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RESEARCH ARTICLE

EFFECT OF COMPACTION AT DIFFERENT ENERGY LEVELS ON THE GEOTECHNICAL PROPERTIES OF STABILIZED SOILS

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ABSTRACT

This study is aimed at evaluating the influence of compaction (at different energy levels) on the geotechnical properties of stabilized soils. To achieve this, four bulk soil samples (BDL1, BDL2 BDL3 & BDT) consisting of termite reworked soils and residual lateritic soils were collected at New Stadium Road, Awo hall, University of Ibadan, Nigeria at a depth of 2m for strength tests and at depths of 1m, 1.5m & 2m for index tests. Geotechnical analysis (index tests and strength tests) and geochemical analysis (X-ray Diffraction) were carried out on the sampled soils. The study revealed that the mineral constituents of the sampled soils are quartz, kaolinite and hematite; with the termite-reworked soil richer in kaolinite content than the quartz schist derived soil with about 125% increase. The values of index tests for both soils met the required Nigeria specification for good soil with termite reworked soil performing better. The values of specific gravity for both soils are close suggesting similar origin. AASHTO classification put termite-reworked soil within the range of A-2-7 (good rating) while most of the residual soil samples fall within A-7-5 to A-7-6 range (fair to poor rating). The stabilisation of residual lateritic soil using termite-reworked soil as stabiliser brought about increase in the values of maximum dry density, uncured unconfined compressive strength as well as the sun-cured unconfined compressive strength of the studied soil. The influence of stabilisation using termite-reworked soil was strongest at the highest level of compaction ((30%) of termite-reworked soil with the weight of residual soil). There also exist a fairly strong positive correlation between the amount of termite reworked soil and energy of compaction and between the uncured and sun-cured unconfined compressive strength was plotted against the number of blows for BDL1, BDL2 and BDL3 respectively. In sum, these stabilised soils are suitable for foundation and landfills materials.

KEYWORDS

compaction; index test; X-ray Diffraction; stabilization; strength test.

1. INTRODUCTION

Lateritic soils abound in most parts of the tropical world including Nigeria and it is predominant in most of the sub-grade soils in Nigeria. These lateritic soils have over the years found a wide range of applications as foundations for structures and more importantly as construction materials for structures such as building, roads, highways, dams and embankments (to show its acceptance). Incessant occurrences of road pavement failure and building collapse have caused more accidents in recent times than before and these place limitations on the growth of a nation (Ale, 2021; Ale et al., 2022). This has informed the decision to properly understand the geotechnical properties of residual lateritic soils. Each of the ubiquitous soils often exhibits unique set of physical, chemical and mineralogical properties (which in turn define the engineering properties).

These properties make lateritic soils fair to good engineering soils. In some cases, the properties of soils in the immediate vicinity of the construction site may not meet the required standards. In such cases it may not be economically justifiable to import materials that meet such standards to the construction sites. For proper utilizations of any engineering purpose, there is need to carry out a thorough geotechnical evaluation. This is to be done through the process of stabilization in order to improve the properties of the available soils (Adeyemi, 2003). Over the years, the process of compaction has aided the stabilization of lateritic soils. As desired by the engineer, the dry density and moisture content of lateritic soils can be economically managed within limits during construction to produces oils that would nearly exhibit the properties like shrinkage, california bearing ratio, unconfined compressive strength, shear strength parameters, consolidation, etc. (Gidigasu, 1976).

Several researchers who have compacted some Nigerian lateritic soils, concluded that soil compaction cannot be underestimated in the construction of sub-grades and stabilized bases (Madu, 1977; Malomo et al., 1983; Meshida, 1985; Ogunsanwo, 1989a&b; Adeyemi, 1992; Adedeji, 2001). Majorly, the level of soil compaction depends on pedogenic factors of parent rock, topography, climate, drainage condition, vegetation, etc. These researchers have investigated the influence of reworking by termites on some engineering properties of lateritic soils, with little efforts

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made at investigating the influence of termite-reworked soil on the engineering properties of such soils. This has led to an attempt to study the variation of strength characteristics of soils with respect to the amounts of termite-reworked soil and energy of compaction. In order to determine which combination of the two variables will yield the best stabilized soil.

2. Study Area

The study area is located in the northern part of Ibadan, and it is between Gongola and Barth Road within the University of Ibadan, Ibadan, Nigeria (Figure 1). The study area lies between Longitudes 3⁰53'10'' and 3⁰53'25'' East of Greenwich Meridian and Latitudes 7⁰26'10'' and 7⁰26'20'' North of the Equator. The elevation ranges from 254m to265m above the mean sea level. The sampling location (longitude 3⁰53'20'', latitude 7⁰26'12'') is along Barth Road, within the University of Ibadan, close to the new sport Complex. This area is characterized by two distinct seasons: the rainy season (April–October); and dry season (November–March). The sampling location is generally accessible through network of roads, footpaths etc. The fieldwork was carried out in October when the vegetation in the area has not been thick, thus making this area more accessible. Extreme temperature of about 29⁰C and 34⁰C occur at the peak of the wet season and onset of the wet season respectively while the lowest temperature being about 21⁰C. The mean annual rainfall is between 788mm and 1884mm (Nigeria Meteorological Agency). These high rainfall and temperatures are likely to enhance the chemical weathering of rocks.

