Abstract- Fifteen samples of coarse-grained lateritic soils obtained from different parts of Anambra State were assessed for their suitability as materials for highway construction. The soil samples were subjected to laboratory tests to obtain their index properties, compaction and California bearing ratio (CBR) characteristics. Three compactive efforts namely, British Standard Light (BSL) compaction, West African Standard (WAS) and British Standard Heavy (BSH) compaction were employed in the compaction tests. Samples were soaked for 48hrs prior to CBR testing. The index properties of the soils were used to classify the soils as silty sand (SM) or silty sand/clayey sand (SM-SC) based on the Unified Soil Classification System (USCS) classification as well as silty soils (A – 4) or silty/clayey gravel and Sand (A – 2 – 4) based on American Association of State Highway and Transportation Officials (AASHTO) classification. All the fifteen soils fell under "grading F" based on AASHTO standard specification designations for particle size distribution. The maximum dry unit weight (MDUW) of the soil samples ranged from 16.203 kN/m$^3$ to 19.424 kN/m$^3$, 17.385 kN/m$^3$ to 19.996 kN/m$^3$ and from 18.126 kN/m$^3$ to 21.473 kN/m$^3$ with corresponding optimum moisture content of 11.4% to 21.4%, 12.45% to 12.5% and 8.5% to 11.75% for WAS, BSH and BSL respectively. The CBR values ranged between 7.92% and 18.87%. Most of the soil (more than 50%) did not meet the lower values of MDUW while only 20% of the soils had CBR values above 10% which is specified for subgrade soils by the AASHTO standard and the Nigerian Highway Design Manual, Federal Ministry of works and Housing.

Keywords- coarse-grained, lateritic soils, highway pavement materials, USCS, AASHTO

1 INTRODUCTION

Lateritic soils can be described as reddish-brown residual soils that are formed by the weathering of pre-existing rocks such as granite, shale, limestone, schist sandstone and gneiss (Okeke et al., 2013). They are mainly formed in tropical climatic regions of the world (Adeyemi, 2002). The geotechnical features/behaviour and performance of most lateritic soils are influenced by some factors including origin, degree of weathering, morphological characteristics, chemical and mineral composition as well as by the environmental conditions. Available data on geotechnical characteristics of laterite soils show that they range in performance from very good to poor for engineering purposes. (Eze et al, 2014)

A substantial increase in soil use for engineering works is expected with any country gearing towards improved infrastructural development and due to the abundance of lateritic soils in tropical areas, these soils are utilized in various forms of engineering works. The relationship between all engineering infrastructure and their foundation soils is of great importance for designers, engineers and contractors. Lateritic soils are utilized as construction materials in a range of civil engineering works as. As road construction material and in view of certain strength requirements, they form the sub-grade of most roads in tropical areas, and can also be used as sub base courses for roads not subjected to heavy traffic. However, the use of unsuitable soil type in road construction results in instability and subsequent failure. Most road failures in some tropical areas are attributed to poor construction materials (Adams and Adetoro, 2014).

In tropical areas, especially because of the variance in geotechnical properties of lateritic soils caused by different formation factors, it is common to find difference in the characteristics and investigation results even within short distances and/or depth (Adeyemi and Wahab, 2008). Thus, the need for investigating the engineering properties of lateritic soils before their use in civil engineering works is important to determine their suitability as a construction material for that particular need. Hence, the objective of this study is to assess the suitability of selected coarse-grained lateritic soils in Anambra State, Nigeria for highway construction, hence providing data for engineers, designers and contractors when they encounter such soils.

2 MATERIALS AND METHODS

Fifteen soil samples labeled STAN 1 – STAN 15 were used in this study. The soils were obtained from different locations within Awka, Anambra State, Nigeria. (06°12’25” N 07°04’04” E) see map of study area in appendix. These soils belong to the group of ferruginous tropical soils derived from acid igneous and metamorphic rocks (Osinubi, 1998a). The reddish-brown coloured lateritic soils used in this study are low-plasticity clays according to the Unified Soil Classification System, USCS (ASTM D 2487). The coordinates of sampling locations are shown in Table 1.

