Research Paper on Geotechnical Investigation of Soil: Case Study And Report

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Abstract- *This work focuses mainly on the Geotechnical properties of mapped areas in Gombe town which forms part of the Upper Benue trough. Representative soil samples were collected from these areas and were investigated for their Geotechnical properties with a view to classifying for their suitability or otherwise for infrastructural development. Hitherto, this has not been done in the Gombe town area. The recent growth which is associated with urbanization in Gombe Township calls for appropriate geotechnical investigation of soils of the area. Twelve representative samples were collected from different locations of the mapped areas around Kanol, Hamatatu, Wurro Daji, Kalshing Forest, Titi Baba, Chongo, Danba, Wurro Ladde, Pantame, Tempure, Tonde, and Kulalum. Samples from each site were collected at 1m depth and analyzed using the following tests: Moisture content test, Particle size distribution test, Atterberg limit test, Specific gravity test, Compaction test. All these tests were carried out using the BS 1377, (1990) Parts 1 - 9 specification. Based on the test results obtained from the study areas, comparison were made with some standard specifications and it was revealed that samples from Pantame, Hamatatu, Tonde, Chongo and Kulalum areas are clayey soils which are unsuitable for most engineering construction because they have poor bearing capacities. While soils from Kalshingi forest, Titi baba, Wuro ladde, Danba, Tempure, Kanol and Wuro Daji are clayey sands. This group would make better sub-grade materials for civil engineering construction.*

I. INTRODUCTION

The mapped area lies within the Gongola arm of the Upper Benue trough of Northeastern Nigeria. It forms an integral part of Gombe (Sheet 152 NW) and lies within the 11˚06’ and 11˚15’E and latitude 10˚25’30’’ and 10’16’30’’ N. It encompasses Gombe Township and its surrounding villages (Fig.1) The Gombe region located in Northeastern Nigeria falls within one of the geographical domains of the Benue trough (Upper Benue Trough). The Nigerian Benue Trough is an approximately 1000km long and 50- 150km wide intercontinental basin, elongated in a direction and overlies the Precambrian shield of West African Mobile Belt (Benkhelil 1989; Guiraud 1990). It was described by Carter et al. (1963) and Wright (1976) as a fault bounded depression filled by 6000m thick marine coastal and fluvial sediments which were compressionally folded in a non-orogenic shield environment. The sedimentary sequence, which is underlained by Basement complex rocks, spans over a considerable area around, Bima Sandstone at the base, Yolde Formation, Pindiga Formation, and finally the Gombe Sandstones at the top. The Bima sandstone is Albian in age, while the overlying Cretaceous rock represents a marine sequence and represents a time range from Lower Turonian to Maastrichtian. The Bima sandstone is succeeded by transitional beds, which pass upwards into a marine sequence of Turonian to Senonian age. Continental conditions were re-established in the Maastichitan and resulted in the deposition of the Gombe Sandstone. The Pan-African orogeny (600 million years) which is the last known tectonic episode to have affected the Basement complex, have lead to deformation of the sandstone formations, forming faults and joints, and also the orogeny has cause an upliftment of the Basement complex there by forming Inliers (Gombe and Liji hills) of considerable height around the Gombe area. The Upper Benue Trough has generated as much controversy compared to other sedimentary rocks. This is because most of the sequences such as the Basement rocks and sedimentary rocks are well exposed and can be studied in details. The earliest detailed work on the geology of the Upper Benue Trough was carried out by Carter et al, (1963). Other works include; Allix (1983), Guiraud (1990).

II. METHODOLOGY

The methodology of research involved desktop survey followed by reconnaissance survey and collection of representative samples. Field equipment used for the study and sampling include a map of the study area, Sampling bags, Sampling tube for undisturbed samples, Global Position System (GPS), Ilwis software, Camera, Measuring tape, Twain Masking tape, Markers, Field note book, Pen, Pencil, Geological hammer, Shovels , Diggers and compass clinometers. A detailed geological field mapping which entailed ground traversing, description of the rock types, identification of sedimentary and tectonic deformation structures (such as joints and faults), delineation of formational boundaries and dip and strike measurements were recorded on a base map. Representative samples were taken from Kanol (Central part of the study area), Hamatatu (Northeastern part), Wuro Daji (Southeastern part), Kalshing Forest (South east), Titi Baba(North east) Chongo (North east), Danba (Southwest), Wurro Ladde (South east), Pantame

(Central), Tempure (South west), Tonde (North east) and Kulalum (North east), (Fig.2). The soil samples were subjected to laboratory testing for natural water content, grain size analysis, Atterberg's Limit Test (Liquid limit and Plastic limit test), Standard compaction Test and Specific Gravity test.

