

EVALUATION OF SOME ENGINEERING PROPERTIES OF LATERITIC SOILS AROUND DALL QUARRY, SANGO AREA, ILORIN, NIGERIA

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ABSTRACT

Lateritic soils at the DALL Quarry in Ilorin metropolis (Sango area), southwestern Nigeria were investigated with respect to their geotechnical properties and their suitability as construction materials. The two samples collected fall within the basement complex and they overlie the migmatite-gneiss complex rocks. The grain size analyses show that sample ADET 1 is silt-clayey, very gravelly sand while sample ADET 2 is gravelly, silt-clayey sand. Atterberg consistency limit test shows that the soil samples are above the activity (A) line in the zone of intermediate plasticity (CL) which means that they are inorganic soils. The samples contain inactive clay (activity 0.95 and 0.63 respectively) with little or no swelling tendency and therefore good for construction material and this would prohibit foundation failure during foundation settlement. The California Bearing Ratio (CBR) values indicate that they are good as sub-grade construction materials. The cohesion ranges from 60-100Kpa (average=75 Kpa) and the angle of internal friction ranges from 31°-35° with an average of 33°. The geotechnical analyses results show that the soils can be used as construction materials. Thus, the soil could support shallow foundation, homogeneous embankments, slope stability and sub-grade materials in road constructions.

Key words: Engineering properties, Grain size, Liquid limit, Plastic limit, CBR

1. INTRODUCTION

Engineering properties of soils play a significant role in civil engineering construction works particularly in road constructions, foundations, embankments and dams to mention a few. This made imperative, the testing of soil, on which a foundation or superstructure is to be laid. This would determine its geotechnical suitability as a construction material. In recent times, the alarming rate at which lives are being lost due to collapsed buildings and road failures calls for a solution. The solution could be brought by critical geotechnical testing of the engineering soil. The present area is situated within latitudes 8°34'N and 8°32'N and longitudes 4°38'15"E and 4°40'00"E (figs. 1 and 2). The rocks in the study area are mainly granite gneiss and banded gneiss with foliations.

Several authors have worked on the geotechnical properties of lateritic soils. Jackson (1980) reported that lateritic soils have been used successfully as base and sub-base materials in road construction. Vallerg et al. (1969) worked on laterite soil in connection with construction of road, highways and airfields. The engineering problems associated with lateritic soil were evaluated by Lyons (1971). Balogun (1984) reported that the addition of lime to the soil increases its optimum moisture content, liquid limit, California Bearing Ratio (CBR) etc. Alao (1983) studied the engineering properties of some soil samples from Ilorin area and discovered that they could be stabilized by compaction and that the samples could yield maximum strength if they are compacted on the dry side of their optimum moisture content (OMC). Ogunsanwo (1989) evaluated CBR and shear strength of some compacted lateritic soils from southwestern part of Nigeria. He reported CBR of 27% in un-soaked and 14% for soaked sample for laterite soils derived from Amphibolites. From mica schist, he obtained 10% for unsoaked and 9% for soaked samples. As such it will be suitable as

sub-base material but its linear shrinkage of 10% is greater than the 8% maximum for sub base material. Furthermore, Ogunsanwo (1989) performed CBR and shear strength tests on compacted lateritic soil from Benin sands. He then concluded that the compacted soil samples are suitable for use as sub-base materials in road construction as their CBR falls within the limits specified for this purpose (7-20%).

Ogunsanwo (1988) also studied laterite soil from Ojota area in Lagos state and obtained liquid limit of 49.5%, plastic limit of 21.8%, plastic index of 28.4% and linear shrinkage of 6.9%. On the basis of the geotechnical properties, he concluded that the soil is a good engineering construction material. Idowu et., al determined the permeability and the grain size characteristics of Sagamu and Ibadan-Toll-Gate lateritic soils in southwestern Nigeria and concluded that the observed stability and failure of the highway pavement were due to the analyzed data, which are geotechnical and/or geological factors.

This paper examines the geotechnical properties of lateritic soils around DALL Quarry (a laterite soil quarry) in Ilorin, Southwestern Nigeria around where road construction is on-going. The study is significant because, the results would show whether the materials are good for the purpose of road construction and also indicate other uses the materials could be useful for.

