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Geotechnical Investigation of Soil around Arawa-Kundulum Area of Gombe Town, North-Eastern Nigeria, Nigeria

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Abstract: *This Project work involves the investigation of soil at Arawa- Kundulum area in Gombe town of North Eastern Nigeria. The study area is a newly developing part of Gombe town but has been defaced by cracks on buildings, and this calls for appropriate geotechnical investigation of soils of the area. Soil samples were collected from eight (8) different locations within the study area. At each trial pit, four (4) samples were collected at intervals of 0.5m, 1.0m, 1.5m and 2.0m depths below ground level and were investigated for their Geotechnical properties with a view to classifying for their suitability or otherwise for infrastructural development. The geotechnical tests carried out on these samples include: Natural moisture content, Specific gravity, Physico-chemical tests, Particle size distribution (Sieve analysis), Atterberg limits and Compaction tests. All these tests were carried out using the BS 1377, (1990) Parts 1 - 9 specification. Based on the test results obtained from the study area, comparison were made with some standard specifications and it was revealed that the soil samples are clayey soils which are unsuitable for most engineering construction because they have poor bearing capacities. However from the investigation above, the main geotechnical problems that affect design and engineering structures are found to be presence of expansive soil composed of silt and clay with high plasticity index. This soil is therefore not recommended for Engineering purposes. In the event of siting a building project, the soil should be stabilized before embarking on the project.*
Keywords: *Bearing Capacity, Geotechnical investigation, Gombe Sandstone, Soil samples, Upper Benue Trough*

I. Introduction

The mapped area lies within Gombe town, the capital city of Gombe state, North-eastern Nigeria. It forms an integral part of Gombe (Sheet 152NW) and it is located between latitudes $10^{\circ}\,18'\,30''$ to $10^{\circ}\,19'\,30''$ N and longitudes $11^{\circ}\,09'\,45''$ to $11^{\circ}\,10'\,45''$ E. It is called Arawa-Kundulum area situated at few meters away from Gombe State University.

The Gombe region located in North-eastern 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[1]; Guiraud 1990[2]). It was described by Carter et al. (1963)[3] and Wright (1976)[4] 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 Maastrichtian 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)[3]. Other works include; Allix (1983)[5], Guiraud (1990)[2].