Geology The mapped area is characterized by two major rock types: The basement complex rocks represented by the rocks of the Migmatite Gneiss Complex of Nigeria and the Cretaceous sedimentary sequence which encompasses; The Bima Sandstone Formation; The Yolde Formation; The Pindiga Formationand the Gombe Sandstone The crystalline basement rocks in the mapped area are represented by the rock types of the migmatite Gneiss Complex of Nigeria. They outcrop in the North-eastern part of the study area forming the Gombe inlier. Exposures of these rocks were also encountered along stream channels in the Northeastern part of the area. The basement rocks constitute about 2% of the mapped area. The rock type is predominantly gneisses of medium to coarse grained texture and mesocratic in color. The alternations of light and dark colored band of minerals are very obvious. The Bima sandstone formation represents the basal formation of the Cretaceous rocks of the Upper Benue trough in the study area. The rocks of the formation are better exposed along stream channels and gullies, though hilly outcrops of highly cemented Bima sandstone were encountered close to the Gombe hill in the northeastern part of the study area. The Bima sandstone Formation consists about 20% of the mapped area. They consist predominantly of medium to coarse grained sandstones interbedded with thin layer of grey to purple clays. The sandstones are generally friable and range in color from cream white to brown. Bima sandstones were observed in Pantame, Kanol, and Danba areas. The Yolde Formation occupies about 15% of the mapped area. The formation was encountered The Yolde Formation occupies about 15% of the mapped area. The formation was encountered in the southwestern and northeastern parts of the study area and is mainly exposed along river channels. The lithological units of this formation include finecoarse-grained sandstones with very thick units of grey shale. The sandstones vary in color from light grey to reddish. Sections of the Yolde Formation are well exposed in the Pantame, Titi Baba. This formation constitutes 25% of the mapped area. It consists of dark grey shales which become silty towards the top and occasionally contain horizons of milky-grey impure Marls coated with fibrous limestone that show syntaxial calcite minerals growth pattern. Exposures of the Pindiga Formation were encountered in Kulalum area. They are best exposed in river valleys and gullies. The Gombe Sandstone Formation is the most widespread sedimentary rock in the study area as it constitutes about 35% of the area. It is found exposed as hills and along river channels and valleys. The Gombe Sandstone Formation consists of fine-grained buff to red coloured sandstones which are often parallel laminated, cross-laminated or crossbedded. Clay interbeds are present at some horizons. Outcrops of the Gombe Sandstone dominate the southeastern parts of the mapped area and some part of Northeast and tend to show high degree of weathering. The sandstones are also characterized by ferrugenized capping. The Keri-Keri formation was identified at Chongo and Tempure having fine to medium grained sandstone, Trough cross bedding and amalgamated bedding. Traces, Erosional surfaces (Fig.3), oolithic and pacilithic materials that are highly ferrugenized, Clay clasts and paraconglomerate were all identified.

III. MATERIALS AND METHODS

Testing refers to the determination of the soil characteristics or properties using laboratory experiment. Representative samples were taken for laboratory analysis under strict adherence to the rules and procedures for soil tests as prescribed in the BS 1377 manual. Preparation of samples for each test depends on the procedure required for such test to be carried out. Some samples were first sun dried before making use of them in the laboratory while some were used in their natural state. Laboratory equipment such as electric oven, sieve shaker, casagrande liquid limit apparatus, density bottle with distilled and gassing machine where deployed for the analysis. The results of experiments.

IV. DISCUSSION GRAIN SIZE DISTRIBUTION

A soil consists of an assemblage of discrete particles of different of various shapes and sizes. For the other entire engineering test to be effective, determination of the particle sizes is important due to its strong relationship with the engineering behavior. Some relevant and useful information can be obtained from a grain size distribution curve. Such information includes the percentage larger or finer than a given size and their uniformity or the range in grain size distribution.