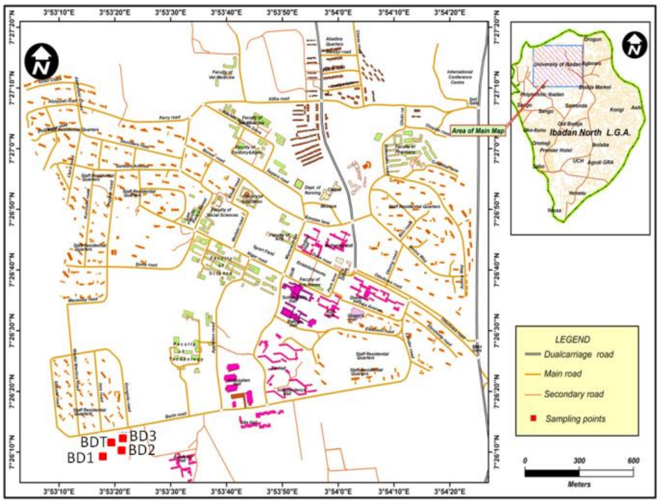

Figure 1: Map showing the accessibility and road network of the study area

3. Geology of The Study Area

The Ibadan study area falls within the Basement Complex of Southwestern Nigeria (Figure 2). The area is dominated by the Migmatite Complex and quartzite of metasedimentary sands. These rocks are intruded by quartz veins, aplite, dolerite, pegmatite, and quartzo-feldspatic intrusions. The Quartz-Schist outcrops occur as long ridges with relatively high elevation making them conspicuous. The sampling points are underlain dominantly by quartz schist with coarse grained texture and the occurrences of quartzo-feldsparthic veins in them.

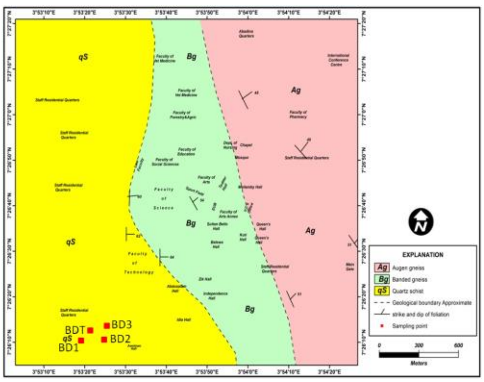

Figure 2: Geological map of study area showing the sampling spot (NGSA 1966)

4. Materials and Methods

The project was carried out in two major stages, namely: field investigation, which included sample collection, description and preparation; and the laboratory analyses, that involved pretest preparation of the samples, classification and strength tests. The four bulk soil samples consisting of 1 termite-reworked soil (TRS; Figure 2) and 3 residual lateritic soils were collected at New Stadium Road, Awo hall, University of Ibadan, at a depth of 2m for strength analysis. For index test, samples were taken at depth 1m, 1.5m and 2m respectively. The Ibadan residual lateritic soils used for the study were collected from test pits established at different locations around a termitarium confirmed to be underlain by Quartz Schist. Bulk samples were strictly taken from the lateritic horizon of complete and well pronounced profile within the vicinity of the termitarium. This is to ensure that they are not transported soils. The laboratory analyses carried out on the samples are the geotechnical analysis (index tests and strength tests) and geochemical analysis (X-ray Diffraction). The basic index properties were determined by following the procedures stipulated by the British Standard 1377 of 1975. However, modifications were introduced whenever necessary. In order to effect adequate segregation of grains of the soil into appropriate size grades, each soil sample was soaked in a dispersing or deflocculating agent known as weak calgon solution (sodium hexametaphosphate solution) i.e. 10 grams in 4 litres of distilled water for 24 hours, during which it was regularly agitated and squeezed before being wet sieved. The soils are generally mottled reddish brown stiff sandy silty clay.

5. Results and Discussion

5.1 Geochemical properties

The mineralogy of the soil showed that they contain no undesirable mineral constituent as they contain mainly quartz, kaolinite and hematite (Table 1and Figure 3). BDL1 and BDT have quartz and kaaolinite as their major minerals. However, termite-reworked soil is richer in kaolinite content than the quartz schist derived soil with about 125% increase. BDL2 and BDL3 compose mainly of quartz, kaolinite and hematite. The hematite content could have been due to the excess iron and aluminium during lateralization (Osinubi and Katte, 1997). Good drainage and slightly acidic conditions favour the formation of laterites containing stable clay minerals such as kaolinite exist in all the locations where the samples were taken (Gididgasu, 1976; Duane and Robert, 1997).

