Geotechnical Evaluation of Lateritic Soil in Baba-Ode Area, Ilorin, North – Central Nigeria

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Abstract

This study was carried out on lateritic soil at Baba-ode,North-central Nigeria with aim of denoting the geotechnical properties of lateritic soil and its suitability as construction materials. Two disturbed lateritic soil samples (sample A and B) were selected for the various laboratory techniques. The grain size analyses, the specific gravity tests, the atterberg limit tests, compaction, California bearing ratio and shear box tests were carried out on the samples. The grain size analysis shows that sample A is gravelly silt – clayey sand while sample B is silt – clayey gravel composition. Atterberg consistency limit test indicate that sample A has 30.0%, liquid limit 19.5% plastic limit, 10.5% plasticity index, 9.1% shrinkage limit while sample B has liquid limit of 27.0%, 16.2% plastic limit, 10.8% plasticity index and 7.4% shrinkage limit. The soil samples are above the activity (A) line in the zone of intermediate plasticity (CL) which suggests that they are inorganic soils. The samples contain inactive clay indicating little or no swelling tendency and therefore good for construction materials and this would prevent foundation failures. The California Bearing Ratio (CBR) values are 2 – 3% (mean = 2.75%) and 2 - 4% (mean = 2.75%) in sample A and sample B respectively. This implies they are good as subgrade construction materials. The compaction tests for the optimum water content for sample A is 15.0% and 13.0% for standard and modified proctor respectively. The standard and modified proctor for sample B is 15.2% and 14.0% respectively. The compaction tests for Sample A indicate a higher fine fraction and thus a higher optimum moisture content while sample B has higher coarse fraction with lower optimum moisture content. The cohesion falls within 70-90Kpa (mean = 80Kpa) and the internal friction ranges from 25^0 - 31^0 with mean of 29^0. The results obtained from geotechnical analysis suggest that the soil have high bearing capacity, hence, it can be used as construction materials in engineering works. The soil could also support shallow foundation, dam construction, embankments, slope stability and subgrade materials in road constructions.

Keywords

Lateritic soil, Compaction, California bearing ratio, Nigeri

1. Introduction

Lateritic soils are formed in situ from the intense weathering of parent material whether primary or sedimentary in the tropical and sub- tropical climatic environment. This weathering process involves the chemical alteration of primary minerals, the release of iron and aluminum sesquioxides, increasing loss of silica and the increasing luminance of new clay materials (such as smectites, halloysite and kaolinite) formed form dissolved materials (Bayewu and Oloruntola, 2012). The understanding of soil behaviour in solving engineering and environmental issues of swelling soil especially expansive lateritic soil can cause significant damage to road and other engineering construction (Oke and Amadi, 2008). Bad road is one of the major causes of road accident which is usually caused by wrong application of lateritic soil as base and sub-base material by construction companies (Nwankwoala *et al*., 2013). For a material to be used as either a base course or sub-base course depends on its strength in transmitting the axle-load to the sub-soil and or sub-grade (the mechanical interlock). The characteristic and durability of any construction material is a function of its efficiency in response to the load applied on it (Oke *et al.,* 2009).

1.1 Location and Geology of the Study Area

The study area (Figure.1, 2) is located in Baba ode area in Ilorin West Local Government area of Kwara state. It lies within latitude $8^{0}27^{1}00$N and longitude $4^{0}33^{1}54^{1}$. The area is accessible through network of roads and well developed footpaths. The area is underlain by rocks of the Precambrian Basement complex (Rahaman, 1976).

Figure.1: Geological map of Nigeria showing the study area (After: Rahaman, 1988)

These rocks are granites, migmatites gneiss, Granite Gneiss, quartzites and the mineral composition that can be found in the rock include feidspar (orthoclase and plagioclase), quartz, muscovite and biotite.