The American Association of State Highway and Transportation Officials (AASHTO) classification is a widely used method for classifying soils for earth work structures, particularly sub-grades, bases, sub-bases, embankments. The system separates soils into granular and silt clays groups. It classifies soils into seven (7) groups based on particles size distribution, liquid limit and plasticity. Furthermore, the unified soil classification system divide soil into two main groups: coarse –grained and finegrained defined by a set of two letters, a prefix and a suffix. The coarse grained designation is assigned to soils for which over 50%, by weight of the material is retained by the no. 200 sieve (0.75mm). Within the coarse grained, the prefix G is assigned to the soils if more than 50%, pass through the no. 4 sieve (4.7mm); G and S is follow by suffix that describes the gradation; W- well graded; P- poorly graded; M- containing silt; C- containing clay. According to AASHTO classification, soil samples from Pantame (P), Hamatutu (Z4), Chongo(C5), Kulalum(H) and Tonde(Z2) contain more than 35% of the soil passing through sieve No. 200 hence the soils are in the Silty Clay Group and all the aforementioned samples fall under group A-6 with the exception of kulalum which falls under A-7.On this basis they can therefore be classified as poor materials. Samples from Kanol (K),Kalshingi forest (L2),Titi baba(G3),Wuro ladde (G1),Danba(M),Wuro Daji(B) and Tempure(C4) have less than 35% passing through No 200 sieve and thus falls under A-2 group of the granular materials which are regarded as the silt or clayey gravel and sand group of soils. They are excellent to good subgrade materials. From the classification, soil sample whose Liquid limit values do not exceed 40 (which is the maximum value for A – 2 soils) and Plasticity Index not more than 11 (which is the maximum value for A- 2 soil are said to be high in quality. Samples from Kashing Forest (L2), Titi Baba (G3), Wuro Ladde (G1),Wuro Daji (B), and Tempure (C4) falls within the range of liquid limit for A – 2 materials, hence these soils can be regarded as good materials. However, plastic index for Danba(M) and Kanol(K) are greater than 11(below the maximum value of A-2 soils) and samples from Kulalum have higher liquid limit values of 64.2, which exceeds 41 been the minimum liquid limit and having . The non-satisfaction of the liquid limit and plastic index requirement indicates that the soil is actually poor in quality when compared to A – 2 soils. The high liquid limit values could be due to increasing porosity leading to increased moisture content as in the case with gravel and sand group of soils. The soil will would require improvement before it can be used as an A- 2 materials. Based on the Unified Soils Classification System (USCS), Kanol, Pantame, Kalshingi forest, Hamatatu, Titi Baba, Wurro Ladde, Chongo, Danba, Wurro Daji and Tempure belong to coarse grained group, while Tonde and Kulalum are under the fine grained group. Atterberg limit: The atterberg limits are an emperically developed but widely used procedure for establishing and describing the consistency of cohesive soil thereby providing useful information regarding soil strength, behaviour, stability and type and state of consolidation besides its use to identify the soil classification. Consistency is frequently used to describe the degree of firmness (e.g soft, medium, firm, or hard) and the consistency of cohesive soil is strongly affected by the water content of the soil. A gradual increase of the water content, for example, may transform dry clay from perhaps a solid state to a semi-solid state, to a plastic state and after further moisture increase, increase into a liquid state. The water content at the corresponding junction points on these states are known as the shrinkage limit, plastic limit and the liquid limit respectively. The result of the liquid limit(LL) and plastic limit (PL) and plasticity index (PI) for the soil investigated shows that the liquid limit ranges between 20.9 and 64.2, while the plasticity index ranges between 5.3 and 30.9. According to the guideline of Federal Ministry of Works (1997), the liquid limit should not exceed 35% to be suitable for use as sub-grade and sub-base or base course materials, hence Kalshing Forest, Pantame, Kanol, Hamatatu, Wurro Ladde, Titi Baba, Chongo, Danba, Tonde, Wurro Daji and Tempure can be regarded as fairly good for sub-base or base course materials except for soil sample from Kulalum whose liquid limit is higher (64.2%). Based on the British Soil Classification Systems, samples from Kalshing Forest, Pantame, Kanol, Hamatatu, Wurro Ladde, Titi Baba, Chongo, Danba, Tonde, Wurro Daji and Tempure have low plasticity and low liquid limit while sample from Kulalum have high plasticity and low liquid limit. Generally, soils with high liquid limit (LL) are clays with poor engineering properties too weak in strength. Soils with intermediate plasticity index and liquid limit would make better engineering properties while those with low plasticity and liquid limit as displayed by most of the samples in the study area would have fair to good engineering properties, According to the specification for Roads and Bridges, Ministry of Works, Bauchi (1990), Samples from Kashing Forest, Pantame, Kanol,Hamatatu, Titi Baba, Wuro Ladde, Chongo, Danba, Tonde, Wuro Daji and Tempure have fulfilled the requirement to be used as fill materials with liquid limit(LL) ranging from 0 – 45% and plasticity index of 0 – 20%.Samples from Kulalum showed high liquid limit and high plastic limit and hence would not make good fill materials. All the samples collected were plotted on a Casagrande Unified Soil Classification Plasticity Chart (Fig.4) and from the plots samples from Pantame, Hamatatu, and Tonde are classified as Clay soils with low plasticity index. Sample 4 appears outside the U – line which could be attributed to laboratory error.

(Table 2) provides the classification of soils using the Attenburg limits. From the results, indicates samples from Danba, Wurro, Ladde, Titi Baba, Tempure, and Kalshing are Clayey sands having low plasticity index. However, those samples from Kanol, Chongo and Wurro Daji contain silty clays of low plasticity index, while Kulalum sample is Clay soil with high plasticity. The Plasticity index of soils is a function of their swelling potentials.