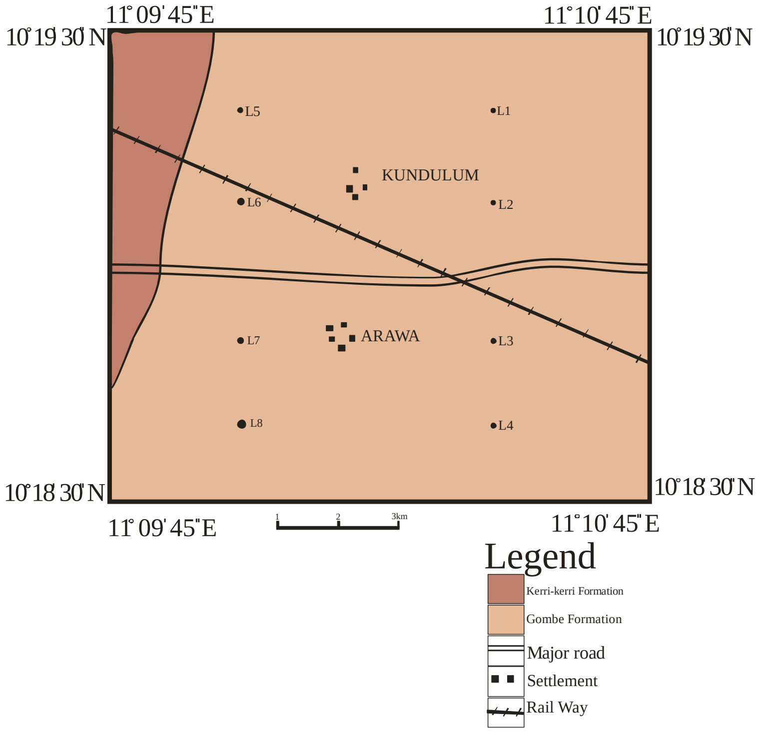


Fig.2.2: Geological map of the study area

II. Methodology

The methodology of research involved reconnaissance survey and collection of representative samples. A wide area of several metres-square was covered in the study area (Fig 3.1) located at Arawa-Kundulum area few metres away from Gombe State University within Gombe town. Soil samples were obtained for analyses. The project was designed in such a way that soil samples were collected at eight (8) locations. Two sampling spots (trial pits) separated by 50m interval in each quadrant (NE,SE,SW and SE) as depicted in the plan view (Fig 3.1). Field equipment used for the study and sampling include a map of the study area, Sampling bags, Global Position System (GPS), , Camera, Measuring tape, Masking tape, Markers, Field note book, Pen, Pencil, Shovels , Diggers and compass clinometers. The soil samples were subjected for laboratory testing of Natural water content, Specific gravity, Physico-chemical tesst, grain size analysis, Atterberg Limits Test (Liquid limit and Plastic limit test), Compaction Test. The geographical coordinates of the various sampling spots are as shown (Table 3.1).

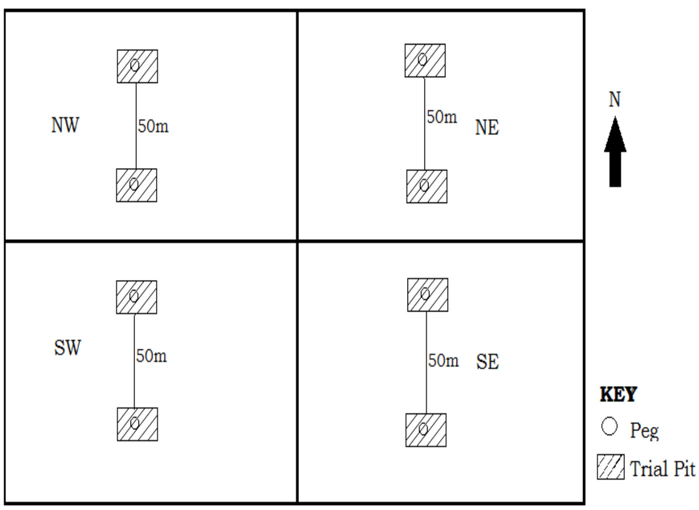


Fig.3.1: Plan view of the study area showing sampling spots

II.I 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; Bima Sandstone Formation; Yolde Formation; Pindiga Formation; Gombe Sandstone and the Kerri-Kerri formation. The continental Bima Sandstone is the base of the sedimentary succession in the Upper Benue Trough, which unconformably overlies the Basement Complex. It ranges in age from upper Aptian to lower Albian.

The Bima Sandstone was named by Falconer (1911)[6] after its type locality at Bima Hill. Early work by Zaborski et al.,(1997)[7] considered the Bima Sandstone as a group rather than a Formation. Carter et al.,(1963)[3] gave descriptions of the sequence exposed in the Lamurde anticline and recognized a threefold subdivision which is the lower Bima (B1), the middle Bima (B2) and the upper Bima (B3). The total thickness is about 3300m.

