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Engineering Evaluation of the Lateritic Soils Around Nepa and Environs, North Central Part of Nigeria for Road Constructions

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Abstract
The need for adequate assessment of the lateritic soils as a construction material will help to prevent failure of civil engineering structures like roads when used. The results of geotechnical test of the lateritic soils of the study area reveals that the Atterberg limit which consist of; the Liquid limit (LL), Plastic limit (PL), Plasticity index (PI) and Linear shrinkage (LS) ranged from 33.0%-43.0%, 16.23%-26.37%, 7.63%-24.77% and from 21.12%-34.12%. The percentage passing of the soil samples from the sieve analysis ranged from 50.88%-91.08%, Soil pH values from 6.5-7.2 and the Specific gravity (SG) from 2.57-2.73. The moisture content of the soil samples ranges from 12.92%-23.26%. The compaction test revealed that; the Optimum Moisture Content (OMC) of the soil samples ranged from 13.22%-20.60% while that of Maximum Dry Density (MDD) is between 1.59g/cm^3-1.88g/cm^3. The soaked and the un-soaked California Bearing Ratio (CBR) values of the soils range from 50.88%-96.51% and from 30.88%-76.51%. The findings have reveals that the lateritic soils are characteristically fair to poor and this may results to road failure when used. The lateritic soils were classified as silty-clay materials and will not be suitable as a good fill material for road construction project due to poor bearing capacity. This information about the engineering evaluation of the soil obtained will serve as base-line information for future road foundation design and construction in the study area to avoid loss of lives and properties. It is recommended that adequate engineering, geophysical and geological investigation of the soil is required to ensure the stability for the road constructions.

Keywords: *Engineering evaluation, Jos North, Lateritic soil, Nigeria, Road construction.*

Introduction

Road construction is an important part of infrastructure that ensures the economic development of any country or a nation at large. The purpose of road construction is to provide means of movement to the stalk holders like road users. According to Wazoh *et al.* (2016), road failures can results to accidents, adverse economic development and poor state reputation. In country like Nigeria, lateritic soils are used as fill materials for road construction (Lar *et al.,* 2011). Lateritic soil contains chemical compositions like iron oxides and alumina sesquoxides with little or no silica contents depends on the weathering activity and decomposition experienced. Abubakar (2016) and Amadi (2008) are of the opinion that, the need to understand the engineering behaviour of lateritic soil such as swelling and expansion will help to determine the damages it poses on road construction. Wrong application of geologic construction materials like lateritic soils by construction industries can results to road accident and this can cause destruction of lives and properties (Oke *et al.,* 2009a; Nwankwoala *et al.,* 2014). For lateritic soil to be used as a construction material for road its strength must depends on the axle-load to the sub-soil and or sub-grade. Roads are actually constructed on rocks and soils, and these materials' properties affect its engineering performances as transport medium.

Major components of several typical flexible highway pavements are; sub-grade, sub-base, base-course and riding surfaces from the base to the top (Adeyemi, 2013; Gupta and Gupta 2003). Causes of road failure around Nepa and its Environs is due to the presence of deformation such as; potholes, cracks, depression and ruts. Other factors may be due to geological, geomorphological, geotechnical, poor design, construction inadequacies and maintenances. Lateritic soils are also used as a foundation material for other engineering structures like; airfield, low-cost housing and compacted fill in earth embankments (Abubakar, 2006; Kamatchueng *et al.,* 2016; Oke and Amadi, 2008). The mineralogical composition of lateritic soil has an effect on the geotechnical parameters such as; Atterberg limits, Specific gravity, Shear strength, Swelling potential, Bearing capacity and Petrographic properties (Amadi *et al.,* 2012). The work of several authors like (Amadi *et al.,* 2012, 2015; Ebuzoeme, 2015; Ehujuo *et al.,* 2017; Enaworu *et al.,* 2017; Jegede, 2000; Meshida, 2006; Okoyeh *et al.,* 2017) has provide an insight about the use of lateritic soil as a construction materials for road.Topographically, the study area is made up of; hills and mountains, dissected terrain, and undulating terrain sloping towards different directions in different locations.The drainage pattern of the area is dendritic type and is the source of the rivers around the Naraguta Mountain and is tectonically controlled in a parallel pattern due to the dominant N-S trends of structures on the host rocks.