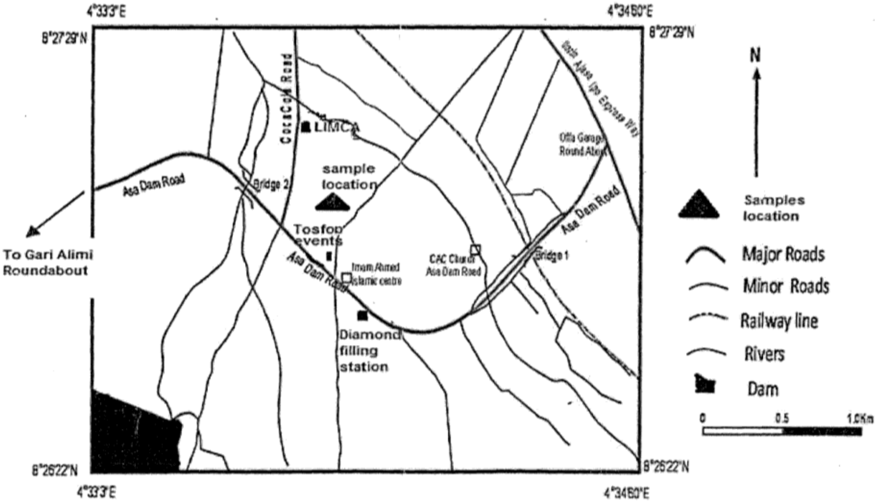


Figure.2: Map of the study area showing sample location

3. Materials and Methods

Two disturbed lateritic soil samples (sample A and B) were obtained at depth ranging from 1 meter to 3 meters from Baba – ode area for various testing techniques. Grain size analyses were performed using the coarse sieve and fine sieve methods to determine the percentage distribution of various particle sizes. The compaction test was carried out by standard and modified proctor methods. The tests carried out for standard and modified proctor tests involves the following materials such as mould dimension of 10cm by 5cm, weight of rammer is 2.5kg, no of layers is 5, no of blows is 25 but 55 for modified proctor and height of rammer is 11.5cm. The CBR tests for both soaked and unsoaked CBR tests were determined using

$$CBR = \frac{\text{test unit load}}{\text{Standard unit load}} \times 100 \quad (1)$$

The tests were carried out at the Civil Engineering laboratory, University of Ilorin, Nigeria.

4. Results And Discussion

4.1 Specific Gravity

The specific gravity of any soil is taken to be the average value for the soil grains. A specific gravity of 2.73 was obtained for sample A while for sample B a value of 2.66 was obtained. However, comparing these values with typical values for specific gravity (Gs) for some soil types after Lambe and Whiteman, 1969; Bowles, 2012, it can be said that sample A and B are both inorganic and organic clay.

Table 1. Typical values of specific gravity of soil particles (Bowles, 2012)

Soil Type	Specific gravity
Sand	2.65 – 2.68
Gravel	2.65 – 2.66
Clay (Inorganic)	2.52 - 2.66
Clay (Organic)	2.68 – 2.72
Silt	2.65 – 2.66

4.2 Grain size analysis or particle size

The fundamental objective of the grain size analysis is to determine the percentage distribution of various particle sizes. This distribution however influences the capability in engineering construction works. The grain size distribution analysis for sample A shows that it consists of gravelly silt-clayey sand with 32% silt, 32% clay, 51% sand and 17% gravel constituents. Correspondingly, sample B could be described as silt-clayey very gravel with 25% silt, 25% clay, 61% sand, and 25% gravel composition. This denotes that both soils can be classified as sandy clay.

4.3 Atterberg limit

The atterberg limit consistency limit test shows that the soil sample A has liquid limit of 30.0%, plastic limit of 19.5% and linear shrinkage of 9.1%. It also has a plasticity index of 10.5%, flow index of 20% and toughness index of 0.5%. Sample B has a liquid limit of 27.0% plastic limit of 16.2%, shrinkage limit of 7.4% and plasticity index of 10.8%. It has a flow index of 15% and toughness index of 0.7% Both soil sample A and B plots are in CL group on the plasticity chart in Figure. 4, from the engineering use chart, this indicates inorganic clay of low plasticity (Table 1). The workability as a construction material is good to fair according to the chart

