

Comparison of the chemical and geotechnical properties of Termitaria and their adjacent laterites in Sabon Pegi – Song, Adamawa State

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Abstract:

Termite mounds (TM) stand steadily without disturbance even after heavy rainfall, showing their having higher shear strength and better geotechnical properties than the adjacent soils. This study compared the chemical and geotechnical properties of the termite mound soils (TMS) and the adjacent lateritic soils (ALS) and also investigated the possibilities of using the cellulase enzyme present in TMS to improve the unconfined compressive strength (UCS) of lateritic soils. Chemical and geotechnical analyses were carried on the TMS and ALS. From the results; the NMC range (3.6% - 13.5%) in the TMS and (3.4% - 11.6%) in the ALS; the LL range (29.3% - 47.5%) and (22.5% - 31.3%) for the TMS and the ALS respectively; the PL ranges (18.2% - 28.1%) in the TMS and (12.3% - 22.0%) in the ALS; the PI ranges (11.1% - 19.4%) and (4.8% - 16.1%) for the TMS and the ALS respectively; the SG for TMS ranges (2.30 - 2.42) while that of the ALS range (2.10 - 2.39); the pH values range (5.6 - 7.0) for the TMS and (5.8 - 6.4) for the ALS; the particle size analyses for the TMS show values in ranges; gravel (0), coarse sand (0.3% - 0.8%), medium sand (11.3% - 33.3%), fine sand (8.0% - 34.1%), silt (22.5% - 50.6%) and clay (7.4% - 26.2%); for the ALS, the ranges are; gravel (0.3% - 16.0), coarse sand (0.85 - 23.5%), medium sand (14.2% - 37.2%), fine sand (11.7% - 50.1%), silt (8.3% - 30.3%) and clay (6.0% - 14.3%). The TMS differ from the ALS; possessing better geotechnical properties. Addition of cellulase enzyme improved the UCS of the lateritic soils. Hence, mixing lateritic soil with artificial enzyme that has some properties as that of the termite saliva can stabilize it.

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1. Introduction

Complex structures of various types, patterns and sizes are provided social insects. Termites construct nests relatively comparable to human town and cities [1]. They are recognized as one of the major ecosystem engineers in tropical soils [2], and cause changes in the physical, chemical and biological properties of the host soil. Their effects on soil are caused mostly by their major construction activities of which the mounds (Termitaria) are the most complex type [1]. TM which are edifices built by tropical termites are found in all parts of the tropics. Materials used are mineral matrix mixed with faeces or saliva [3]. The construction process causes both physical and chemical changes in the soil [4]. The effects of termites on soil reflect their feeding habits. *Cubitermes niokoloensis* is the group that builds mounds from a fine mixture of soil and faeces containing dense microbes [1].

TM have very specific properties arising from the combination of materials derived from soil and faeces. This creates an increased richness in clay, minerals with respect to neighbouring soil [5]. Termites build structures which are organo-mineral in form [6]. In the process, they often concentrate the organic materials they collect as forage in

the vicinity of the nest [6]. Construction of mounds involves excavating soil and shifting it to the surface. The soils are then mixed with saliva, faeces materials and some debris to form a tough material with variable composition [7, 8]. Momah, *et al.* [9] and Adeoye, *et al.* [10] compared TM and the adjacent soils and found out that the pH and the contents of organic C and N, P, Ca and Mg were significantly higher in TM compared to the adjacent areas. The microbial biomass of mound materials was approximately six times that of the adjacent soils [11]. By their symbioses with mutualistic microbes, termites can degrade cellulose; and can also produce their own cellulases. A *Bacillus* sp. strain isolated from termite mound soil can produce extracellular carboxymethyl cellulase [12]. The stability of a soil mass depends on the availability multivalent cations and the content of polysaccharides, glycoprotein, micro and macro aggregates. Adekayode [13] opined that increasing polysaccharides in soil matrix leads to increase in shear strength, reduction in coefficient of permeability and making the soil resistant to soil.

The objectives of the study include the study of physiochemical properties of the TMS and compare with the ALS and the geotechnical properties of the termite mound

soil and compare with the ALS. Other objectives are to study the stabilizing chemicals of the TMS and to check the influence of cellulase on the unconfined compressive strength of lateritic soils.