Geologic Setting

The study area is underlain by different rock lithology, these are; The Neil's Valley granite porphyry, Rafin Jaki granite porphyry, Aplo-pegmatitic-granite gneiss, Migmatite and the Laterite (Figure 1). Due to the influence of environmental factors that results to weathering activity of the rocks in the area has led to the formation of the laterites (Lar *et al.,* 2011). The Aplo-pegmatitic granite gneiss are the predominate rock units in the area. According to Daku *et al. (*2019) it occur as crosscutting sheets with irregular structural shape. The Neil's valley granite porphyry has intruded into the Basement and it occurs as massif pluton with relief as high as 1100m above sea level. The Rafin Jaki Granite Porphyry is made up of the Biotite-Granite which cuts across the Migmatite in a linear pattern. The Migmatite are rocks that have been subjected to multiple episodes of geologic deformation such as the Eburnean (2000±200Ma), Kibaran (1100±150Ma) and Pan-African (6000±1500Ma) Orogeny Wright *et al. (*1985). The Structural patterns on the rock that serve as evidence of deformation are dykes, fractures, joints, foliations, veins, fold and faults. These features have different trends as seen in the Basement and Younger Granite Complex of Nigeria. They form as a result of high degree of regional tectonism that accompanied the emplacement of the older granites suites during the period of the Pan-African Orogenic events. These have resulted to the formation of well-defined and extensive N-S trend in different part of the Basement Complex of Nigeria (Bala *et al.,* 2015). The prominent hilly features in the study area that are of geologic and environmental significance are Inselbergs, and whalebacks which belong to the category of residual hills commonly associated with massive granites bodies.

