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Geotechnical and Geochemical Properties of Residual and Termite Reworked Soils within the Premises of the Polytechnic Ibadan, Southwestern Nigeria

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Abstract

Three representative samples each from residual and termite reworked soils were collected within the premises of The Polytechnic Ibadan, southwestern Nigeria. Their suitability for construction purposes was determined by assessing their geotechnical and geochemical properties. Geotechnical tests carried out include moisture content, specific gravity, Atterberg limits, particle size distribution, compaction, UCS test and CBR. AAS was used to analyze the oxides composition of the soils. Both soil types were classified as low – intermediate plasticity clays with liquid limit between 25.5%-43.1%. The CBR values ranged from 80% - 85% and 20% - 50% for termite reworked soils and residual soils respectively. UCS ranged from 212.1KPa - 226.3 KPa and 191.7KPa – 200.0 KPa for the termite reworked and residual soils respectively. The OMC and MDD values for termite reworked soil ranged from 5.8% - 8.4% and 1968 kg/m^3 - 2020kg/m^3 respectively and between 12% - 15.2% and 1800 kg/m^3-1940 kg/m^3 for residual soils. Geochemistry result shows that the termite reworked soils contained a mean of 60.1% SiO_2, 31.05% Al_2O_3, 1.7% CaO and 4.9% Fe_2O_3 while the residual soils contained a mean of 59.8% SiO_2, 28% Al_2O_3, 1.6% CaO and 4.6% Fe_2O_3. This accounts for the better geotechnical properties exhibited by the termite reworked soils.

Keywords: Geotechnical, Geochemical, Reworked Soils, Residual soils, Construction purposes

Introduction

Lateritic soils can be found in most parts of the tropical world Nigeria inclusive. Over the years, the soils have been used for various purposes not only as foundations for structures but also as construction materials such as building, roads, highways, dams and embankments. It has been discovered from various researches (Gidigasu, 1976; Townsend, 1985) that lateritic soils possess physical, mineralogical and geotechnical characteristics that make them good engineering soils although their properties may need to be improved upon whenever the need arises. The process used to improve the properties of a soil in order to make it suitable for a given purpose is known as soil stabilization.

Termites are recognized as one of the major ecosystem 'engineers' in tropical soils. Their effects on soil are caused mostly by their major construction activities of which the mounds (Termitaria) are the most complex type. Termitaria which are edifices built by tropical termites of the order isoptera abound virtually in all parts of the tropics. A termitarium is usually built from a mineral matrix mixed with faeces or saliva, depending upon the termite species. The construction of these mounds causes both, physical changes (in water-holding capacity, bulk density, porosity, permeability and structural stability) and chemical changes (in cation-exchange capacity and organic matter content) (Turner, 2014 and Jouqet *et al.*, 2006). The effect of termites on soil is closely linked to their feeding habits and the type of constructions they build (Fall, *et al.*, 2004). 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 underneath to the surface (Olowofoyeku *et al.*, 2016). Termitaria is made of different types of soil and engineers are interested in the engineering usefulness of the anthills and its effect on the surrounding soils around its habitation.

The determination of the engineering properties of soils at a particular place is essential before the execution of any construction project (Adegbesan *et al.*, 2020). This research work is carried out to determine, characterize and compare the geotechnical and geochemical analyses of lateritic and termite reworked soil of The Polytechnic, Ibadan, South-western Nigeria.

Materials and Methods

Three disturbed samples each for both termite re-worked and residual lateritic soils were collected from three locations. The termite reworked soils were obtained from termite hills while the residual lateritic soils were obtained at a depth of 1m below the surface at each location. The soil samples were collected into the sample bags at each location and labeled for easy identification before being taken to the geotechnical laboratory for analyses. The geotechnical tests carried out include moisture content, specific gravity, grain size distribution, consistency limits, compaction at the standard protocol, California Bearing Ratio (CBR), Natural Moisture Content, Unconfined Compressive Strength (UCS). The geochemical analysis was done using Atomic Absorption Spectrophotometry (AAS) method.

Results and Discussion

Specific Gravity and Grain size distribution

The results of specific gravity and soil parameters from grain size distribution test is presented in Table 1. The specific gravity of the residual lateritic soils ranges from 2.58 to 2.66 with a mean of 2.64, while the specific gravity of termites reworked lateritic soil remain constant at 2.65. The termite reworked soils contain no gravels which implies that they are gap graded since one particle size is completely missing in it. The residual soils are classified as well graded due to the presence of a representation of all the particle sizes. Well graded soils have more interlocking between the particles hence a higher friction angle. Well graded soils are more suitable for construction than the poorly graded soils (Khan 2022). The termite reworked soil contains lower amount of clay and higher silt content thus it contains higher percentage of fines than the residual soils, hence it is perceived to be more laterized .The lower the clay size fraction, the higher the degree of laterization and consequently the higher the crushing strength (Adeyemi *et al.*, 1990). From the particle size distribution curves in Figure 3, the soils are generally well graded.