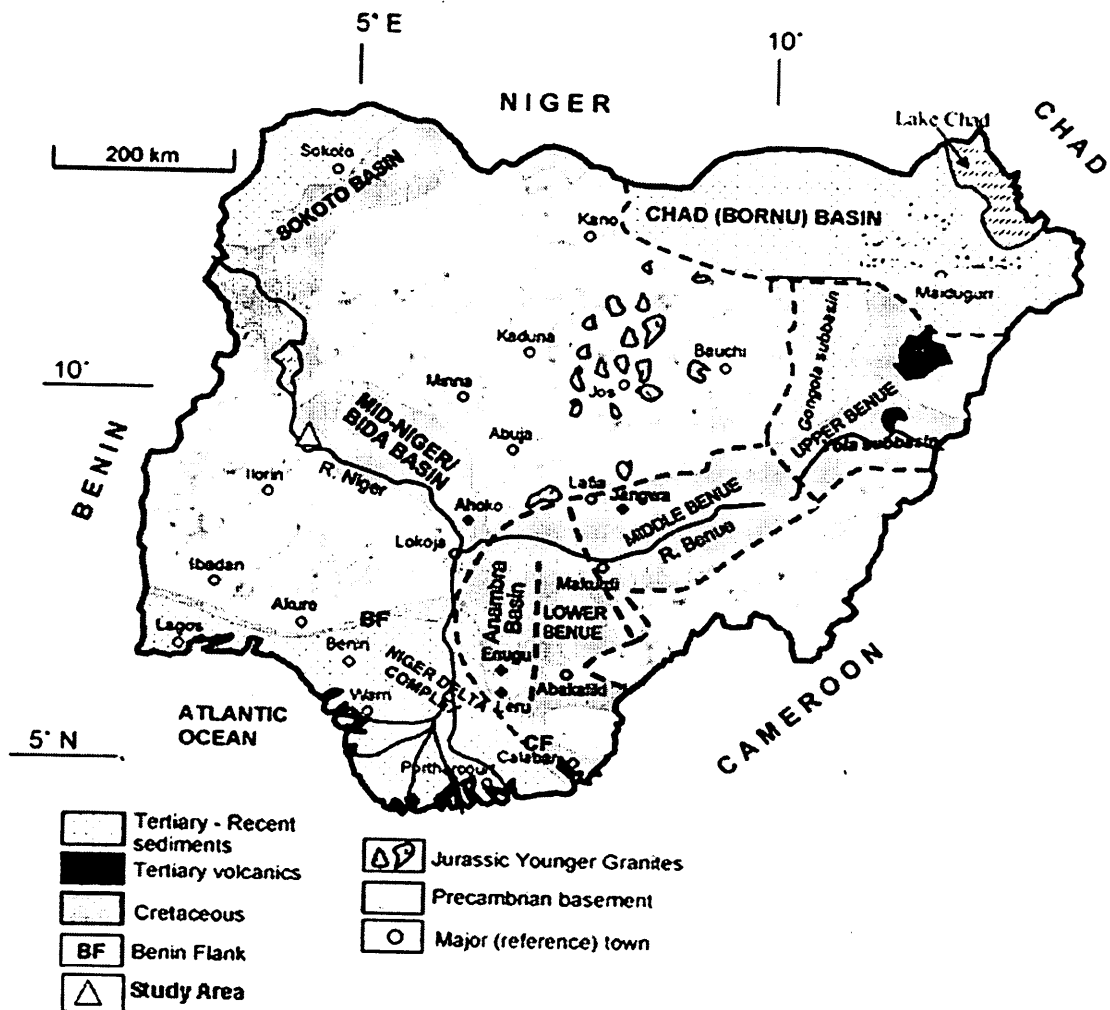


Figure : Geological Map of Nigeria showing the Study Area (Obaje et al., 2004)