Table 1: Quantitative mineralogical composition of studied soils

Samples	Major Minerals	Minor Minerals
BDL1	Quartz-88.47%	Kaolinite-11.53%
BDL2	Quartz-88.51%	Kaolinite-8.39%, Hematite-3.09%
BDL3	Quartz-78.06%	Kaolinite-16.16% Hematite-5.78%
BDT	Quartz-65.06%	Kaolinite-34.94%

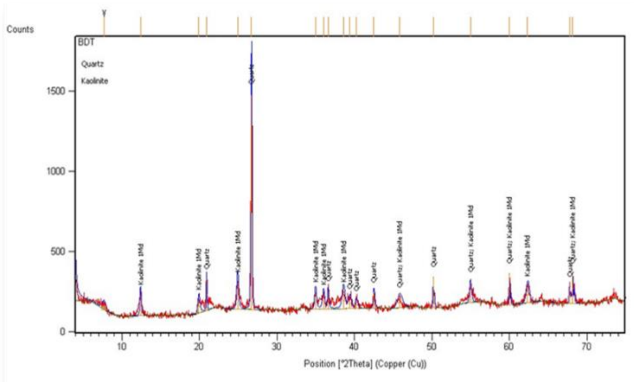

Figure 3: Diffractogram showing the mineralogy of BDT

5.2 Index properties

Table 2 shows the summary of the results of index tests on the soil samples. The liquid limit of the termite-reworked soil samples (BDT10-BDT12) range from 41.29% to 44.77% while those of the residual lateritic soil samples (BDL1-BDL9) range from 41.31% to 56.41%. This shows that the liquid limits of the termite-reworked soil samples are lower than those of the residual lateritic soil samples. The plasticity indexes of the termite-reworked soil samples (BDT10-BDT12) ranges from 16.62%-17.39% while those of the residual lateritic soils ranges from 16.76%-22.12%. The plasticity values were generally lower than 25, the maximum value recommended for sub-grade tropical Africa soils (Medina 1963; Simon et al., 1973). Both the termite-reworked soil samples and the residual lateritic soil samples meet this standard specification. According to Federal Ministry of Works and Housing, subgrade/fill material should have liquid limit ≤50% and plasticity index ≤30% while for sub-base, liquid limit should be ≤ 30% and plasticity index ≤ 12% (Federal Ministry of Works and Housing, 1997). Also, according to the liquid limit values of 40% and above are assumed high in pavement construction (Wright, 1985).

They pointed out further that plasticity index value of 10% and above are also assumed high in pavement design. All the soils meet the requirement for use as subgrade/fill materials. The lower values of the termite-reworked soils make them better road construction materials than the Quartz schist-derived lateritic soil samples. The Casagrande chart classification (Figure 4) places virtually all the soil samples in the medium plasticity/ compressibility region (except BDL1, BDL4 and BDL6), hence these soils would be expected to exhibit medium swelling potential (Ola, 1983). The values of the linear shrinkage of the studied soil range from 6% to 16% (Table 2). The average linear shrinkage of the termite-reworked soil (7%) was lower than the maximum value of 8% and 10% recommended by for highway sub-base and sub-grade soils respectively (Madedor, 1983). While the average linear shrinkage values of the nearby residual lateritic soil was higher than the maximum value of 8% and 10% recommended for highway sub-base and sub-grade soils respectively (Madedor, 1983). Therefore, the residual lateritic soil would pose a field compaction problem unless it is stabilized.

The lower values exhibited by termite-reworked soil samples agrees with that of the plasticity index. The specific gravity values of the sampled soils range from 2.60 to 2.66 (Table 2). Alexander and Cady gave values of 2.50 to 3.60 for specific gravity of lateritic soils while De-Graft Johnson recommended a range of value between 2.60 and 3.40 for specific gravity of lateritic soils (Alexander and Cady, 1962; De-Graft Johnson, 1969). Thus, the specific gravity value of the derived soil samples falls within the stipulated range. Again, there is a very close range in the values of the specific gravity of the grains of the studied soils which is an indication that the soils are of the same genetic origin and similar weathering environment. It is worthy of note that the termite-reworked samples gave the highest values while the soil samples derived from Quatrz Schist exhibit the lowest values. The difference in the value of specific gravity can only be due to reworking by termites (in termite-reworked soils). The grading curves of the studied soils are presented in Figures 5. The summary of the grain size distribution characteristics of the studied soils are shown in the Table 2 below.

The coarse contents of the soils range from 33.88% to 63.05% while the fine contents of the soils range from 33.95% to 66.12%. It can be seen that termite-reworked soils have a much lower percentage of fines (clay and silt-sized particles) (with an average of 34.92) than the nearby residual lateritic soil indicating better geotechnical characteristics. The reworking by termites on the termite-reworked soil has some remarkable influence on the grain size distribution. Daniel recommended number of fines of at least 20% for landfill seals i.e. for soil that can be good for base of landfill (Daniel, 1993b). Therefore, the studied soils meet this standard specification and can be used for base of landfill. Using the American Association of State Highway and Transportation Official (AASHTO) classification in table 2, termite-reworked soils (BDT10, BDT11 and BDT12) fall within the A-2-7.

