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GEOTECHNICAL PROPERTIES OF TERMITE MOUND SOIL FROM IKA AREA OF DELTA STATE, NIGERIA

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ABSTRACT

The determination of geotechnical properties of habited termitaria (termite mounds) from nine different locations in Ika community, Delta State, Nigeria was carried in this paper. The geotechnical properties investigated were grain size, Atterberg limits, shear strength, California bearing ratio (CBR), and specific gravity. Chemical properties of the termite mound soil were also examined in comparison with the adjacent surrounding soil. Idumuesah sample shows very high plasticity, while the other eight showed medium plasticity. The plasticity index carried out to compare plasticity characteristics showed the soil to be non-cohesive and non-plastic and its value ranged from 10.83% to 28.45% at both areas. The compaction test shows that the optimum moisture content (OMC) ranged from 7.20% to 17.10%, while the maximum dry density (MDD) ranged from 1.74KN/m^2 to 2.10KN/m^2. The MDD are generally low which indicates the soils are not compact but very loose. The specific gravity ranged between 2.34 to 2.58.

1. INTRODUCTION

Termites are an important soil forming factor in many areas, helping in soil turnover and creating small zones of better aerated and more fertile soils by bringing soil material up from the subsurface to the surface (Olowofoyeku *et al.*, 2016). Nest construction by termites ranges from inconspicuous belowground chambers to large aboveground mounds called termitaria. The termitaria are built of soil and earth particles which are cemented together to form hard bricklike material which are very resistant to weathering and erosion as well as being very difficult to chip with a sharp pick (Adeyemi and Salami, 2004). Termites, through activity of mound and subterranean gallery construction and soil particle redistribution, alter mineral and organic soil composition, topography, hydrology and drainage, and nutrient flow rates which can ultimately influence vegetation and regional biodiversity (Dangerfield *et al.*, 1998).

These modifications of soil properties associated with termitaria, further affects tree establishment and plant species composition and richness which ultimately alter the distribution of other vertebrate and invertebrate animal species (Longair, 2004).

Kosemani (2010) studied the use of termites' clay materials partial as replacement for fine aggregate of the concrete mix used in the production of interlocking concrete paver. Results from this research showed that compressive strength of the interlocking concrete pavers increased with age and decreased with increasing replacement of fine aggregate with termitaria material. Olusola *et al.* (2006) also carried out studies on termite hill and lime as partial replacement for cement in plastering. Test results showed that the compressive strength of the mortar cubes increases with age and decreases with increasing percentage replacement of cement with lime and termite hill. The soil association with termitaria typically has lower soil bulk density and elevated mineral carbon, nitrogen, phosphorus, magnesium, calcium, and clay content compared to the surrounding soils adjacent to the termitaria (Sileshi *et al.*, 2010). Ayininuola (2009) and Abe and Oladapo (2014) recorded a higher organic carbon content, C/N ratio, Ca, Mg, K and P in termitaria of Macrotermes and Odontotermes spices than the surrounding soils in Ado Ekiti, Nigeria.

Furthermore, due to the fact that termites are bioturbators, they are responsible for the higher levels of the metals in termitaria soil since termites are known to feed on organic matter which could result in elevated levels of elements in termitaria. Konate *et al.* (1998) discovered that there were elevated levels of iron and titanium in termitaria soils compared to the surrounding soils in their quest in finding various means of prospecting for these two metals. They therefore concluded that termitaria sampling can be used as preliminary step in mineral prospecting since they provide an indication of the potential of the positive anomaly and enables a judgment on the scale of the ore metal accumulation. Some of the soil properties that can be modified by *Macrotermes* species activity have great influence on structural features, such as bulk density and structural stability (Holt and Michel 2000).

Generally, soils are being reworked by the activities of termites. The determination of the effect of reworking by termites on the geotechnical properties of the soil and the use of these termitaria as an engineering material is the major objective of this study.

2. MATERIALS AND METHODS

2.1. Sample Collection

Termite mound soil samples were collected from nine different locations (Abavo, Agbor, Owa, Igbodo, Umunede, Otolokpo, Ute-Okpu, Ekuku-Agbor and Idumuesah) in the Ika area of Delta State (Figures 1 and 2). At each location, samples were taken from the top, middle and base of each of five termitaria and composited. The samples were dried overnight, ground in an agate mortar and a representative fraction was selected for analysis. The apparatus used for this test included B.S Test Sieves, Mechanical Shaker, Weighing Balance and Sieve brush. Known weights of samples were placed on carefully selected sieves.