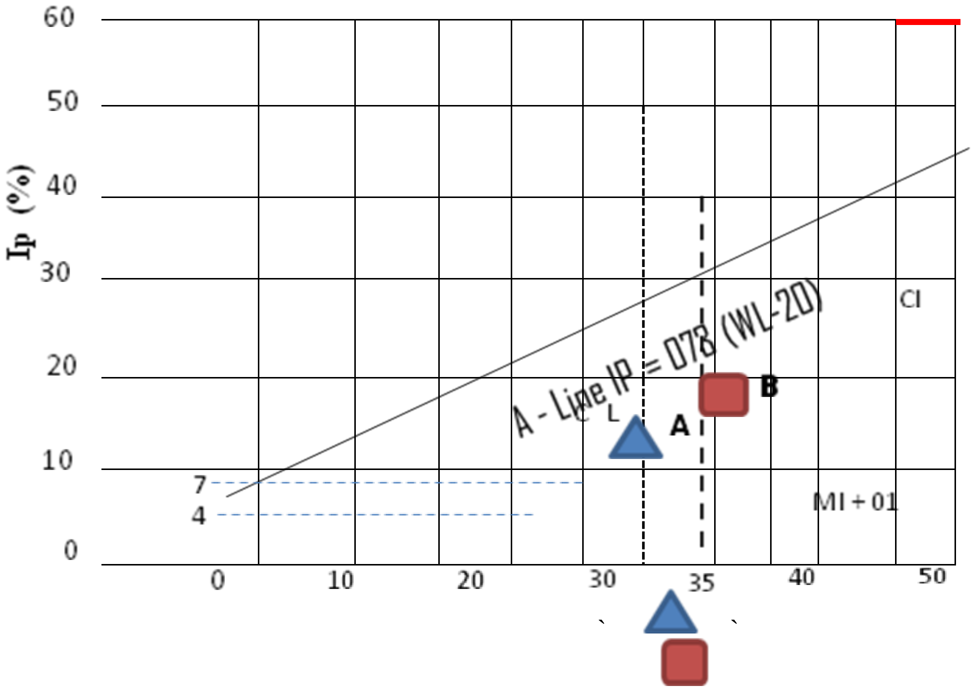


Figure. 3: Plot of the soil sample on plasticity chart

The sample with higher fine fraction has higher optimum moisture content while the sample with lower fine fraction or higher coarse fraction has the lower optimum moisture content. Sample A has higher fine fraction and thus, has higher optimum moisture content.

