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Geotechnical Properties of Offa Lateritic Soils and its Suitability as Subbase and Base Materials

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ABSTRACT; The determination of the suitability of the base, subbase and subgrade materials are important in road construction. This study evaluates the geotechnical properties of Offa lateritic soils and its suitability for use as subbase and base materials. The index properties, compaction, CBR and coefficient of permeability were conducted on the lateritic soils from the pits. The results revealed that the SG of the soil from the pits are within the specified range for lateritic soil. The NMC of pits A to D, conform to specified limit for road constructions while sample E does not conform to the specified range. The soils from pits A and B; and C and E, fall under group A-6 and A-7-6, respectively, while soil from pit D fall under group A-2-7. Soils from four pits are within the specified limit for LL while soil from one pit is above the limit. The CBR value of WAS shows that lateritic soils from three pits are suitable for use as subbase materials while lateritic soils from two pits are suitable for use as base materials. Lateritic soils from four pits under the AASHTO unsoaked are suitable for use as base materials, whereas only soils from one pit are suitable for use as subbase materials. However, all lateritic soils from under BS are suitable for use as subbase materials. The results of this study will be useful for road construction in Offa and its environs, thereby serving as guide for future road pavement design.

Keywords: Offa-Lateritic soil, Index properties, Strength properties, Subbase and Base

I. INTRODUCTION

The determination of the suitability of the base, sub-base and sub-grade materials are important for a highway Engineer to enable him identify and classify the materials, measure its strength, evaluate its drainage properties and help in processing the soil as a highway material. Base, sub-base and sub-grade materials are majorly composed of lateritic soil, which in the engineering field refers to all unconsolidated material in the earth crust i.e. all material above bedrock. Soil samples contain; Mineral and organic particles Water Air. The relative amounts of these three phases are indication of the soils properties and conditions (Oke et al., 2009; Nwankwoala and Amadi, 2013).

Lateritic soils are common surface deposits occurring in the tropical and subtropical regions of the world, enriched in iron and aluminium and developed by intensive and long lasting weathering of the underlying parent rock. In Nigeria, laterites serve as the perfect soil materials to solve construction problems such as construction of earth dams, highways, embankments, airfields and foundation materials to support structures without considering its classification as problem and non-problem types and the actual field geotechnical performance of the soils (Amadi et al.,2015; Ademila, 2017).

Inadequate information on soils and their properties has led to failures of some road construction works in Nigeria. Base on poor condition of road in Offa (case study of Offa-Irra Road, Taiwo Road, Atanoba-Aleluya Road, Olofa Way-Idiogun Section, Orita Merin-Igbonna Road) Local Government Area, North Central of Nigeria, this study evaluate the geotechnical properties of Offa lateritic soils and its suitability for use as subbase and base materials for road construction. Hence, summary of some previous related study is as presented in Table 1.

Table 1: Summary of Some Previous Study on Lateritic Soils

Author	Title	Conclusion	Limitation
Olofinyo et al., (2019)	Engineering properties of residual soils in part of Southwestern Nigeria: implication for road foundation	The investigation revealed that the subsoils are poor road construction materials due to its fine fractions and plasticities.	The experiment was conducted in Ekiti and samples was taken at a depth of 1.0m
Amadi et al., (2015)	Assessment of the Geotechnical Properties of Lateritic Soils in Minna, North Central Nigeria for Road designand Construction	The study opined that the geotechnical information obtained will serve as base-line information for future construction in the study area	The sub-soil conditions was investigated by excavating five trial pits from existing ground level to a maximum of 4.5 m
Ademila (2017)	Engineering evaluation of lateritic soils of failed highway sections in South-western Nigeria	The results of the study was found to be useful in rehabilitation and reconstruction works of the failed sections of the road	Twenty-eight bulk samples from the sub-grade soils were collected from seven trial pits in Akure at a depth of 0.5-2m
Oghenero et al., (2014)	Classification and compaction characteristics of lateritic soils of Warri, Delta state, Nigeria	CBR values indicated that the soils were suitable sub-grade materials	A total of eight samples were collected by disturbed sampling
Oluyinka and Olubunmi (2018)	Geotechnical properties of lateritic soil as subgrade and base material for road construction in Abeokuta, Southwest Nigeria	Lateritic soil present throughout the study area were found suitable for use as sub-base and base materials	Five representative samples were collected from Mohammad Buhari Estate in Abeokuta area of Ogun State at a depth of 0.25m
Okoyeh et al., (2017)	Evaluation of Ihiala laterites for use as sub-grade material in road construction	The study concluded that soil samples should undergo appropriate tests to determine their suitability for a particular purposes and strength improved where necessary before it can be used as subgrade material	A total of ten samples of about 25 kg each, were randomly collected at laterite exposure at Ihiala, Anambra State at adepth of1m

