# Mechanical Stabilization of a Migmatite-Gneiss Derived Lateritic Soil from Ibadan, Southwestern Nigeria

**A. S. Adeoye, G. O. Adeyemi, B. A. Alo**

***Abstract: Samples of migmatite-gneiss-derived lateritic soil from Moniya, Ibadan southwestern Nigeria were stabilized with between 0 and 20% by volume of nearby termite-reworked soil under different energies of compaction. This was with a view to determining the influence of termite-reworked soil on some engineering properties of the soil. The amounts of termite-reworked soil mixed with the adjacent residual lateritic soil prior to compaction were 0, 10 and 20%, while each mixed soil was subjected to 10, 20, 30, 40, 50 and 60 blows of a 4.5 Kg Rammer falling from a height of 0.46 metre during compaction. Strong positive correlations of 0.94 and 0.99 were established between the maximum dry density and the percentage of volume of stabilizer of the samples compacted with 30 and 60 blows respectively. Negative correlations of -0.87 and -0.91 were found between the optimum moisture content and percentage of termite-reworked soils compacted at 30 and 60 blows respectively. The highest uncured and sun-cured compressive strength of 206KPa and 2148KPa were `respectively The influence of termite-reworked soils on the compaction characteristic of the soil thus increases with the energy of compaction. The influence of stabilization with termite-reworked soil on the unconfined compressive strength of the soil was found to be strongest upon compaction at highest levels for the sample stabilized with 20%by volume of termite-reworked soil. The highest unsoaked CBR value of 42.83% and soaked CBR value of 16.20% were obtained when 20% by volume of stabilizer was added to the soil. This implies that the influence of stabilizer was strongest when 20% by volume of termite-reworked soil was added to the studied soil. Results showed that the termite-reworked soil samples had better geotechnical properties than the soil developed over migmatite-gneiss based on the grading and plasticity characteristics. Compaction parameters, unconfined compressive strength and California Bearing Ratio of the stabilized samples were found to be significantly improved when compacted with 20% by volume of the termite-reworked soil. The sun-cured unconfined compressive strength of 2148KPa obtained for samples compacted at the modified American Association of the State Highways and Transportation Officials level shows they can be good for building bricks and road construction.***

***Keywords: Migmatite-Gneiss; Stabilization; Termite-Reworked Soil; Unconfined Compressive Strength; California Bearing Ratio***

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## I. INTRODUCTION

Soil stabilization is gaining wide popularity not only in Nigeria but in most parts o the tropical world. Physical and engineering properties of Nigerian soils are being modified to be suitable for utilities not only as construction materials but also as foundations for structures. Several researchers such as Ola (1974),

Olowe (1985) and Abolurin (1992) have stabilized Nigerian soil with cement. Adedeji (2001) while working on a residual lateritic soil in Ago-Iwoye, Southwestern Nigeria established fairly strong positive correlations between the geotechnical properties such as California Bearing Ratio (CBR) and unconfined compressive strength and energies of compaction of a residual lateritic soil from Ago-Iwoye. Adeyemi et al. (2004) confirmed statistically significant improvement in geotechnical properties of termite-reworked soil samples from Ago-Iwoye over those of nearby lateritic soil samples taken from identical depths. Ogunjobi (2006) noticed appreciable improvement in engineering properties suc h as CBR and unconfined compressive strength when samples of amphibolite derived soils from Ifewara road, Ile-Ife, were stabilized with 25% by volume of termite-reworked soil. Little or no attempts have, however, been made at investigating the influence of varying amounts of termite-reworked soil combined with energies of compaction on some basic engineering properties of Nigerian soils. Oyediran et al. (2008) recorded substantial improvement in engineering properties such as plasticity index, specific gravity and CBR of termite-reworked lateritic soils over those of lateritic soils form Akungba-Akoko. It is on the basis of this consideration that the influences of termite-reworked soil and energy of compaction on some basic geotechnical properties of a migmatite-gneiss-derived soil from Ibadan in Southwestern Nigeria were investigated.

## II. STUDY AREA

The study area is in the humid tropical part of southwestern Nigeria which is underlain by migmatite complex. The area which is located at the northern part of Ibadan is within Akinyele Local Government area of Oyo State. The area of study covers about 28 square kilometres. It lies between longitudes 3º53´ and 3º56´ and latitude 7º31´and 7º34´ (Fig. 1) with elevation range of 254m to 265m above the mean sea level.


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The study area falls within the Basement Complex of Southwestern Nigeria. The sampling location (longitude 3º54´55´´, latitude 7º33´23´´) is along Ibadan-Oyo expressway, located within the Deeper Life Camp Ground, via Moniya, Ibadan.