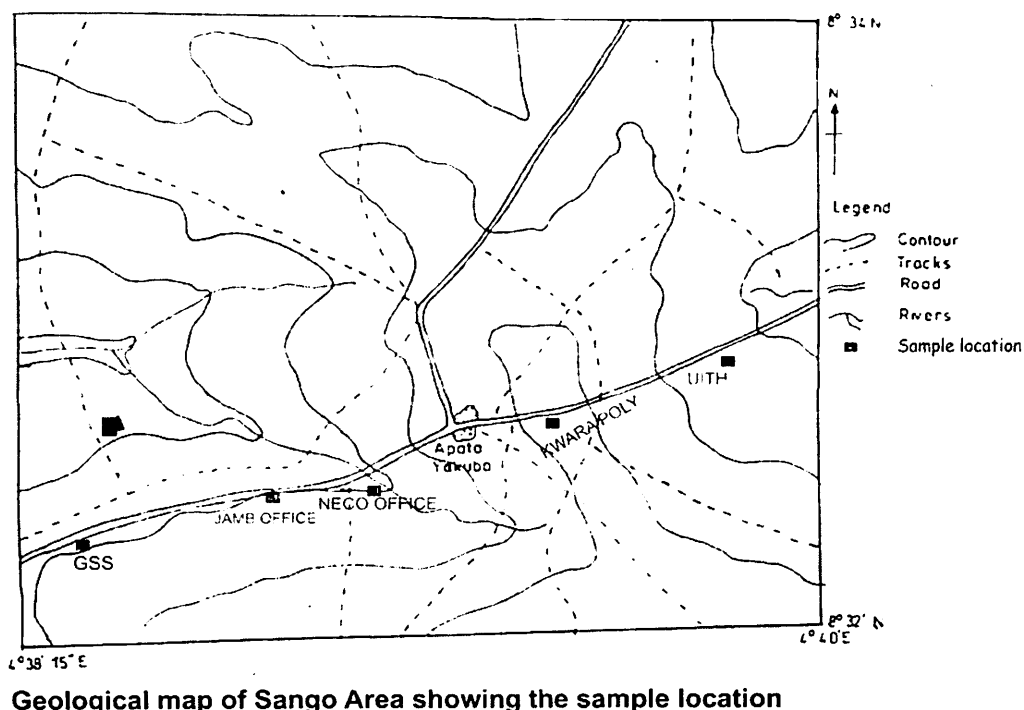


Figure 2: Sample Location Map showing Sample Locality

2. MATERIALS AND METHODS

Two lateritic soils were sampled (ADET 1 AND ADET 2) and selected for the various testing techniques. Grain-size analyses were performed using ASTM D6913 - 04(2009) Standard test methods for particle-Size distribution (gradation) of Soils using sieve analysis. The compaction test was carried out by standard and modified Proctor methods. ASTM D 698 and ASTM D 1557 standard methods were used respectively (2007). The CBR tests (soaked CBR test and un-soaked CBR test) are determined using:

ASTM Standard D1557, (2009), Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort, ASTM International, West Conshohocken, PA, DOI: 10.1520/D.1557-09

$$CBR = \frac{\text{test unit load}}{\text{Standard unit load}} \times 100$$

The analyses were carried out at the Civil Engineering Laboratory, University of Ilorin, Nigeria.

3. RESULTS AND INTERPRETATIONS

3.1 Specific Gravity

The results of the specific gravity analysis of both soil samples, ADET 1 and ADET 2 are 2.68 and 2.63 respectively. Comparing these results with some standard results or values, ADET 1 could be regarded as sand and ADET 2 could be regarded as inorganic clay (Bowles, 1979).

3.2 Grain Size Distribution

The tests are performed to determine the percentage of different grain sizes contained within the soil. The distribution of different grain sizes affects the engineering properties of soil which in turn

influences their usability in construction works. The grain size distributions show that ADET 1 is silty-clayey very gravelly sand, having 23% clay and silt, 47% sand and 30% gravel compositions. Similarly, ADET 2 could be described as gravelly silt-clayey sand with 36% clay and silt, 52% sand and 12% gravel compositions.

3.3 Atterberg Limits

The Atterberg consistency limit tests carried out on the soil samples show that ADET 1 has liquid limit of 40.0%, plastic limit of 18.2%, plasticity index of 21.8%, shrinkage limit of 7.4%, toughness index of 1.16 and activity of 0.95 while ADET 2 it has liquid limit of 46.0%, plastic limit of 23.5%, plasticity index of 22.5%, shrinkage limit of 8.2%, activity of 0.63 and toughness index of 0.82. The plots of plastic index against liquid limit on the plasticity chart show the Atterberg limits plots above "A" and it is in the zone of inorganic clayey silts, clays of low plasticity (CL) for both samples (Fig 3). This indicates Inorganic clays of low to medium plasticity, gravelly clays, sandy clay and silty clay. According to engineering use chart, the soil samples are impervious and inorganic clays useful for erosion resistance in canal constructions. They can also be useful in homogenous embankment in rolled earth dams because of their good to fair workability as construction materials and their fair shearing strength when compacted and saturated (Wagner, 1957). The values of activity (0.95 and 0.63 respectively) also indicate inactive clay content which means that volume change is minimal and may not be problematic in the samples (Raymond, 1997; Das, 2006). The values obtained could also be compared with the values obtained by Ogunsanwo (1988) who suggested that 'the soil should be good engineering construction materials when compacted'.