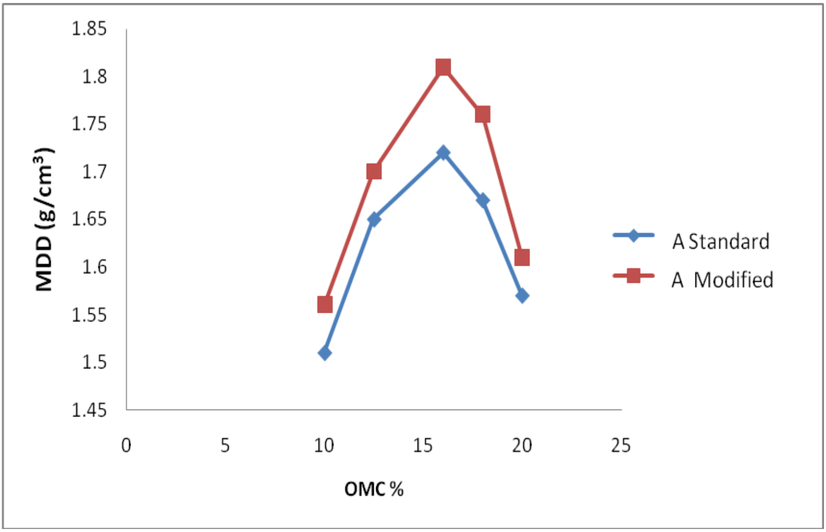


Figure. 4: Compaction curve of soil sample A standard and modified

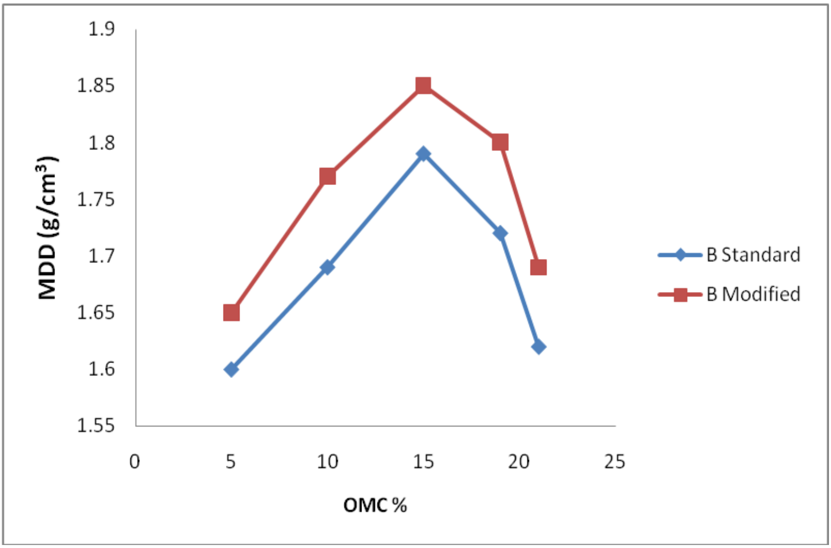


Figure. 5: Compaction curve for sample B standard and modified

Table 2. Summary of compaction tests results

Sample Name	Standard Proctor		Modified Proctor	
	OMC (%)	MDD (g/cm^3)	OMC (%)	MDD (g/cm^3)
A	15.0	1.80	13.0	1.90
B		15.2 1.70	14.0	1.78

4.5 California Bearing Ratio

The CBR values of the samples are stated in Table 3 and 4. It shows the general rating of soil materials based on the CBR values of the materials and for use as a sub-grade to base course material for support of flexible pavements.

Standard proctor unsoaked and soaked for sample A has 3% and 2% CBR values respectively. Sample B also has 2% values for both unsoaked and soaked respectively. Similarly, modified proctor unsoaked and soaked, sample A has 3% CBR respectively, and sample B has 4% CBR and 3% CBR respectively. Based on the values obtained, they fall within CBR value range of 0-3% and 3-7% respectively (Bowles, 1990). Consequently, the soil could be useful for slope stability and as sub-grade materials for road construction.

Table 4. Specification for Standard and Modified Proctor Test Variables Using the 996.2cm^2 mould

Specification	Standard Procto	Modified Proctor
Weight of Rammer (kg)	2.5	7.5
Height of Rammer drop (m)	03	0.45
Volume of Mould (M^3)	996.2 X 15^{-4}	996.2 X 15^{-4}
Compactive Energy (MNm/m^3)	0.597	2.686
Number of layers	3	5
Number of blows per layer	25	55

Table 4a. Compaction tests for samples A and B.

Sample Number	Standard Proctor (%)		Modified Proctor (%)	
	Unsoaked (%)	Soaked (%)	Unsoaked (%)	Soaked (%)
A	3	2	3	3
B	2	2	4	3

Table 4b. General Rating of Soil Materials Using CBR Values (After Bowles, 1990)

CBR Value	General	Uses	Classification System
0-3	Very Poor	Sub-grade	OH,CH,MH,OL
3-7	Poor fair	Sub-grade	OH,CH,MH,OL
7-20	Fair	Sub-grade	OL,CL,ML,SC
20-50	Good	Base, Sub-grade	GM,GC,SW,SM,SP,GP
50	Excellent	Base	Gw, GM

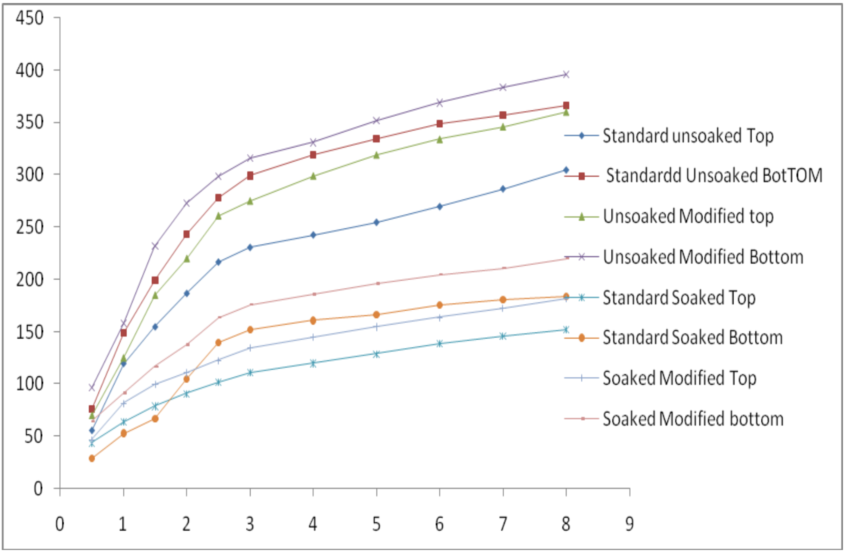


Figure. 6: Plot of Shear stress (kpa) vs strain (%) for standard proctor and mod proctor compacted soil sample A