II. STUDY AREA

Offa is a city located in Kwara State (Figure 1), North Central of Nigeria. Offa Local Government is a town located on latitude 4.62^0 to 4.74^0 N and longitude 8.11 to 8.22^0 E (Figure 2). Offa is 100% bordered by Oyun Local Government with savanna vegetation and the main occupation in the town is farming (Jimoh and Sholadoye, 2011).

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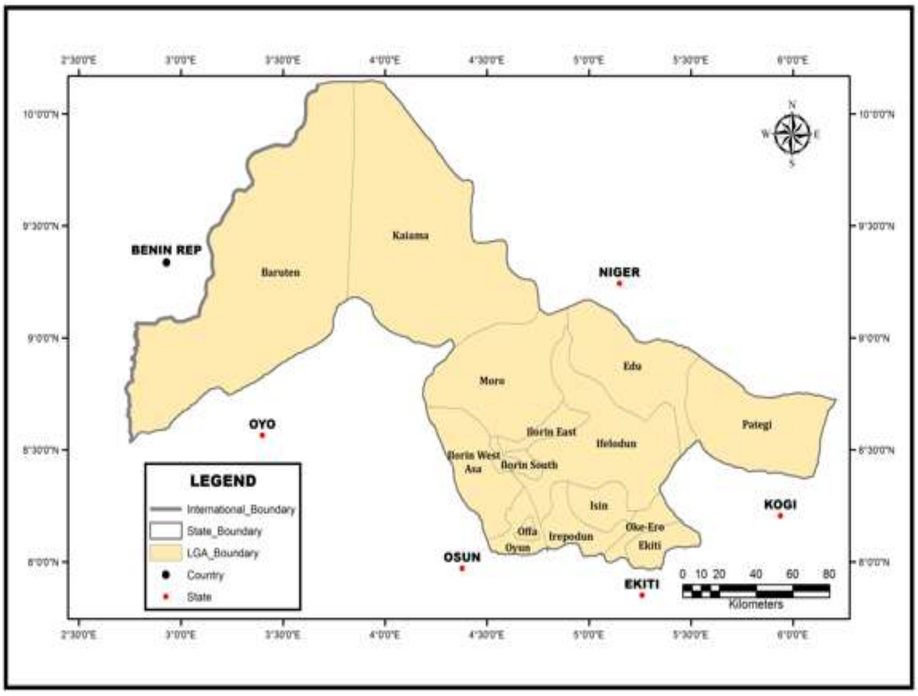

