The following are the break down of the collection: Mounds A, B and C have heights 2.0, 1.1 and 1.2 m respectively with diameters of about 4.5 to 8.5 m. Samples were collected between 16th and 18th May 2008.

The chemical analysis were determined by standard methods similar to that reported (Awadzi *et al.*,2004)**.** The soil samples were air dried and passed through a 2-mm sieve, and the content of gravel (>2 mm) by weight was determined. Particle size distribution was determined by sieving sand fractions and by using the hydrometer method for determining the silt and clay fraction. Soil pH was determined potentiometrically in 0.01 M CaCl2 at a soil-solution ratio of 1:2.5. Exchangeable cations were extracted with 1M NH4OAc at pH 7. Calcium (Ca) and magnesium (Mg) were determined by atomic absorption spectrophotometry while potassium (K) was determined by flame photometry. Exchangeable acidity (H^+ and Al^{3+}) was extracted with 1 M KCl and determined by titration with NaOH. Total carbon content was determined by dry combustion using an Eltra CS500-apparatus. Total nitrogen (N) was determined by the Kjeldahl method. Total phosphorus (P) was determined spectrophotometrically by the molybdenum blue method using ascorbic acid as a reductant after the soil samples were heated to 550 ºC and extracted with 6 M sulphuric acid

Shear strength determination (In situ)

This was carried out at the field (in situ) on all the samples and a shear vane tester (16mm diameter vane) was used to determine the shear strength at different location on each sample and the average strength was calculated. The moisture content of all the samples was determined. Measurements were taken at depth 40, 80 and 120 mm for each sample and this mean value of each set of three depths readings were calculated.

The fieldwork was carried out on the 15th August, 2008.

Shear strength determination of compacted soil (Laboratory work)

The test was conducted on all the samples sieved with 2 mm sieve size, using the shear vane tester. The soil samples were subjected to 5, 10 and 15 blows respectively with a standard proctor rammer (2.5 kg) at different moisture content level in a cylindrical metal mould. The mould is 100 mm in diameter and 120 mm height. A round wooden pad was placed on the soil before compaction in order to ensure uniform compaction of the soil in the mould. The shear vane is graduated in kilopascal (kPa). Measurements were taken at depth 40 and 80 mm respectively on each sample and the mean value of each set of two-depth reading were calculated and recorded.

RESEARCH RESULTS

Soil Textural Classification

The results of the nine soil samples that were analyzed in the laboratory to determine the textural classification of the three mounds sampled are shown in Table 1

Table 2 shows the physical, chemical properties of the termite mound soils.

Table 3 shows the values for the consistency limits as determined in the laboratory, that is, the liquid limit, plastic limit, shrinkage limit and plasticity index.

Table 1. Soil Textural Classification

S/N	Samples	Sand (%)	Silt (%)	Clay (%)	Class
TERMITE MOUND A					
1	SAT	34	38	28	CL
2	SAB	34	20	46	C
3	SAR	54	8	38	SC
TERMITE MOUND B					
4	SBT	32	22	46	CL
5	SBB	32	22	46	CL
6	SBR	38	16	46	CL
TERMITE MOUND C					
7	SCT	32	24	44	CL
8	SCB	34	24	42	C
9	SCR	40	22	38	CL

CL=clayloam,C=clay,SC=sandyclay

Shear strength (*In situ)*

The In situ shear strength of the termite mounds soil samples determined at different moisture content levels are as show in Table 4. The influence of moisture content on the shear strength of compacted termite mound soils at different compaction levels of proctor hammer blows , 5, 10, and 15 and different moisture content are presented in Figs. 1-3. for termite mound A, B and C respectively.

Table 2. Physical, chemical and organic properties of TMS

S/N	Samples	O/M (%)	O/C (%)	N (%)	P (mg/kg)	Ca^{2+} (Cmol/kg)	K^{+} (Cmol/kg)	Mg^{2+} (Cmol/kg)	Na^{+} (Cmol/kg)	PH
MOUND A										
1	SAT	1.69	0.98	0.12	6.92	1.30	0.351	1.00	0.148	6.06
2	SAB	1.38	0.80	0.10	4.16	1.50	0.289	1.00	.0130	5.85
3	SAR	2.10	1.22	0.15	5.27	1.20	0.241	1.00	0.126	5.98
TERMITE MOUND B										
4	SBT	1.62	0.94	0.12	6.87	2.00	0.249	1.70	0.139	5.19
5	SBB	1.62	0.94	0.13	1.76	2.00	0.233	1.10	0.126	5.30
6	SBR	2.13	1.24	0.16	0.80	2.00	0.264	1.40	0.165	4.91
TERMITE MOUND C										
7	SCT	1.93	1.12	0.14	4.24	2.00	0.295	1.00	0.157	5.76
8	SCB	1.96	1.14	0.15	7.11	1.90	0.282	1.00	0.161	5.62
9	SCR	2.27	1.32	0.17	3.36	1.30	0.287	1.00	0.161	5.82