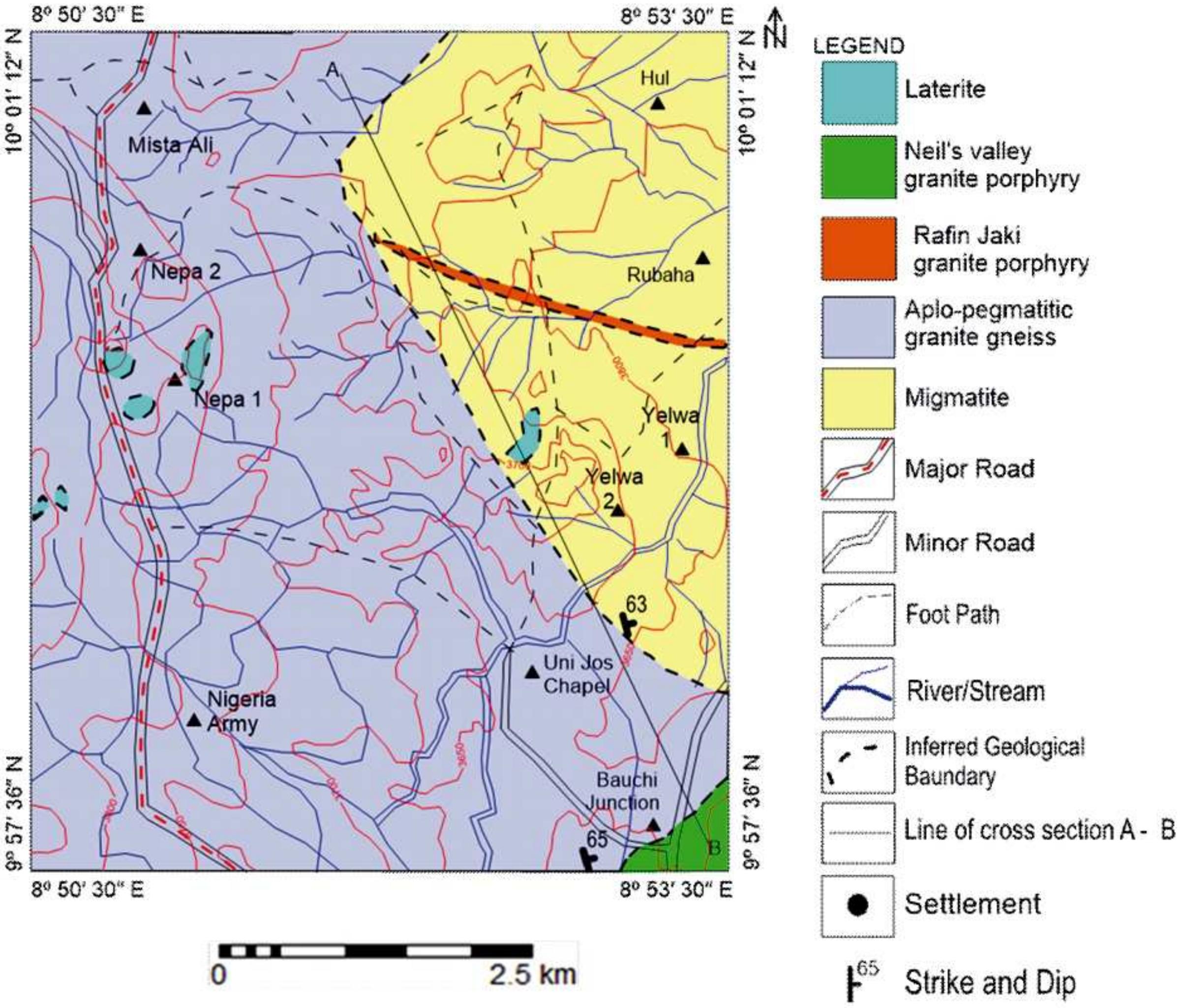

Fig. 1: Geological map of the area

Description of the Study Area

The area is located in Jos North Local Government area of Plateau State in the North Central Part of Nigeria. It falls between latitude 9° 57′36″ N to10° 01′12″N and longitude 8°50′30″E to 8°53′30″E (Figure 2). The presence of footpath, minor and major road makes the study area to be accessible. According to 'AW' Koppen's classification, the climatic condition of the area is characterised by alternating dry and wet seasons. The areas experiences a mean annual rainfall of about 1260mm (1050-1403mm), with the highest peak between the month of July and August with the mean temperatures that ranges from 19.4°C-24.5°C (Okpara *et al.,* 2015). The favourable climatic condition of the study area has lured the people of the study area to engage in farming activities. The vegetation of thearea is of Guinea Savannah type classified as woodland Savannah dominated by grasses (Abiem, 2016). The area is made up of lateritic soil that overlies the weathered bedrock. The formation of the soil is due to favourable climatic condition and other factors that includes; parent rock, topography, vegetation and time. The settlement pattern of the study area is of urban type with dense built up areas and has influenced by physiographic factors and the emergence of new transport routes. Other human activities like mining has also occur in the study area due to the presence of laterites and some economic minerals deposits like tin, columbite, zircon and tantalite and this has created a source of livelihood to the citizens.