Figure 1: Kwara State Map Showing Offa

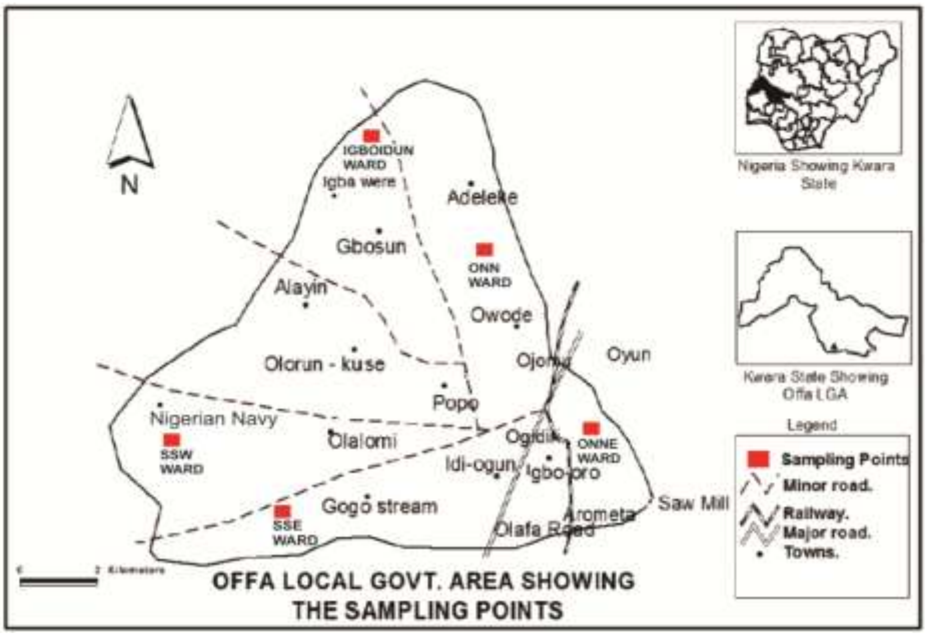

Figure 2: Map of Offa Local Government Area showing Sample points

III. MATERIALS AND METHODS

This study evaluate the geotechnical properties of Offa lateritic soils and its suitability for use as subbase and base materials for road construction. Fifteen disturbed samples (three each) at a depth of 1.5m were taken from Five (5) borrow pits namely: Igberiogun pit, Federal Poly Offa pit, Igbawere pit, Alaya pit and Egunkara pit, and were denoted as pit A, B, C, D and E, respectively. All the soil samples were labelled and transported in a sealed polythene bags (in order to prevent contamination and loss of moisture) to Soil and Concrete Laboratory, Civil Engineering Department, The Federal Polytechnic Offa, Offa, Nigeria. The index properties (Specific gravity, natural moisture content, particle size distribution

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and Atterberg limits) were determined using relevant standard. While compaction, California Bearing Ratio (CBR) and coefficient of permeability were conducted on strength properties of the soil. The compaction, CBR tests were subjected to West Africa Standard (WAS), American Association of State Highway and Transportation Officials (AASHTO) and British Standard (BS) all unsoaked in comparison to Nigerian FMWH (1997) specification for subbase and base materials for road construction.

IV. RESULTS AND DISCUSSION

4.1 Index Properties of Offa Lateritic Soils

Specific Gravity (SG) depends significantly on the factors which are size of samples, position of samples in soil profiles, grading characteristics, mineralogical composition of parent rocks and so on. The SG of lateritic soil falls within a range of 2.60 to 3.40 (Oyelami, 2017). The results of the SG of the soil samples in this study ranged from 2.66 to 2.77 (Table 2) and this has been classified as inorganic soils (Ramamurthy and Sitharam, 2005).

The Natural Moisture Content (NMC) of the selected pits (Table 2) were 11.8, 13.8, 14.3, 14.0 and 18.6 for pit A, B, C, D and E, respectively. The NMC of pits A to D, are within the average range of 5 – 15% specified by FMWH (2000) for roads construction. However, sample from pit E does not conform to the specified range. This shows that soils from pit E has high NMC, which is an indication of high water adsorption capability of the soil material.

The particle size distribution carried out on the Five (5) borrow pits are shown in Figure 3. Only lateritic soil samples from pit D are suitable for subgrade, subbase, and base materials as the percentage by weight finer than No. 200 BS sieve is less than 35% (Amadi et al., 2015; FMWH, 1997). The soils of pit A and B; and C and E, fall under group A-6 and A-7-6, respectively of AASHTO classification suggesting poor road construction material while samples D fall under group A-2-7 of AASHTO classification suggesting good road construction material.

Atterberg limits (Table 2) evaluates the settlement and strength characteristics of soils for road construction Olofinyo et al., (2019). The Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI) results of the soils ranged from 36 - 53%, 18 - 22% to 14 - 35%, respectively. Soil from pits A, B, C, and D are within the maximum standard LL of 50% specified by FMWH (2000), thereby making them suitable for subgrade, subbase and base materials. While sample from pit E value is above 50% rendering it unsuitable materials.