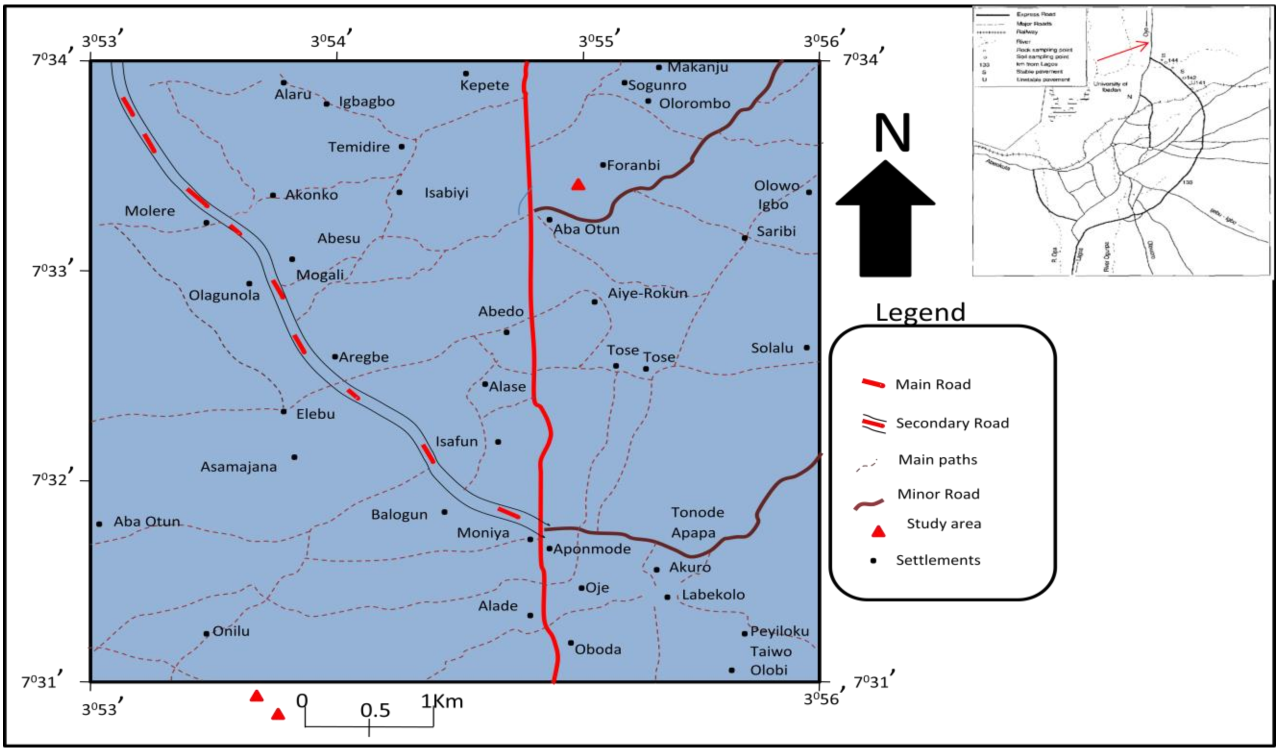


**Figure 1: Map Showing The Study Area**

The sampling location is generally accessible through network of roads, footpaths etc. The fieldwork was carried out in April when the vegetation in the area has not been thick, thus making such area more accessible.

## III. GEOLOGY

The study area, Ibadan, forms part of the area underlain by the Precambrian Basement Complex rocks of southwestern Nigeria which comprises igneous and metamorphic rock units such as gneisses, masses, including older granite ridges and pegmatites. The area is underlain dominantly by migmatite-gneiss. It has a coarse grained texture with occurrences of quartzo-feldsparthic veins in them. Essentially, the metamorphic rocks and igneous intrusions such as vein dykes and pegmatites underlie the area. These rocks occur either directly exposed or covered by shallow mantle of superficial deposits. Though the assemblages have been variedly classified, they may be broadly subdivided into the ancient migmatite-gneiss complex, the schist belts and Pan-African (ca. 0.6ga) intrusive series or the older granites plus minor rocks. Radiometric ages obtained from ancient migmatite-gneisses are notably between ca. 2.8 and 2.0 ga (23) older dates (> 3.0ga) have more recently been derived from some. The schist belts occur prominently within the western half of the country though a few have more recently been highlighted in the central and southern.

The study area in Ibadan southwestern Nigeria is shown in figure 1. The rock in the study area is migmatite-gneiss.

## IV. METHOD OF INVESTIGATION

The field investigations included the study of the geological and geotechnical settings of the area and collection of rock samples and four bulk soil samples within the study area at a depth of 2m. Bulk samples were strictly taken from the laterite horizon of complete and well pronounced profile within the vicinity of the parent rock. This ensures that they are not transported soils.

The Ibadan residual lateritic soils used for the study soil were collected from test pits established at different locations around a termitarium confirmed to be underlain by migmatite-gneiss. The termite-reworked soils were collected from termitarium in the same vicinity.

The samples were described in terms of consistency, colour and texture. The soils are generally mottled reddish brown stiff sandy silty clay.

Petrographic analysis was carried out on the rock samples collected, while the laboratory investigation procedures involved the use of air dried sample which were subjected to laboratory classification tests including; grain size distribution and consistency limits (liquid limit and plasticity limit). Other engineering tests often employed in evaluating highway sub-grade material were also conducted.


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These include: Compaction test, California Bearing Ratio (CBR) test, Unconfined Compression test, using British Procedure with some modification where necessary. The amounts of termite-reworked soil mixed with the adjacent residual lateritic soil prior to compaction were 0, 10 and 20%, while each mixed soil was subjected to 10, 20, 30, 40, 50 and 60 blows during compaction.

## V. RESULTS AND DISCUSSION

### A. Petrography of The Rock

Petrographic study of the parent rock (migmatite-gneiss) gave an approximate composition of the rock to be predominantly of quartz (45%), alkali feldspar (19%), plagioclase feldspar (8%), biotite (14%) muscovite (9%), and others (5%).

