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(Research Article)

Geotechnical properties of termite mound soils from Idoma area of Benue State

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Abstract

The aim of this research was to examine the geotechnical properties of the termitaria from the Idoma area of Benue State, Nigeria. The samples were collected from four termitaria and their surrounding soils in the sampled locations, air dried, ground and used for the analysis.

The geotechnical tests carried out on the termite mound soil samples included grain size, atterberg limits, compaction and triaxial tests. The range of values of the determined parameters vary in sizes: particle size indices show high disparity in values with uniformity coefficient [Cu] having wide range of values from 0.001mm in Oju termite mounds to 73.14mm in Agatu surrounding soil; coefficient of curvature [Cc] shows more linear range of values from 0.03 mm in Otukpo surrounding soil to 3.20 mm in Ogbadibo surrounding soil. From the results, Oju and Ogbadibo termite mounds could be regarded as clay while the mound soils from other sampled locations are coarse, poorly graded and poorly sorted. The results of the Atterberg limits show that the values of plasticity index vary from 2.81% in Otukpo surrounding soils to 33.37% in Agatu termite mounds. These values indicate that the mound soils have low plasticity to medium plasticity. The liquid limit (LL) varies from 23.56% in Otukpo termite mounds to 59% in Agatu termite mound while plastic limit varies from 14.63% in Otukpo termite mounds and peaked at 26.21% in Agatu termite mounds; plasticity index varies from 2.81% in Otukpo surrounding soil to 33.37% in Agatu termite mounds; plasticity limit ranges from 14.63% in Otukpo termite mounds to 26.21% in Agatu termite mounds; linear shrinkage ranges from 5.70% in Oju termite mounds to 7.90% in Ogbadibo termite mounds; optimum moisture content ranges from 11.20% in Otukpo surrounding soil to 13.10% in Ogbadibo termite mounds; maximum dry density ranges from 1.61g/cm3 in Ogbadibo termite mounds to 1.89 g/cm3 in Otukpo surrounding soil; angles of friction from 0.53° in Ogbadibo surrounding soils to 21.08° in Otukpo surrounding soil and cohesion of up to about 2.00 KN/m2 in Otukpo surrounding soils to 89.00 KN/m2 in Oju surrounding soils. The specific gravity of the mound soils vary within a narrow range; 2.15 in Oju surrounding soils to 2.62 in Otukpo termite mounds and within the organic soil range (1.0 ϴ - 2.65 ϴ). The results suggest that the termite mound soils analysed may have limited geotechnical applications.

Keywords: Geotechnical properties; Termite mound soils; Idoma area; Benue state

1 Introduction

The soil is the outer covering of the earth surface. It contains silt, sand, clay and organic matter. The soil is useful to plants, man and both micro and macro organisms. One of organisms is the termite. Termites belong to the taxonomy order of Isoptera. Termites are eusocial insects and live in colonies which are housed in mounds (termitaria).These mounds despite severe climatic conditions can withstand and survive the test of time. The termite mounds are built from termite saliva secretions, clay, dungs/wastes and organic matter.

Termite mounds in the study area are generally found in association with different types of vegetation, soil and rock. They are in various shapes and sizes such as conical, elongated, bald and rounded even irregular. The mounds also vary

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in average height from 0.83 m to 1.65 m in height with the average base diameter varying from 0.89 m to 3.10 m. The termite mounds sampled are dark reddish brown and brown in colour.

In general, soil provides a more stable environment for organisms than condition above the ground and therefore serves as a refuge for many epigeal invertebrates [1]. In tropical regions, soil invertebrates macrofauna play a key role in organic matter, recycling [2]. The invertebrate fauna is dominated by termites in terms of density. Termites are terrestrial insects found approximately between 45°N and 45°S. Within these latitudinal limits they are restricted by a combination of extreme aridity and lack of vegetation and are rarely found at altitudes above 3000 m. Within this range, termites can be found in all soil types, except those which are semi- permanently water-logged and severally cracking vertisols [1]. The impact of termites is usually due to their building ability where mounds (termitaria) represent spectacular biogenic structures. Termite mound density can be very high covering substantial land area (2) and limiting available land for cultivation [3]. The mode of mound construction differs among termite species: soil feeding species build their mounds with soil particles glued together with faeces [4] while funges – graving species mix soil particles with their saliva [5].

Earlier researches have studied ecological, biological and geotechnical of termite mounds [2]. Comparative studies [3, 4] of termite mound and the adjacent soils were been carried out in previous researches [5, 6]. In this study, termite soils and their adjoining surface soils were studied in the Idoma area of Benue State, Nigeria.