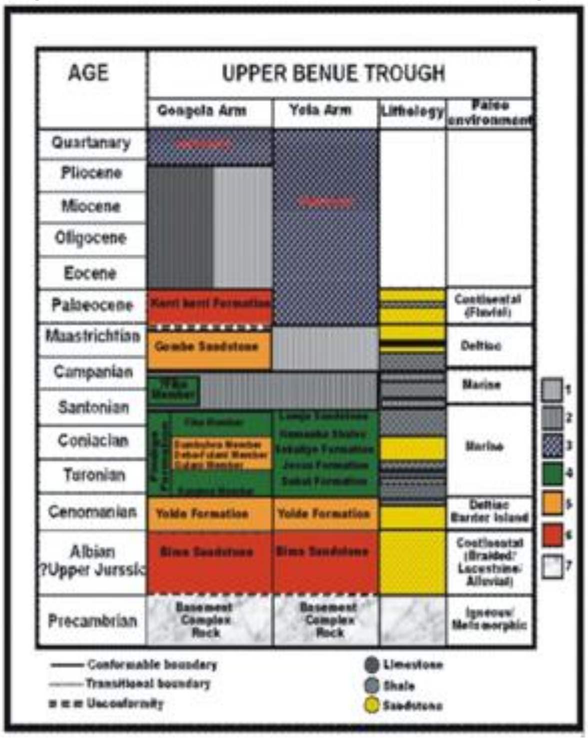
The Yolde Formation is a transitional bed between the continental Bima Sandstone and the succeeding marine Formation. The Formation is composed of transition beds which was first recognized by Falconer (1911)[6] and the name Yolde Formation was proposed by Carter et al.,(1963)[3]. The type locality was designated in the Yolde stream on the western part of Yola arm. The Yolde Formation has been described in Yola arm by Carter et al.,(1963)[3]. It consist of alteration of coarse to fine grained, cross bedded or ripple bedded sandstones and grey to greenish shales. Thin limestones or calcareous sandstones especially in its upper part where oyster beds are common (Zaborski et al.,1997)[7].

The Pindiga Formation developed in the Gongola Basin is equivalent to Dukul Formation, Jessu Formation, Sekkuliye Formation, Numanha Shale and Lamja Sandstone of the Yola Basin. In the Gongola-Gombe sub basin, the Gongila Formation and Fika Shale are the lateral equivalents of the Pindiga Formation. Lithologically, the Pindiga Formation is made up of dark/black carbonaceous shales and limestones intercalated with pale coloured limestone, shale and minor sandstone. Earlier, Zaborski et al,(1997)[7] regarded the Pindiga Formation as consisting of five members, from bottom to top, the members are the Kanawa member, Dunbulwa member, Deba-Fulani member, Gulani member and lastly the Fika member.

The Gombe Sandstone overlies the Pindiga Formation and represents the youngest Cretaceous sediments in the Gongola arm of the Upper Benue Trough, The Gombe Sandstone is a sequence of estuarine and deltaic sandstones, shales, siltstones and ironstones which overlie the Pindiga, Gongila and Fika shale Formations in the Gongola arm of the Upper Benue Trough. Falconer (1911)[6] named Gombe Sandstone near Gombe town as Gombe grits and clays and assigned an Eocene age to it. Raeburn and Jones (1963)[8] described the Gombe Sandstone at Kware stream as consisting of well bedded fine to medium grained sandstone, sandy and silty micaceous shale and occasional mudstones. Matheis (1989)[9] described the Gombe as consisting of three(3) major lithofacies; lower bed characterised by mudstones and ironstones, middle bed composed of well bedded sandstones and siltstones, while the upper bed is composed of cross-bedded sandstones and siltstones. The Maastrichtian Gombe Sandstone is lithologically similar to the Bima sandstone, attesting to the reestablishment of the Albian palaeoenvironmental conditions (Obaje,2009)[10].

The Kerri-Kerri Formation represents the record of Early Tertiary sedimentation in North-eastern Nigeria, and overlies the Cretaceous Gombe Sandstone unconformably in the Gongola Basin of the Upper Benue Trough. The Formation is essentially flat-laying to gentle dipping of about 5^0 (Carter et al.,1963)[3]. The Kerri-Kerri Formation consist predominantly of grits and ferruginous sandstones, siltstones and claystones often kaolinite with well developed cross-bedding. The maximum thickness of the Kerri-Kerri Formation is about 300m, Although it varies from 300m to over 320m. (Dessauvagie,1975[11]; Dike,1993[12]). This sequence is deposited in a wide range of environments inducing fluviatile, deltaic and marginal lacustrine (Dike,1993)[12]. The type section of this Formation is exposed at Kadi about 100km north of Kaforati. The Formation is considered to be Palaeocene in age.

Table 1: Stratigraphic Sequences of the Upper Benue Trough (Obaje, 1999)



- 1-Hiatus, 2-Santonian- Cenomanian tectonism, 3-Basalt, 4- Marine sediments, 5-Transitional-marine sediments, 6- Continental sediments and 7- Basement complex

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 are shown in Table 2.