The rock is coarse grained. The texture and mineralogy of the parent rock are likely to reflect in the engineering properties of the derived soils such as texture and plasticity.

### B. Specific Gravity of Grains

The specific gravity of soil particles is an important engineering index property often employed in estimating the degree of laterization of lateritic soil (Lohnes and Demirel, 1973; Truncer and Lohnes, 1977). It is an important property in identifying and evaluating aggregates for construction purpose (Gidigasu, 1976).

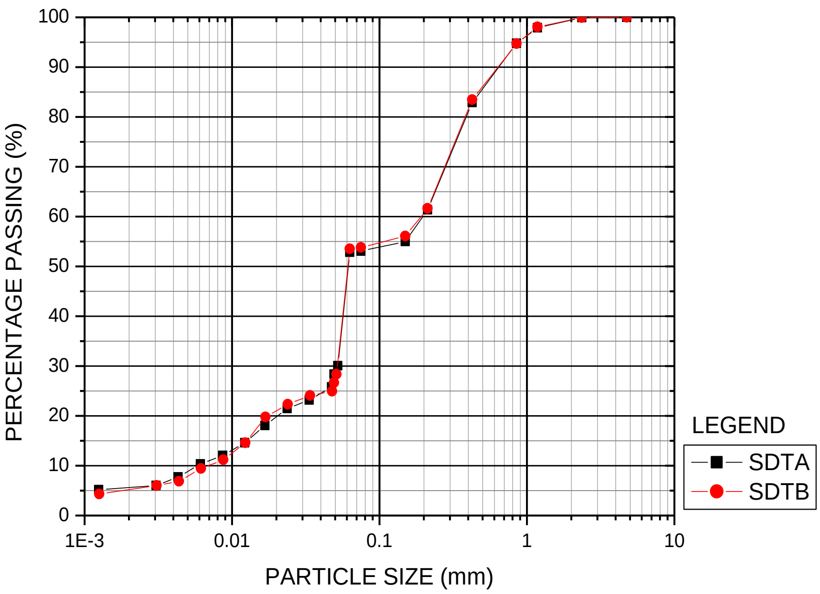
The specific gravity value of the derived soil samples fall within the stipulated range given by Alexander and Cady (1962) which is between 2.50 to 3.60 and the one given by De-Graft Johnson (1969) which is also between 2.60 and 3.40.

**Table 1: Result of Specific Gravity of the Migmatite-Gneiss-Derived Soil Samples at Depth 2m**

| Sample | SD1$^{A}$ | SD1$^{B}$ | SD2$^{A}$ | SD2$^{B}$ | SD2$^{A}$ | SD2$^{B}$ | SDT$^{A}$ | SDT$^{B}$ |
|---|---|---|---|---|---|---|---|---|
| Specific Gravity | 2.52 | 2.52 | 2.55 | 2.55 | 2.60 | 2.60 | 2.65 | 2.65 |
| Average Specific Gravity | 2.52 | | 2.55 | | 2.60 | | 2.65 | |

### C. Grading Characteristics

The termite-reworked soil samples on the average contain 2% gravel-size grains, 50.5 % sand-size grains and 47.5% fines. The residual lateritic soil samples on the average contain 3.75% gravel-size grains, 36.1% sand-size grains and 60% fines. It can be seen that termite-reworked soils have a much lower percentage of fines (clay and silt-sized particles) 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.




| Clay | Silt | Sand | Gravel |
|---|---|---|---|

**Figure 2: Grading Curves of Termite-Reworked Soil Samples**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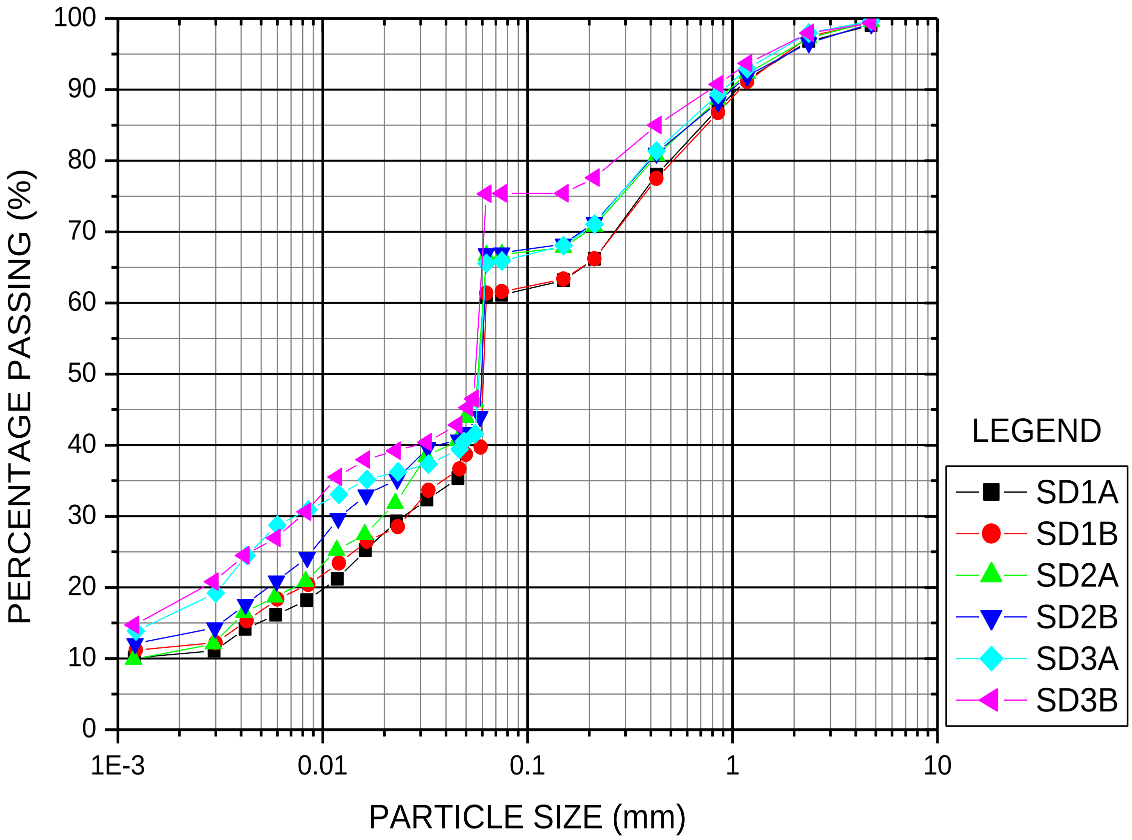