2. Methodology

2.1 Location and geomorphology

The study area is located in Song; between longitudes 12°36'E and 12°40'E and latitudes 9°48'N and 9°52'N; about 72km north of Yola, Adamawa state capital as shown in Figure 1. It is characterized by hilly topography with structural ridges and inselbergs surrounding the alluvial plains [14].

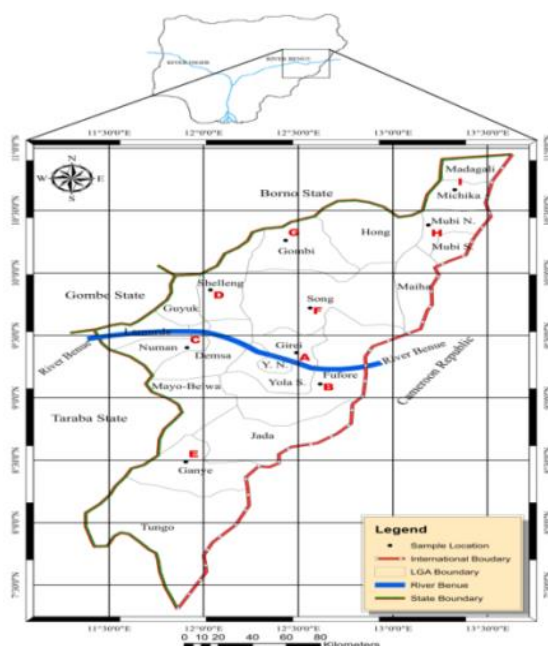


Figure 1: Map of Adamawa State, Nigeria showing the Study Area

2.2 Climates

The climate is tropical with distinct dry and wet seasons. The rainy season lasts from April to October, while the dry season lasts from November to March; with mean annual rainfall 900 mm [15]. Temperature is high (up to 42°C) between March and June and also in October and November before the onset of the harmattan. It drops in December and January (20°C due to the harmattan dusts in the sky; and also between July and September (26°C), due to humid maritime air mass. There is a seasonal variation in relative humidity in the study area; in rainy season, the relative humidity rises up to 90% and reaches its peak in August and September [15].

2.3 Geology

The study area is a basement complex terrain which have undergone both pre-pan African and pan-African orogenies and resulted into consequent granitization. The upper underlying geology has been weathered to superficial deposits consisting of a mantle of gravels, sands, loamy

sands and clayey soils. However, outcrops of the basement rocks are still preserved in the hilly regions.

Lithologically, the rocks are coarse-grained; made up of feldspar, mica, quartz and biotites which occur as large circular masses. During the Pan-African orogeny, granites were emplaced into the metamorphic Basement Complex of Nigeria, and mark the terminal end of the event [16]. Geodynamic disturbances and magmatic activity generated deep within the Earth's crust initiated faulting exploited by the granites. Thus, tectonism in the area seems to be so strong to have led to the emplacement of Older Granites Series [16].

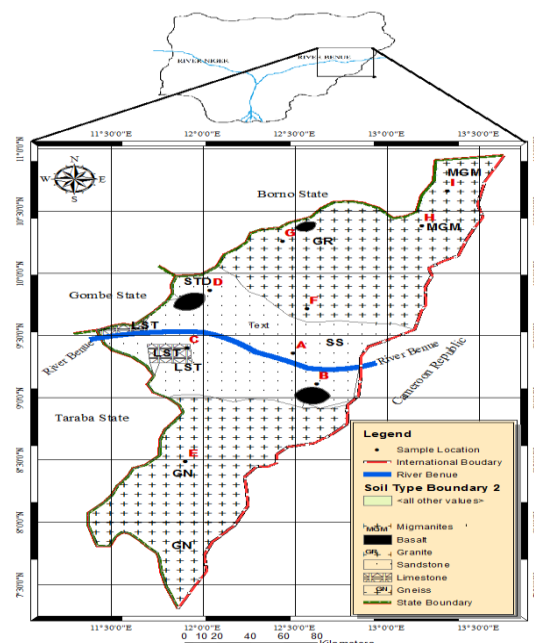


Fig.2. Geologic Map of the Study Area

2.4 Sample Collection and Procedure

This research was conducted on five pairs of samples collected from Sabon pegi - Song, Adamawa State Northeastern Nigeria between February and May 2024. Each sample pair consists of termite-affected soil taken from an active mound and the samples of lateritic soils adjacent to it. Figure 3 shows one of the TM under investigation.