S=sample A=mound A T=top B= bottom/base R = surrounding/adjacent soil

Table 3. Consistency Limits of TMS

TERMITE MOUND A					
S/N	Samples	W_{LL} (%)	W_{PL} (%)	W_{SL} (%)	P.I.
1	SAT	36.0	20.0	10.0	16.0
2	SAB	38.0	22.0	11.0	16.0
3	SAR	29.0	19.0	5.0	10.5
TERMITE MOUND B					
4	SBT	43.0	28.0	12.0	15.0
5	SBB	42.0	22.0	15.0	20.0
6	SBR	35.0	22.0	9.0	13.0
TERMITE MOUND C					
7	SCT	34.0	19.0	11.0	15.0
8	SCB	33.0	21.0	9.0	12.0
9	SCR	29.0	19.0	7.0	10.0

Table 4. *In Situ* Shear Strength of TMS

	MOUND A			**MOUND B**			**MOUND C**		
	SAT	SAB	SAR	SBT	SBB	SBR	SCT	SCB	SCR
MC (%)	13.0	20.9	16.7	17.8	16.9	24.5	18.0	16.2	21.6
Depth (mm)	Shear strength (kPa)								
40	67.3	32.71	25.98	88.84	103.64	48.46	48.05	84.39	41.73
80	80.76	66.89	37.69	100.28	123.83	72.01	73.09	117.51	66.36
120	75	89.78	57.88	95	132.85	96.91	109.96	152.50	70.93
Mean values	74.43	63.13	40.52	94.74	120.11	72.46	77.03	118.13	59.67

S=sample A=mound A T=top B= bottom/base R = surrounding/adjacent soil

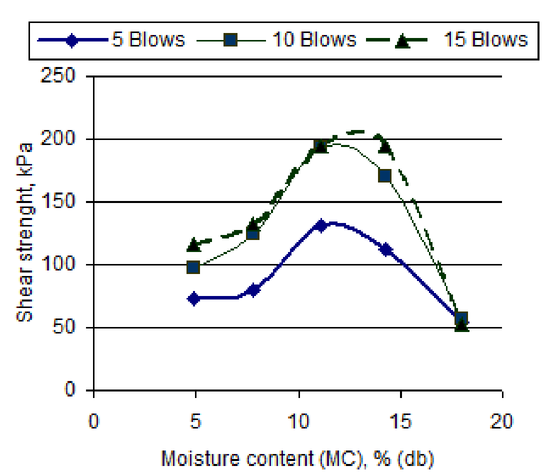

Fig.1a. Effect of moisture content on shear strenght of TMS (sample SAT)

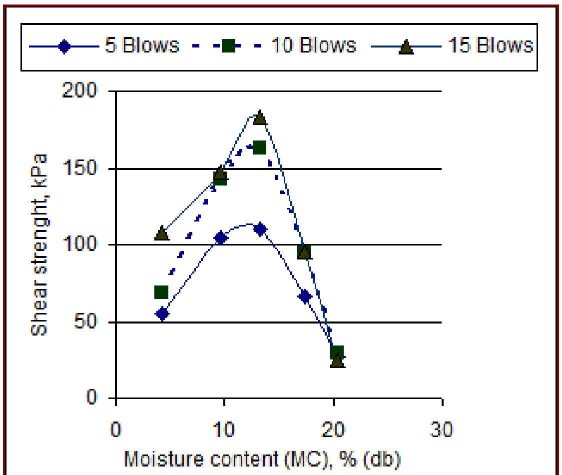

Fig.1b. Effect of moisture content on shear strenght of TMS (sample SAB)

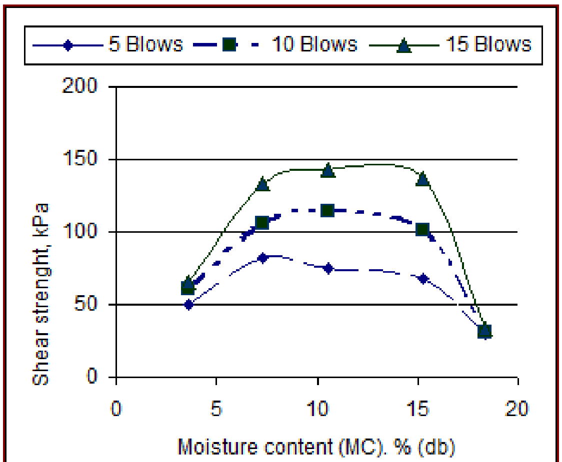

Fig.1c. Effet of moisture content on shear strenght of TMS (sampleSAR)

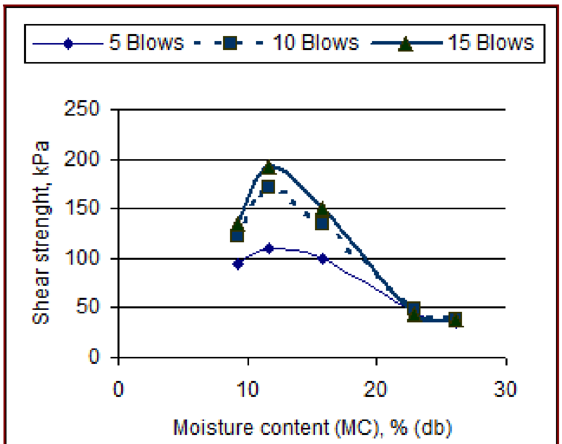

Fig.2c. Effect of moisture content on sher strenght of TMS (sample SBR)