Shrinkage limit: Soil samples from Kanol, Pantame, Klashing Forest, Hamatatu, Titi Baba, Wurro Ladde, Chongo, Danba, Tonde, Wurro Daji, and Tempure have low degree of expansion and shrinkage limit <15(Table 6) and this implies that they are likely to develop cracks when used as fills or embankments. It is important to note that among the above samples some showed plasticity values higher than 12 which is the highest limit for class 1and can thus be classified as low-medium degree of expansion and shrinkage limit. The sample from Hamatatu falls under class 4 with shrinkage limits >60 and a very high degree of expansion. Such soils are unsuitable for most engineering purposes. Compaction: When soils are used as construction materials in any type of field or embankment, they nearly always require compaction to prevent settlement and to reduce permeability. With all soils, an increase in the compactive effort, results in an increase in the maximum density and a decrease in optimum water content, (Smith, 1975). When the values of dry densities and moisture content are plotted, the resulting curve has a peak value of dry density and corresponding moisture content (OMC). The reason for this is that at low moisture values, the soil is stiff and difficult to compact resulting in a low density with a high void ratio. As the moisture is increased the water lubricates the soil, increasing the workability and producing high dry density and low void ratios. The specification for road and bridges, (1975) states the significance of the moisture – density test as an aid in the field compaction of soils so as to develop the best engineering properties of the material, since it is assumed that the strength or shearing resistance of the soil increases with higher densities. The moisture density relationship, i.e. the compactive curves (not shown in this paper) showed a maximum dry density ranging from 1945g/m³ for the lowest curve at and 2831kg/m³ for the highest curve at an optimum content of 5.9 and 15.0% respectively. Since the curve indicates the maximum bulk density to which the soil may be compacted by a given force and the water content of the soil that is optimum for maximum compaction, when the soil is either drier or wetter than these values, the compaction will be more difficult, Brady and Well (1999). Based on the range of values anticipated for the standard moisture density test stated above, the soils in the study area falls in the clays and silt clay range which also agree with the results indicated by the Atterberg limit classification and grain size distribution.

The results show that, to compact a soil in the field, the sample with the least optimum moisture content will require small amount of water to bring each to its highest density. It could also mean that the samples with high range of moisture absorption capacity may have an advantage in an exceptionally moist area and may easily become saturated and so lose its strength relatively fast, (Alabo, et al., 1984). According to the criterion by the researchers for determining the suitability of soil for construction of embankment, samples from Kanol, Kalshing forest, and Tempure are proven to be excellent while samples from Chongo and Wurro Daji are good to excellent materials that are suitable for construction. Some of the soils in the study areas exhibit fair to good engineering properties. The areas include; Pantame, Hamatatu, Titi Baba, Wurro Ladde, Danba, Tonde while sample taken from Kulalum have poor engineering properties and therefore will have poor bearing qualities. Specific gravity: This is the ratio of weight in air of a given volume of soil solids to the weight of an equal volume of distilled water, at a given temperature. The specific gravity of engineering soils usually varies between 2.6 to 2.8. If it is less than 2.6, it may indicate possible presence of organic matter (IS). It can be deduced from that samples from Pantame, Tempure, Chongo, and Tonde have their specifiv gravity values to be between 2.60 to 2.63, which makes them good materials for engineering construction. The least value is from Wurro Ladde whose value is 2.51. Based on the above it can be deduced that most of the samples are fair for use as sub-grade materials. Natural Moisture Content: From (Table 3), it is observed that the average moisture content are low for samples gotten from Titi Baba, Hamatatu, Kanol, Wurro Daji, Chongo, Tempure, Pantame, Kulshing Forest, Tonde, Danba, Wuroo Ladde ranging from 2.03 to 10.95%, hence they may constitute good construction materials, such as subgrades for roads and foundations. Wikipedia, (2009) suggests that soils with low percentage (%) moisture content, (less than 16%), have a good property for construction. The Kulalum reading on the other hand, is very high, the moisture content value is 33.66% . According to Wikipedia (2009), soils that have more than 16% natural moisture content is assumed to be a saturated soil and will not be good as a construction material.

V. CONCLUSION

The geotechnical properties obtained shows that soil samples from Pantame, Hamatatu, Tonde, Chongo and Kulalum areas are clayey soils which are unsuitable for most engineering construction because they have poor bearing capacities. They would make fair to poor sub grades because of their grain sizes and relatively high plasticity index but can be useful as dam embankment materials. Samples collected from Kalshingi forest, Titi baba, Wuro ladde, Danba, Tempure,Kanol and Wuro Daji are clayey sands. This group has better engineering properties as they would make good subgrade materials for road construction and they are also good as fill materials. Generally all the soils in the study area are clayey in nature and hence great care must be taken when they are put to use in engineering construction. This is because clays can be expansive in nature especially when they come in contact with water.

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