The TM were excavated and dismantled. Lateritic soil samples were collected adjacent to the mounds. Soil samples were collected from a depth below 1.2m to maintain uniformity of test results. All soil samples were collected in polyethylene bags and taken to the laboratory. The enzyme used for the study, cellulase which was derived out of *Aspergillus Niger* brought from Biotechnology Centre, University of Nigeria, Nsukka.

2.5 Laboratory Analysis

Chemical and geotechnical tests were conducted on all the soil samples. The geotechnical analysis of the soil samples followed [17] laboratory procedures. The mineralogy of both soils was analyzed by X-ray Diffraction (XRD). Chemical analyses were done by X-ray Fluorescence (XRF) technique for the major and trace elements.



Figure 3: One of the termite mounds under investigation

3. Results and discussion

The results of the research were presented in Table 1 and the following sections give the details data of the termite mound soil (TM) and the adjacent lateritic soil (ALS).

3.1 Natural Moisture Content (NMC)

The first two pair of soil samples was collected in February and March 2024 and the other three samples in April and May 2024. Table 1 show that the NMC in the TMS range from 3.6% to 13.5% while that in the ALS range from 3.4% to 11.6%. There is higher moisture content in the TMS for the first two samples. This may be due to abundance of organic matter, clay, chemical/enzymes in the TMS and presence of finer soil particles [18].

3.2 Liquid Limit (LL)

Cone penetrometer method was used in liquid limit test. From Table 1, the LL values range from 29.3% to 47.5% and from 22.5% to 31.3% for the termite mound and the ALS respectively. The LL values for the TMS are greater

than that of ALS in all the cases. This may be due to substantial content of organic matter, clay content, chemical/enzymes and finer soil particles [19].

3.3 Plastic Limit (PL)

Table 1 provides the plastic limit of the different sample pairs. From Table 1, the PL for the TMS range from 18.2% to 28.1% and that of the ALS range from 12.3% to 22.0%. As the clay content in the TMS is higher than the ALS, their plastic limit values are also higher [19].

3.4 Plasticity Index (PI)

Plasticity in. It was observed that the TMS are more stable since they record values higher values of plasticity index than the ALS. Higher plasticity index and low moisture content indicate more cohesion making the TM stable [19]. Other reasons for higher plasticity index values of the TMS dex of the soil samples was obtained by subtracting the values of plastic limits from the values of liquid limits. As shown in Table 1, the PI ranges from 11.1% to 19.4% and 4.8% to 16.1% for the TMS and the ALS respectively may be higher chemical/enzymes, organic content and the clay content.

3.5 Specific Gravity (SG)

Table 1 show that the specific gravity values for TMS range between 2.30 and 2.42 while that of the ALS range from 2.10 to 2.39. It was observed that the specific gravity values in all termite mound soil samples are less compared to the ALS. This is due to lesser amount of iron content and high organic content [20].

3.6 pH

The pH of the soil samples was determined using a digital pH meter. 10g of each soil sample was mixed 100ml of distilled water and allowed to stand for 24 hours. Table 1 shows that the pH values from 5.6 to 7.0 for the TMS and between 5.8 and 6.4 for the ALS. This indicate that all the soil samples were acidic; but TMS being less acidic comparatively.