Plate 1: Excavated Pit

Table 2: Geotechnical Laboratory test results

S/NO	Sample Location	Sample Letter	Natural Moisture Content(%)	Specific Gravity (g/cm^3)	LL (%)	PL (%)	PI (%)	LS (%)	FS (%)	Field description	Percentage passing sieve no. 200
1.	L1 (NE)	A	3.31	3.50	39	20.1	18.9	5.7	5	Dark brown silty sand	0.2
2.	L1 (NE)	B	4.54	3.19	38	19	19	7.9	7.5	Brownish silty sand	0.5
3.	L1 (NE)	C	4.94	2.74	27	16.4	10.6	3.9	10	Brownish silty sand	0.5
4.	L1 (NE)	D	15.03	3.09	32	19.1	12.9	8.2	15	Light brown	0.3

										silty sand	
5.	L2 (NE)	A	8.64	2.41	36	18.7	17.3	9.3	5	Dark brown silty sand	0.4
6.	L2 (NE)	B	10.80	2.46	32	21.2	10.8	8.2	5	Brownish silty sand	0.2
7.	L2 (NE)	C	28.90	2.47	28.5	16.5	12	6.4	15	Light brown silty sand	0.5
8.	L2 (NE)	D	31.00	2.55	30	17.5	12.5	7.5	22.5	Light brown silty sand	0.3
9.	L3 (SE)	A	11.30	2.56	37	19.5	17.5	10.4	5	Light brown sandy soil	0.5
10.	L3 (SE)	B	14.00	2.56	34	18.9	15.1	7.1	7.5	Brownish silty sand	0.2
11.	L3(SE)	C	7.70	2.43	28.5	17.3	11.2	8.9	15	Brownish silty sand	0.0
12.	L3 (SE)	D	12.30	2.48	30	19.6	10.4	8.9	7.5	Light brown sandy soil	0.4
13.	L4 (SE)	A	13.80	2.57	35	21.9	13.1	9	0	Light Brown sandy soil	0.2
14.	L4 (SE)	B	16.50	2.50	29.6	19.1	10.5	6.8	5	Brownish silty sand	0.5
15.	L4 (SE)	C	18.90	2.42	25	14.5	10.5	3.9	10	Brownish sandy soil	0.4
16.	L4 (SE)	D	21.50	2.44	27	18.5	8.5	8.6	20	Brownish silty soil	0.5
17.	L5 (NW)	A	3.32	2.54	36	21.6	14.4	7.5	0	Light brown sandy soil	0.3
18.	L5 (NW)	B	4.94	2.58	35	20.6	15.6	9.3	2.5	Light brown sandy soil	0.3
19.	L5 (NW)	C	6.36	2.62	27	19	8	10	0	Light brown sandy soil	0.0
20.	L5 (NW)	D	5.74	3.55	42	22.9	19.1	11.1	0	Light brown sandy soil	0.4
21.	L6 (NW)	A	7.70	2.68	40	16.5	23.5	9.6	0	Reddish sandy soil	0.3
22.	L6 (NW)	B	8.20	2.46	42	24.2	17.8	11.1	0	Reddish silty sand	0.4
23.	L6 (NW)	C	6.90	2.31	39	19.2	19.8	9.3	5	Reddish silty sand	0.8
24.	L6 (NW)	D	5.32	2.46	39.5	18.1	21.4	8.9	7.5	Reddish silty sand	0.4
25.	L7 (SW)	A	4.54	2.49	35	19	16.	8.2	2.5	Reddish brown silty sand	0.2
26.	L7 (SW)	B	11.30	2.53	32	22.4	9.6	8.2	5	Reddish brown silty sand	0.2
27.	L7 (SW)	C	11.40	2.53	37	19.2	17.8	9.3	5	Reddish brown silty sand	0.2
28.	L7 (SW)	D	10.50	2.36	38	22.9	15.1	9.3	7.5	Reddish brown sandy soil	0.2
29.	L8 (SW)	A	6.10	2.62	35	24.3	10.7	7.1	5	Light brown silty sand	0.3
30.	L8 (SW)	B	16.9	2.55	32	20.5	11.5	6.4	7.5	Light brown silty sand	0.8
31.	L8 (SW)	C	13.80	2.50	27	18.5	8.5	8.6	5	Light brown silty sand	0.5
32.	L8 (SW)	D	14.50	2.61	29.5	19.3	10.2	8.2	7.5	Light brown silty sand	0.5