This implies that the soil samples are rated between excellent to good sub-grade materials while the residual lateritic soils (BDL1, BDL4, BDL6) fall within A-7-5, BDL2, BDL3 fall with A-7-6, BDL5, BDL7, BDL8, and BDL9 fall within A-2-7. This implies that most of the residual lateritic soils are rated under the range of fair to poor, hence needs to be improved (stabilized). From the results obtained the values of the soils activities range between 0.41 and 0.63 (Table 2). This implies that the clay minerals present in all the soils is kaolinite. Soils rich in kaolinite are less hydrophilic and plastic in nature. These are characterized by low moisture affinity because of their small surface area and inter layer spacing of 7Å. Hence, they are good materials for engineering construction.

Table 2: Summary of all the engineering index tests on the soil samples

Sample	LL	PL	PI	LS	SG	Fines (%)	Percent of Course (%)	Activity	GI	AASHTO	USCS	Clay type
BDL1	52.38	32.13	20.25	16	2.60	66.12	33.88	0.45	13.5	A-7-5	CH	kaolinite
BDL2	47.11	28.73	18.38	**12**	2.60	51.06	48.94	0.46	6.8	A-7-6	CI	kaolinite
BDL3	44.14	26.06	18.08	12	2.60	51.72	48.28	0.49	6.8	A-7-6	CI	kaolinite
BDL4	56.41	34.29	22.12	17	2.65	35.69	64.31	0.46	6.8	A-7-5	CH	kaolinite
BDL5	41.31	21.73	19.58	16	2.65	41.53	58.47	0.63	3.9	A-2-7	CI	kaolinite
BDL6	50.77	32.01	18.76	12	2.60	51.48	48.52	0.43	7.4	A-7-5	CH	kaolinite
BDL7	48.02	30.82	17.20	11	2.65	41.12	58.88	0.41	3.4	A-2-7	CI	kaolinite
BDL8	43.24	26.48	16.76	7	2.65	35.87	64.13	0.45	1.6	A-2-7	CI	kaolinite
BDL9	46.10	29.07	17.03	7	2.65	41.90	58.10	0.43	3.6	A-2-7	CI	Kaolinite
BDT10	43.56	26.46	17.10	8	2.65	33.95	66.05	0.46	1.8	A-2-7	CI	Kaolinite
BDT11	41.29	24.67	16.62	6	2.66	34.30	65.70	0.48	1.2	A-2-7	CI	Kaolinite
BDT12	44.77	27.38	17.39	7	2.65	36.52	63.48	0.46	2.0	A-2-7	CI	kaolinite

LL liquid limit, *PL* plasticity limit, *PI* plasticity index, *LS* linear shrinkage, *SG* specific gravity, *GI* group index,

AASHTO American Association of State Highway Transportation Office.

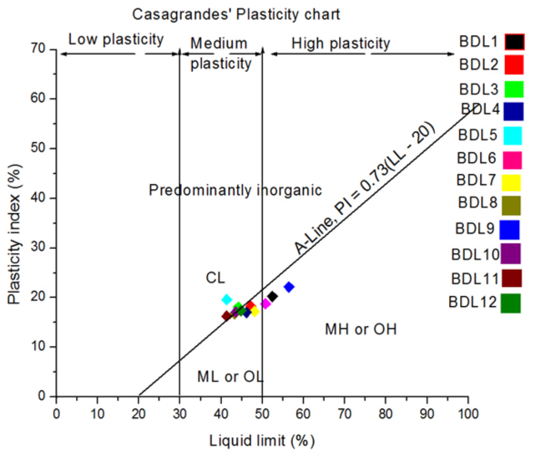

Figure 4: Casagrande Chart Classification of the Studied Soil Samples

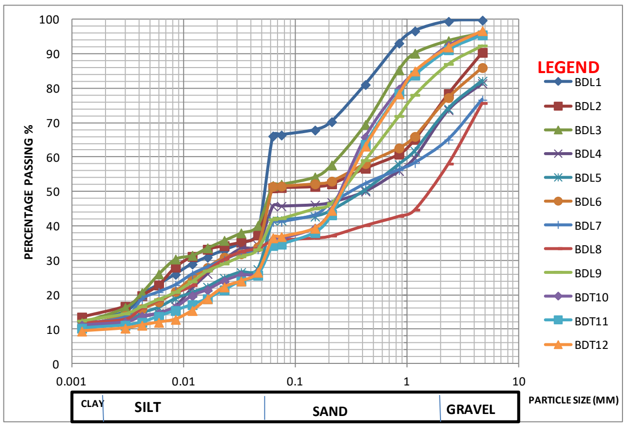

Figure 5: Grading curves of all soil samples (residual lateritic and termite-reworked soils)