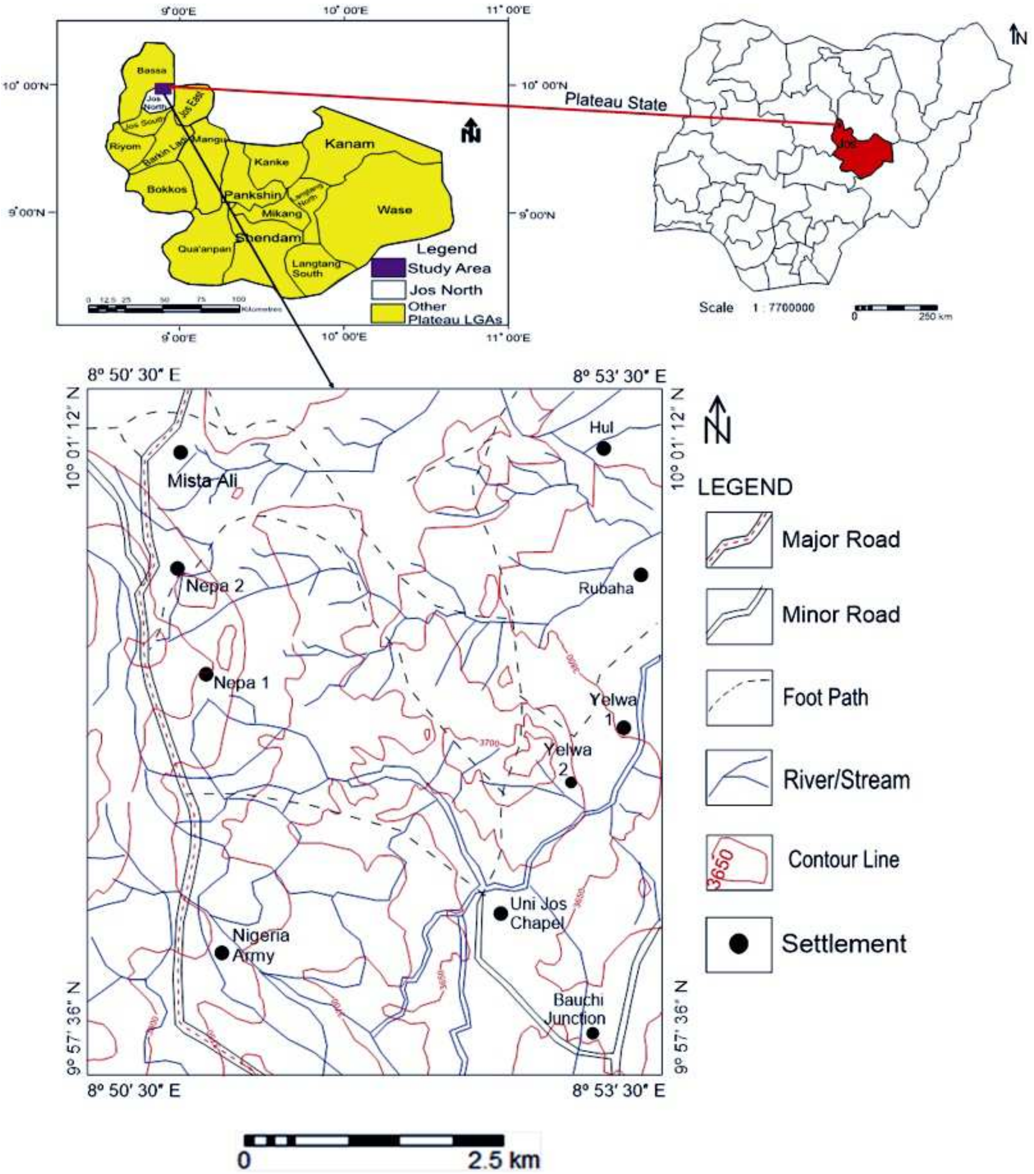

Fig. 2: Map of the study area.

Materials and Methods

A reconnaissance survey of the study area was carried out to examine the local geological condition of the area via the use of tools like; Geologic map, Sledge hammer, and Global Positioning System (GPS). Ten disturbed and undisturbed fresh soil samples were both collected at the depth of 1.0m by using digging tools by making ten different trial pits, while the rocks were only studied in the field. The undisturbed samples were obtained via the use of core-cutters and were sealed at both ends with polythene materials to prevent loss of moisture content before carrying to the laboratory for analysis. These samples were subjected to direct shear, Moisture content and consolidation test. The disturbed samples were collected in Baggo sacks and later air-dried for a period of ten days in the laboratory. Test such as; Sieve analysis (grain size distribution), Atterberg limit, Specific gravity, Compaction, California Bearing Ratio (CBR), and Soil pH were carried out in other to determine its geotechnical engineering parameters for the purpose of road construction.

Laboratory Analysis: This analysis was carried out according to British Standard methods of test for soil for civil engineering uses (BS 1377: 1990). The laboratory test was performed to evaluate the engineering property of the soils for roads constructions work:

(1) **Atterberg Limits (Liquid Limit and Plastic Limit):** This test were carried out in other to determines the clay content in terms of its liquid limit, plastic limit, plasticity index and shrinkage potential to estimate the plasticity, strength and settlement characteristics of the soil sample. For determination of the liguid limit, the soil sample passing through 425 μm sieve, weighing 200 g was mixed with water to form a thick homogeneous paste material. The paste was collected inside the Casangrade's apparatus cup with a grove created by using grooving tool and the number of blows to close it was also recorded. Then, for the plastic limit determination, the soil sample weighing 200 g was also taken from the material passing the 425 μm test sieve and then mixed with water till it became homogenous and plastic to be shaped to ball shape. The ball of the soil was rolled on a glass plate until the thread cracks at approximately 3 mm in diameter. The 3 mm diameter sample was placed in the oven at a temperature of 105°C in other to determine the plastic limit.

(2) **Sieve Analysis:** This was carried out in other to determine the particle (grain) size distribution of the soil sample. Representative sample of approximately 500 g were used for the test after washing and oven-dried for a period of 24 hours. The sample was washed using the BS 200 sieve and the fraction retained on the sieve was air dried and used for the sieve analysis. The sieving was done by means of mechanical method using an automatic shaker machine with a set of sieves of different sizes being mounted on top of it.

(3) **Soil pH (Soil and Water) test:** Was carried out to determine the acidic, neutral and alkaline properties of the soil samples. Apparatus like beaker, pH Meter (Hanna), a 40 g of dried and sieved soil with 40 mL of distilled water and a spoon to transfer the soil was used. The distilled water and the soil were thoroughly mixed with a spoon by stirring. The stirred mixture was carried out for 30 seconds and then was waited for three minutes for a total of five stirring/waiting cycles. Then, the mixture was allowed to settle until a supernatant forms. The pH of the supernatant was measured using the pH meter by dipping inside the supernatant. The pH value was recorded on the Soil pH Data Sheet.