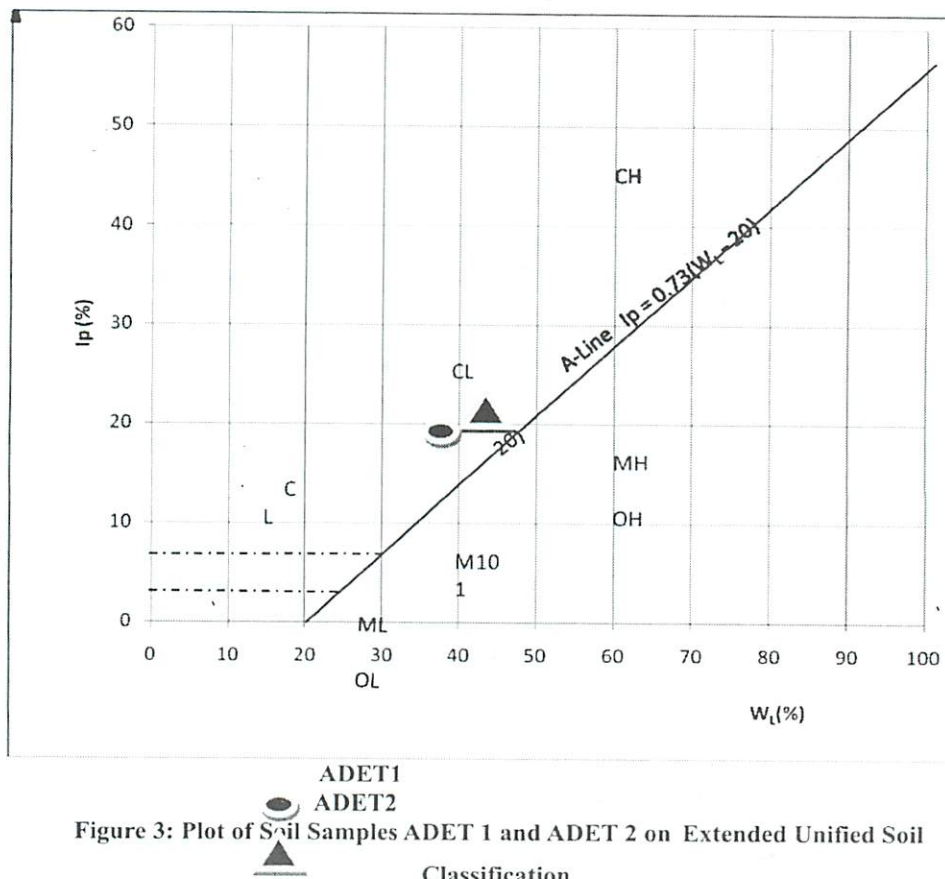


Figure 3: Plot of Soil Samples ADET 1 and ADET 2 on Extended Unified Soil Classification

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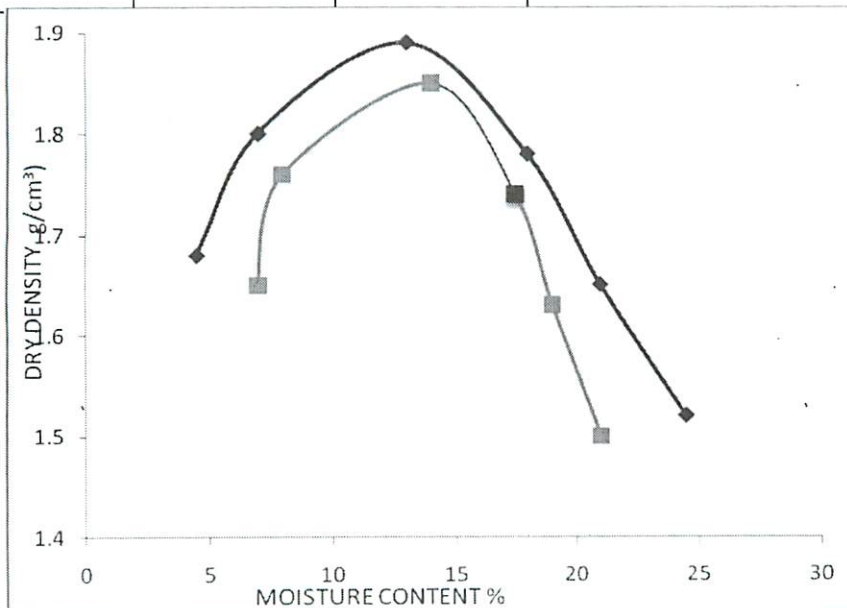
sample ADET 2. the maximum dry density is 1.84 g/cm³ at standard proctor and 1.90 g/cm³ for modified proctor (fig. 4). This falls within the observed range of 1.3- 2.4 g/cm³ obtained by Madu (1975), Gidigasu (1976) and Ogunsanwo (1989). There is slight decrease of maximum dry density down the profile in this study. The optimum moisture content (OMC) for sample ADET 1 is 14.0% at standard proctor and 13% at modified proctor. For ADET 2 the optimum moisture content is 15% at standard proctor and 14% at modified proctor. The OMC serves as guide to know the amount of water to add during construction.

Table 1: Specification for Standard Proctor and Modified Proctor Test Variables using 1000 cm³ Mould

	Standard Proctor	Modified Proctor
Weight of rammer (kg)	2.5	4.5
Height of rammer drop (cm)	30	45
Volume of mould (cm ³)	1000	1000
Number of layers	3	5
Number of blows	25	25

Table 2: Compaction Tests Results

Sample	Standard Proctor		Modified Proctor	
	OMC (%)	MDD(g/cm ³)	OMC (%)	MDD(g/cm ³)
ADET 1	14.0	1.85	13.0	1.84
ADET 2	15.0	1.84	14.0	1.90



Standard proctor
 Modified proctor

Figure 4: Compaction Curve for Soil Sample ADET 1 Standard and 1 Modified

3.4 California Bearing Ratio (CBR) Tests

The results of the CBR are presented in table 3. For standard Proctor compaction unsoaked and soaked, ADET 1 has 3% CBR and 1% CBR values respectively. ADET 2 also has 4% CBR values respectively. Similarly, modified Proctor compaction unsoaked and soaked, ADET 1 has 4% and 2% CBR values respectively and ADET2 has 5% and 3% CBR values respectively. Considering the values obtained, they fall within CBR value range of 0-3% and 3-7% respectively hence, the soils could be useful as sub-grade materials for road constructions (Bowles, 1990).