5.3 Soil Strength Properties

The maximum dry density (MDD) values of the studied soil range from 1761.10 Kg/m³ to 1911.15 kg/m³ while the optimum moisture content (OMC) values of the studied soil range from 16.40% to 20.41% at all the levels of compaction (Table 3). The termite-reworked soils had better compaction parameters than those of residual lateritic soils when compacted and also, the optimum moisture content of the studied soils reduce drastically. The influence of level of compaction is stronger at 30% by volume of stabilizer than what was obtained at 10% and 20% (table 4, figure 6). Regression method was employed to establish relationships between some of the geotechnical parameters and the quantity of the applied stabilizer. This was done to understand the degree of influences of the parameters on each other and on the overall behaviour of the soils. This is confirmed by the strongest positive correlation of 0.96 established at 55 blows (figure 7 & 8). For any soil to be suitable for general filling and construction of sub-grade and sub-base courses of roads, the maximum dry density (MDD) must exceed 1700 Kg/m³ (Nigerian General Standard Acceptable Limits FMW,1997). All of these sampled soils exceed the required standard.

Table 3: Summary of compaction test result

Sample	Level Of Compaction	
	West African Level	
	MDD	OMC
Termite –reworked soil (BDT)	1911.15	16.40
Residual lateritic soil (BDL1)	1761.10	20.41
Residual lateritic soil (BDL2)	1817.88	17.22
Residual lateritic soil (BDL3)	1872.03	18.61

Table 4: Variation of the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) with termite-reworked soil content for sample BDL1-BDL3 compacted at different levels

Sample	Stabilizer (%)	Level Of Compaction							
		25 BLOWS		35 BLOWS		45 BLOWS		55 BLOWS	
		MDD (Kg/m³)	OMC (%)	MDD (Kg/m³)	OMC (%)	MDD (Kg/m³)	OMC (%)	MDD (Kg/m³)	OMC (%)
BDL1	10	1781.47	19.61	1811.32	20.01	1832.16	19.62	1862.34	20.06
	20	1791.47	20.00	1830.24	21.21	1849.75	21.61	1892.24	20.82
	30	1806.50	20.09	1842.14	20.81	1861.34	22.02	1930.01	21.61
BDL2	10	1871.95	17.60	1890.39	18.03	1912.81	19.20	1925.30	19.60
	20	1886.54	18.02	1901.84	18.41	1921.82	18.82	1939.92	18.99
	30	1891.66	18.37	1911.26	18.61	1940.05	19.01	1961.24	19.62
BDL3	10	1881.03	18.40	1890.04	18.80	1912.14	17.62	1929.88	19.61
	20	1870.14	18.20	1891.23	18.40	1921.95	19.00	1901.99	18.62
	30	1892.65	18.81	1912.08	18.61	1926.49	18.43	1940.16	18.00

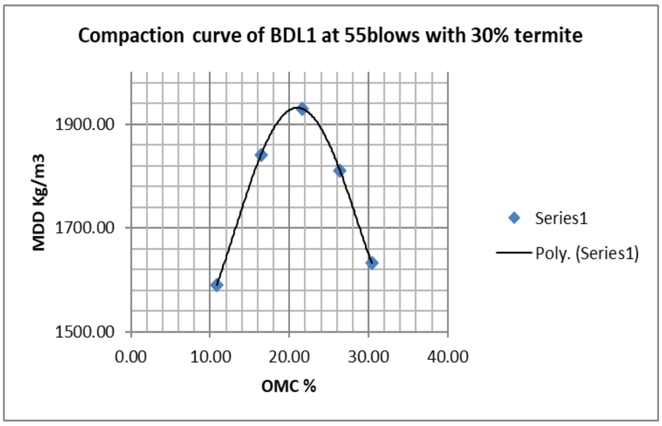

Figure 6: A compaction curve of a typical studied soil (BDL1 at 55blows with 30% termite rework soils)

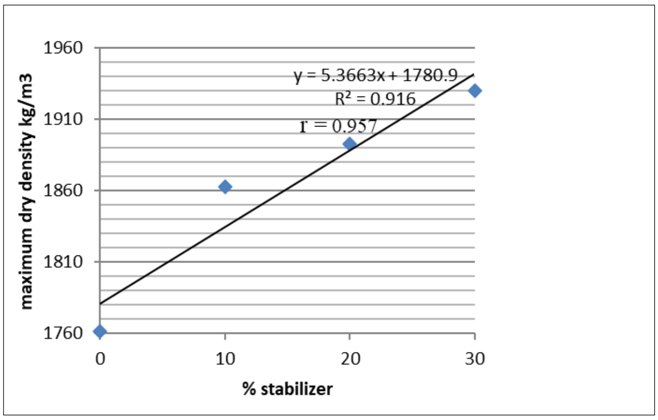

Figure 7: The regression line of the relationship between MDD (kg/m³) and Termite-reworked soil content (%) of sample BDL1 at 55 blows