Table 2: Index Properties of Offa Lateritic Soils

Pit	SG	NMC (%)	AASHTO Classification	LL	PL	PI	Types of Soil
A	2.77	11.8	A-6	36	22	14	Clayey soils
B	2.66	13.8	A-6	38	21	17	Clayey soils
C	2.76	14.3	A-7-6	43	20	23	Clayey soils
D	2.68	14.0	A-2-7	41	22	19	Silty or clayey Gravel and sand
E	2.72	18.6	A-7-6	53	18	35	Clayey soils

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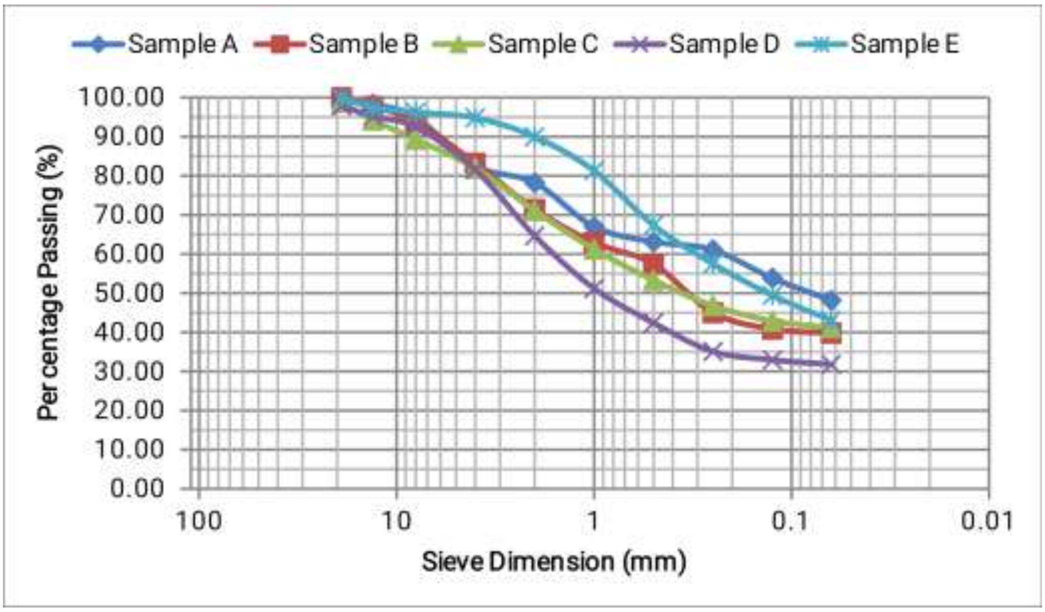

Figure 3: Combined graph for Particle Size Analysis for all Samples

4.2 Strength Properties of Offa Soils

The strength properties of subsoils for roa d construction are controlled or dictated bythe soilr esistance to distress under load application (Olofinyo et al., 2019). The results of the strength properties (compaction, CBR and coefficient of permeability) determined are summarized in Tables 3 and 4.

Compacting soils for roads and airfields requires attaining a high degree of density during construction to prevent detrimental consolidation from occurring under an embankment's weight or under traffic. However, compaction reduces the detrimental effects of water (Ademila, 2017; Olofinyo et al., 2019). The MDD and OMC (from compaction test) for WAS, AASHTO and BS were 1.84-2.01 g/cm^3 and 11.6-14.6%; 2.01-2.05 g/cm^3 and 10.4-13.2%; and, 1.65-2.00 g/cm^3 and 14-17.8%, respectively. Only two results (from BS) out of 15 results (from WAS, AASHTO and BS) in pit A-E (Table 3) have MDD values below the maximum 1.70g/cm^3 as specified by FMWH (1997). Therefore, the residual soils have low bearing capacities and cannot ultimately serve as construction barriers except if well compacted and stabilized to reduce voids, to increase the strength and reduce its permeability. However, the best soil for foundation is the soil with highest MDD at lowest OMC (Jegede, 2004; Ademila, 2017; Olofinyo et al., 2019).

