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GEOTECHNICAL INVESTIGATION OF BLACK COTTON SOIL AROUND DEBA AREA, NORTH-EASTERN NIGERIA

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ABSTRACT

This geological and geotechnical study was carried out to investigate the engineering properties of black cotton soil around Gombe – Deba area and environs. Geological field survey was carried out around the study area and geotechnical laboratory analysis comprising of Atterbergs limits, linear shrinkage, natural moisture content, CBR, UCS, and compaction test was conducted on four different soil samples collected from the field. The study area is underlain by the Pindiga and Gombe formations and the main lithological units are limestone, shale, sandstone with large superficial deposits of Black cotton soil covering the study area. The results of the geotechnical analysis revealed low unconfined compressive strength value of 116.6KN/m^2 as the maximum of the four samples analyzed, CBR values for the soaked test are 3%, 4.6%, 4.5% and 4.3% and the unsoaked values of 9.1%, 8.5%, 8.8% and 7.5% for pits no. 1,2, 3, and 4 respectively. The OMC values of 24.03% and 19% with corresponding MDD of1.33mg/m^3 and 1.53mg/m^3 were obtained as the maximum and minimum values respectively. The soil of the study area show a high liquid limit with an average value of 62% and high plasticity index having average of 35%. These results indicates that the black cotton soil of the area fall within the CH group and A-7-6 group and are considered as weak materials in engineering construction. In addition these soils are highly expansive; hence need to be suitably stabilized to upgrade the engineering performance of the soils.

Keywords: Black cotton soils; geotechnical; geological; soil strength; Pindiga and Gombe formations.

INTRODUCTION

Soil is an indispensable element of nature that plays a very significant role in sustaining live, providing habitat and supporting structures. How the soil performs any of these functions is a subject of its composition, nature and distribution. Soils can be used for construction either as a sub- base material or a base on which structures is supported (Osinubi, 2011). Black cotton soils are tropical expansive clay deposits which are particularly troublesome due their high swelling and shrinkage potentials, and are rich in montmorillonite which is responsible for it expansive nature (Tamhane, 2014). As such any sound construction within an area associated with this type of soil requires an in depth investigation of their geotechnical properties prior to the construction.

Black cotton soils have been described as "margalitic soils" by Madedor, (1991) a term which they used to represent "black or greyish black, in the eroded phase greyish-white" heavy loam or clays; which crack when dry and swell when moistened. These soils are mostly rich in alkaline metals, where horizons of calcium concretions or lime concretions sometimes develop and are found scattered throughout the soil profile (Rajakumar, 2014). These soils are characterized by the prevalence of montmorillonite and other minerals of the Smectite group (Ola, S. 1983;

Narasihma, 2014;). The black cotton soils were also defined by USAID/BRRI (1971) as being dark grey to black soil with a high content of clay usually over 50%, in which montmorillonite is the principal clay mineral and are highly expansive. Shrinkage during the dry season often lead to surface cracks that could open up to 50mm or more and several millimeters deep (Osinubi, 2011), as shown in Fig. 2.

The road heaving that occurred severely in many towns around Deba area and building deformation in form of cracks constitute a serious engineering problem. In order for soils to be used in engineering construction as a road base or sub base, it has to meet the conventional road base specification or must not be so far beyond from it. Considering the widespread prevalence of black cotton soils in this part of the state, and the challenges they pose to structures founded on them. There is need to understand their peculiar characteristics, behaviors and some basic geotechnical properties, to enable effective utilization of these soils, and this is the main focus of this research work.

MATERIALS AND METHODS

Study Area

The research was conducted in two phases; geological field studies with collection of soils samples and then laboratory analysis. The experimental work was conducted on black cotton soils collected from the study area. The soil samples were obtained along Kanawa-Deba-Jauro-Gotel road, mostly around Deba town of Gombe state, north eastern Nigeria (Fig.1). After careful surveying, suitable pits were located and excavation made to a depth of about 1.5-2m. The samples were collected manually using shovel and dig axe and were preserved in Polythene bags and sacks.