(4) **Moisture Content:** This test was carried out to determine the moisture content ofthe soil sample. These involved the use of; Electric oven, moisture content cans, scoop, weighing balance, desiccator and soil sample. The test was carried out with an undisturbed soil sample collected from the field. Three moisture cans was obtained and their identification numbers was known and was weigh using the weighing balance empty with their lids in place. The soil sample was mixed thoroughly and about 45g of the soil was introduced into each of the cans. The can containing the wet soil was weighed and was put into the electric oven at the regulated temperature between 105ºC-115ºC with the lids opened. The can was remained in the oven at the regulated temperature range for 24hours to ensure total dryness. After dryness the container was removed from the oven and the lids was replaced. The can was allowed to cool in the desiccator for few minutes and the can containing the dried soil was weighed. All the data obtained was recorded to compute the moisture content. The average of the calculated moisture content of the cans give the moisture

content of the soil tested.

(5) **Compaction Test:** This involves the re-arrangement of the soil particles via the use of mechanical equipment. This makes the soil particle to become more closely packed resulting in an increase of the ratio of horizontal effective size to the vertical effective stress. The degree of compaction is measured in term of its dry weight and it increase in the bearing capacity ofthe road foundation, stability of slopes, controls undesirable volume changes and curb undesirable settlement of structures due to volume change. The mould is filled and compacted with soil in five layers via 25 blows of a 4.5 rammer.

(6) **Specific gravity test:** This involves the use of; Sample tray, 50ml density bottle, Scoop, weighing balance, funnel, soil sample, distilled water and Aspirator (washed bottle). The soil sample was first obtained and was sun dry. The empty 50ml density bottle was weighed. About 50g of the dried soil sample was put into the density bottle; the cap was first replaced and was weighed with the dry sample inside the bottle. The Aspirator was used to add the distilled water into the density bottle half way and the content was shaked. The content was added with distilled water to the brim of the density bottle and was replaced with the cap. The water content outside the surface of the density bottle was wiped with a clean cloth. The density bottle, the soil and the distilled water was also weighed. The contents of the density bottle were emptied and were washed again. The density bottle was filled with distilled water and the excess water on the outside surface of the density bottle was wiped and the density bottle plus the mixture (distilled water plus the soil) was also weighed only. The data obtained was recorded in other to compute the specific gravity of the soil. The average value of the calculated specific gravity test was obtained in other to give the final Specific gravity (Gs) of the soil tested.

(7) **Consolidation test (Oedometer):** This was carried out to determine the settlement parameters of the soil sample; with respect to Coefficient of Consolidation (Cv), Coefficient of Compressibility (Mv), Total settlement (Pc) and Coefficient of permeability (K) via the use of undisturbed soil sample. This involve the use of; Oedometer Machine, Slotted (standard) weights, Spatula, Distilled water, Electric Oven, Moisture content cans, Aspirator, weighing balance readable to 0.01g and timer (stop watch or table clock). The specimen was prepared by pressing the consolidation ring against the soil until the ring fully accommodates the soil in it. The excess soil was trimmed on both top and bottom of the ring to obtain a specimen equal the rate dimension of the consolidation ring that is 50mm in diameter and 19mm in height. The specimen was placed in the ring on the porous stone in the consolidation cell. The guide was placed to hold the specimen firmly in position and the nuts was screwed. The porous stone was placed on the specimen and the loading frame was adjusted to have contact with the soil. The dial gauge was adjusted to zero and distilled water was added to the consolidation cell and was allowed to stay for few minutes before loading. The dial gauge was Re-adjusted to zero and the timer to 00: 00:00. The system was loaded via the loading yoke with 1.00kg load and was simultaneously observed by dial gauge readings. The timer was started and was notice until the time elapsed. The dial gauge readings was taken to the corresponding time from the start of the loading; 0.00, 0.25, 1.00, 2.25, 4.00, 6.25, 9.00, 12.25, 25.00, 60.00, δ120.00, 240.00, 360.00 and 1440.00. Iftwo successive dial readings have the same values at two successive times, the prevailing load on the system should be doubled at any time, as the case may be. The loads were removed after taking the complete dial gauge readings. The moisture content of the specimen was determined after the test and also the specific gravity of the soil specimen. The change in thickness (δh), thickness of the specimen (h) and the mean thickness of the specimen was computed.