| Clay | Silt | Sand | Gravel |
|---|---|---|---|

**Figure 3: Grading Curves of Residual Lateritic Soil Samples**

**Table 2: Grain Size Distribution Characteristics of the Studied Soils**

| SAMPLES | % GRAVEL | % SAND | % SILT | % CLAY | AMOUNT OF FINES (%) | UNIFORMITY COEFFICIENT($D_{60}/D_{10}$) |
|---|---|---|---|---|---|---|
| $SD1^A$ | 4.0 | 38.0 | 48.0 | 10.0 | 58 | 30.5 |
| $SD1^B$ | 4.0 | 41.0 | 44.0 | 11.0 | 55 | - |
| $SD2^A$ | 3.0 | 37.0 | 47.0 | 12.0 | 59 | - |
| $SD2^B$ | 5.0 | 37.0 | 44.0 | 14.0 | 58 | - |
| $SD3^A$ | 3.0 | 37.0 | 44.0 | 16.0 | 60 | - |
| $SD3^B$ | 3.0 | 27.0 | 52.0 | 18.0 | 70 | - |
| $SDT^A$ | 2.0 | 51.0 | 41.0 | 6.0 | 47 | 36.36 |
| $SDT^B$ | 2.0 | 50.0 | 43.0 | 5.0 | 48 | 28.57 |

### D. Plasticity Characteristics

Table 4 summarizes the consistency limits of the studied soils. The Table presents that the liquid limit of the termite-reworked soil samples ($SDT^A$ and $SDT^B$) range from 35.02% to 36.25% while those of the residual lateritic soil samples range from 44.10% to 50.25%. This shows that the liquid limits of the termite-reworked soil samples are lower than those of the residual lateritic soil samples. The plasticity indices of two termite-reworked soil samples range from 15.91% to 16.24% and the plasticity indices of residual lateritic soil samples range from 17.21% to 20.29%. The plasticity values were generally lower than 25, the maximum value recommended for sub-grade tropical Africa soils (Medina 1963, in Simon *et al*. 1973). Both the termite-reworked soil samples and the residual lateritic soil samples meet this standard specification. The average linear shrinkage of the termite-reworked soil was lower than the maximum value of 8% and 10% recommended by Madedor (1983) for highway sub-base and sub-grade soils respectively.



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**Table 3: Consistency Limits of The Studied Soils**

| SAMPLES | LIQUID LIMIT (%) | PLASTIC LIMIT (%) | PLASTICITY INDEX (%) |
|---|---|---|---|
| **SD1[A]** | 49.60 | 28.78 | 17.31 |
| **SD1[B]** | 48.00 | 29.64 | 18.36 |
| **SD2[A]** | 44.10 | 24.01 | 20.09 |
| **SD2[B]** | 45.07 | 25.64 | 21.57 |
| **SD3[A]** | 50.21 | 29.99 | 20.29 |
| **SD3[B]** | 45.24 | 24.95 | 20.29 |
| **SDT[A]** | 36.25 | 20.01 | 16.24 |
| **SDT[B]** | 35.02 | 19.11 | 15.91 |