*Corresponding Author
The samples were subjected to moisture content tests, specific gravity test, sieve analysis test (hydrometer method), Atterberg limit test, compaction test, and California Bearing Ratio (CBR) test in the laboratory. Sieve analysis and Atterberg limit tests were carried out in accordance to BS 1377-2:1990. The compaction tests were carried out with three different compaction energies of BS Light compaction energy (BSL), BS Heavy compaction energy (BSH), and West African Standard (WAS) compaction energy. The BSH and BSL are the British Standard (BS) equivalents of the Modified and Standard Proctor compactions (ASTM D 1557 and ASTM D 698), respectively. The WAS or Intermediate compaction is the conventional energy level commonly used in the region and consists of the energy derived from a 4.5-kg rammer falling through 45.72 cm unto five layers in a BS 1,000 cm³ mould, each receiving 10 blows (Ola 1983; Osunbi 1998a, b). CBR test was carried out according to the procedure described in ASTM D1883-16 (ASTM D1883-16, 2016).

### 3 RESULTS AND DISCUSSIONS

#### 3.1 PHYSICAL PROPERTIES

The physical properties of the soils used in this study and a descriptive analysis of the range of index properties is shown in Tables 2a and 2b, respectively. Index properties of these soils can be used to classify based on AASHTO (American Association of State Highway and Transportation Officials) and USCS (Unified soil classification system) as shown in Table 3. From Table 3, it is seen that all the lateritic soils considered are not suitable for sub base.

#### 3.2 INDEX PROPERTIES

| Sample | Specified gravity, 𝑔 | % Fines | LL (%) | PI (%) |
|--------|----------------------|---------|--------|--------|
| STA 1  | 2.35                 | 36.13   | 28.3   | 26.69  | 1.61   |
| STA 2  | 2.64                 | 36.67   | 26     | 23.89  | 3.12   |
| STA 3  | 2.6                  | 33.34   | 29     | 25.41  | 5.59   |
| STA 4  | 3.21                 | 32.4    | 30     | 25.33  | 4.67   |
| STA 5  | 2.59                 | 36.96   | 28.3   | 24.80  | 3.50   |
| STA 6  | 2.45                 | 34.97   | 28.1   | 26.69  | 1.41   |
| STA 7  | 2.64                 | 32.64   | 28.5   | 25.41  | 3.09   |
| STA 8  | 2.63                 | 38.13   | 30.8   | 25.88  | 4.92   |
| STA 9  | 2.59                 | 30.42   | 28.5   | 25.86  | 2.64   |
| STA 10 | 2.48                 | 29.52   | 28     | 24.62  | 3.38   |
| STA 11 | 2.6                  | 37.71   | 30.4   | 26.02  | 4.38   |
| STA 12 | 2.45                 | 28.91   | 27     | 24.89  | 2.11   |
| STA 13 | 2.64                 | 27.24   | 27.6   | 25.01  | 2.59   |
| STA 14 | 2.58                 | 27.12   | 27.8   | 24.24  | 3.56   |
| STA 15 | 2.48                 | 37.57   | 29     | 22.47  | 6.54   |

### 3.3 CLASSIFICATION OF THE LATERITIC SOILS ACCORDING TO USCS AND AASHTO

| Sample designation | USCS classification system | AASHTO classification system | Suitability as construction material USCS | General rating as sub-grade (AASHTO) |
|--------------------|---------------------------|-------------------------------|------------------------------------------|-------------------------------------|
| STA 1              | SM                        | A-4                          | fair                                     | Fair - poor                         |
| STA 2              | SM                        | A-4                          | fair                                     | Fair - poor                         |
| STA 3              | SM-SC                     | A-2-4                        | Fair - good                             | Excellent - good                    |
| STA 4              | SM-SC                     | A-2-4                        | Fair - good                             | Excellent - good                    |
| STA 5              | SM                        | A-4                          | fair                                     | Fair - poor                         |
| STA 6              | SM                        | A-2-4                        | fair                                     | Excellent - good                    |
| STA 7              | SM                        | A-2-4                        | fair                                     | Excellent - good                    |
| STA 8              | SM-SC                     | A-4                          | Fair - good                             | Excellent - good                    |
| STA 9              | SM                        | A-2-4                        | fair                                     | Excellent - good                    |
| STA 10             | SM                        | A-2-4                        | fair                                     | Excellent - good                    |
| STA 11             | SM-SC                     | A-4                          | Fair - good                             | Excellent - good                    |
| STA 12             | SM                        | A-2-4                        | Fair - good                             | Excellent - good                    |
| STA 13             | SM                        | A-2-4                        | Fair - good                             | Excellent - good                    |
| STA 14             | SM                        | A-2-4                        | fair                                     | Excellent - good                    |
| STA 15             | SM-SC                     | A-4                          | Fair - good                             | Fair - poor                         |