Table 1: Physical properties of TM and ALS

Parameters	Sample pair 1		Sample pair 2		Sample pair 3		Sample pair 4		Sample pair 5	
	TM 1	ALS 1	TM 2	ALS 2	TM 3	ALS 3	TM 4	ALS 4	TM 5	ALS 5
Natural Moisture Content (%)	13.5	9.1	3.6	3.4	7.2	7.4	3.7	3.8	7.5	11.6
Liquid Limit (%)	47.5	31.3	42.1	28.4	38.2	29.7	29.3	22.5	31.2	28.6
Plastic Limit (%)	28.1	22.0	18.4	12.3	22.2	18.2	18.2	17.7	20.0	18.8
Plasticity Index (%)	19.4	9.3	23.7	16.1	16.0	11.5	11.1	4.8	11.2	9.8
Specific Gravity	2.30	2.10	2.42	2.24	2.37	2.38	2.38	2.39	2.34	2.26
pH	5.8	5.9	6.8	5.8	5.9	6.0	7.0	6.4	5.6	5.8

3.7 Particle size Analysis

The textures of the soil samples were determined using wet sieve and hydrometer analyses. Table 2 shows the results of the soil particle sizes of the TMS and the ALS. The results indicated the soil particle size values for the TMS range as; gravel (0), coarse sand (0.3% - 0.8%), medium sand (11.3% - 33.3%), find sand (8.0% - 34.1%), silt (22.5% - 50.6%) and clay (7.4% - 26.2%). For the ALS, the ranges of particle sizes are; gravel (0.3% - 16.0), coarse sand (0.8%

- 23.5%), medium sand (14.2% - 37.2%), fine sand (11.7% - 50.1%), silt (8.3% - 30.3%) and clay (6.0% - 14.3%). The Percentage passing 0.075 mm sieve size ranges are (32.2% - 74.7%) and (32.0% - 44.4%) for the TMS and the ALS respectively as can be seen in Table 2. This results indicated that for mound construction, termites are using more percentage of medium sand compared to fine sand and more percentage of silt content compared to clay content; proper gradation for the construction of stabled mound.

Table 2: Particle sizes of TM and ALS

Composition	Sample pair 1		Sample pair 2		Sample pair 3		Sample pair 4		Sample pair 5	
	TM 1	ALS 1	TM 2	ALS 2	TM 3	ALS 3	TM 4	ALS 4	TM 5	ALS 5
Gravel	0	10.6	0	0.5	0	0.3	0	0.4	0	16.0
Coarse sand (%)	6.0	23.5	0.0	2.4	0.3	3.1	0.4	0.8	0.5	6.0
Medium sand (%)	11.3	14.2	30.2	37.3	14.5	28.1	33.3	34.3	20.5	18.8
Fine sand (%)	8.0	11.7	29.6	31.9	20.8	24.1	34.1	50.1	33.3	27.2
Silt (%)	50.6	30.3	22.5	19.5	38.2	30.1	24.8	8.3	36.8	26.0
Clay (%)	24.1	9.7	17.7	8.4	26.2	14.3	7.4	6.1	8.9	6.0
% of passing through 0.075mm sieve size	74.7	40.7	40.2	37.9	64.4	44.4	32.2	14.4	45.7	32.0

3.8 Chemical Analysis

The XRF analysis showed that the main oxides present in sample pair 1 are SiO₂, Al₂O₃ and Fe₂O₃. About 75 to 80 % of sample pair 2 is contributed by SiO₂. It can be observed that the amount of Al₂O₃ is higher in the TMS compared to the ALS. This suggests that the higher percentage of Al₂O₃ may contribute to the cementation of TMS [21]. Tables 3 and 4; show the chemical composition of TM and ALS. The XRD analysis indicated that the TM soils consisted more of clay minerals with quartz and mica, while the lateritic soils contained more iron rich clay minerals; indicating no significant difference in clay minerals which is kaolinite in all the samples.

Table 3: Chemical Composition of TM and ALS

Composition	Sample pair 1		Sample pair 2	
	TMS 1	ALS 1	TMS 2	ALS 2
SiO ₂ (%)	38.15	37.27	76.11	82.85
Al ₂ O ₃ (%)	23.46	22.33	16.85	10.66
TiO ₂ (%)	1.64	1.32	1.23	1.29
MnO (%)	0.11	0.07	0.01	0.02
Fe ₂ O ₃ (%)	13.09	14.75	4.10	0.11
CaO (%)	0.49	0.48	0.46	3.58
MgO (%)	0.88	0.76	0.42	0.39
Na ₂ O (%)	0.23	0.25	0.20	0.37
K ₂ O (%)	0.68	0.65	0.51	0.51
P ₂ O ₅ (%)	0.33	0.34	0.11	0.22
LOI (%)	20.94	21.78	NIL	NIL
Total (%)	100.00	100.00	100.00	100.00