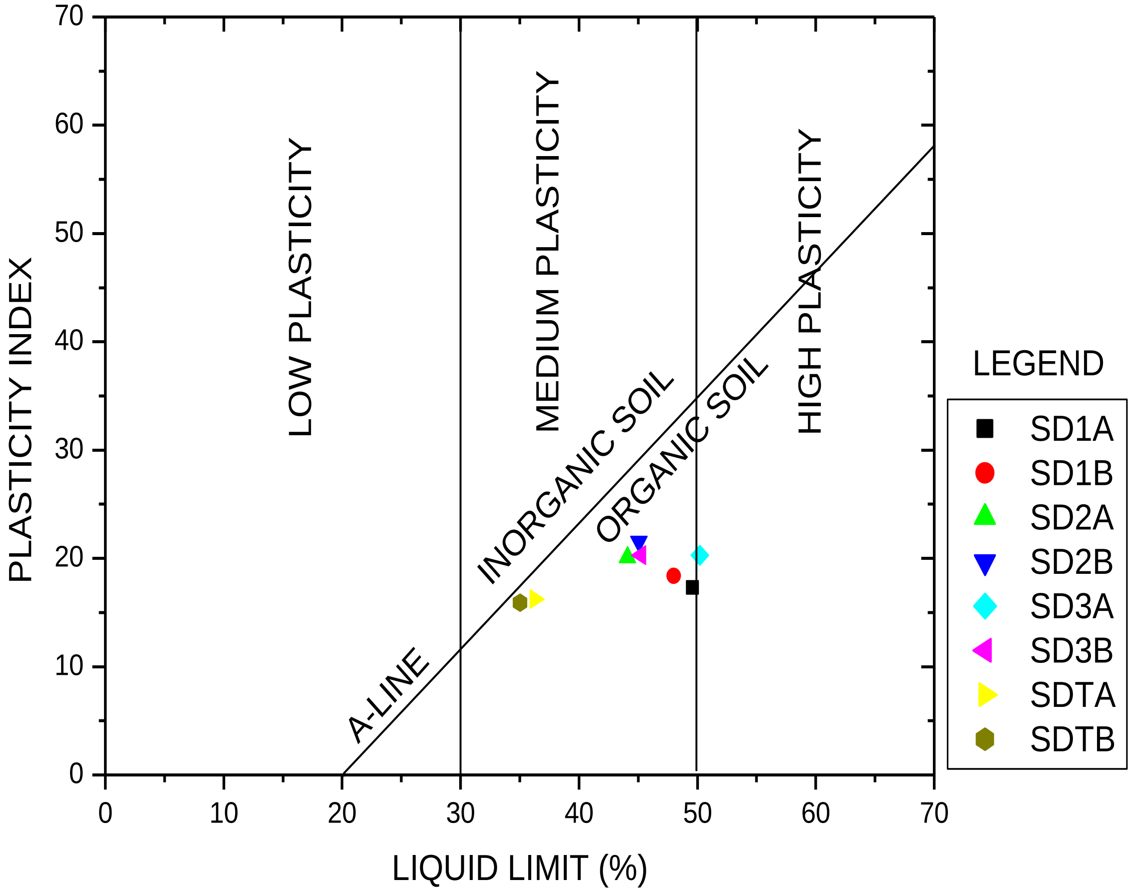


**Figure 4: Casagrande Chart Classification of the Studied Soil Samples**

### E. Compaction Characteristics

The dry density and optimum moisture content of the soils compacted at different energy levels are shown in the Table 5. The data show that the highest MDD of 1840 kg/m$^3$ and the lowest OMC of 18% are exhibited by soil sample mixed with 20% termite-reworked soil and subjected to 60 blows of the compaction rammer. The influence of level of compaction is stronger at 20% by volume of stabilizer than what was obtained at 10%. The optimum moisture content (OMC) values of the studied soil range from17.20% to 20.07% at all the levels of compaction. The increase in energy of compaction drastically reduces optimum moisture content of the studied soils.

The results obtained in this study confirmed that the addition of 10% by volume termite-stabilized soil to samples of lateritic soils subjected to modified AASHTO level of compaction can produce soil of adequate strength for highway sub-base (De-Graft Johnson and Bhatia 1970). The study also showed that stabilization of the residual lateritic soil using 20% by volume of the termite-reworked soil and compaction at 60 blows is the most suitable combination because it produced the best moisture content and dry density parameters.


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**Table 4: Influence of Energies of Compaction and Amounts of Termite-Reworked Soil on the Compaction Parameters of Optimum Moisture Content (OMC) and Maximum Dry Density (MDD).**

| % STABILIZER | LEVEL OF COMPACTION | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 BLOWS | | 20 BLOWS | | 30 BLOWS | | 40 BLOWS | | 50 BLOWS | | 60 BLOWS | |
| | MDD Kg/m3 | OMC % | MDD Kg/m3 | OMC % | MDD Kg/m3 | OMC % | MDD Kg/m3 | OMC % | MDD Kg/m3 | OMC % | MDD Kg/m3 | OMC % |
| 0 | **1650.3** | **17.20** | **1670.1** | **17.50** | **1720.1** | **17.90** | **1670.05** | **18.00** | **1675.5** | **18.05** | **1790.25** | **18.20** |
| 10 | **1670.2** | **18.40** | **1690.2** | **18.00** | **1730.1** | **18.00** | **1770.0** | **19.20** | **1790.4** | **19.70** | **1810.07** | **20.07** |
| 20 | **1700.2** | **17.40** | **1720.2** | **17.60** | **1770.1** | **18.00** | **1800.0** | **18.40** | **1825.0** | **18.25** | **1840.15** | **18.00** |