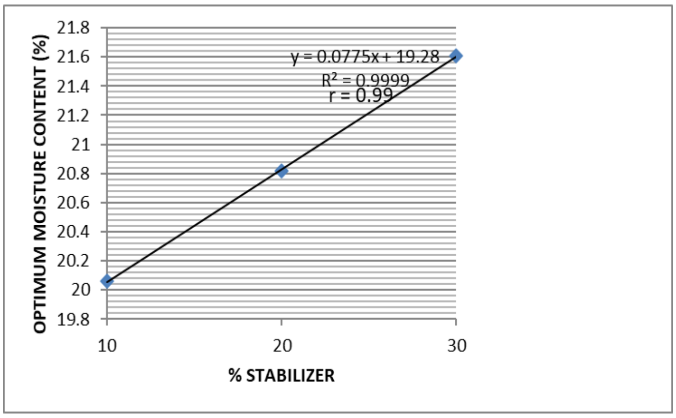

Figure 8: The regression line of the relationship between OMC (%) and Termite-reworked soil content (%) of sample BDL1 at 55 blows

The obtained results of uncured strength of the soils range from 240KN/m² to 450KN/m². The sun-cured strengths of the studied soil range from 1080KN/m² to 2800KN/m² (Table 5, Figure 9). Table 5 present a summary of the strength characteristics (uncured and sun-cured) of the stabilized soil samples compacted at West Africa level, 25 blows, 35 blows, 45 blows, and 55 blows. Soils compacted at 55 blows have higher uncured and sun-cured strength than those compacted at other levels. The Central Road Research Institute of India recommended 1034KN/m² as the minimum value for the cured strength of road soils (De-Graft-Johnson and Bhatia, 1969). On the other hand, the minimum acceptable value for uncured strength of soils is 103KN/m² (Ola, 1977). Both the uncured and sun-cured strength of the soil samples supersede this standard except BDT1 when compacted at West Africa level with 0% stabilizer as seen in table 5. From values obtained, the strength of the soil increased as a result of curing of the sample.

Furthermore, addition of 30% by volume of termite-reworked soil has greater positive influence on both the cured and uncured unconfined compressive strength of Quartz-schist-derived soil. Table 6 shows the summary of the Regression Equation and Correlation Coefficient of samples BDL1, BDL2 and BDL3 with variation of % stabilizer of TRS. A very strong positive correlation coefficient range of 0.77-0.99, 0.77-0.99 and 0.45-0.95 was obtained when the uncured and sun-cured unconfined compressive strength was plotted against the number of blows for BDL1, BDL2 and BDL3 respectively (Figures 10 and 11). This also confirms the positive influence of compaction on the strength of soil and substantiates the fact that the tropical soils are better compacted at Modified AASHTO level (55 blows). The summary of the regression equation and correlation coefficient of samples BDL1, BDL2 and BDL3 at varying energy levels of compaction are presented in table 7.

Table 5: Influence of levels of compaction on the unconfined compressive strength (C_o) of stabilized samples BDL1-BDL3

SAMPLE	% STABILIZER	LEVEL OF COMPACTION (WEST AFRICAN)							
		25 BLOWS		35 BLOWS		45 BLOWS		55 BLOWS	
		UNCURED (KN/m²)	CURED (KN/m²)	UNCURED (KN/m²)	CURED (KN/m²)	UNCURED (KN/m²)	CURED (KN/m²)	UNCURED (KN/m²)	CURED (KN/m²)
BDL1	10	200	1080	380	1200	400	1540	420	1800
	20	280	1240	400	1600	400	1680	400	1800
	30	320	1240	360	1640	400	1640	400	1900
BDL2	10	240	1680	360	1800	400	2000	400	1900
	20	360	1880	400	1950	400	2100	400	2200
	30	400	2200	400	2500	400	2550	450	2800
BDL3	10	380	1680	400	1800	380	1880	400	2200
	20	400	1800	400	1800	400	1950	400	2000
	30	400	2500	400	2400	400	2700	450	2750

Table 6: Summary of the Regression Equation and Correlation Coefficient of samples BDL1, BDL2 and BDL3 with variation of % stabilizer of TRS