IV. Discussion

Natural Moisture Content: - The moisture content of a soil is a percentage, comparing the weight of water to the weight of dry soil. The moisture content of various soils varies generally ranging from about 10 to15% for sand, 15 to 30% for silt and 30 to 50% for clay. Some soil such as bay mud have moisture contents of 100 to 200%. The result of the analysis in L1-L8 shows that, the moisture contents of the samples ranges from 3.31 to 31% with an average value of 17% as shown in (table 2). The sample with the lowest moisture content is L1A and the highest moisture content is L2D shown in table 2. The reason for high moisture content of the sample could be attributed to fact of high rainfall which could increase the water table. The low value of natural moisture content indicates that the water table fluctuates during the dry season.

From the results, the average moisture content which is 17% shows that the soil is not good for engineering purpose. High moisture content can have a significant effect on the soils behavioural properties when used for construction purposes and foundations (Gebremedhin,2002[13]).

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. This affects structures when it comes in contact with, thereby weakening the foundations of buildings. The moisture content within the soil makes the material to expand and the net attractive force between the particles becomes weak. Natural moisture content of soil below 16% is suitable Engineering purpose and those above 16% contributes to weakening of foundation structures. During raining season there is a rise in the water table which increase moisture of soil and during dry season there is fall in the water table which reduces the moisture content of soil. From the result, the moisture content is high which is not suitable for Engineering purpose.

Specific Gravity: Specific gravity of a soil particle depends on the gravity of the parent rock. Specific gravity is defined as the ratio of the weight of a given volume of soil solids at a given temperature to the weight of an equal volume of distilled water at that temperature both weight being taken in air. Its significance is to determine the density, bearing capacity of the materials although strictly it vary among the mineral constituents of the soil from size fraction. The normal range is 2.65 to 2.67 for sand, 2.67 to 2.70 for silty sand, 2.70 to 2.80 for organic clay, 2.75 to 3.00 for soils with micas or iron and for organic soil it varies but it may be <2.00 (Lambe,1951)[14]. From the result, the Specific gravity value ranges from 2.31 to 3.5 g/cm^3, as shown in (table 2). The lowest is from L6C and the highest from L5D. This slight variation may be due to different soil properties (Physical and Chemical) that differ from one to another. The result have shown that the average is 2.61g/cm^3, This shows that the soil is suitable for Engineering purpose because the average standard for Engineering construction is 2.5g/cm^3.

Physico-Chemical test: PH is the negative logarithm of the H^+ ion concentration. The hydrogen ion concentration with the value of the PH for soil samples obtained at 1m depths only in each of the eight sample locations ranges from 5.36 to 6.97 as shown in (table 3). These values indicate that the soil is acidic in nature. Under the condition in which rainfall exceeds evapotranspiration (leaching) during most of the year, the basic soil cations (Ca^{2+},Mg^{2+},K^+,Na^+,Al^{3+}) are gradually depleted and replaced with cations held in colloidal soil reserves, leading to soil acidity. PH is influenced by the nature of the parent material. This lead to corrosion of materials used for construction and thus deteriorating structures placed on such materials.

Table 3: PH

Location	L1 (NE)	L2 (NE)	L3 (SE)	L4 (SE)	L5 (NW)	L6 (NW)	L7 (SW)	L8 (SW)
Sample	B	B	B	B	B	B	B	B
PH (33^0C)	6.22	5.36	6.95	6.85	6.64	6.97	6.88	5.45

The measure of electrical conductivity (EC) is related to the salinity of the soil. The values obtained range from 677µS/cm to 1276µS/cm with an average value of 976.5µS/cm as shown in (table 4) which indicates that the soil has high salinity, and signifies that it is corrosive in nature (Abramson,1996)[15]. This is done to know the amount of salt present in the soil since soil conduct current due to its salinity content and thus helps in knowing the kind of stabilization to tackle or can suite in solving the problem of building or construction failure.