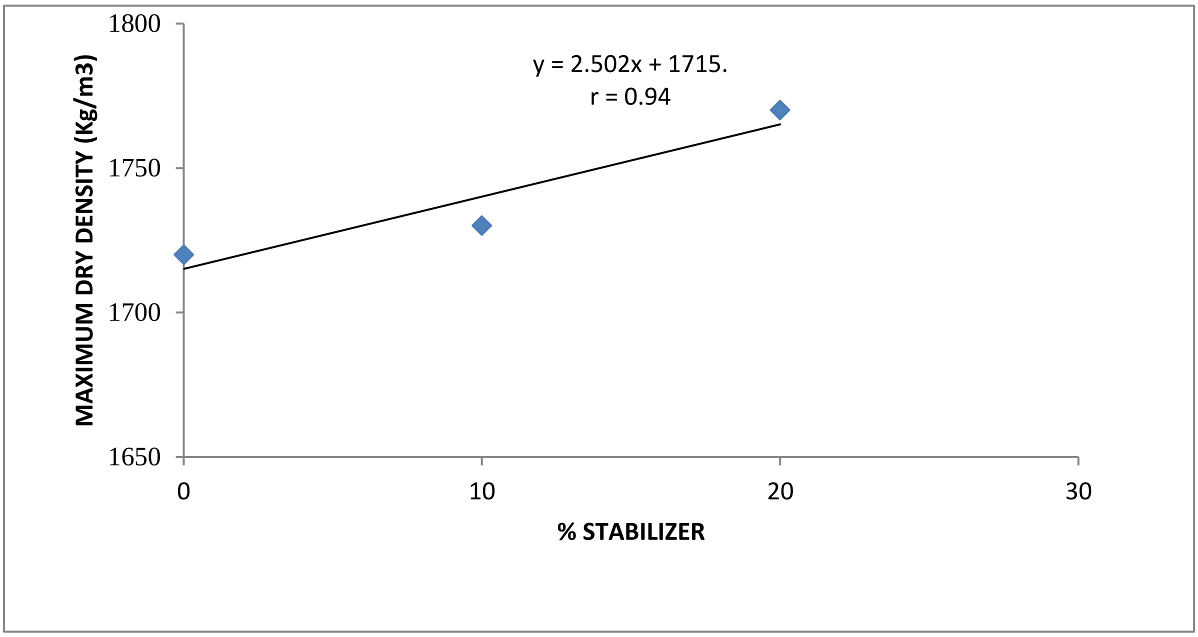


**Figure 5: The Regression line of the Relationship Between MDD (kg/m$^3$) and Termite-Reworked Soil Content (%) of Sample at the West African Level**

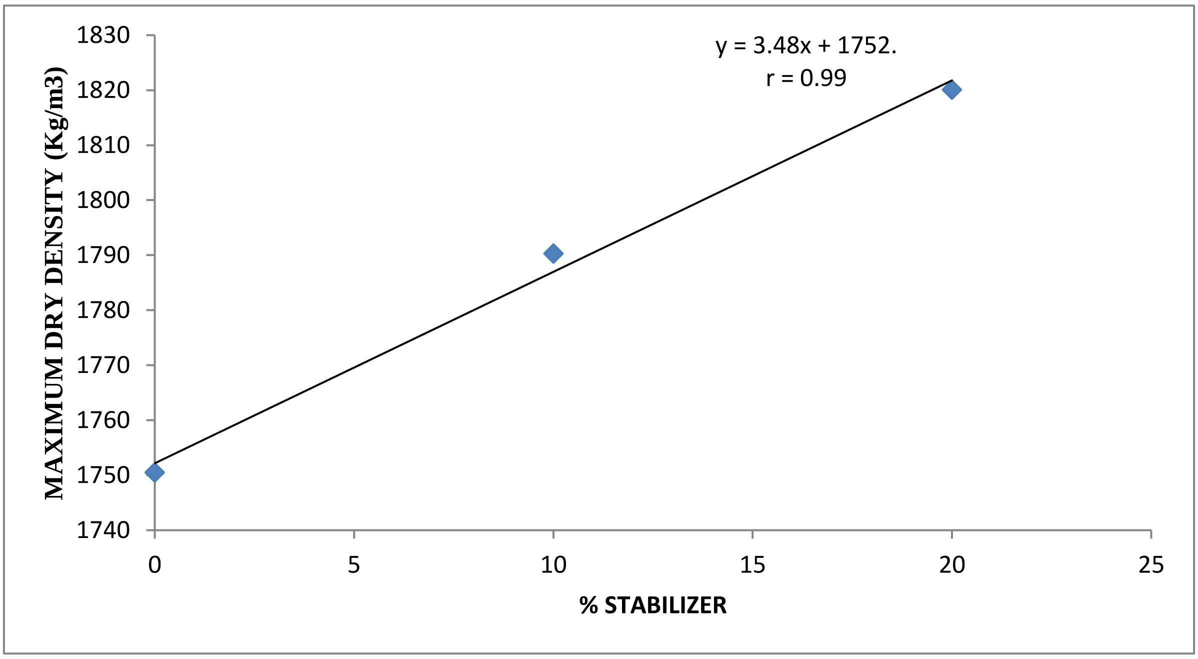


**Figure 6: The Regression Line of the relationship Between MDD (kg/m3) and Termite-Reworked Soil Content (%) of Sample at the Modified AASHTO level**