Table 3: Summary of CBR Tests Results

Sample Number	Standard Proctor %		Modified Proctor %	
	Unsoaked %	Soaked %	Unsoaked %	Soaked %
ADET 1	3	1	4	2
ADET 2	4	4	5	3

3.5 Direct Shear Tests

The direct shear test is used to determine the angle of internal friction of soil, the cohesion of the soil and the effective pressure. The tests show that soil sample ADET 1 compacted at standard Proctor exhibits cohesion value of 70KPa and angle of internal friction of 34°, when compacted at modified proctor, the cohesion (C) is 100KPa and angle of internal friction 32°. Sample ADET 2 compacted at standard proctor has cohesion of 60KPa and internal friction of 35°. When compacted at modified proctor, the cohesion is 70KPa and angle of internal friction is 31°. The graphical representation is shown in figures 5-8 and the standard and modified Proctor shear strength readings are shown in tables 4a-4d. The shear box tests revealed that the soils are of high strength having cohesion values ranging from 60KPa to 100KPa with an average of 75KPa. Similarly, the angle of internal friction ranges from 31° to 35° with an average of 33°. Alao and Opaleye 2011 obtained an average value of cohesion, 65KPa and an average value of angle of internal resistance, 26°. Das (1990) also provided typical values of angle of internal friction for lateritic soils ranging from 26-45°, it can therefore be deduced from the results of the test that the soil samples have a medium angle of internal friction which implies that the soils are hard according to the above references. Hence, the soils could support slope stability and shallow foundation depending on the height of the slope and the weight of the structure.

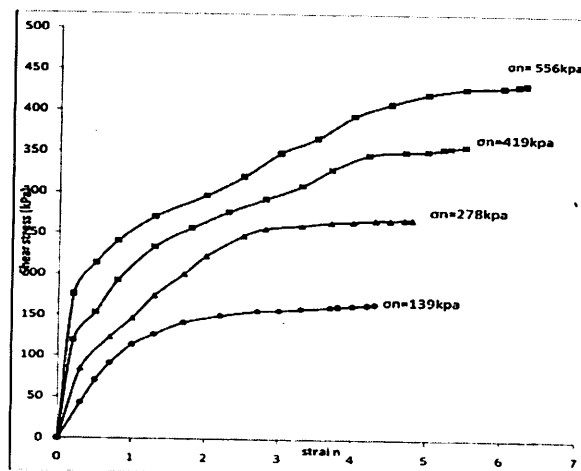


Figure 5a: Plots of Shear Stress (KPa) Vs Strain (%) for Standard Proctor Compacted Soil Sample ADET 1

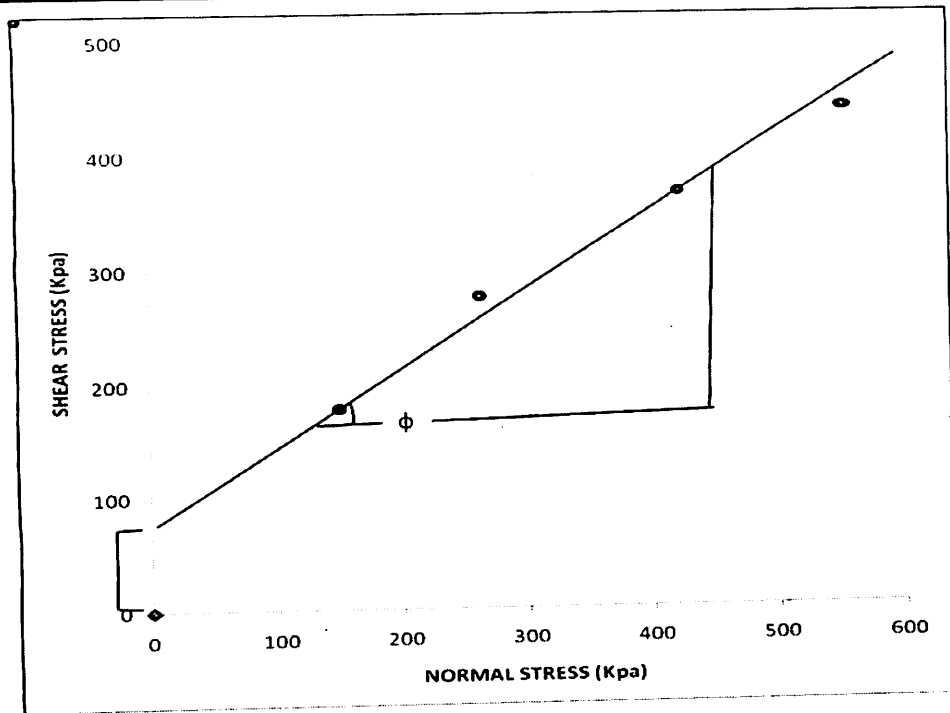


Figure 5b: Plot of Shear Stress (KPa) Vs Normal Stress (KPa) for Standard Proctor Compacted Soil Sample ADET 1