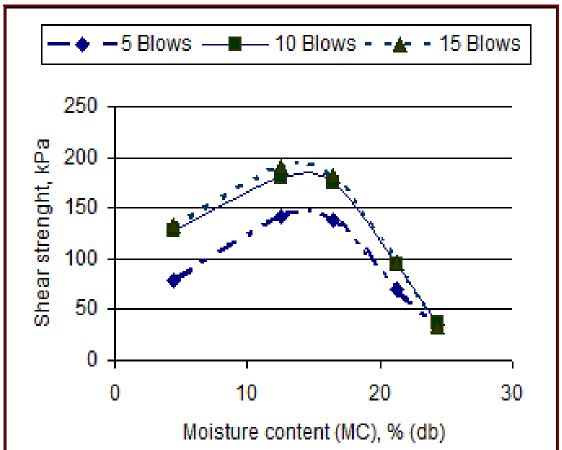

Fig.2a. Effect of moisture content on shear strenght of TMS (sample (SBT)

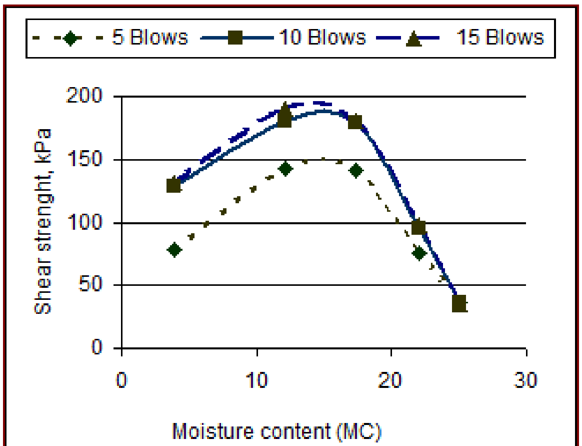

Fig.2b. Effect of moisture content on shear strenght of TMS (sample SBB)

DISCUSSION AND CONCLUSIONS

Textural classification

The textural classes of the TMS samples show tha clay fraction is dominant class that is common in termites mounds. It was observed that the textural class of a TMS may not necessarily be all clay from top to bottom of the mound as shown in mounds A and C. It was also observed that the surrounding soil may have a textural class that is actually different from that of the mound.

Physical, chemical and organic properties

The Table 2 seem to show that termite mound soils are acidic soils but less acidic (greater pH values) than surrounding soils without termite mounds, though for mound C, the soil seem to be more acidic (lesser pH values). The organic matter content of the TMS were lesser than that of the surrounding soil where there is no mound as shown Tabl2 2. This, however is contrary to some reports that claim that termites activities increases organic matter of the mounds where they live.

Consistency limits

It was observed that the termite mound soil samples have high plasticity index which indicate that they have high clay fractions. But sample SAR, SBR and SCR have low P.I. comparing the mounds. The liquid limit of mound B is the highest among the three mounds with high plastic limit, shrinkage limit and plasticity index.

Insitu shear strength

The shear strength of the termite mound soil increased with depth. The base of the mounds recorded highest shear strength compared to the top portion of the mounds. The shear strength of the surrounding soils is low compared to the mounds, but SBR has high shear strength than other surrounding soil i.e. SCR and SAR. The mounds shear strength increase when the moisture content is very low especially during dry season and decrease as the water content increase (raining season) and it may even break during excess rainfall as a result of high water content, in the case of mound A, which had collapsed due to heavy amount of rainfall. Mound B has the highest mean shear strength of the total mean value of 94.56 kPa top portion (SBT) and 120.11 kPa base portion (SBB), this is due to high clay content present in it. Also SBR has 72.46 kPa. Mound A has the least shear strength of the total mean value of 74.03Kpa top portion (SAT) and 63.13Kpa base portion (SAB), this is due to presence of sandy soil mixed with clay soil. It was also discovered that each mound has holes or central holes within the mound building strong wall/structure to cover it.

Shear strength of compacted termite mound soils

The shear strength of the compacted soil in the moulds increased with depth for instance SAT under 5-blows has shear strength of 16.15 kPa at 40 mm depth and 129.22 kPa at 80 mm depth. The result of the tests shows that the basal portion of each mound has higher shear strength with depth compared to the top portion; SCT has a total mean value at 5-blows to be 140.66 kPa at maximum value while SCB has total mean value of 145.37 kPa at maximum value. Samples SAT, SAB and SAR have the least or lowest shear strength, this is as a result of higher percentage of sandy soil in the mounds and the immediate surrounding (Figs 1a 1c).

From the test, it was observed that mound B has the highest total mean value of shear strength as shown (Fig 2). This isprobably due to the high clay content present in which made it more cohesive than others, likewise SBR has the highest shear strength of 121.14Kpa at 5-blows of the maximum values. This is also a result of the high cohesiveness and presence of clay content compare to the other samples SAR and SCR.

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