Geological Field Work

This involved the field mapping work to identify and delineate geologic features and structures with a view of understanding the origin and distribution of black cotton soils with respect to geologic setting within the study area. The field work involved the geological mapping of the area, which first involved reconnaissance survey round the study area for an onsite observation before the geological survey which involved making observation at an outcrop and recording observations in field notebook and on a topographical map. Part of this fieldwork was to establish and measure stratigraphic sections as a means of selecting the soil horizons to be sampled. Soil samples were obtained at the site by excavating the trial pits to a depth of about 1.5-2m, disturbed samples was taken from the pits for laboratory analyses. A total of four (4) samples were obtained at different locations within the study area.

Laboratory Methods

From the engineering point of view, soils may poses varying degree of problems. The solution to most of the soil engineering problems involves determining the soil properties in order to ascertain its suitability for the chosen engineering construction. All the experimental procedures in this research were carried out in accordance with the British Standards for the testing of soils (BS 1337 part 2, 1990). The test carried out on the natural black cotton soil includes; Moisture content, Atterberg limits, compaction, specific gravity, unconfined compressive strength, California bearing ratio and linear shrinkage. These tests were carried out to evaluate the properties of black cotton soils of Deba area for engineering constructions

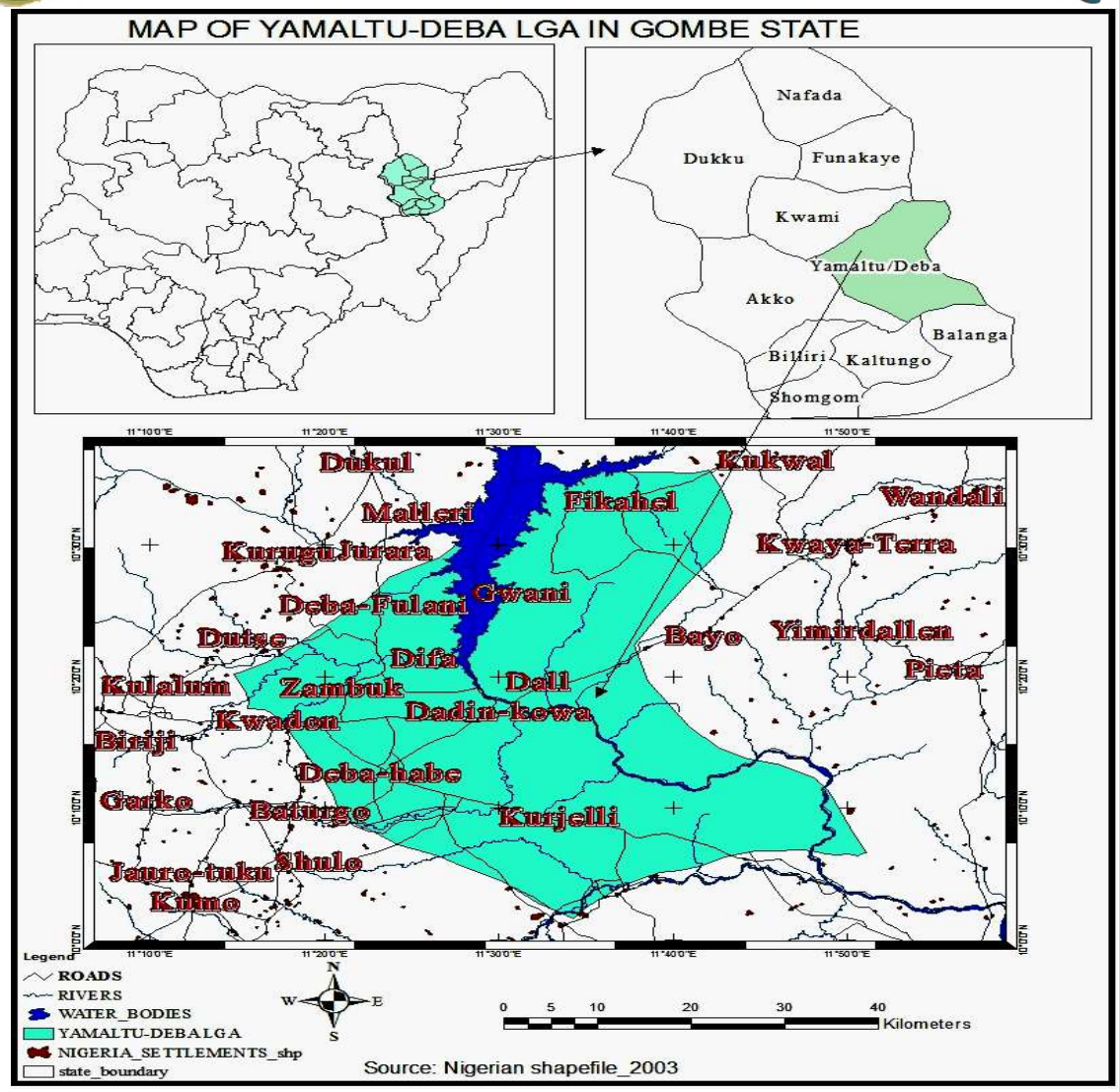

Figure 1: Map of Gombe showing Yamaltu Deba and the study area

Figure 2: Cracks observed in a typical black cotton soil of the study area

RESULTS