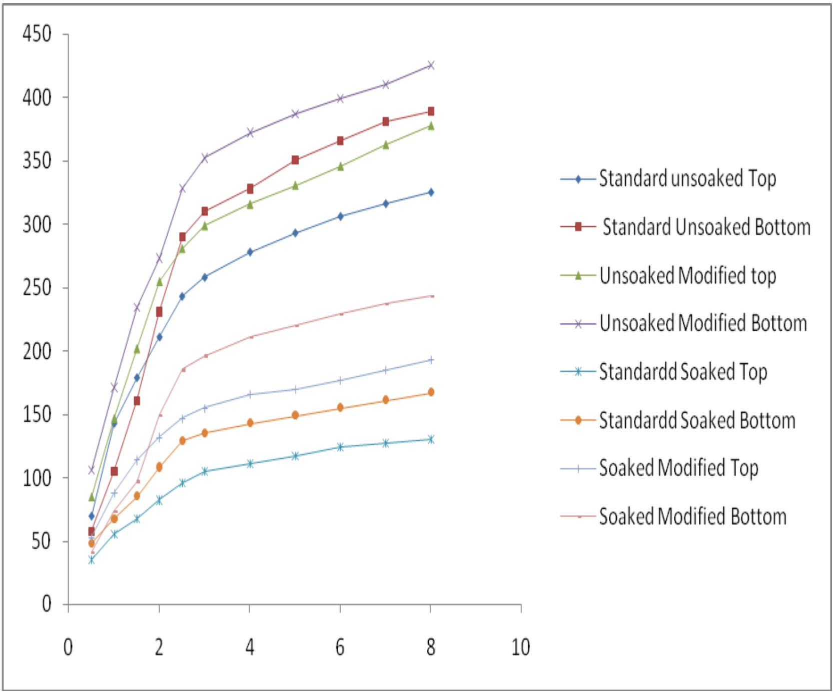


Figure. 7: Plot of Shear stress (kpa) vs strain (%) for standard proctor and mod proctor compacted soil sample B

4.6 Direct Shear Tests

Direct Shear test is one of the oldest forms of shear test upon the soils. The direct shear test is used to determine the angle of internal friction of soil and the effectiveness of pressure. It shows that sample A compacted at standard proctor reveals cohesion value of 70Kpa and angle of internal friction of 28^0 while modified proctor compacted soil sample A gave cohesion (C) of 90Kpa and has internal friction of 25^0. Sample B compacted at standard proctor has a cohesion of internal friction of 90Kpa and 31^0 respectively. The modified proctor gave a cohension (C) and internal friction (ϕ) of 70Kpa and 30^0 respectively. Hence, from the graphical representation as shown in Figureure 5-8, the shear box test revealed that the soil has high bearing capacity having values ranging from 70Kpa to 90Kpa with average of 80Kpa. Similarly, the angle of internal friction ranges from 25^0 to 31^0 with average of 29^0. The tests show that the soil is made up of sands and clays. Therefore, both samples are good as engineering construction (foundation) materials, support slope stability and also both samples can be used moderately in steep embankment. (Figure. 8a - d).

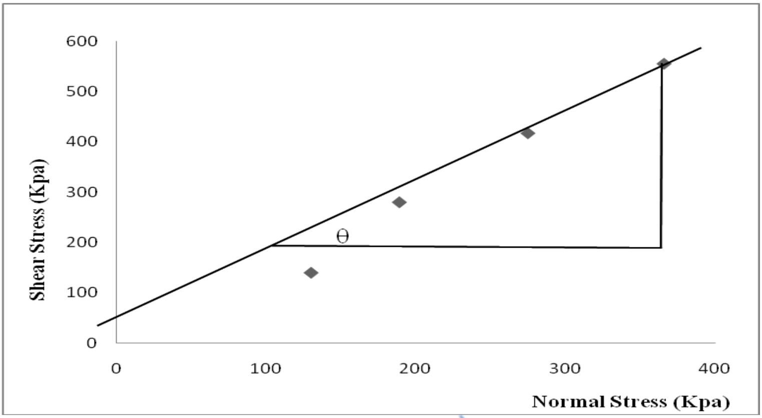


Figure 8a Plot of shear shear stress (kPa) vs normal stress (kPa) for standard proctor for sample A