(8) **Direct shear strength test:** The test was carried out to determine the shear strength of the soil. The Apparatus used for conductingthe test are; Shear box, Shear box container, Base plate with cross groves on its top, Porous stones, Plain Grid plates, Perforated grid plates, Loading pad with steel ball, Digital weighing machine, Loading frame with loading yoke, Proving ring, Dial gauges, Weights, Tampering Rod, Spatula, Rammer and Sampler. This involves the collection of the soil specimen which is undisturbed. The two halves of the shear box were attached with the locking pins and were placed on the base plate at the bottom.

The undisturbed soil sample was directly transferred to the shear box.Above the soil specimen, the upper grid plate was placed and the whole box was placed in a container and was mounted on the loading frame.The proving ring was arranged in such a way that it is in contact of the upper half of the shear box. The Loading yoke was placed on the steel ball of loading pad of shear box. The two dial gauges were fitted one to the container for measuring shear displacement and the other one is to the loading yoke for measuring the vertical displacement. The locking pins were removed from the shear box and the spacing screws were placed in their respective positions of the box. The upper half of the box is raised slightly with the help of spacing screws. The spacing was decided depending upon the maximum size of the particle. The normal stress of 10 kN/m^2 was applied. The shear load was also applied at a constant rate of the strain. The box starts reacting to the loads applied for every 30 seconds and the readings of proving ring and dial gauges were noted. The proving ring was able to reach the maximum and suddenly drops which means the specimen has failed. The maximum value was noted which is nothing but failure stress. Finally the box was removed and the water content of the specimen was measured.The same procedure for the normal stresses of 20 and 30 kN/m^2 was repeated.

(9) **California Bearing Ratio (CBR):** This is a penetration test carried out to evaluate the mechanical strength of the soil. It measures the shearing resistance, controlled density and moisture content. The soaked and un-soaked method of CBR was conducted to examine the lateritic soil for use as a base or sub-base material for road construction. A portion of theair-dried soil sample was mixed with about 5% of its weight of water. This was put in CBR mould and was divided into 3 layers with each layer compacted with 55 blows using 2.5 kg hammer at drop of 450 mm (standard proctor test). The compacted soil and the mould was weighed and placed under CBR machine and a seating load of approximately 4.5 kg was applied. Load was recorded at penetration of 0.625, 1.9, 2.25, 6.25, 7.5, 10 and 12.5 mm.

Results

The results of the geotechnical evaluation of the lateritic soils of the Nepa area and Environs are presented in Table 1, 2 and 3 below.

Table 1: Geotechnical Results of the lateritic soils

Trial pit	Sieve Analysis	Compaction		Atterberg Limit				Soil pH
-	Percentage (%) passing B.S No. 200	MDD (g/cm^3)	OMC (%)	LL (%)	PL (%)	LS (%)	PI (%)	-
1	34.74	1.78	15.22	33.00	17.24	10.00	15.76	5.7
2	27.30	1.72	16.23	27.00	16.78	8.57	10.22	5.8
3	53.86	1.60	17.72	36.00	15.96	15.71	20.04	7.2
4	33.62	1.70	17.15	34.00	21.14	8.61	12.86	6.2
5	27.14	1.65	18.29	21.00	18.86	12.86	2.14	5.5
6	24.14	1.69	21.60	32.00	21.83	10.71	10.17	6.3
7	67.10	1.63	18.21	37.00	19.21	11.43	17.79	7.7
8	41.70	1.67	15.66	38.00	13.81	12.14	24.19	7.1
9	58.64	1.79	19.69	42.00	19.05	9.75	22.95	7.5
10	30.54	1.71	17.30	31.00	15.83	13.57	15.17	5.4

Discussions

The geotechnical results of the lateritic soils are shown in Table 1, 2 and 3, under the results section. The Atterberg limit which consist of the liquid limit (LL), linear shrinkage (LS), plastic limit (PL) and plasticity index (PI) ranges from (21.0-42.0)% (8.57-15.71)%,(13.81–21.83)% and (2.14–24.19)% (Table 1) respectively. According to Mallo and Akuboh (2012), the Atterberg limits describe the consistency of a cohesive soil in other to provide useful information regarding the soil strength, behaviour, stability, type and

Table 2: Geotechnical Results of the lateritic soils.