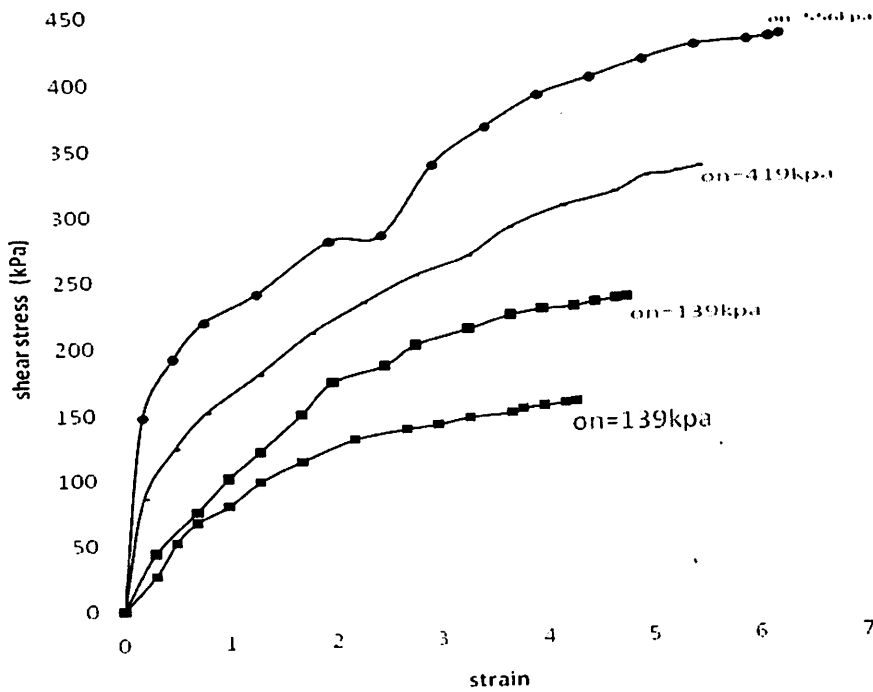


Figure 6a: Plots of Shear Stress (KPa) Vs Strain (%) for Modified Proctor Compacted Soil Sample ADET 1

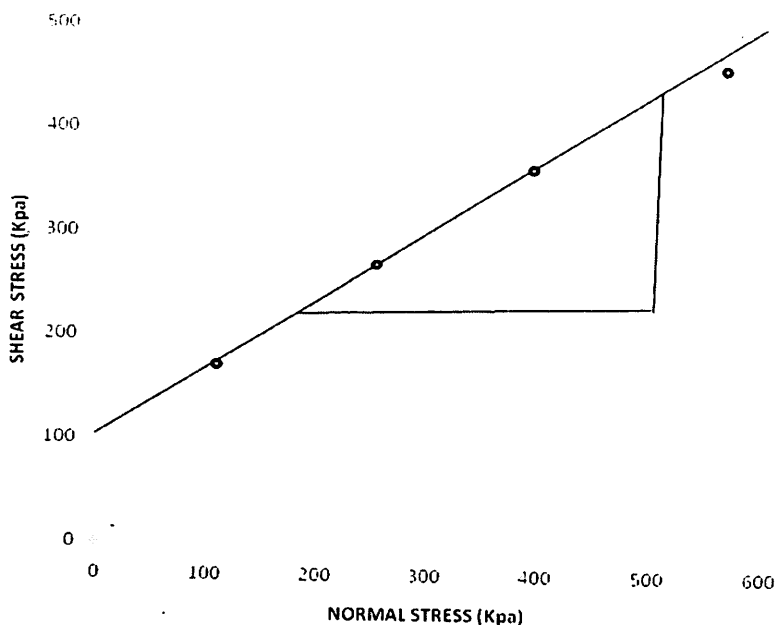


Figure 6b: Plot of Shear Stress (KPa) Vs Normal Stress (KPa) for Modified Proctor Compacted Soil Sample ADET1

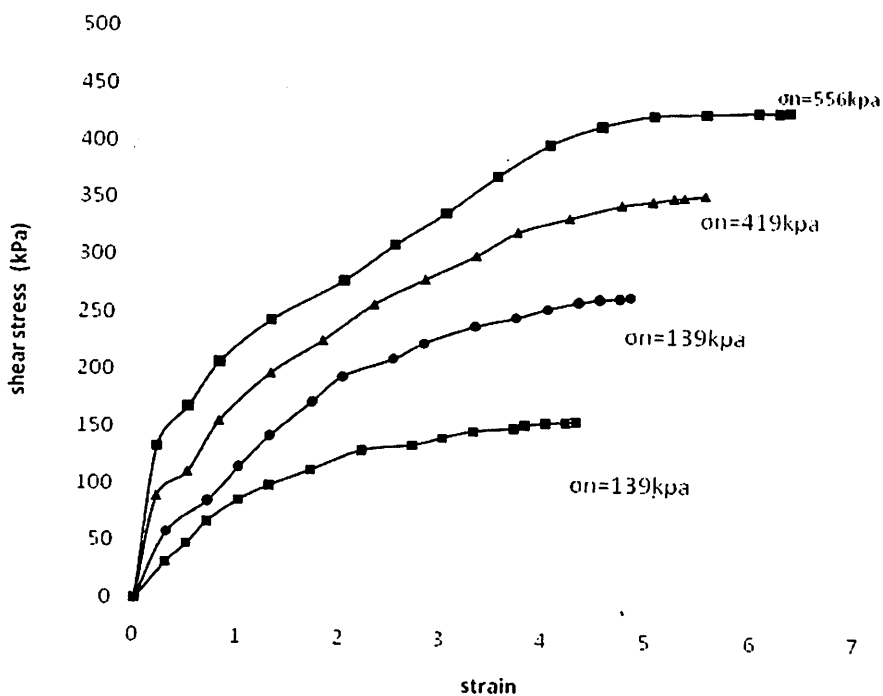


Figure 7a: Plots of Shear Stress (KPa) Vs Strain (%) for Standard Proctor Compacted Soil Sample ADET 2