Sample code/no of blows	Regression equation	Correlation coefficient (r)	Regression equation	Correlation coefficient (r)
BDL1 AT 25BLOWS	Y= 1.453X + 1763.4	0.991	Y_0 = 0.024X + 19.42	0.941
BDL1 AT 35BLOWS	Y = 2.6024X + 1771.9	0.946	Y_0 = 0.04X + 19.87	0.650
BDL1 AT 45BLOWS	Y= 3.183X + 1778.3	0.914	Y_0 = 0.12X + 18.88	0.930
BDL1 AT 55BLOWS	Y = 5.3663 + 1780.9	0.957	Y_0 = 0.0775 + 19.28	0.990
Sample code/no of blows	**Regression equation**	**Correlation coefficient (r)**	**Regression equation**	**Correlation coefficient (r)**
BDL2 AT 25BLOWS	Y = 2.359X + 1831.6	0.901	Y_0 = 0.0385X + 17.227	0.998
BDL2 AT 35BLOWS	Y = 2.9159X + 1836.6	0.885	Y_0 = 0.029 + 17.770	0.984
BDL2 AT 45BLOWS	Y = 3.755X + 1841.8	0.886	Y_0 = 0.0095X + 19.20	0.500
BDL2 AT 55BLOWS	Y = 4.447 + 1844.4	0.898	Y_0 = 0.001X + 19.383	0.028
Sample code/no of blows	**Regression equation**	**Correlation coefficient (r)**	**Regression equation**	**Correlation coefficient (r)**
BDL3 AT 25BLOWS	Y = 0.504X + 1871.5	0.630	Y_0 = 0.0205X + 18.06	0.659
BDL3 AT 35BLOWS	Y= 1.206X + 1873.4	0.950	Y_0 = 0.0095X + 18.793	0.470
BDL3 AT 45BLOWS	Y = 1.7319X + 1882.2	0.900	Y_0 = 0.0405X + 17.54	0.580
BDL3 AT 55BLOWS	Y = 1.765X + 1884.5	0.745	Y_0 = 0.0805X + 17.133	0.990
WHERE Y = Maximum Dry Density (MDD), X = % of TRS Stabilizer WHERE Y_0 = Optimum Moisture Content (OMC)				

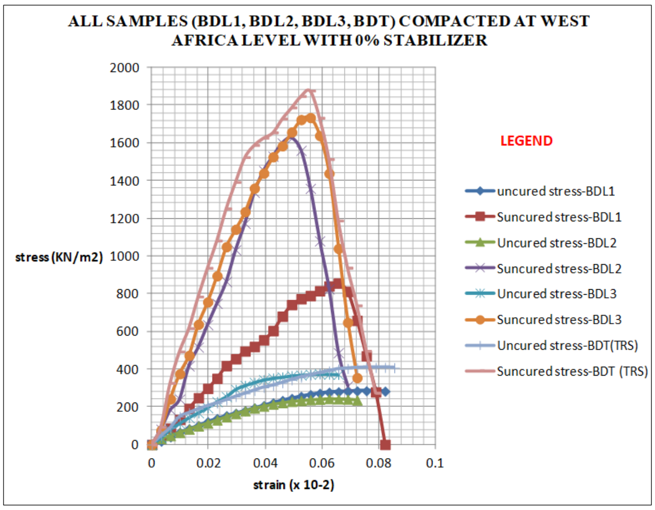

Figure 9: Representation of uncured and sun-cured strength for all samples at West African level

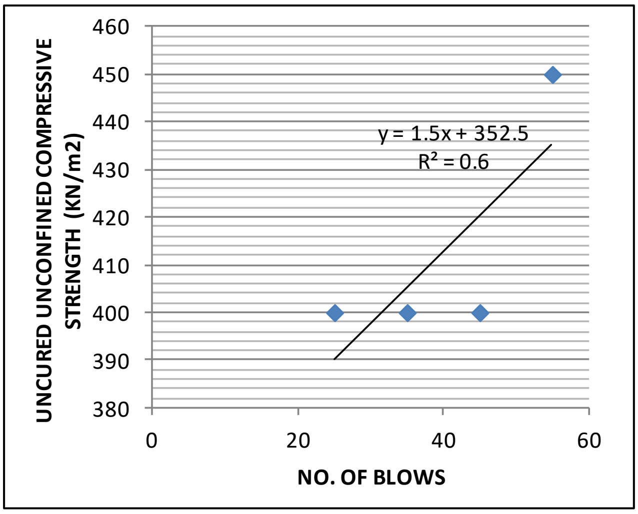

Figure 10: Regression line of the relationship between uncured UCS and the level of compaction (No of blows) at 30% TRS for BDL3