A good number of studies on geotechnical properties of termite mounds have been carried. One of such studies is the work of [7] from some locations in the Ika area, Delta State of Nigeria. Based on the data on geotechnical properties, it was suggested that the termite mound soil may have limited application in soil stabilization and concrete works.

Termites live in nests called termitaria and are categorized according to the shapes of their termitaria and methods of feeding. For instance, the forage termites Trinervitermes build dome-shaped mounds usually less than a meter in height, mushroom-shaped mounds are built by decomposers, Cubitermes, and the most prominent in Africa the fungus termites, macrotermes which live in cathedral mound as high as 20 meters dotting many landscape of tropical grassland [8]. The processes involved in building these large epigeal mounds lead to concentration of minerals in the termitaria since soils as deep as 50m below the earth surface are brought up to the surface [9].

Emerging economies like Nigeria can derive numerous unquantifiable benefits from studying geotechnical characteristics of termite with their applications in engineering projects such as roads, bridges, buildings and other others in infrastructural development.

It has been suggested that mound building activity results in the upward transfer of clay, silt, sand and fine grain particles to the surface, a process which is opposite to leaching and this results in significant mobilization and dispersion of trace elements [10]. The use of termite mound soil sampling in geochemical exploration has these become an active area of research [11]. The ecological and geochemical significance of termite mound soils requires their systematic investigation. In this paper, the geotechnical properties of termite mound soil in the Idoma area Benue State, Nigeria are reported.

2 Methodology

2.1 Sampling sites

The Idoma area occupies the southern fringes of Benue State. The State lies within the lower river Benue trough in the middle belt region of Nigeria. Its geographic coordinates are longitude 7° 47’ and 10° 0’ East. Latitude 6° 25’ and 8° 8’ North; and shares boundaries with five other states namely: Nassarawa to the north, Taraba to the east, Cross-River to the south, Enugu to the south-west and Kogi to the west.