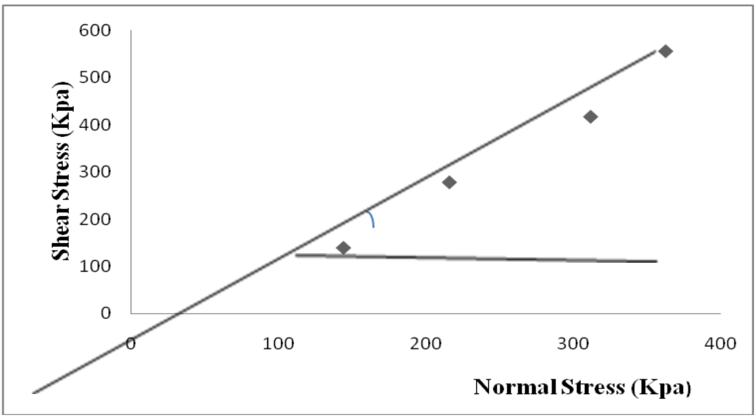


Figure 8b Plot of shear stress (kPa) vs normal stress (kPa) for modified proctor for sample

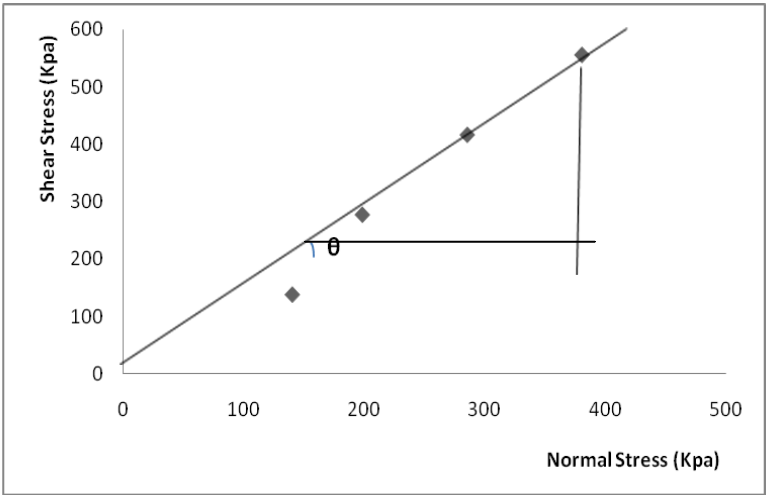
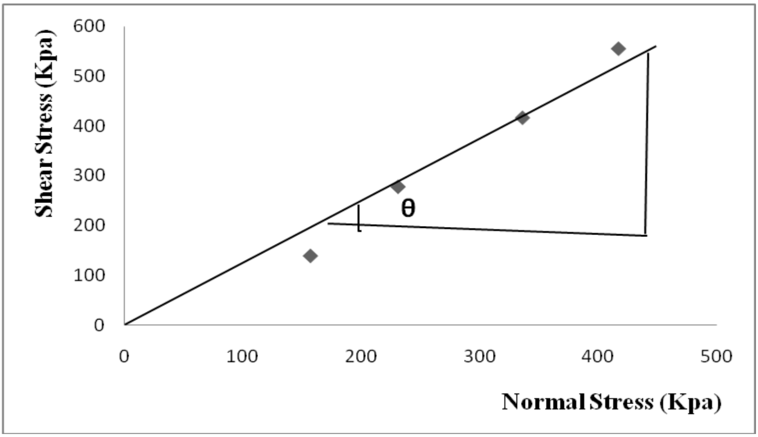


Figure 8c Plot of shear shear stress (kPa) vs normal stress (kPa) for sndard proctor for sample B



Figuree 8d Plot of shear shear stress (kpa) vs normal stress (kpa) for modified proctor for sample

5. Conclusion

The tests carried out in this research work were mainly concerned with using basic geotechnical properties of soil with regards to their uses as construction materials. The grain size analyses show that both samples are sandy clay. From the atterbergs consistency limit for samples A and B as it falls on CL-group, it tells us that both samples contains an Inorganic clayey soil of Low plasticity. In compaction tests, the maximum dry densities obtained for both sample indicates that the soil is suitable as construction materials for embankments, core of earth dams and as mineral seal due to their being impervious on compaction (low permeability) as stated in engineering use charts for soils. According to CBR numbers obtained from this research work, the values indicate that the soil can be used for sub-grade materials in pavement (road) design. The result under direct shear tests shows that both samples have high bearing capacity due to low cohesion and high angle of internal friction. Hence, they are good as engineering construction (foundation materials).

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