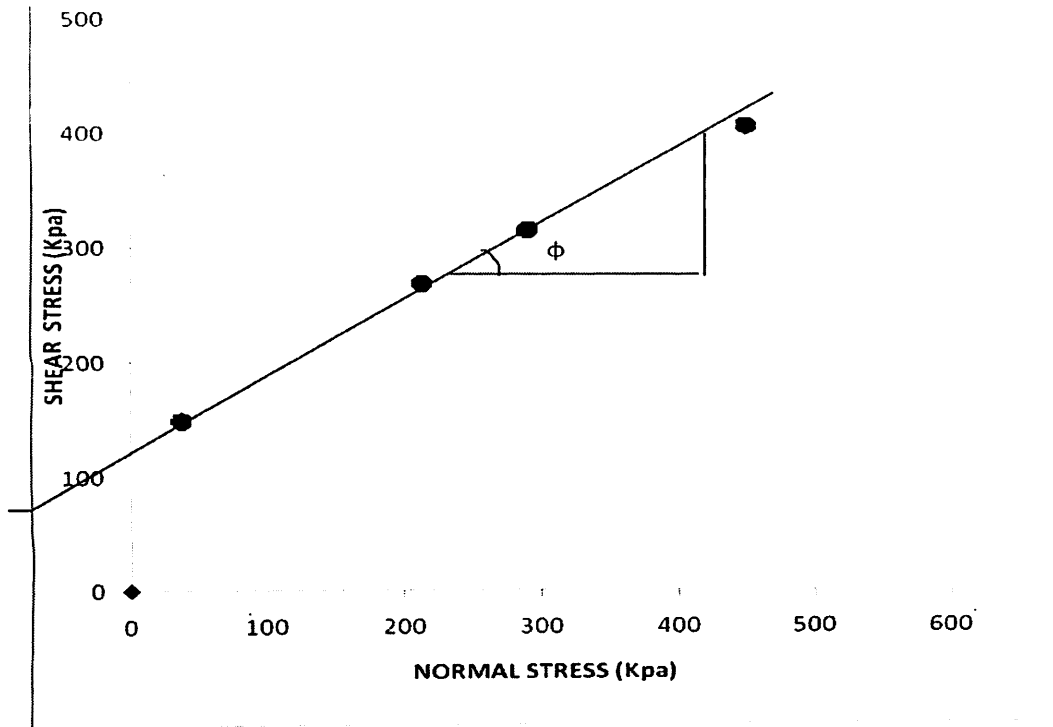


Figure 7b: Plots of Shear Stress (KPa) Vs Strain (%) for Standard Proctor Compacted Soil Sample ADET 2