3.9 Effects of Cellulase Enzyme on Lateritic Soil

Unconfined compression (UCC) tests were conducted on the lateritic soils added with different percentages of cellulase (0, 0.5, 1 and 1.5) and also by giving different curing period (1-3 days) at 30% water content. Tables 5, 6 and 7 show load deformation plot of soil for untreated and treated with different percentages and curing periods respectively.

Table 4: Trace Elements in TM and ALS

Trace Elements in µg/g	Sample pair 1		Sample pair 2	
	TM 1	ALS 1	TM 2	ALS 2
V	243	286	78	73
Cr	232	396	45	35
Co	19	14	7	5
Ni	166	94	16	13
Cu	59	31	17	13
Zn	91	72	55	53
Rb	44	28	30	20
Sr	38	48	54	42
Zr	953	966	948	965
Nb	24	24	24	24
Ba	28	193	273	142
La	59	48	59	43
Ce	124	93	116	92
Pb	32	33	32	33

Table 5: Load-deformation values of cellulase treated lateritic soil (1 day curing)

Untreated		0.5% Cellulase		1.0% Cellulase		1.5% Cellulase	
Load (Kg)	Deformation (mm)	Load (Kg)	Deformation (mm)	Load (Kg)	Deformation (mm)	Load (Kg)	Deformation (mm)
0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
0.30	0.4	0.35	0.8	0.30	0.8	0.30	0.8
0.50	1.0	0.54	0.9	0.50	1.0	0.65	1.2
0.55	1.5	0.60	1.0	0.68	1.5	0.75	2.0
0.65	2.0	0.70	2.0	0.80	2.3	0.90	2.7
0.70	2.8	0.80	2.8	1.00	2.5	1.00	3.0
0.80	3.2	0.90	3.0	1.10	4.0	1.10	4.0
0.90	4.0	1.00	4.0	1.30	5.0	1.35	5.0
1.10	5.2	1.20	5.0	1.50	6.0	1.45	6.0
1.20	6.0	1.30	6.0	1.60	7.0	1.60	7.0
1.30	6.8	1.40	7.0	1.70	8.0	1.70	8.0
1.40	8.0	1.50	7.0	1.80	10.0	1.75	9.0
1.50	9.2	1.60	8.0	1.90	11.0	1.80	10.0
1.60	10.8	1.65	9.0	1.93	12.0	1.85	11.0
1.65	13.6	1.68	12.0	1.95	13.0	1.90	12.0
1.70	14.1	1.70	13.0	1.98	14.0	1.95	14.0
1.75	15.3	1.75	15.0	2.00	15.0	2.00	15.0
1.80	16.2	1.80	16.0	2.00	16.0	2.00	16.0

Table 6: Load-deformation values of cellulase treated lateritic soil (2 day curing)

Untreated		0.5% Cellulase		1.0% Cellulase		1.5% Cellulase	
Load (Kg)	Deformation (mm)	Load (Kg)	Deformation (mm)	Load (Kg)	Deformation (mm)	Load (Kg)	Deformation (mm)
0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
0.30	0.5	0.35	0.5	0.30	0.5	0.30	0.5
0.45	1.0	0.50	1.0	0.40	0.8	0.40	0.8
0.60	2.0	0.55	1.5	0.50	1.0	0.50	1.0
0.70	2.5	0.65	2.0	0.60	1.5	0.60	1.5
0.80	3.0	0.75	3.0	0.70	2.0	0.70	2.0
0.90	4.0	0.85	3.5	0.80	2.5	0.85	2.5
1.00	5.0	0.95	4.0	0.90	3.0	1.00	3.0
1.20	6.0	1.10	5.0	1.05	4.0	1.08	4.0
1.30	7.0	1.25	6.0	1.20	5.0	1.30	5.0
1.40	8.0	1.35	7.0	1.40	6.0	1.40	6.0
1.50	9.0	1.45	8.0	1.60	7.0	1.60	7.0
1.60	10.0	1.50	10.0	1.70	8.0	1.70	8.0
1.65	12.0	1.60	11.0	1.80	9.0	1.80	9.0
1.70	13.0	1.70	12.0	1.90	10.0	1.90	10.0
1.72	14.0	1.75	14.0	2.00	11.0	2.00	11.0
1.74	15.0	1.80	15.0	2.02	12.0	2.01	12.0
1.76	16.0	1.80	16.0	2.04	13.0	2.02	13.0
				2.06	14.0	2.03	14.0
				2.08	15.0	2.04	15.0
				2.10	16.0	2.05	16.0