Table 1: Specific gravity and Grain size distribution

Soil sample	specific gravity	Clay (%)	Silt (%)	Fine sand (%)	Medium sand (%)	Coarse sand (%)	Gravels (%)	Amount of fines (%)	Amount of coarse fraction (%)
LS1	2.65	10.24	15.36	31.2	34.8	7.5	0.9	25.6	74.4
LS2	2.66	16.37	17.73	15.6	21.9	15.2	13.2	34.1	65.9
LS3	2.58	3.76	13.34	32.7	46.2	3.4	0.6	17.1	82.9
LT1	2.65	8.8	33.3	35.5	22.2	0.2	0	42.1	57.9
LT2	2.65	6.2	33.8	29.5	29.9	0.6	0	40	60
LT3	2.65	4.1	23.7	23.2	48.5	0.5	0	27.8	72.2

Consistency

Soil consistency is the strength with which materials are held together or the resistance of soils to deformation and rupture. Consistency limits test is used in the selection of laterites and associated soils as sub-base and sub-grade materials. Table 2 showed the results of consistency limits. For the residual lateritic soil samples, liquid limit, plastic limit and plasticity index values range from 32.6-43.1%, 19-24% and 13-19% respectively while for the termite reworked soils, it ranged from 25.5-33.1%, 12-22% and 9-13% respectively. One of the surrounding soils was found to be non-plastic. From the values presented in Table 1, it is observed that the termites reworked soil samples (LT) have a lower liquid limit and plastic limit values than the residual lateritic soil samples (LS), this justifies the higher clay content. Soils with a high clay content usually has high liquid limit and plastic limit.

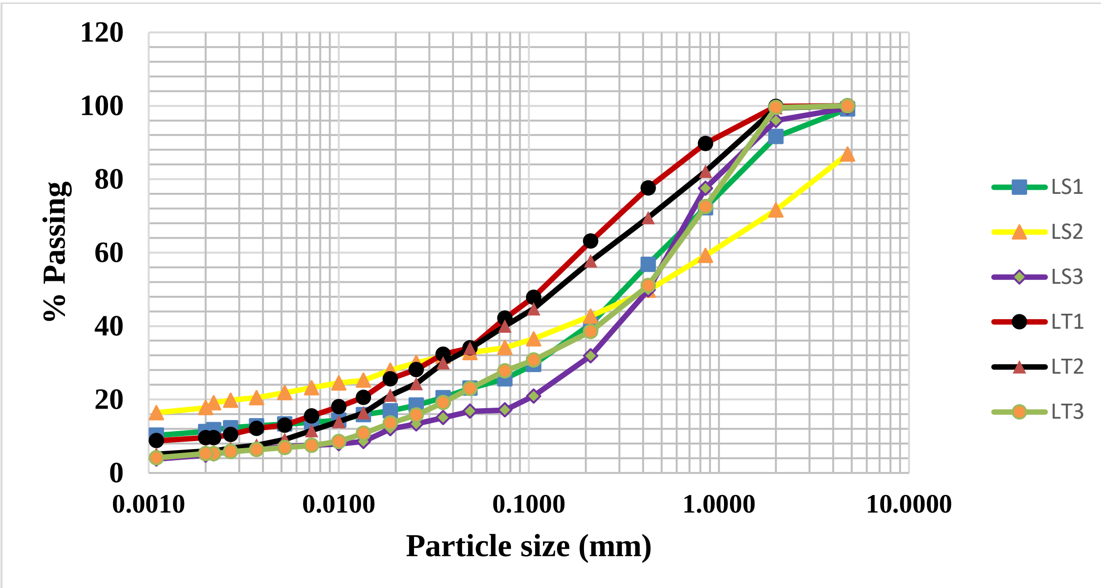

Figure 3: Particle size distribution for all samples

The plasticity index also gives a good indication of compressibility, the greater the plasticity index, the greater the compressibility (FAO 2014) this indicates that the residual lateritic soils are more compressible than the termite reworked soils hence, the termite reworked soils possess better geotechnical properties since compressible soils are not desirable for construction or foundation purposes. From Gidigasu 1972, all the soils are classified as low to medium plasticity soils. The unified soil classification system (USC) classified all the soils as coarse-grained soils since they all contain less than 50% fines.

Table 2: Summary of the consistency limits

Samples	LL (%)	PL (%)	PI (%)	MC (%)	Plasticity
LS1	32.6	19	13	3	Low plasticity clay
LS2	43.1	24	19	4	Intermediate plasticity clay
LS3	Non-plastic	-	-	2	Non- plastic soil
LT1	28.4	19	9	2	Low plasticity clay
LT2	33.1	22	11	1	Low plasticity clay
LT3	25.5	12	13	3	Low plasticity clay

Compaction

In any engineering construction works, compaction of soils is done to achieve soils with improved engineering properties. The process of compaction results in a soil mass that is free of large continuous interclods voids, increases its density and strength and reduces its hydraulic conductivity (Benson and Daniels, 1990).