Figure 1 Map of Nigeria. Showing Benue state

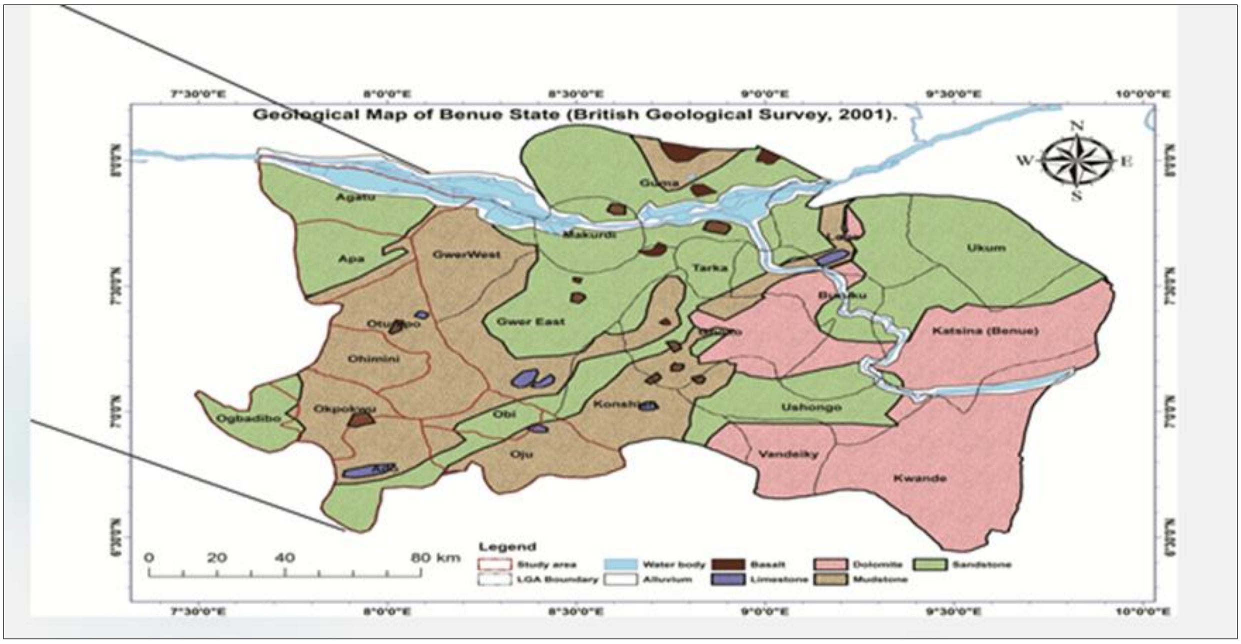

Figure 2 Map of Benue State with the sampling areas

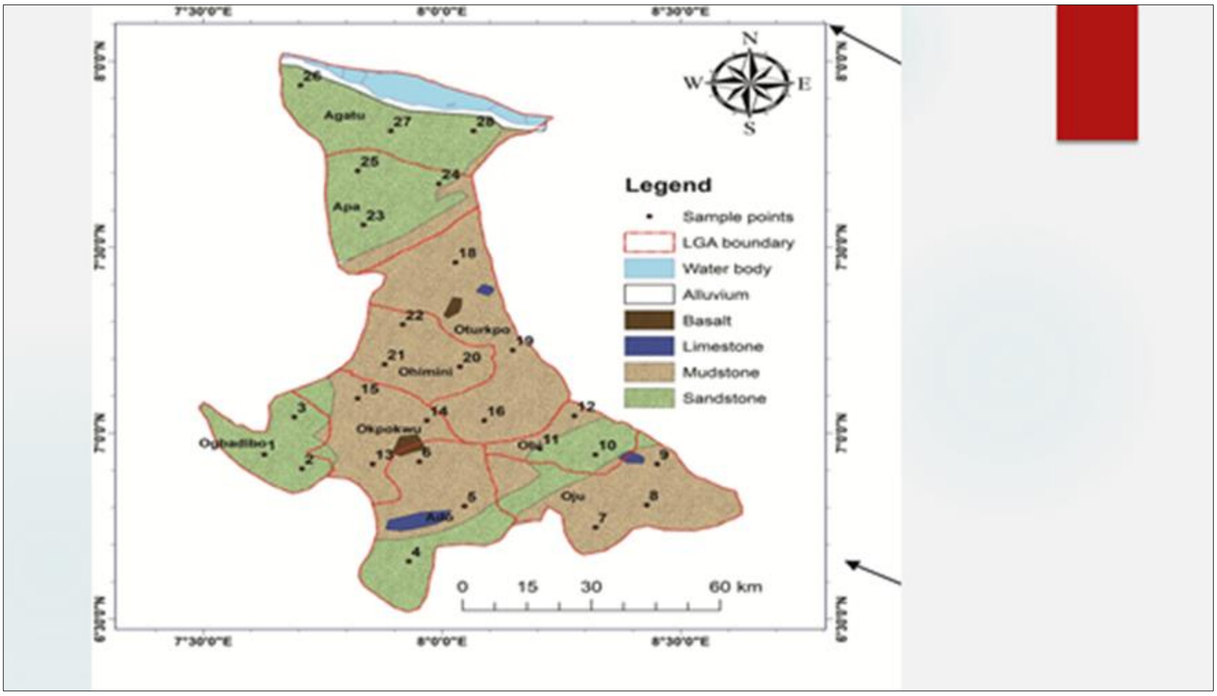

Figure 3 Map of Idoma Areas of Benue State showing the sampling points

The study area experiences two distinct seasons, the wet/rainy season and the dry/summer season. The rainy season lasts from April to October with annual rainfall in the range of 100-200mm [12]. The samples were collected from four (4) local government areas (LGAs) of Otukpo, Oju, Agatu and Ogbadibo. In each of the LGA, three different termitaria were sampled.

2.2 Collection of Samples

The method of Bode et al., [11] was adopted with some modifications, where termitaria were surveyed in the sampling location with the help of the local residents. Termitaria of various sizes were randomly chosen for sampling. Samples of termite mound and the surrounding soils were collected from selected sites in the four LGAs in the study area and used for the analysis. Hoe and cutlass were used to collect samples around the foot, middle portion and the top of the termitaria in a circular way to get a composite sample from each. This was done for three (3) termitaria in the selected local government areas and the composite samples used for the analysis.

Furthermore, the surrounding soils around each termitarium were taken. This was done by removing the soil surface in three spots around 2-4 m deep around each termitarium and samples collected from up to 15 cm in depth which serve as control. The samples were mixed to form composite control sample and stored in properly labeled polythene bags and conveyed to the laboratory.

2.3 Sampling and Sample Preparation

Geozoological method of prospecting for solid minerals sampling technique was utilized in this method. Soils from termitaria were sampled and analyzed for presence of solid minerals which in turn served as an indicator of mineral deposits [12]. The three samples from each location were air-dried, gently crushed, mixed well and then sieved through a 2 mm mesh. The sieved samples were stored for both geotechnical analyses.