Table 7: The summary of the regression equation and correlation coefficient of samples BDL1, BDL2 and BDL3 at varying energy levels of compaction		
Ucs/ % Stabilizer Of Trs (Bdl1)	**Regression Equation**	**Correlation Coefficient (R)**
UNCURED /MIX WITH 10% TRS	Y = 6.8X + 78	0.87
SUN-CURED/ MIX WITH 10% TRS	Y = 26X + 405	0.99
UNCURED /MIX WITH 20% TRS	Y = 3.6X + 226	0.77
SUN-CURED/ MIX WITH 20% TRS	Y = 17.6X + 876	0.94
UNCURED /MIX WITH 30% TRS	Y = 2.8X + 258	0.94
SUN-CURED/ MIX WITH 30% TRS	Y = 19.8X + 813	0.94
Ucs/ % Stabilizer Of Trs (Bdl2)	**Regression Equation**	**Correlation Coefficient (R)**
UNCURED /MIX WITH 10% TRS	Y = 5.2X + 142	0.89
SUN-CURED/ MIX WITH 10% TRS	Y = 8.6X + 1501	0.81
UNCURED /MIX WITH 20% TRS	Y= 1.2X + 342	0.77
SUN-CURED/ MIX WITH 20% TRS	Y = 1101X + 1588.5	0.99
UNCURED /MIX WITH 30% TRS	Y = 1.5X + 352.5	0.77
SUN-CURED/ MIX WITH 30% TRS	Y = 1.5X + 352.5	0.97
Ucs/ % Stabilizer Of Trs (Bdl3)	**Regression Equation**	**Correlation Coefficient (R)**
UNCURED /MIX WITH 10% TRS	Y = 0.4X + 374	0.45
SUN-CURED/ MIX WITH 10% TRS	Y = 16.4X + 1234	0.95
UNCURED /MIX WITH 20% TRS	Y = 1.5X + 352.5	0.77
SUN-CURED/ MIX WITH 20% TRS	Y = 7.5X + 1587.5	0.94
UNCURED /MIX WITH 30% TRS	Y = 1.5X + 352.5	0.77
SUN-CURED/ MIX WITH 30% TRS	Y = 10.5X + 2167.5	0.82
Where Y = Uncured/ Sun-Cured Unconfined Compressive Strength (Ucs), X = No. Of Blows		

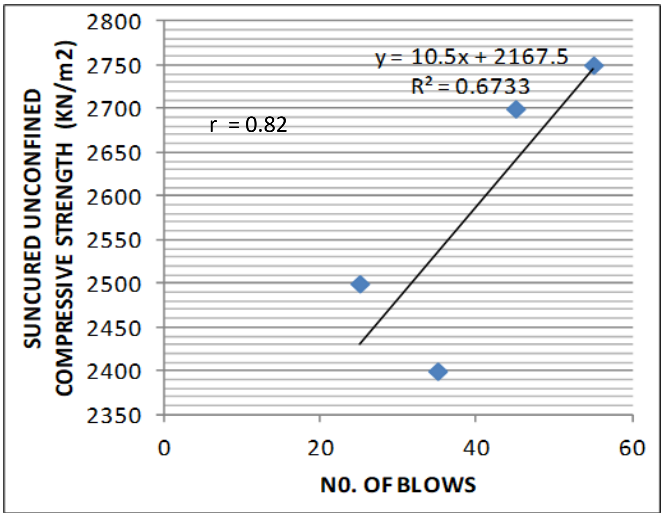

Figure 11: Regression line of the relationship between Sun-cured UCS and the level of compaction (No of blows) at 30% TRS for BDL3

The relationship between shear strength and sun-cured strength of samples compacted at West Africa level show that the studied soils possess good shear strengths (table 8). However, result confirms that the termite-reworked soils have higher compressive strength as well as shear strength than the residual lateritic soils at both cured and uncured conditions. Hence, the strength of the termite-reworked soil (BDT) is twice that of the lateritic residual soils (BDL1, BDL2, BDL3) derived from quartz-schist.

Table 8: Relationship between shear strength and sun-cured strength of samples compacted at West Africa level

Sample	Sun-Cured Stress (KN/m²)	Uncured Stress (KN/m²)	Shear Strength (KN/m² = K pa)	
			Sun-Cured	Uncured
BDL1	840	300	420	150
BDL2	1640	240	820	120
BDL3	1760	400	880	440
BDT	1900	400	950	475

5. Conclusions

The mineralogy of the soil showed that they contain no undesirable mineral constituent as they contain mainly quartz, kaolinite and hematite; with the termite-reworked soil richer in kaolinite content than the quartz schist derived soil with about 125% increase. Both the residual lateritic soil samples and termite-reworked soil samples are well graded and they exhibit medium to high plasticity. Values of Liquid limit of termite-reworked soil samples are lower than those of the residual lateritic soil samples. The plasticity indices of the samples taken from termitarium meet the specifications of the Federal Ministry of Works for roads and bridges. They also have lower plasticity indices than the residual lateritic soils therefore they can be used to stabilize the weaker residual lateritic soils. Conclusively, the stabilization of residual lateritic soil using termite-reworked soil as stabilizer brought about increase in the values of maximum dry density, uncured unconfined compressive strength as well as the sun-cured unconfined compressive strength of the studied soil. The influence of stabilization using termite-reworked soil was strongest at the highest level of compaction ((30%) of termite-reworked soil and subjected to the highest compactive energy). Both the amount of termite-reworked soil and energy of compaction show fairly strong positive correlations with the strength of the studied soil with values ranging from 0.63-0.99.

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Availability of data and material (data transparency): All the analysis was carried out in accordance with the code of investigation and practice.

Code availability (software application or custom code): Surfer and Excel were used

Authors' contributions (optional: please review the submission guidelines from the journal whether statements are mandatory) very good but can be made faster.

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