Trial pit	California Bearing Ratio (CBR) of the soil (%)		Moisture Content (%)	Specific Gravity
	SOAKED	UNSOAKED	-	-
1	72.10	69.30	19.45	2.64
2	64.50	71.50	16.05	2.54
3	67.30	65.20	17.54	2.63
4	58.30	66.20	19.81	2.71
5	61.00	81.80	22.08	2.62
6	47.70	73.60	22.36	2.65
7	93.20	85.30	17.73	2.62
8	60.60	50.80	20.27	2.70
9	80.30	96.40	12.92	2.71
10	87.50	91.60	23.26	2.75

state of its consolidation. Based on the prescription of the Nigerian Federal Ministry of Works and Housing (2010), liquid limit should not exceed 35% for it to be suitable for use as sub-grade, sub-base or base course materials for road construction and design. Soil samples 1, 2, 4, 5, 6 and 10 are the only samples that can be regarded as a good material for road construction as shown in Table 1. Based on engineering perspective, soils with high liquid limit (LL) are said to be classified as clays. In civil engineering construction clay exhibit poor engineering properties. Soils with intermediate plasticity index that ranges from (0–20)% would make better engineering properties and thus samples 3, 7, 8 and 9 (Table 1) has meet the required criteria. The values of the plastic limit are very important for the construction of earth roads and other excavation works. Prakash and Jain (2002) are of the opinion that soil with plasticity index greater than seventeen (PI>17) is clay and it will exhibit high plasticity with cohesive nature. Sample 3, 7, 8, and 9 has PI>17 (Table 1), and this will results to cracks in roads when it shrinks and swelling when it absorbs water. The results of the sieve analysis presented in Table 1, has shown that the percentage passing of the soil samples ranges from 24.14%-67.10%. Apparao and Rao (1995) explained that the sieve analysis which is known as the grain size analysis is widely used in classification of soils. Bowles (2012) found that sieve analysis is one of the suitable criteria of soils for roads construction work. According to the Nigerian Federal Ministry of Works and Housing (2010), the specification required of a sample to be used for roads constructions the percentage by weight of the soil passing the BS Sieve No. 200 shall be less than but not greater than 35%. Sequel to the above, the samples under review were not good samples becausethe percentage by weight passing of the soil sample has exceed 35% except the sample collectedatlocation 3, 7, 8 and 9. The Soil pH values of the soil samples ranges from 5.4-7.7 (Table 1).Soil pH from 0-7 is acidic, 7 are neutral and from 8-14 is alkaline.The result of the soil pH shows that most of the soil samples are within the acidic limit except the sample collected at location 3, 7, 8 and 9 which are neutral. According to Oyubu (2015) acidic soil can lead to extreme rate of corrosion and pitting of metallic objects. A neutral pH of 7 is the most desirable for used in civil construction in other to minimize the potential damage to earthen structures. Olayinkanola*et al.* (2016) reported that, fine-grained soils such as clays and some silts are considered to have a greater corrosion potential because they typically have low hydraulic conductivity resulting from the accumulation of acid and base forming materials which cannot be leached out very quickly. Soil pH below and above 7 will have strong influence on the engineering properties of the soil in the presence of moisture/water. The specific gravity for the soil samples ranged from

Table 3: Geotechnical Results of the lateritic soils

S/N	Direct Shear test			Consolidation test		
	Cohesive strength (c) KN/m^2	Angle of internal friction (Ø°)	Unit weight (Y) KN/m^3	Coefficient of consolidation (Cv) m^2/year	Coefficient of volume compressibility(Mv) m^2/KN	Total settlement (Pc) M
1	7	15	20.93	101.259	0.0092	0.0009
2	6	18	18.51	103.814	0.0070	0.0007
3	28	10	19.98	102.521	0.0081	0.0008
4	18	13	21.20	106.421	0.0047	0.0004
5	22	13	19.44	104.601	0.0063	0.006
6	21	13	18.63	98.413	0.0116	0.0011
7	15	14	20.20	99.400	0.0131	0.0012
8	22	11	21.13	103.059	0.0076	0.0007
9	25	10	17.68	106.928	0.0068	0.0007
10	15	16	19.42	104.368	0.0090	0.0009