Table 3: Compaction parameters (MDD & OMC), Unconfined Compressive strength and California Bearing Ratio

Sample	MDD (Kg/m^3)	OMC%	UCS Kpa	CBR%
LSI	1800	14	191.7	19
LS2	1824	15.2	197.74	30
LS3	1940	12	200.01	50
LT1	2020	8.4	212.9	85
LT2	1964	7.4	212.1	60
LT3	2130	5.8	226.3	80

From Table 3, the compaction parameters of the termites reworked soils and that of residual lateritic soils show MDD and OMC of 1964kg/m^3 - 2020 Kg/m^3 and 5.8-8.4% as well as 1800 - 1940 kg/m^3 and 12.0-15.2% respectively. The termite reworked soils showed higher maximum dry densities which could be an indication of the improvement caused as a result of reworking by the termites on the studied soils. As a result, the higher the maximum dry density, the better graded, coarse and granular the soil becomes (Enaworu *et al.*, 2017) Therefore, there is a significant influence of reworking by termites on the compaction parameters of the studied soils (Adeoye *et al.,* 2019).

Unconfined compressive strength

Unconfined compressive strengths and CBR of soils are often used to evaluate highway sub-grade and sub-base soils (Simeon et al 1973). They are often used to estimate the shear strength of engineering soils. Generally, for clayey soils, the shear strength is about half of the unconfined compressive strength (Krynine and Judd, 1957). UCS values for the lateritic surrounding soils range from 191.70 - 200.01 kPa while that of termite reworked soils ranged from 212.1 - 226.3 kPa. The result in Table 3 shows that the unconfined compressive strengths of the termite reworked are significantly higher than those of the surrounding lateritic soils.

California Bearing Ratio

The California bearing ratio (CBR) characteristic is a semi-empirical test often used to estimate and evaluate the bearing capacity of highway sub-grade and sub-base soils (Simon et al, 1973; Gidigasu, 1980). The results of un-soaked CBR of the soil samples compacted at optimum moisture contents of the West African level are presented in the Table 3. The Federal ministry of works and housing (1997) has specified minimum CBR values of 80% for base course, 30% for subbase and 5% for subgrade. Hence, all the samples are suitable for subgrade and foundation soils, all the samples except LS1 are suitable as subbase while only LT1 and LT3 are suitable as base course materials.

Geochemical Classifications

Major elemental oxides geochemistry

The major elemental concentration in the soil samples under investigation are presented in Table 4. It can be noted from the table that the soil samples consist mainly of SiO_2, Al_2O_3, Fe_2O_3, TiO_2, CaO, MgO of the main constituents. The most abundant mineral oxides includes the SiO_2 which range in percentages from 59.5 - 60.4% and Al_2O_3 which ranges from the 26.25-31.5%. The percentages of MnO_2, CaO, K_2O, Na_2O, MgO, TiO_2 and P_2O_5 range from 0.05-1,75% while Fe_2O_3 is from 4.6 - 4.9% with a mean value of 4.8%.

Table 4: Major elemental oxides Distribution

Elemental Oxide (%)	**Soil Samples**					
	LS1	**LS2**	**LS3**	**LT1**	**LT2**	**LT3**
SiO_2	59.8	59.5	60.1	60.4	59.9	60.25
Al_2O_3	29.2	29.6	26.25	30.2	31.45	31.5
MnO_2	0.06	0.06	0.05	0.07	0.55	0.06
CaO	1.65	1.6	1.6	1.7	1.65	1.75
K_2O	0.9	0.95	0.85	0.9	0.7	0.8
Na_2O	0.85	0.9	1	1.1	1	1.1
MgO	1.1	1	1.1	1.1	1.1	1
Fe_2O_3	4.6	4.7	4.7	4.9	4.85	4.9
TiO_2	1.1	1.15	1.15	1.1	1.1	1.05
P_2O_5	0.45	0.45	0.45	0.5	0.4	0.3

From the results shown on Table 4, the Al_2O_3 contents in the residual lateritic soils samples range from 26.25-29.6% with an average value of 28.35% while in the termites reworked soil samples it ranged from 30.2-31.5% with an average value of 31.05%, It is observed that the Al_2O_3 contents in the termites reworked soil increased by an average value of 2.70%. The presence of aluminium and iron oxides minerals in soils has a favorable effect on soils physical properties increasing the aggregates stability, permeability, porosity, friability and hydraulic conductivity and reducing swelling, clay dispersion, bulk density and modulus of rupture (Goldberg 2008).

Conclusion

This research work is carried out to characterize the geotechnical and geochemical properties of termites reworked soils and its surrounding residual lateritic soils. From the results obtained, the termite reworked soils are more laterized due to the actions of termites. As a result of this, the geotechnical and engineering characteristics of termite reworked soils are better than the surrounding residual soil. The increments in some certain oxides generated by termite reworked soils leads to further increase in the favorable conditions of the soil physical properties. Most of the soils are suitable as subgrade and subbase soils for roads and also good for foundation material.

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