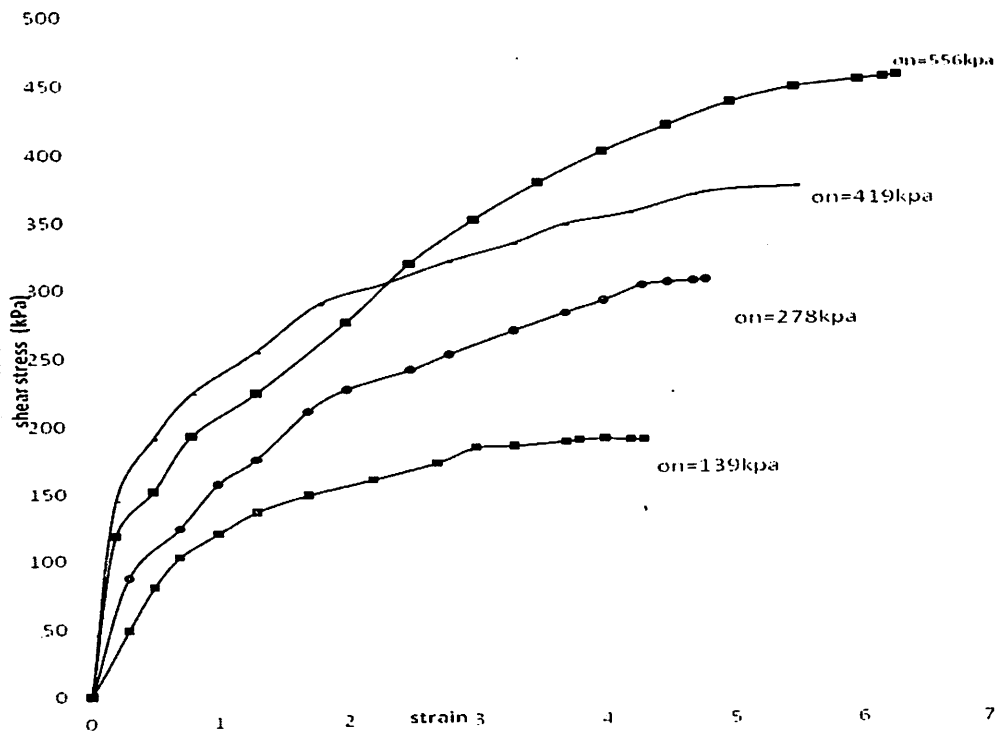


Figure 8a: Plots of Shear Stress (KPa) Vs Strain (%) for Modified Proctor Compacted Soil Sample ADET 2

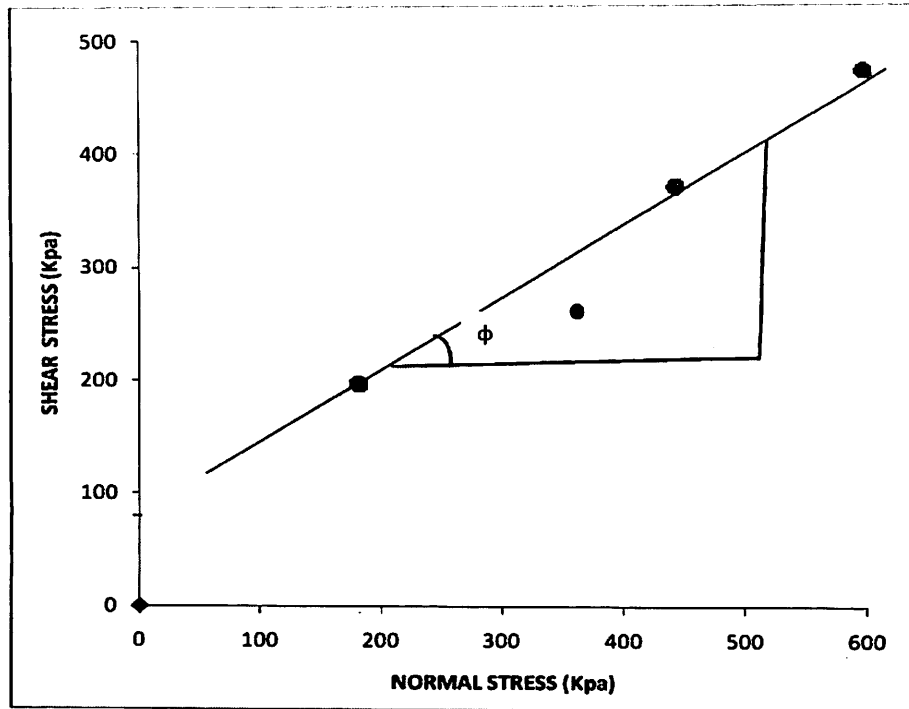


Figure 8b: Plot of Shear Stress (KPa) Vs. Normal Stress (KPa) For Modified Proctor Compacted Soil Sample ADET 2

Table 4a: ADET 1 Standard Proctor Shear Strength Reading

Load (kg)	Shear Stress	Normal Stress
5	166	138.9
10	269	277.8
15	358	416.7
20	433	555.6

Cohesion=70 KPa, Angle of internal friction $\Phi = 34^\circ$

Table 4b: ADET 1 Modified Proctor Shear Strength Reading

Load(kg)	Shear Stress	Normal Stress
5	186	138.9
10	304	277.8
15	372	416.7
20	454	555.6

Cohesion= 100Kpa, Angle of internal friction $\Phi = 32^\circ$

Table 4c: ADET 2 Standard Proctor Shear Strength Reading

Load (kg)	Shear Stress	Normal Stress
5	160	138.9
10	269	277.8
15	359	416.7
20	433	555.6

Cohesion=60Kpa, Angle of internal friction $\Phi = 35^\circ$

Table 4d: ADET 2 Modified Proctor Shear Strength Reading

Load (kg)	Shear Stress	Normal Stress
5	153	138.9
10	231	277.8
15	320	416.7
20	428	555.6

Cohesion $C=70\text{Kpa}$, Angle of internal friction $\Phi = 31^\circ$

4. CONCLUSIONS

Based on the grain size analysis, the soil sample ADET 1 is silt-clayey very gravelly sand and ADET 2 is classified as gravelly, silt-clayey sand.

Atterberg consistency limit tests carried out on ADET 1 show the soil samples are above the activity (A) line in the zone of intermediate plasticity clays (CL). In addition, ADET 1 and ADET 2 contain activity values of 0.95 and 0.63 respectively. This suggests negligible or low swelling property of the soils and can be chosen as construction materials.

The CBR values and direct shear test results show that the soils may be useful as sub-grade materials in road construction and could also be useful for slope stability Olabaniyi et. al (2005).

Based on the values obtained from the various tests carried out on the soil samples, it could be concluded that they are good construction materials in building industries, road constructions and slope stability.

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