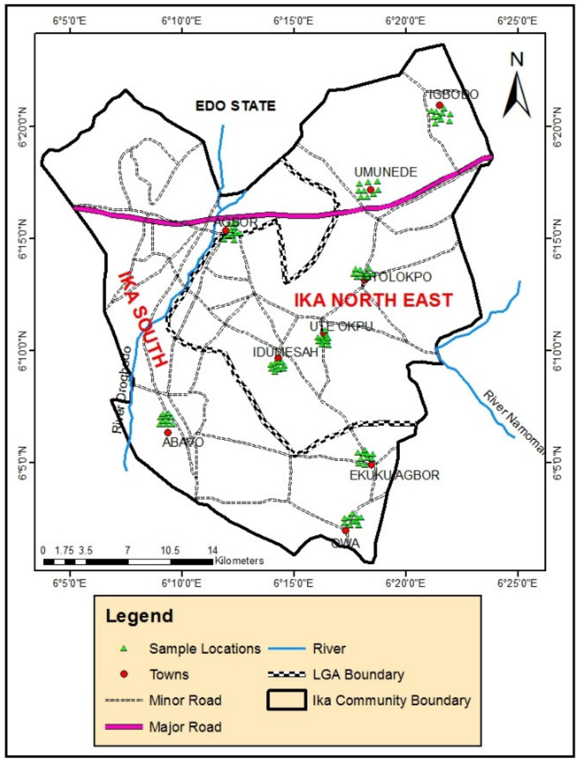

Figure 1: Map of Ika area showing sampling locations

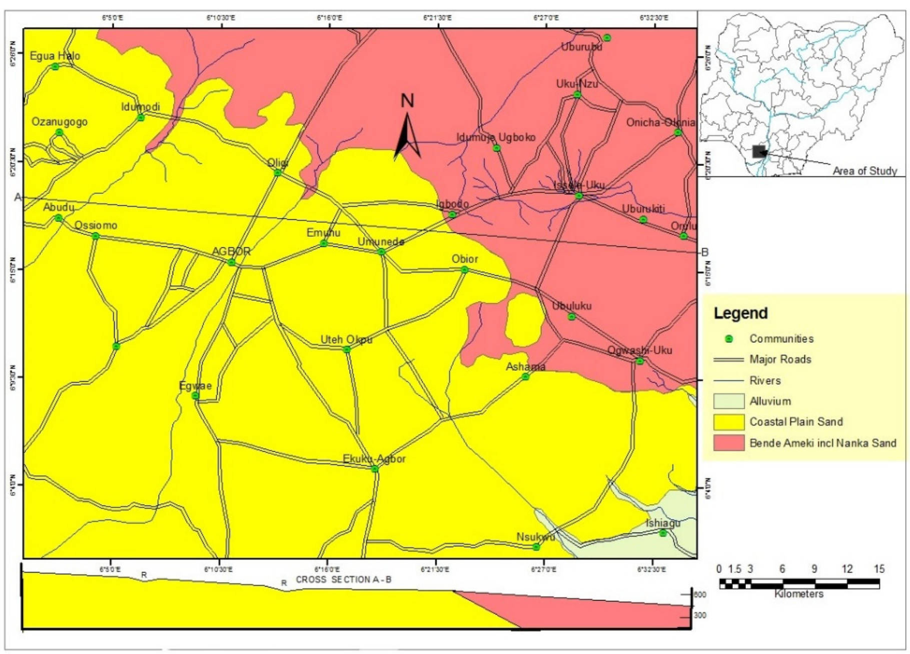

Figure 3: Geological map of study area

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2.2. Determination of Geotechnical Properties

Geological investigations were carried out which include both field and laboratory studies. Nine distributed samples were taken for laboratory analysis. Three index properties including Atterberg limit, sieve analysis and specific gravity were determined and two performance tests; compaction and triaxial test were conducted.

2.2.1. Sieve analysis

Sieving was done by means of internal and vertical movement of the sieve accompanied by a jarring action. The cumulative percentage retained and cumulative percentage passing were calculated. The coefficient of uniformity (C_u) and coefficient of curvature (C_c) were calculated to determine the grading of soil. For a material to be well graded it must fulfill one or all of the following: that C_c is between 1.0 and 3.0; and or C_u must be greater than 4.0 for gravels and greater than 6.0 for sands. Otherwise it is poorly graded. D_{10} = grain size value at 10% passing, D_{30} = grain size value at 30% passing, D_{60} = grain size value at 60% passing has been used to calculate C_c andC_u. 200g of prepared samples were sieve washed and dried. The following formulae were used to calculate C_u and C_c respectively.

$$Cu = \frac{D_{60}}{D_{10}} \tag{1}$$

$$Cc = \frac{(D_{30})^2}{(D_{10})(D_{60})} \tag{1}$$

2.2.2. Atterberg limit test

2.2.2.1. *Liquid limit (LL)*

A certain quantity of oven-dried soil sample was pulverized and sieved through 425µ (Micrometer) British Standard (B.S.) No. 40 sieve. The soil material was then mixed with water until a uniform paste was achieved and the paste was placed in the cup of the liquid limit device. The crack of the device was then turned and the number of blows necessary to close groove were noted. Care was taken to ensure that the groove was closed by a flow of the soil and not by slippage between the soil and the cup.