Table 4: Electrical Conductivity

Location	L1 (NE)	L2 (NE)	L3 (SE)	L4 (SE)	L5 (NW)	L6 (NW)	L7 (SW)	L8 (SW)
Sample	B	B	B	B	B	B	B	B
E.C (32^0C)	736	782	963	1276	677	1162	722	747

The chemical constituents of the soil were measured using XRF in percentage oxides. SiO_2 has the highest value in all locations and followed by Na_2O and Al_2O_3 (Table 5). This is an indicative that the soil is acidic and is as a result of rainfall and leaching, acidic parent material, organic matter decay, and harvest of high-yielding crops(Jeff,1999)[16]. Perhaps rainfall, leaching and acidic parent material are the likely causes. But Organic matter decay is unlikely as a result of the low Specific gravity values of above 2.0g/cm^3 obtained in this study. So this may lead to corrosion of materials used for construction and thus deteriorating structures placed on such materials.

Table 5: X-RF Chemical Constituents Test

Parameter	L1 (NE)	L2 (NE)	L3 (SE)	L4 (SE)	L5 (NW)	L6 (NW)	L7 (SW)	L8 (SW)
Sample	B	B	B	B	B	B	B	B

SiO_2	36.4	33.2	29.0	24.7	30.2	36.2	37.8	35.5
Al_2O_3	29.5	28.2	28.1	19.7	29.0	26.8	21.7	22.5
Na_2O	28.6	31.4	33.6	37.2	26.6	30.5	37.8	31.0
CaO	3.22	4.24	3.26	2.96	5.36	4.22	3.08	3.97
K_2O	9.43	7.32	12.55	14.00	11.80	16.10	14.24	15.66
MgO	11.8	12.2	17.5	16.3	18.4	13.5	11.6	13.00
Fe_2O_3	5.72	5.58	2.66	4.23	3.56	4.212	3.90	3.66

Result in wt. % oxide.

Particle Size Distribution: This analysis is carried out to determine the soil group by classifying them according to their grain size and shapes. The objectives of sieving procedures are; to break up fibrous and frictionally bound aggregates, to destroy particle size only for microcrystalline material strongly bonded by covalent, ionic and hydrogen bonds. Several soils have several engineering usage and so they are classified to determine their suitability for a particular purpose.

Within the limit of experimental error, the plots Particle Size Distribution (particle size distribution curve) indicated that the soil is sandy with silt and clay materials present. Although the clay materials have undergone washing and drying (See table 1). The diameter or size range is adopted from American Society for Testing and Materials (ASTM) as follows: 4.75 mm (No.4) gravel; 4.75 – 0.075 mm (No.200) sand; 0.075 – 0.002 mm silt and < 0.002 mm clay.

Atterberg's limits: The atterberg limits test is 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.

To serve as a guide, Table can be used in evaluating the index properties of the soils and ascertaining their suitability, Handa (2002)[17].

Table 6: IS Classification System(IS: 1498)

Liquid limit (LL)%	Plasticity Index (PI)%	Linear Shrinkage (LS)%	Free Swell (FS) %	Degree of Expansion	Danger of Severity
12-35	<12	< 15	< 52	Low	Non-Critical
35-50	12-23	15-30	50-100	Medium	Marginal
50-70	23-32	30-60	100-200	High	Critical
70-90	>32	>60	>200	Very high	Severe

Liquid limit**:**

The moisture content at which a soil passes from plastic to the liquid state, is determined by the liquid limit test. The soil is at verge of bearing viscous fluid. From the result obtained, the liquid limit ranges from 25% to 42% with an average value of 34% as shown in (table 2). When the soil absorbed so much water above the liquid limit, the soil will flow like water and this also cause structures such as undulation and crack to the structure placed on such area. The degree of expansion and danger of severity are low and non-critical respectively (Table 6). Casangrande plasticity chart depicts that all soils liquid limit (LL) less than 30% are of low plasticity, LL less than 10% are cohensionless soils, LL ranging between 35-50% are of intermediate plasticity and LL above 50% are not plastic. Federal Ministry of Works and Housing, (1997)[18] states that material to be used as sub-base and base course, for building and road construction should have liquid limit less than 30. From the result given above, the soil is therefore not suitable for engineering purpose unless been stabilized using lime.