2.54-2.75(Table 2). Generally according to specification, a good lateritic soil should have specific gravity that ranges from 2.50-2.75. The specific gravity is an important geotechnical property of soils that is closely linked with mineralogy or chemical composition according to Oyediran and Durojaiye (2011). Based on the geotechnical analysis of the soil samples it has fall within the acceptable specification required for road construction. Increase in specific gravity can result to increase in the shear strength parameters such as cohesion and angle of shearing resistance Roy and Dass (2014). The direct shear test of the soil samples shows that; the cohesive strength (c) ranges from (6-28) KN/m^2, angle of internal friction (ø) from (10-18)^o, unit weight (Y) from (17.68-21.20) KN/m^3 (Table 3). These indicate low strength due to low angle of internal friction due to the presence of silty-clay materials. According to Mollahasani et al. (2011) soils with high plasticity like clayed soils have lower angle of internal resistance. Low angle of internal resistance of a soil can be attributed to the presence of expansive clay Obiora and Umeji (2004). The geotechnical result of the consolidation test of the lateritic soil shows that; the Coefficient of consolidation (Cv) ranges from (98.413-106.928) m^2/year, Coefficient of volume compressibility (Mv) from (0.0047-0.0131) m^2/KN, Total settlement (Pc) from (0.0007-0.0012) m (Table 3). These indicate that the soil is of silt-clay materials because of its relatively high coefficient of consolidation. This may be attributed to the poor engineering hydraulic conductivity of the soil; hence the soil will continue to reduce in volume over a long period of time after the immediate settlement and may be several times greater than the immediate settlement.PrakashandJain (2002), are of the opinion that, data obtained from the consolidation testcan beusedto predict the rate and amount of settlement ofengineering structure founded on clay primarily due tochange in volume of the soil. The values of the soil moisture content ranges from 12.92%-23.26% (Table 2). Based on the work of Ramamurthy and Sitharam (2005), the moisture content is one of the factors that affect the dry density of soils. The role of natural moisture content in road construction is crucial in the increasing or reducing density indices of soil particles to increase its shear strength. The compaction test reveals that; The Optimum Moisture Content (OMC) of the soil samples ranged from 15.22%-21.60% while that of Maximum Dry Density (MDD) is from 1.60g/cm^3-1.79g/cm^3 (Table 1). O "Flaherty (2001) reported that the ranges of values when using the standard proctor test methods are: for clay, OMC may fall between 20%-30% and MDD between 1.44mg/m^3-1.685mg/m^3. For silty-clay OMC and MDD may range between 15%-25% and 1.6 mg/m^3-1.845mg/m^3. For sandy-clay material, OMC is between 8% and 15% and MDD between 1.76 mg/m^3-2.165mg/m^3 (Table 1). Looking at the results, it could be noticed that the soil samples are of silty-clay materials. The results of the geotechnical analysis of the California Bearing Ratio (CBR) of the lateritic soil samples for both the soaked and the un-soaked values ranges from 47.70%-93.20% and 50.80%-96.40% (Table 2). According to Nigerian Federal Ministry of Works and Housing (2010), the recommendation for the lateritic soil to be used as a sub-base and base material, the soaked value for the CBR should be ⩾ 30%, and Un-soaked value should be ⩾ 80%, Liquid Limit (LL⩽ 35%) and Plasticity Index (PI⩽12%).The overall rating of the soil shows that it can only be used as a Sub-base except the samples collected at location 7, 9 and 10 which can only be used as a Base material.The values of the California Bearing Ratio (CBR) test can be used to examine the strength of sub-grade, sub-base and base course materials for supporting roads.

Conclusion and Recommendations

Engineering Evaluation of the lateritic soils around Nepa and Environs area in Jos North was carried out Based on the British Standard methods of soil testing. The overall results revealed that, the studied soil samples are of poor materials due to the presence of high silty-clay materials. The tested soil indicate a general cohesive nature with high moisture content and low granular material which is not suitable for road use in road construction work except the samples collected in locations 3, 7, 8 and 9. These geotechnical data obtained from the soil analysis can be used for civil engineers for the design and construction of roads to ensure maximum durability and efficiency. The following recommendations were derived from this study in other to make use of the lateritic soil as a constructional material:

(1) Contractors of road construction need to carry out engineering confirmatory test on the soils before any construction.
(2) Stabilization of failed lateritic soil with either cement, sand, crushed stone need to be carry out effectively in other to meet the desired criteria.
(3) In other to avoid reduce in the shear strength of the soil, over compaction should be avoided to make the material suitable for road construction.
(4) In-situ assessment of the soil should also be carried out in the study area in order to examine

its field strength.

(5) Further work should be carried out on the soil such as; triaxial test, water absorption capacity, and permeability to ascertain its full performance.

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