2.2.2.2. *Plastic limit (PL)*

The PL is defined as the moisture content in percentage at which the soil crumbles when rolled into threads. The test is simple and is performed by repeatedly rolling an ellipsoidal soil mass by the finger on a glass plate. Some amount of the pulverized soil sample that was sieved through sieve B.S. No. 40 sieve was used for plastic limit test. The test soil thoroughly mixed with water and to such an extent of water content, which just allowed a thread of about 3.2 mm to be rolled. The rolled sample was achieved on a glass plate and the process was repeated until a thread of about 3.2 mm in diameter began to show signs of crumbling. Some of the crumbling materials were taken for water content determination, which when arranged, gives the plastic limit. Two of these determinations were obtained which were averaged to give the plastic limit.

2.2.2.3. *Plastic index*

This difference between the liquid and the plastic limit of any particularly disturbed sample (LL – PL).

2.2.3. ***Specific gravity test***

The following formula was used to calculate the specific gravity after necessary measurement were taken:

$$\text{Specific gravity} = \frac{M_2 - M_1}{(M_4 - M_1)(M_3 - M_2)} \tag{3}$$

Where: M_1= mass of conical flask, M_2 = mass of conical and soil, M_3 = mass of conical flask, soil and water, M_4 = mass of conical flask and water.

2.2.7. Compaction test

This was done by mechanical means (Brian, 1978).

2.2.8. Triaxial shear test

Triaxial test was used to determine the shear strength properties of soil samples. The type of the triaxial test conducted was consolidated undrained teast. Test samples of 50mm in diameter with a height to length ratio between 2 and 3 using the optimum moisture content obtained from compaction test were prepared. The samples were encased by a thin membrane and placed inside a plastic cylinder chamber that was filled with water. Each sample was subjected to a normal stress or confining pressure (δ_3) by compression of the fluid in the chamber. Axial stress (load, δ_1- δ_3) also called deviator stress was applied constantly through a vertical loading ram. Rock work software were used to plot the graph of normal stress to determined angle of internal frictional and cohesion.

3. RESULTS AND DISCUSSION

3.1. Geotechnical

Typical grain size distribution of sample termite mound is shown in Figure 3, and the results show that the termite mound soil has higher clay content than the surrounding top soil samples and with particle sizes more homogenized in comparison with the top soil samples. Termites have the capacity for enriching the termitaria with clay particles during the reworking activities, a characteristic that affects the physical, chemical and nutrients availability (Lee and Wood 1971; Huldo and McDowell, 2004). This figure shows that the sample is largely constituted of sands which ranges from fine to medium grain size (0.074mm – 0.420mm) for fine sand and 0.42mm – 2.00mm for medium sand) using Unified Soil Classification System (USCS). This type of fine to medium grain sands can act as good sub-grade materials showing high specific gravity and it also correlates with high mechanical strength for sub-grade materials.

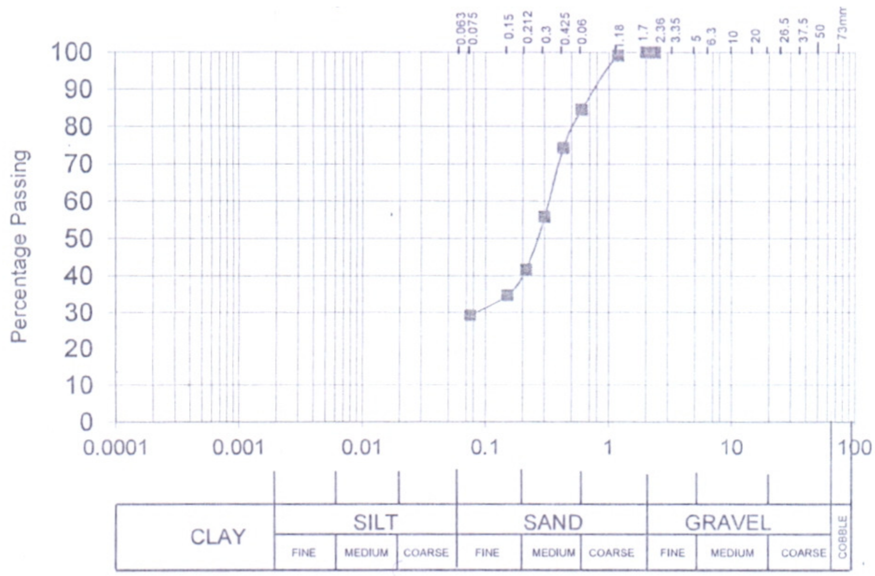

Figure 3: Typical grain size distribution chart from Agbor sampled location

3.2. Liquid Limit

The values of liquid limits showed in Table 1 of the termite mound soil samples from the nine locations are (A) 29.24% (B) 24.64% (C) 31.63% (D) 27.55% (E) 29.01% (F) 32.32% (G) 27.35% (H) 30.50% and (I) 53.75% with the highest value recorded at 53.75% compared to 24.64% recorded at sample (B).