Plastic limit: The Plastic limit is the water content below which the remoulded sample ceases to behave as a plastic material and become friable and crumbly. From the results obtained the plastic limit ranges from 14.5% to 24.3% with an average value of 19.5% as shown in the (table 2). This shows that the soil is plastic in nature because it is made up of silt and clay material, thus not suitable as a construction material (Federal Ministry of Works and Housing Nigerian Standard, 1997)[18].

Plasticity Index: This is the numerical difference between the liquid and plastic limit of a soil. The plasticity index is a measure of plasticity of a soil. From the results obtained, it shows that the plasticity index ranges from 8% to 23.5% with an average value of 14% as shown in the (table 2). Higher plasticity index in most location is as a result of increase in depth. This causes cracks on structures as a result of expansion and contraction. The degree of expansion and danger of severity are medium to marginal respectively (Table 6). Federal Ministry of Works and Housing , Nigerian Standard,(1997)[18] states that material to be used for sub-base and base course should have plasticity index less than 12%, which is good in construction. Therefore the soil is not suitable for Engineering purposes unless been stabilized.

Linear Shrinkage limit: Linear shrinkage is the moisture content below which no further soil volume reduction occurs. This can also lead to or affect structures during contraction on drying and expansion on wetting which cause cracks on structures or buildings. The linear shrinkage result ranges from 3.9 to 11.1% with an average value of 7.5% as shown in (table 2). Therefore, with linear shrinkage less than 15% means that the degree of expansion and danger of severity are low and non-critical to marginal respectively (Table 6).

Free Swelling test: Free swelling of soil is the increase in volume of soil. From the result of the experimental analysis, it has shown that it ranges from 2.5% to 22.5% as shown in (table 2). It is evident within the limits of experimental error that the soil has high swelling property value. The high amount of montmorillonite in the soil is the likely cause of excessive swelling of the soil. According to Holtz(1956)[19] cited in Bell(1983)[20], soils having free swell as high as 100% can cause considerable damage to lightly loaded structures and soils having value below 50% seldom exhibit appreciable volume change under very light loadings, therefore this have less effect on the study area. From Handa,(2002)[17] the soil is non-critical (Table 6).

Compaction test: 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)[21]. 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) tested at 1m depth of each of the eight (8) sample locations showed a maximum dry density ranging from 1.97g/cm^3 to 2.20 g/cm^{3}and an optimum moisture content from 6% to 11.3%. 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)[22]. Based on the range of values obtained 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)[23].

According to the criterion by the researchers for determining the suitability of soil for engineering construction, the soil samples have poor engineering properties and therefore will have poor bearing qualities.

Table 6: Compaction Test

Location	Sample	Mould	Rammer (kg)	Blows	Layer	MDD (g/cm$^{3)}$	OMC (%)
L1(NE)	B	Proctor	2.5	25	3	2.10	9.75
L2 (NE)	B	Proctor	2.5	25	3	2.00	11.3
L3 (SE)	B	Proctor	2.5	25	3	2.10	8.6
L4 (SE)	B	Proctor	2.5	25	3	1.99	11
L5(NW)	B	Proctor	2.5	25	3	2.16	6
L6(NW)	B	Proctor	2.5	25	3	1.98	10.7
L7 (SW)	B	Proctor	2.5	25	3	2.20	8.5
L8 (SW)	B	Proctor	2.5	25	3	1.97	9

V. Conclusion

The geotechnical properties obtained shows that the soil samples 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. 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.