2.4 Analytical procedure

2.4.1 Geotechnical tests

The geotechnical tests were conducted in accordance with the BSI 1377 methods (1998). The grain size analysis was done by dry-sieving methods (sieve analysis). The percentage passing was plotted against sieve sizes (mm) as distribution (gradation) curve where the uniformity coefficient, Cc and coefficient of curvature, Cu of the test mound soil samples were obtained. Consistency limits were determined by the Atterberg tests and compaction test was used to determine the maximum dry density and optimum moisture content of the termite mound soil samples. Shear strength measured as cohesion and friction angle was determined by triaxial test.

3 Results and discussions

The results of the geotechnical tests carried out on the termite mound soil samples are given in Table 1.

Table 1 Results of geotechnical analysis

Location/	Particle size indices		Plasticity %					Compaction		Shear strength	
Sample	**CU**	**CC**	**LL**	**PL**	**PI**	**Linear shrinkage**	**S.G**	**MDD (g/cm^3)**	**OMC**	**Friction angle**	**Cohesion (KN/m^2)**
Agatu TM	45.21	0.08	59.59	26.21	33.37	6.40	2.34	1.66	12.20	11.65	34.00
Agatu SS	73.14	0.17					2.39	1.63	13.09	13.00	5.34
Ogbadibo TM	0.002	0.81	42.09	19.79	22.31	7.90	2.32	1.61	13.10	1.86	12.00
Ogbadibo SS	22.23	3.20	55.21	22.64	32.67	7.10	2.41	1.68	11.40	0.53	3.00
Oju TM	0.001	1.50	44.98	22.69	23.29	5.70	2.33	1.81	11.50	11.99	29.00
Oju SS	12.32	0.14	48.80	24.39	24.42	6.40	2.15	1.65	12.10	10.20	89.00
Otukpo TM	10.00	0.82	23.56	14.63	8.94	7.90	2.62	1.89	11.50	10.61	2.05
Otukpo SS	57.64	0.03	43.33	22.52	2.81	7.10	2.34	1.66	11.20	21.08	2.00

Cu = uniformity coefficient; Cc = coefficient of curvature, LL = liquid limit, PL = plastic limit, PI = plasticity index, Gs = specific gravity, MDD = maximum dry density (g.cm-3) OMC = optimum moisture content (%); cohesion KN.M-2. TM= termite mound; SS = surrounding soils.

3.1 Particle size

The uniformity coefficient, Cu and coefficient of curvature Cc of the soils samples were obtained from the grain-size distribution curve using the relationships below:

$$Cu = D60/D10$$

Cc = (D230) / (D60) (D10), whereD10, D30, and D60 are the effective sizes (diameters) corresponding to percent fines at 10, 30, and 60%, respectively.

The particle size indices uniformity coefficient, Cu and coefficient of curvature, Cc obtained for the mound soils varied from 0.001mm in Oju termite mound to 73.14 mm in Agatu surrounding soils and Cc ranges from 0.03 mm in Otukpo surrounding soils and 3.20 mm in Ogbadibo surrounding soils, respectively. From the results, Oju and Ogbadibo termite mounds could be regarded as clay while the mound soils from other sampled locations are coarse, poorly graded and poorly sorted [13] [14].

Several organizations have attempted to develop the size limits for different soil types based on the grain sizes present in soils. Table 2 presents the size limits recommended by the American Association of State Highway and Transportation Officials (AASHTO) and the United Soil Classification Systems (Corps of Engineers, Department of the Army, and Bureau of Reclamation):

Table 2 Classification of soils

Classification system	Grain size (mm)
Unified	Gravel: 75 mm to 4.75 mm Sand: 4.75 mm to 0.075 mm Silt and clay (fines): < 0.075 mm
AASHTO	Gravel: 75 mm to 2 mm Sand: 2 mm to 0.05 mm Silt: 0.05 mm to 0.002 mm Clay: < 0.002 mm

Source: Geotechnical Properties of Soil and of Reinforced Soil (Lectures 1 to 4): NPTEL - Advanced Foundation Engineering-1

3.2 Atterberg limits

The results of the Atterberg limits of the termite mound soils are given in Table 1. The values of plasticity index vary from 2.81% in Otukpo surrounding soils to 33.37% in Agatu termite mounds. These values indicate that the mound soils have low plasticity [15], medium plasticity [16] and are cohesion [17].