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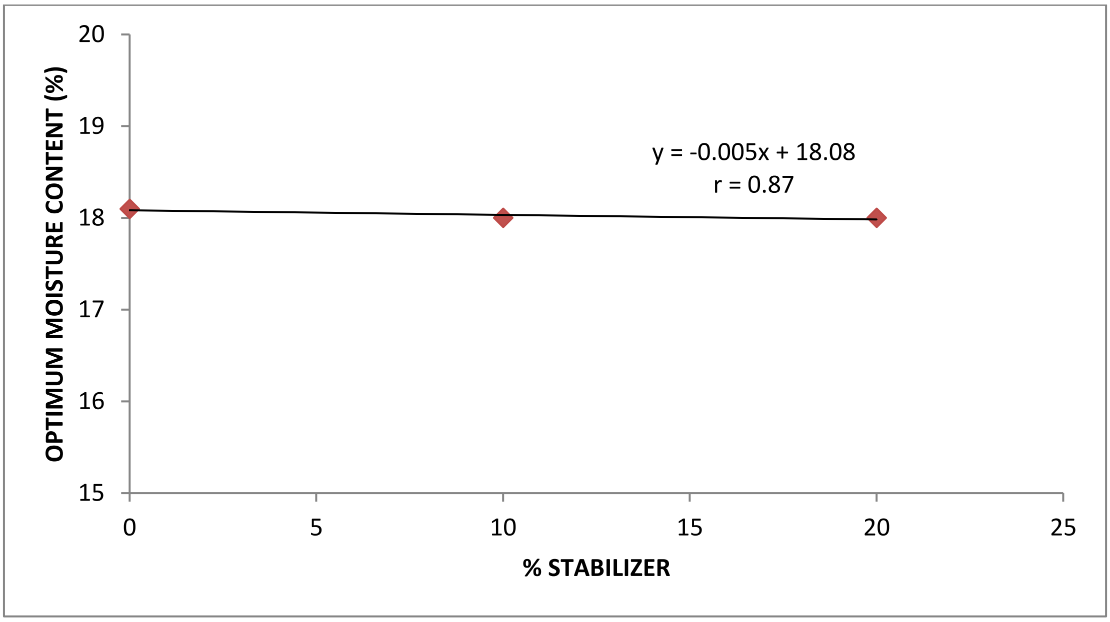


**Figure 7: The regression line of the relationship between OMC (%) and termite-reworked soil content (%) of sample at the West African Level**

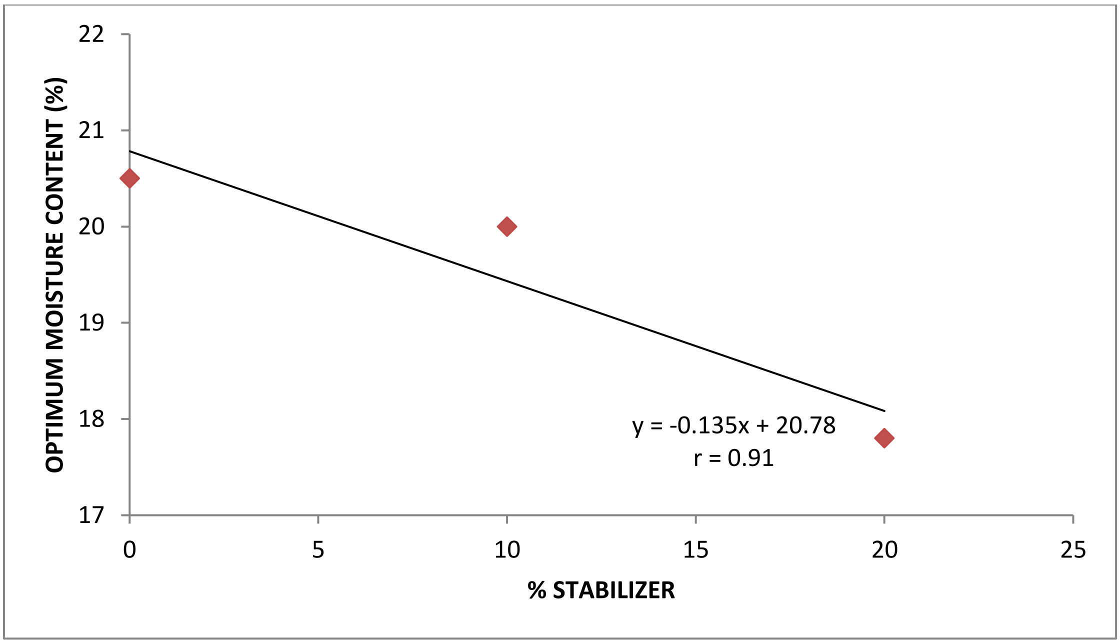


**Figure 8: The regression line of the relationship between OMC (%) and termite-reworked soil content (%) of sample at the Modified AASHTO level**

### F. California Bearing Ratio (CBR)

The results of unsoaked and soaked CBR of the soil samples compacted at optimum moisture content are presented in Tables 6 and 7. From the Tables it is evident that there is a general increase in the soaked and unsoaked CBR values from 10 blows to 60 blows. It was revealed that the highest unsoaked CBR value of 42.83% and soaked CBR value of 16.20% were obtained for sample SD2 when 20% by volume of stabilizer was added to the soil. This implies that the influence of stabilizer on CBR was strongest when 20% by volume of termite-reworked soil was added to the studied soil.