Conclusively, the possible causes of cracks on the wall of structures, buildings could be the acidic nature of the soil which can reduce its life span leading to damaging of buildings and structures and also the use of material with lower strength. Causes of cracks is also attributed to the low bearing capacity of the soil because silt which is predominant in the study area is too light to hold buildings or structures and clay soils are mostly expansive.

References

[1]. J. Benkhelil, Borno, Benue Trough, the Niger Delta and its offshore, Tectono Sedimentary reconstruction during the Cretaceous and Tertiary from Geophysical data and Geology: in Kogbe, C.A. [Ed], Geology of Nigeria.(Abi print and pak Ltd, Ibadan,1989, 309p.

[2]. Guiraud, M. (1990). Tectono Sedimentary Framework of the Early Cretaceous continental Bima Formation. Upper Benue Trough, North-eastern Nigeria. Journal of Africa Earth Sciences. 111, 341-353.

[3]. Carter, I.D, Barber, W and Tait, E.A, The Geology of parts of Adamawa, Bauchi, Gombe and Borno provinces in Northeastern Nigeria, (Bullet in Geological Survey of Nigeria. No 30, 1963).

[4]. Wright, J.B, Origin of the Benue Trough. In Geology of Nigeria. C.A Kogbe (Ed) Elizabethan Pub.Co.

[5]. Allix, C, The Benue trough Structure and Evolution (172 – 201, 1983).

[6]. Falconer, J.D, The Geology and Geography of Northern Nigeria (Macmillan Publishers, London, 1911).

[7]. P. Zaborski, U. Francis, I. Alexander, N. Paulinus, and I. Kalu, Stratigraphy and Structure of the Cretaceous Gongola Basin, Northeast, Nigeria. Bullettin Centre Res, Elf Explor.Prod, 1999, 169-171

[8]. Raeburn, C. and Jones, B, The Chad Basin: geology and water supply. (Bulletin Geological Survey Nigeria. 15, 1-61,1934).

[9]. Matheis, S.G, Short Review of the Geology of the Chad Basin in Nigeria,(Elizabeth Publication Company, Lagos, Nigeria, 1976).

[10]. Obaje, N.G. and Abaa, S.I, Potentials for Coal derived gaseous hydrocarbon in the Middle Benue Trough, Nigeria, Journal of Petrol. Geol. 19, 74-89, 1996.

[11]. Dessauvagie, T.F.J, Explanatory note to the Geology map of Nigeria, Journal of Mining and Geology, 9, 3-28, 1975.

[12]. Dike, E.F.C., Stratigraphy and Structure of the Kerri-Kerri Formation basin, North-eastern Nigeria, Journal of Min. and Geol. 29,(2)

[13]. Gebremedhin, B, Engineering Geological Investigation of Mekelle area, Tigray, Northern Ethiopia, M.Sc. Thesis, Addis Ababa University, Addis Ababa, Ethiopia,2002.

[14]. Abramson, L.W., Lee, J.S., Sharma, S and Boyce, G. M, Slope Stability and Stabilization Methods, (John Wiley and Sons, Inc., New York.629p,1996).

[15]. Handa, B, Gate in Civil Engineering, (1st ed), New Delhi, S.M.T. Publication. 17p.

[16]. Federal Ministry of Works and Housing, Nigerian General Specifications for Roads and Bridge works (NGS), Federal Highway Department, 1997, Vol 2.

[17]. Holtz, R.D. and Kovac, W.D, An Introduction to Geotechnical Engineering, (Prentice-hall Inc. Englewood-cliff, N.J. 32p,1981).

[18]. Bell, F. G, Fundamentals of Engineering Geology. (Butterworth and Co. Limited. London, 1983).

[19]. Brady, C.N and Well, R.R, The nature and properties of soils, (5thed. New Jersey Prentice Hall, 1999).

[20]. B.S. 1377, Method of Test for Soil for Civil Engineering Purpose. (Gr.10, British Standard Institutions. Hamlet Press London, 1975).

[21]. British Standard 1377 Part 1, General Requirement and Sample Preparation, (British Standard Institute, London, 1990)

[22]. British Standard 1377 Part 2, Classification Test,(British Standard Institute, London, 1990).