Geological and geotechnical investigations, involving both field and laboratory tests were carried out. The results reveal that the study area is characterised by two geologic Formations; Pindiga which consists of Limestone and Shale units and Gombe Formation consisting mainly of Sandstone. These lithologic units are covered by large superficial deposits of Black Cotton Soils in most of the study area. The results of the properties obtained from the laboratory analysis conducted on the four samples of the black cotton soils comprising of; moisture content, Atterberg limits, compaction, specific gravity, unconfined compressive strength in their natural state are presented in the Table 1 and California bearing ratio (CBR) test result for both unsoaked and soaked analysis are given in Table 2. Using the AASHTO classification system, the black cotton soils of the study area were classified as A-7-6 and CH using the USCS classification.

Table 1: Laboratory results

Pit/Sample No.	**1**	**2**	**3**	**4**
Liquid limit (LL %)	60	51	66	67
Plastic limit (PL %)	28	23	29	31
Plasticity index (PI %)	32	28	37	36
Linear Shrinkage (Ls %)	15.3	17	16.1	18.7
Natural Moisture Content (%)	30.7	33.8	29.4	33
MDD(mg/m^3)	1.42	1.33	1.53	1.44
OMC (%)	21.5	24.03	19	20
Specific Gravity (Gs)	2.76	2.70	2.68	2.74
UCS (KN/M^2)	116.6	99.3	93.9	92.6

Table 2: CBR Result

Pit no.	**Soaked CBR (%)**	**Unsoaked CBR (%)**
1	3.0	9.1
2	4.6	8.5
3	4.5	8.8
4	4.3	7.5

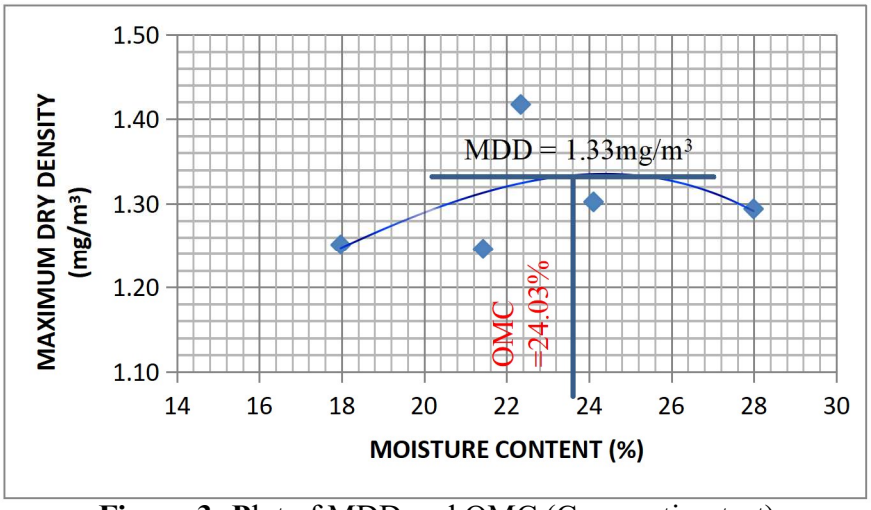

Figure 3: Plot of MDD and OMC (Compaction test)

DISCUSSION

Natural Moisture Content and Atterbergs Limits

The moisture content values of studied samples follow the pattern of the fines. The larger the fines content, the more cohesive the soil and the more water retention capacity it will have. If the moisture content of the soil is close to swelling moisture, then the structures are not subjected to appreciable deformation when foundations are wetted. The result of the natural moisture content indicates the high finer material content in the black cotton soils.