Table 1: Atterberg limit test results

S/No	Sample No	Atterberg Limit Tests			Plasticity
		LL (%)	PL (%)	PI (%)	
1	A	29.24	16.81	12.42	Medium
2	B	24.64	13.49	11.15	Medium
3	C	31.63	18.25	13.37	Medium
4	D	30.55	19.72	10.83	Medium
5	E	29.61	17.57	12.03	Medium
6	F	32.32	18.56	13.76	Medium
7	G	27.35	14.36	12.99	Medium
8	H	30.50	17.56	12.94	Medium
9	I	53.75	25.30	28.45	High

3.3. Plastic Limit

The plastic limit shows (A) 16.81%, (B) 13.49% (C) 18.25% (D) 19.72% (E) 17.57% (F) 18.56% (G) 14.36% (H) 17.56% and (I) 25.30%. There was a noticeable variation also in the plastic limit with 25.30% in sample (I) compared to 13.49% in sample (B). Variations in different locations are shown in Table 1. The result revealed that the termite mound soil was predominantly sand with poor clay percentage, except for sample I (Idumuesah) which has predominantly silt with a good clay percentage. The liquid and plastic limits were used to obtain the plasticity index which is a measure of plasticity of the soils (Onwumesi 1990).

3.4. Plasticity Index

The values of the plastic index obtained ranged from 10.83% to 28.45%. This shows low plasticity, except Idumuesah sample with medium plasticity at 28.45% according to Burmister (1997). In the standard range of plastic limit of soil, according to Clayton and Juckes (1978), plastic limit of soil below 35% shows low plasticity. In Table 1 the result of plastic limit test presented ranged from 13.49% to 25.30% < 35%. The soil from the Ika area appears not cohesive.

3.5. Soil Compaction Test

Compaction test shows the maximum dry density (MMD) and the optimum moisture content (OMC) of the soil. One of the major reasons for carrying out compaction test on soil is to increase the soil strength and to prevent seepage of water through the soil. Hence both soil water content and the bulk density (dry density) affect soil strength, which will increase when the soil is compacted to a higher density and when the soil loose water, it dries and hardens. The compaction results in Table 2 showed that the optimum moisture content (OMC) ranged from 7.20 – 17.10% while the maximum dry density (MDD) ranged from 1.74 – 2.10 g/cm^3. These values are within the range classified as sandy clay by O' Flaherty (1988). Also, similar values reported by Ishaku *et al.* (2002) was classified as low and that such soil are considered loose with little amount of clay as binding material. The triaxial shear test results show that the angle of friction is between 2.83 – 24.77 while the cohesion (C) is between 0.00 – 50.11kN/m^2. These values are low when compared with 65 kPa cohesion and 26 degrees angle of friction (ϕ) classified as average by Alao and Opaleye (2011) and thus, can only offer little resistance to the effect of both surface water and subsurface flow. This is responsible for failure of structures like drainage and culverts, therefore for construction of culverts and drainages, quantities of cementing materials like clay should be applied along construction zones to strengthen the soil.

Table 2: Geotechnical Properties of Termitaria

Termitaria Location	AGs	MDD	OMC	C (kNm^{-2})	ϕ (^{o})
A	2.58	1.77	12.80	50.11	11.80
B	2.55	1.74	15.40	21.11	10.08
C	2.48	2.10	14.40	0.00	24.77
D	2.55	1.91	13.80	36.24	3.95
E	2.52	2.00	7.20	21.11	10.08
F	2.48	1.74	17.10	19.79	9.69
G	2.54	1.85	11.60	23.56	2.83
H	2.34	1.82	12.00	42.86	8.13
I	2.57	1.84	16.20	30.77	21.04

3.6. Specific Gravity Test Result

The specific gravity test is s measure of unit weight of a soil according to AASHTO. The results of specific gravity obtained from the analysis range from 2.34 to 2.58 (Table 2). This shows that the soil within Ika area are sandy and very light which makes them susceptible to surface runoff and hence erosion.

4. CONCLUSION

The results obtained from this study revealed low plasticity of most termite's mound soil, except Idumuesah with medium plasticity indicating little clay enrichment in the mound soil and good indication of compressibility. The soil generally in the area are not cohesive, not compact and non-plastic, giving explanation to the vast ravaging gully erosion within Ika area. It is therefore recommended that if termite mound is encountered during construction, they can be used as earthwork rather than discarding them.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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