SM - Silty sand, SM-SC - Silty sand-Clayey sand, A-4 - Silty soils and A-2-4 - Silty or clayey gravel and Sand
3.2 PARTICLE GRADATION

Particle gradation of each lateritic soil sample used in this study is shown in Fig. 1.

Most of the engineering properties of coarse-grained soils are closely associated with the predominant particle size (Gidigasu, 1976). The percentage of fines has significant effect on the performance of the base and sub-base materials (Garg 2009). The lateritic soils used in this study can be classified under “grading F” based on the AASHTO standard specification designation as shown in Table 4. However the requirement for soils to be used as sub-base include that the plasticity index shall be not more than one thirds of the fraction passing the 0.425 mm sieve and if it is to be used as base course, the aggregate shall meet the grading for B, C or D of AASHTO standard Specification. The fraction passing the 0.075 mm sieve shall be not more than one thirds of the fraction passing the 0.425 mm sieve and plasticity index of not more than 6. Although these soils satisfied the requirements for use as sub – base, the minimum of fines do not. Hence these soils do not satisfy the criteria for sub – base and base – course based on particle size distribution.

3.3 COMPACTION CHARACTERISTICS

Results of the compaction test are shown in Table 5, from the compaction results, it is observed that he maximum dry unit weight (MDUW) of the soil samples ranged from 16.2033 kN/m³ to 19.4242 kN/m³, 18.1255 kN/m³ to 21.473 kN/m³ and 17.3853 kN/m³ to 19.9955 kN/m³ with corresponding optimum moisture content of 21.4% to 11.4%, 8.5% to 11.7%, and 12.45% to 12.5% for BSL, BSH and WAS compaction efforts respectively.

3.4 CBR CHARACTERISTICS

The CBR values are shown in Table 6. Comparisons have been made between experimental values and values from standard tables extracted from Yoder and Witzczak (1975) for USCS and AASHTO classifications. Values of CBR ranged between 7.92% and 18.87%. About 80% of the samples had CBR values less than 10%. The plot of CBR values against fines content to sand content ratio (FC/SC) shown in fig 2a tends to suggest that CBR values decreased as FC/SC values increased. This is in agreement with the findings of Sreedhar and Fatima (2017) who showed that soaked CBR values decreased consistently with increase in fines content. Increase in fines content...
corresponds with decrease in sand content and hence increase in FC/SC ratios. Inan et al. (2016) also showed that CBR values decreased as fines contents increased.

Results obtained indicate that only STAN 10, STAN 11 and STAN 13 with CBR values of 11.96, 10.27 and 18.87 fall within the typical range of CBR according to AASHTO and USCS. This shortfall could as a result of the 48hrs of soaking which reduces the CBR as compared to the un-soaked typical range of CBR according to AASHTO and USCS. However, only STAN 10, STAN 11 and STAN 13 with CBR values of 11.96, 10.27 and 18.87 respectively fall within the range of 10% to 25% CBR value specified for sub grade soils by the AASHTO standard and the Nigerian Highway Design Manual, Federal Ministry of Works and Housing. All soil samples tested are unsuitable for use as sub-base and base material in road pavement construction since the CBR values are less than 30% and 80% respectively as recommended by the Nigerian Highway Design Manual, Federal Ministry of Works and Housing (1997).

4 CONCLUSION

Fifteen samples of coarse-grained lateritic soils are subjected to basic laboratory tests in order to assess their suitability as highway construction materials. MDUW values obtained from BSL compaction did not meet the lower limits of typical MDUW values indicated by USCS for some lateritic soils. Soaked CBR values were higher for soils with lower fines content/sand content ratios. Soaked CBR values were higher for soils with lower fines content/sand content ratios. The soaked CBR values can be used to determine lateritic soils that are suitable for different pavement layers, while considering the influence of fines contents characterized by fines content/sand content ratios. Measured values of MDUW may not be adequate for determining the suitability of lateritic soils for pavement construction.