The maximum and minimum values of liquid limits for the pure soils samples are 51% and 67% respectively. A high plasticity index was obtained that ranges between 28% and 37% (Table 1). This shows that the degree of expansion is high and danger of severity is critical for all the soil samples from the study area. The high plasticity index may be due to the high amount of fine clay content in the soil. The high liquid limit may indicate relatively high organic matter content in the black cotton soils as well as the type and the amount of clay minerals present, which has been reported predominantly montmorrilonite.

Compaction Test

The maximum dry density (MDD) values which are obtained by the majority of the soil samples indicate closer particle spacing which means greater repulsive force between particles and high swelling index due to presence of substantial amount of clay minerals (Glendinning et al. 2014). The irregular shape of the compaction curve (Fig. 3) indicated by the clayey soil in low moisture content range may be explained by the interaction of aggregations during compaction and their ability to fit together through translation and rotation, a strong link between the dry density and moisture content is revealed.

Specific Gravity

The specific gravity of the grains of any soil is important in estimating its degree of weathering (Tuncer and Lohones 1977). In the present study specific gravity value for samples are within 2.68-2.76. Based on IS (1498-1970) recommended values of specific gravity is 2.72, therefore the values obtained from the soil samples in this research are within the permissible limit, and they lie in the range given for inorganic soils.

Uniaxial Compressive Strength (UCS)

The Uniaxial Compressive Strength (UCS) of 116.6KN/m2 and 92.6KN/m2 values were obtained as the maximum and minimum values respectively, this figures indicates that the black cotton soils of the studied area is very weak and unsuitable in their natural state. This result is in conformity with other parameters obtained for the black cotton soil of the area (Ibrahim, 2006).

California Bearing Ratio (CBR) and Linear Shrinkage

The black cotton soil samples show low CBR score for both soaked and unsoaked conditions. The CBR values range between 3.0% and 4.5% for soaked condition, as minimum and maximum respectively. For unsoaked condition the CBR values range between 8.5% and 9.1% respectively, similar results were reported in some literatures (Verma and Maru 2013). The remarkable differences between the soaked and unsoaked CBR values indicate that the engineering performance of the black cotton soil could be negatively affected by water, hence the CBR values indicates that the soil strength is drastically declined by presence of water. The linear shrinkage result obtained (Table 1) for the soil sample indicates that the soil is very expansive a low CBR. These values connote the inadequacy and the expansive nature of the black cotton soil of the study area. The

swell and shrinkage nature of the soil may cause some distress to structures on it due to the seasonal volume change of these soils and can easily turn into weak soils.

CONCLUSION

This research work was carried out to understand the engineering geological behaviors and some basic geotechnical characteristics of the black cotton soils around Deba area in Gombe state. Geotechnical analysis shows that the black cotton soils are weak materials for engineering constructions and have tendency for swelling, it expansive behavior should be taken into account in any engineering construction around the area. The soil strength characteristics obtained fall below the minimum requirement for sub-base and base requirement. This is in agreement with results of other researchers (Adesunloye 1987; Oyediran 2005). The black cotton soil of the area is classified as A-7-6 in accordance with AASHTO (1986) soil classification system and as CH (i.e. clay of high plasticity) in accordance with unified soil classification system, thus unsuitable for road construction without improvement. The linear shrinkage results obtained indicate high swelling and expansive nature of the soils, hence showing intensive wide and deep polygonal cracks on the surface. These suggest that, the frequent cracks on buildings and damages to road pavements in the study area can be attributed to expansive nature of the clays of the area. Thorough geotechnical investigations should be conducted prior to engineering constructions on the black cotton soils in the area, and the engineering properties of the black cotton soils of the area should be stabilized and upgraded since replacement of the black cotton soils with other materials of superior engineering qualities may not be economically feasible due to large area of land covered with this soil.

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