Table 3: Summary of Compaction of Offa Lateritic Soils

Pit	**Sampling Depth (m)**	**MDD (g/cm^3)**			**OMC (%)**		
		WAS	**AASHTO**	**BS**	**WAS**	**AASHTO**	**BS**
A	1.5	2.01	2.04	1.88	13.2	11.8	16.6
B	1.5	2.00	2.05	2.00	11.6	10.4	14.0
C	1.5	1.84	2.01	1.65	14.6	13.2	17.8
D	1.5	1.98	2.01	1.82	13.2	12.8	15.0
E	1.5	1.84	1.96	1.60	17.1	14.5	22.5

California bearing ratio is a penetration test used to evaluate soil strength in subgrade, subbase, and base course materials used in road and airfield pavement design, thereby measuring the shearing resistance, controlled density and moisture content (Adeyemi, 2002; Amadi et al., 2015; Ademila, 2017; Olofinyo et al., 2019). The CBR results (Table 4) for unsoaked soils from borrow pit A-E for WAS, AASHTO and BS, ranged from 20-35%, 30-74%, and 12-29%, respectively. Federal Ministry of Works and Housing, FMWH (1997) CBR recommendation for soils for use as: subgrade, subbase and base materials are: ≤ 10%, ≤ 30% and ≤ 80%, respectively for unsoaked soils. The CBR value of WAS shows that lateritic soils from pit “C, D and E” are suitable for use as subbase materials having CBR values ≤ 30% while lateritic soils from pit “A and B” are suitable for use as base materials having CBR values ≤ 80%. Lateritic soils from Four (4) pit (A, B, C and D) under the AASHTO CBR test (Table 4) are suitable for use as base materials having CBR values ≤ 80% whereas only soils from pit “E” are suitable for use as subbase materials having CBR values ≤ 30%. All lateritic soils from pit A-E using BS approach are ≥ 10% and ≤ 30%. This implies that lateritic soils from pit “A, B, C, D and E” under BS are suitable for use as subbase materials having CBR values ≤ 30%. The combined graph of CBR test from the Five (5) pits for WAS, AASHTO and BS are presented in Figures 4 to 6.

The coefficient of permeability (Table 4) for the soils (pit A-E) ranged from 1.80 x 10^{-6} to 9.79 x 10^{-7}. Olofinyo et al., (2019) opined that the range of soils in this study can be classified as practically impermeable, medium permeable to low permeability, thereby making the soils suitable as road materials for construction purposes. However, when these soils come in contact with water, the soils will retain water and lead to the rapid weakened due to poor drainage and exposure to the surface.

Table 4: Summary of CBR and Coefficient of Permeability of Offa Lateritic Soils

Pit	Sampling Depth (m)	CBR (%) WAS	AASHTO	BS	Coefficient of Permeability (k = cm/sec)
A	1.5	35	53	12	3.57 x 10^{-6}
B	1.5	41	74	29	3.83 x 10^{-6}
C	1.5	20	34	20	1.80 x 10^{-6}
D	1.5	30	41	17	2.28 x 10^{-6}
E	1.5	23	30	12	9.79 x 10^{-7}