The Asphalt Institute (1962) cited in Adeyemi (1992) recommended an unsoaked CBR value of 7% to 20% for sub-base material and CBR of 0% to 7% for highway sub-grade materials. The Federal Ministry of Works and Housing (1974) specified minimum values of 15% and 10% for unsoaked and soaked samples respectively. The unsoaked and soaked CBR of the stabilized lateritic soils are thus qualified to be used as both sub-base and sub-grade materials because they meet the specifications of both the Institute and FMWH.

### G. Unconfined Compressive Strength

Table 14 presents a summary of the strength characteristics (uncured and suncured) of the stabilized soil samples compacted at different energy levels.


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Soils compacted at 60 blows have higher uncured and suncured strength than those compacted at other levels. The obtained uncured strength of the soils range from 59.50KN/m$^2$ to 206.00KN/m$^2$ and the suncured strengths of the studied soil range from 481.12KN/m$^2$ to 2148KN/m$^2$. The addition of 20% by volume of termite-reworked soil has greater positive influence and remarkable improvement on both the cured and uncured unconfined compressive strength of the soil. Soils compacted at 60 blows have highest uncured and suncured strength.

It is the soil stabilized with 20% by volume of termite-reworked soil and compacted at 60 blows that yields the maximum uncured strength which is twice of the minimum values of 103KN/m$^2$ recommended by Ola, (1977) for road construction materials and the highest cured strength of 2148KN/m$^2$ which is by far higher than the minimum value of 1034KN/m$^2$ recommended by the Central Road Research Institute of India (De-Graft-Johnson and Bhatia, 1969) for road soils. Considerable increases of 16.68%, 8.75% and 4.11% were obtained for all samples SD1, SD2 and SD3 respectively, when the unconfined compressive strength at 10% by volume of stabilizer was compared with the unconfined compressive strength at 20% by volume of stabilizer. The addition of 20% by volume of termite-reworked soil has greater positive influence on both the cured and uncured unconfined compressive strength of the soil.

**Table 5: Influence of Levels of Compaction on the Unconfined Compressive Strength (Co) of Stabilized Sample SD1**

| % STABILIZER | LEVEL OF COMPACTION | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | WEST AFRICAN | | 10 BLOWS | | 20 BLOWS | | 30 BLOWS | |
| | UNCURED (KN/m$^2$) | CURED (KN/m$^2$) | UNCURED (KN/m$^2$) | CURED (KN/m$^2$) | UNCURED (KN/m$^2$) | CURED (KN/m$^2$) | UNCURED (KN/m$^2$) | CURED (KN/m$^2$) |
| 10 | 133.78 | 1241.4 | 63.50 | 844.40 | 149.68 | 1128.66 | 147.04 | 1612.74 |
| 20 | 137.00 | 1500.86 | 160.12 | 1318.18 | 153.96 | 1448.44 | 149.5 | 1881.82 |

| % STABILIZER | LEVEL OF COMPACTION | | | | | |
|---|---|---|---|---|---|---|
| | 40 BLOWS | | 50 BLOWS | | 60 BLOWS | |
| | UNCURED (KN/m$^2$) | CURED (KN/m$^2$) | UNCURED (KN/m$^2$) | CURED (KN/m$^2$) | UNCURED (KN/m$^2$) | CURED (KN/m$^2$) |
| 10 | 192.34 | 1665.7 | 203.32 | 1921.78 | 213.16 | 2105.62 |
| 20 | 199.66 | 1956.76 | 210.76 | 2070.78 | 218.00 | 2149.22 |

## VI. CONCLUSIONS

From the foregoing interpretation and discussions of the basic geotechnical properties of the studied soils, the following conclusions can be drawn:

The termite-reworked soil had a better grading and plasticity characteristics than the nearby residual lateritic soils. The addition of termite-reworked soils to the residual lateritic soil improved the geotechnical properties of the studied soil such as maximum dry density, unsoaked CBR, soaked CBR, uncured unconfined compressive strength and suncured unconfined compressive strength of the studied soil. The highest uncured compressive strength of 206KPa and the highest suncured strength of 2148KPa were obtained for the sample stabilized with the highest amount (20%) of termite-reworked soil and subjected to the highest compactive energy (60 blows). Results showed that the termite-reworked soil samples had better geotechnical properties than the soil developed over migmatite-gneiss based on the grading and plasticity characteristics. Compaction parameters, unconfined compressive strength and California Bearing Ratio of the stabilized samples were found to be significantly improved when compacted with 20% by volume of the termite-reworked soil. The sun-cured unconfined compressive strength of 2148KPa obtained for samples compacted at the modified American Association of the State Highways and Transportation Officials level shows They can be good for building bricks and road construction. This investigation has thus confirmed that termite-reworked soil is viable in the stabilization of the studied soils with 20% by volume as the optimum amount needed.

## RECOMMENDATION

Based on this study, the following recommendations could be made: Similar investigations should be extended to many tropical lateritic soils developed over parent rocks of widely different mineralogy and texture. The importance of geology in the choice and/or quantities of this stabilizer will thus be further revealed. Since the tested soils suffer significant reduction as a result of soaking adequate site drainage facilities should be provided if soils are to be used for construction purpose. It is also recommended that further investigations of mechanical stabilization are undertaken in order to further elucidate the influence of termite-reworked on the improvement of the strength properties of residual lateritic soil. This will facilitate a thorough understanding of the combined influence of the amount of termite-reworked soil and comp active effort on the strength characteristics of lateritic soils.


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