REFERENCES

Adams J.O. and Adetoro A. E. (2014) Analysis of Road Pavement Failure caused by soil properties along Ado-Ekiti - Akure Road. *Nigeria International Journal of Novel Research in Engineering and Applied Sciences (IJNREAS)* vol.1 No. 1, pp 1-7.

Adeyemi, O.A. (2002) Geotechnical Properties of Lateritic Soil Development over Quartz Schist in Ishara Area Southwestern Nigeria. *Journal of Mining and Geology*. Vol. 38 No 1, pp 57 – 63.

Adeyemi, G.O. and K.A. Wahab, (2008). Variability in the Geotechnical Properties of a Lateritic Soil from South Western Nigeria. *Bulletin of Engineering Geology and Environment*. Vol. 67, pp 579-584.

American Association of State Highway and Transport Officials (AASHTO) (2011). AASHTO M147-65. Materials for aggregate and Soil Aggregate subbase, base, and surface courses. In *Standard Specifications for Transportation materials and methods of sampling and Testing*.

ASTM Designation D1883, (2007). “Standard Test Method for CBR (California Bearing Ratio) of Laboratory Compacted Soils, pp 2-3. D1883-16:2016.

ASTM (1993): D 2487-93 – Unified Soil identification and Classification. *ASTM International*, West Conshohnocken, PA, 19428-2959, United State of America

BSI377 (1990). Specification for Roads and Bridges in Nigeria. Vol. 2, pp. 137-275.

Eze E. O., Adeyemi. G. O. and Fasanmade P. A. (2014). Variability in Some Geotechnical Properties of Three Lateritic Sub-Base Soils
Along Ibadan Oyo Road. IOSR Journal of Applied Geology and Geophysics. Vol 2:5, pp 76-81

Federal Ministry of Works and Housing (1997) *General Specification for Roads and Bridges*, Federal Highway Department, FMWH: Lagos, Nigeria, vol. 2, pp. 317.

Garg, S. K. (2009). Soil Mechanics and Foundation Engineering. *Khana publishers, New Delhi* vol 7, No 1, pp. 673–683.

Gidigasu, M.D. (1976). “Lateritic Soil Engineering” Elsevier Scientific Publishing Company Amsterdam http://en.wikipedia.org/wiki/polyethylene,polyethylene, Accessed date August 8, 2006.

Inan, I.I.I, Mampesarachchi, W.K, and Udayanga, P.A.S (2016) Effect of fine percentage on the properties of sub-base material Engineer (The Institution of Engineers, Sri Lanka). Vol XLIX, No. 4, pp 15 – 25.

Ola, S. A. (1983). Geotechnical behaviour of some Nigerian lateritic soils. Published in “Tropical Soils of Nigeria in Engineering Practice”, edited by Ola, S.A. (pp. 85-101): A.A. Balkema/Rotterdam

Okeke, O.C., Ogbunyiba,O.O. and Chukwujekwu, D. (2013).Geotechnical Evaluation of Lateritic Soil Deposits in parts of Abuja (Nigeria), for Road Construction”. *International Journal of Environmental Issues*, vol 10 No 1, pp. 148-160.

Osinubi, K.J. (1998a), Influence of compactive efforts and compaction delays on lime treated soils, *Journal of Transportation Engineering*. A.S.C.E, vol. 124 No 2, pp 149-155.

Osinubi, K.J. (1998b), Pemeability of Lime treated laterite soil, *Journal of Transportation Engineering*, A.S.C.E vol 124, No 5, pp. 456-469.

Sreedhar, M.V.S and Fatima, Z. (2017), Influence of plastic fines on compaction and CBR characteristics of soil mixtures. *International journal of Engineering Research and Technology*, Vol. 6, No. 7, pp 233-239.

Yoder, E.J. and Witczak, M.W. (1975) “Principle of Pavement Design”. *John Wiley & Sons, Hoboken*, vol 1, No 2, pp. 711.

Younoussa M, Karfa T, Raguínaba O, Kalsibiri K, Philippe B, and Jean H. (2008) Geotechnical, mechanical, chemical and mineralogical characterization of lateritic gravels of Sapouy (Burkina Faso) used in road construction. *Construction and Building Materials (Elsevier)*. Vol. 22, pp 70–76.