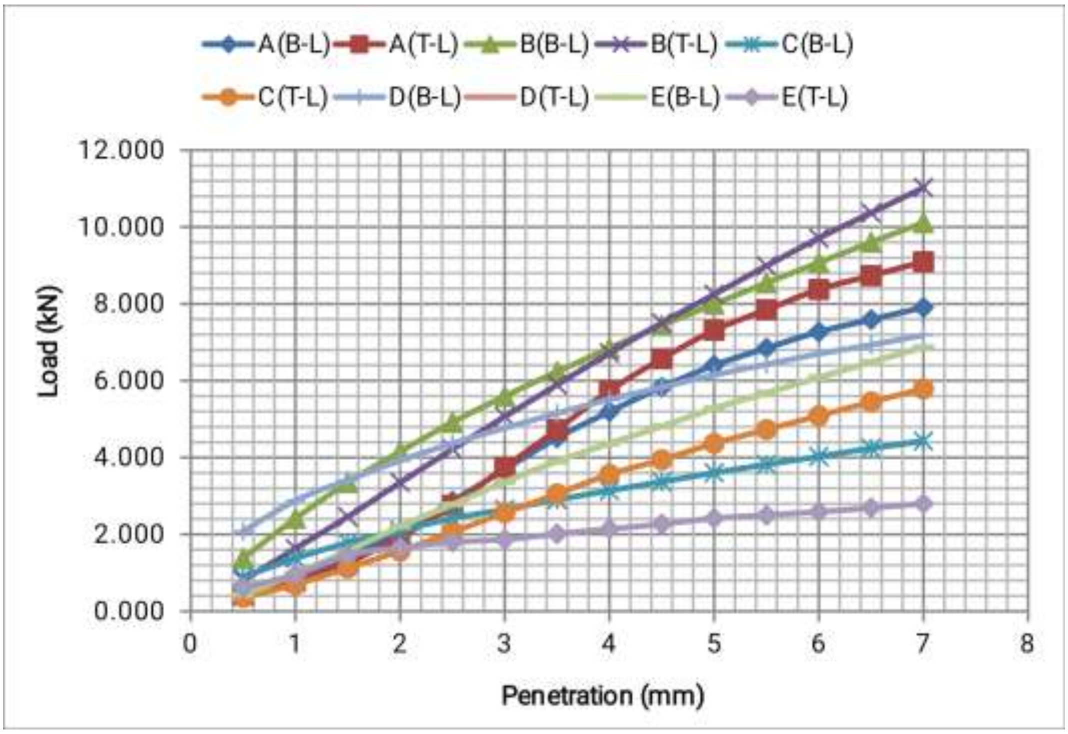

Figure 4: Combined graph for CBR Test on WAS Unsoaked for all Pits

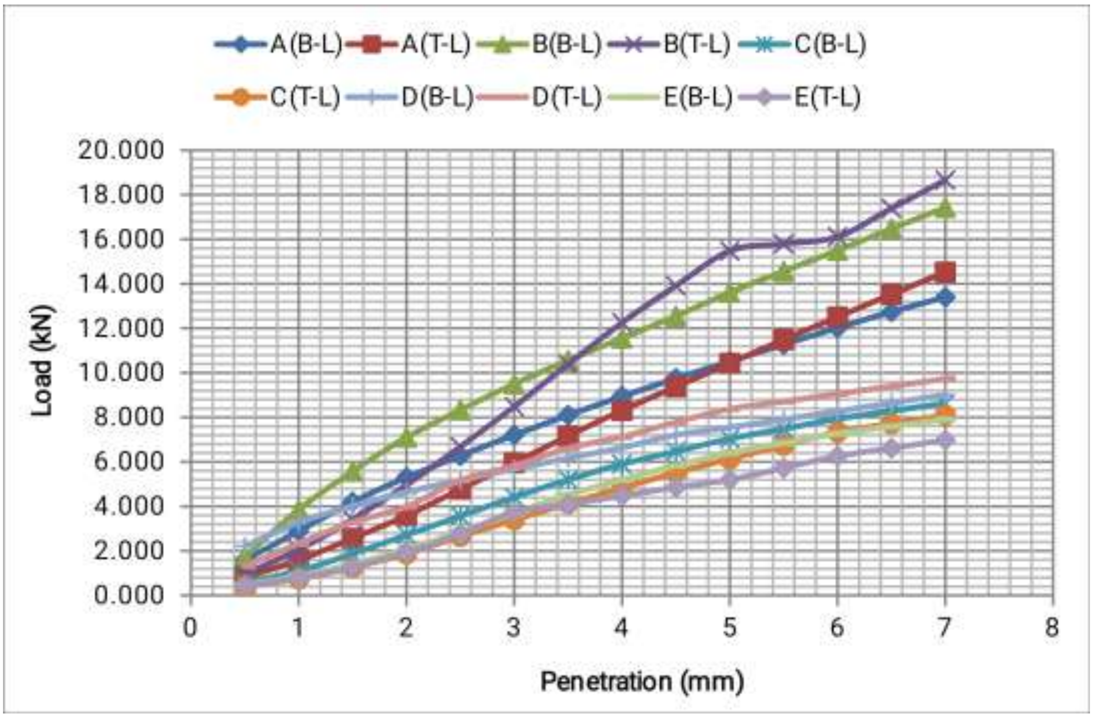

Figure 5: Combined graph for CBR Test on AASHTO Unsoaked for all Pits

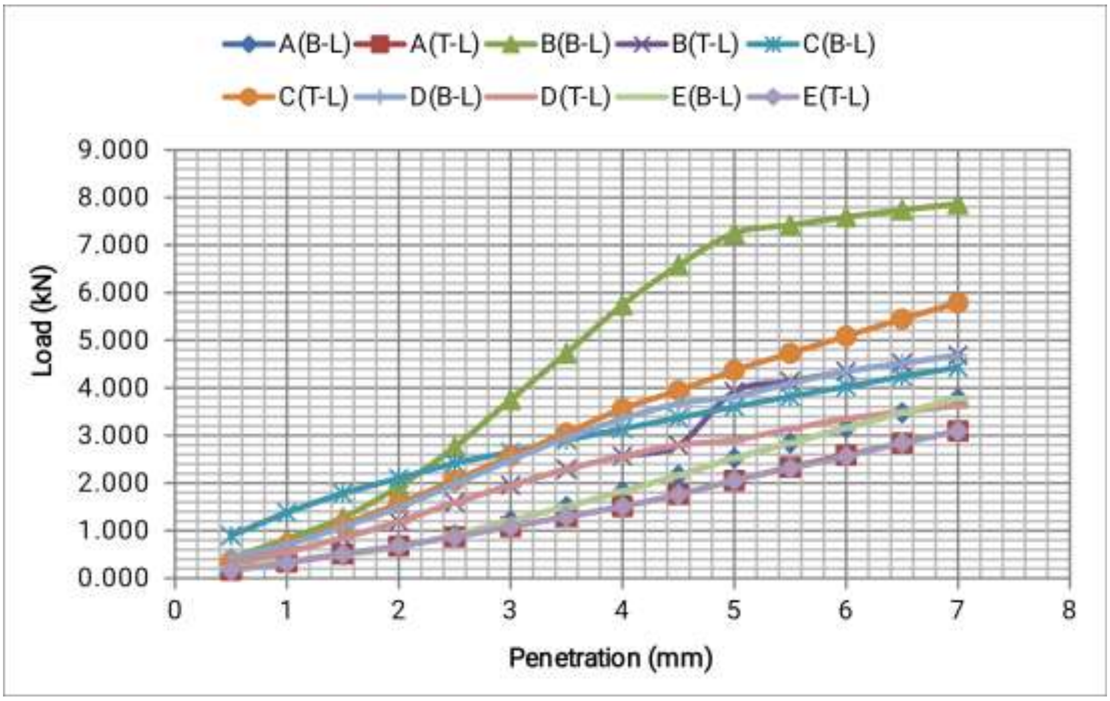

Figure 6: Combined graph for CBR Test on BS Unsoaked for all Pits

V. CONCLUSION

The suitability of geotechnical properties of lateritic soil in Offa for use as subbase and base materials has been investigated. The results revealed that the SG of the soil from the pits are within the standard ranged for lateritic soil. The NMC of pits A to D, conform to specified limit for road constructions while sample E does not conform to the specified range. Based on AASHTO classification, the soils of pits A and B; and C and

E, fall under group A-6 and A-7-6, respectively, while soil from pit D fall under group A-2-7. Soils from pits A, B, C, and D are within the maximum specified limit for LL, thereby making them suitable for subgrade, subbase and base materials. While sample E value is above specified limit. The CBR value of WAS shows that lateritic soils from pit "C, D and E" are suitable for use as subbase materials while lateritic soils from pit "A and B" are suitable for use as base materials. Lateritic soils from Four (4) pit (A, B, C and D) under the AASHTO CBR test are suitable for use as base materials, whereas only soils from pit "E" are suitable for use as subbase materials. However, all lateritic soils from pit A-E under BS are suitable for use as subbase materials having CBR. The results of this study will be useful for road construction in Offa and its environs, thereby serving as guide for future road pavement design.

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