Table 7: Load-deformation values of cellulase treated lateritic soil (3 day curing)

Untreated		0.5% Cellulase		1.0% Cellulase		1.5% Cellulase	
Load (Kg)	Deformation (mm)	Load (Kg)	Deformation (mm)	Load (Kg)	Deformation (mm)	Load (Kg)	Deformation (mm)
0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
0.30	0.8	0.30	0.8	0.35	0.8	0.35	0.7
0.40	1.0	0.42	1.0	0.42	1.0	0.50	1.0
0.50	1.5	0.50	1.5	0.55	1.7	0.65	1.5
0.60	2.0	0.80	3.0	0.80	2.5	0.75	2.0
0.70	2.5	0.95	4.0	0.90	3.0	0.80	2.5
0.80	3.0	1.15	5.0	1.10	4.0	0.90	3.0
0.90	4.0	1.25	6.0	1.20	5.0	1.25	4.0
1.00	5.0	1.40	7.0	1.35	6.0	1.40	6.0
1.20	6.0	1.45	8.0	1.50	7.0	1.50	7.0
1.30	7.0	1.55	9.0	1.60	8.0	1.65	8.0
1.40	8.0	1.60	10.0	1.70	9.0	1.80	9.0
1.45	9.0	1.70	11.0	1.80	10.0	1.85	10.0
1.50	10.0	1.73	11.5	1.90	11.0	1.90	11.0
1.60	12.0	1.76	12.0	2.00	12.0	2.00	12.0
1.65	13.0	1.79	13.0	2.05	13.0	2.04	13.0
1.68	14.0	1.81	14.0	2.10	14.0	2.06	14.0
1.73	15.0	1.83	15.0	2.15	15.0	2.08	15.0
1.75	16.0	1.85	16.0	2.20	16.0	2.10	16.0

It was observed that the strength of the soil increases with increase of percentage of cellulase up to 1% but does not show considerable increase with 1.5%. With curing, the UCC increased in day 1 and 2 day but does not increase in day 3. This suggests to reduction in the available substrate after 2 days and the cellulose present in the soil is converted into cellobiose and glucose. Polysaccharide production within soil matrix increases with increase in shear strength [18].

4. Conclusions

Comparative investigation of TMS and ALS in Sabon pegi Song, Adamawa State, Northeastern Nigeria; was carried out in this research. Cellulose compounds were reduced by organic matter decomposing microorganisms

into polysaccharides and amino sugars. These polysaccharides results in the soil particle aggregation. From this research, it can be concluded that the liquid limits of TMS are more than the ALS. The TMS show increase in the plasticity index values; indicating more cohesion and stability. The specific gravity values obtained are in the range of 2.1 to 2.42; indicating the presence of organic content in the soils, which is in the range of 5%-9%. Particle sizes analysis results indicated that for mound construction, termites are using more percentage of medium sand compared to fine sand and more percentage of silt content compared to clay content; proper gradation for the construction of stabled mound.

The main difference in percentages of chemicals present in termite mound and ALS are Al_2O_3 and Fe_2O_3 and

these chemicals might have given the cementation/cohesive nature of the mound soils. The strength of the cellulase treated adjacent lateritic soil is 1.19 times more for soil treated with 1 % cellulase for 3 days curing compared to untreated soil and does not give significant difference in strength with soil treated with 1.5% cellulase for 3 days. Percentage increase in strength is 19.16%.

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