The liquid limit (LL) varies from 23.56% in Otukpo termite mounds to 59% in Agatu termite mound while plastic limit varies from 14.63%in Otukpo termite mounds and peaked at 26.21% in Agatu termite mounds. Agatu surrounding soils have no clay and therefore, Atterberg limits were not computed for the sample. Generally, the termite mounds have less Atterberg limits than the surrounding soils.

When a clayey soil is mixed with an excessive amount of water, it may flow like a semiliquid. If the soil is gradually dried, it will behave like a plastic, semisolid, or solid material depending on its moisture content. The moisture content, in percent, at which the soil changes from a liquid to a plastic state, is defined as the liquid limit (LL). Similarly, the moisture contents, in percent, at which the soil change from a plastic to a semisolid state and from a semisolid to a solid state are define as the plastic limit (PL) and the shrinkage limit (SL), respectively.

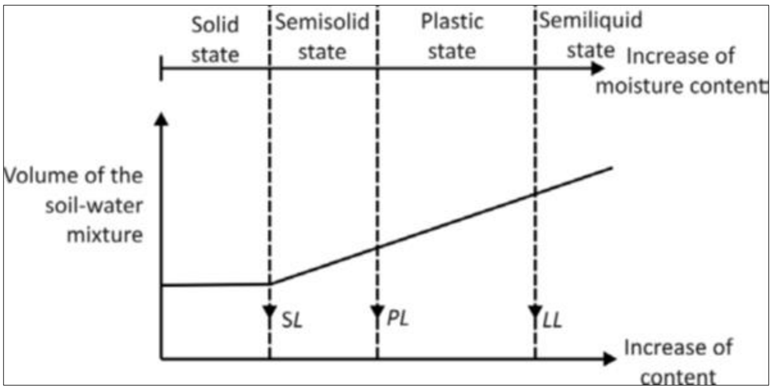

Figure 4 Atterberg Limits

3.3 Compaction Test

The moisture content at which soils are compacted in the field is controlled by its optimum moisture content, while the compaction energy applied is determined by its maximum dry density. The values of the optimum moisture content (OMC) and maximum dry density (MDD) of the mounds soils can be seen in Table 1.

The values of the MDD and OMC of the compaction test vary from 1.61g.cm2 in Ogbadibo termite mounds soils to 1.89 g.cm2 in Otukpo termite mounds and 11.20 in Otukpo surrounding soils to 13.10 in Ogbadibo termite mounds respectively. The mound soils can therefore be classified as sandy soil [18] or loose with little amount of clay [19].

3.4 Specific gravity

Except for peat and highly organic soils, the general range of the values of specific gravity, Gs of soil solids found in the nature is rather small. Table 3 gives some representative values.

Table 3 Representative values of specific gravity (Gs)

Soil type	**Gs**
Quartz sand	2.64-2.66
Silt	2.67-2.73
Clay	2.70-2.9
Chalk	2.60-2.75
Loess	2.65-2.73
Peat	1.30-1.9

Source: NPTEL - Advanced Foundation Engineering-1. Module 1 Geotechnical Properties of Soil and of reinforced soil (lectures 1 to 4)

From table1, the specific gravity of the mound soils vary within a narrow range; 2.15 in Oju surrounding soils to 2.62 in Otukpo termite mounds and within the organic soil range (1.0 Ɵ - 2.65) [20].

3.5 Shear Strength

The values of shear strength indices; angle of friction and cohesion for the mound soils have wide spatial variation. The values for angle of friction vary from 0.53o in Ogbadibo surrounding soils and 13 o in Agatu surrounding soils, while cohesion varies from 2.0 KN/M2 in Otukpo surrounding soils to 89 KN/M2 in Oju surrounding soils

These relatively low values of shear strength indicator may be related to grallation and consistency of the mound soils; and suggests that the mound soils may have limited soil engineering applications [12].

The shear strength parameters of soils defined as cohesion and friction angle depend on the effective stress, drainage conditions, density of the particles, rate of strain and direction of stain [20], [12].

Shear strength is affected by the consistency of the material, mineralogy, grain size distribution; shape of particles, initial void ratio and features such as layers, joints, fissures and cementation [21].

4 Conclusions

From the results of the parameters obtained, it could be concluded that the mound soils from the sampled locations in Idoma area of Benue State, Nigeria may not be suitable materials for civil construction and other geotechnical applications.

Compliance with ethical standards

Disclosure of conflict of interest

The authors have not declared any conflict of interests

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