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GEOLOGY AND ENGINEERING PROPERTIES OF CLAY- SOIL IN NIBO AND IT'S ENVIRON.

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ABSTRACT

Failures of engineering structures such as buildings and roads erected on expansive soils that occur extensively in the study area have been observed. Expansive soils are a clayey soil that swells or increases in volume when in contact with water but also shrinks or decreases in volume when the water is removed. This study was undertaken to evaluate the engineering properties of soils in the study area Nibo and environs, in relation to the failures of engineering structures in the areas. The study area is located bounded by latitude 60 101N and longitude 70 41 1.111E. A surface Geological mapping of the area revealed that there are two dominant formations in the area; the Eocene Nanka Formation and the Paleocene Imo Formation. A total of 9 soil samples were collected in different locations of the study area and their geotechnical properties determined in the laboratory. The geotechnical properties analyzed in the laboratory includes: sieve analysis and atterberg limit test. Water samples were also taken to analyze the Hydro geochemical properties so as to determine its portability. Results from the sieve analysis showed that soil samples analyzed are poorly graded with grain sizes ranging from medium to coarse sands, the Atterberg limit test shows that shales found in the shaley areas has high plasticity thus having high swelling potential while soils obtained from sandy areas exhibited low to medium plasticity thus suitable as foundation materials. Result from the water analysis carried out shows that the water resources present in the area do not meet up with the World Health Organization (W.H.O) standard and hence not potable. The area has industrial earth materials such as clay, laterite, sandstone and ironstone which are actively quarried for various industrial purposes.

Keywords: **Engineering Structures, Engineering Properties, Expansive Soils, Sieve analysis, Atterberg limit.**

INTRODUCTION

Many a times engineering and geologic structures are jeopardized due to crude and inefficient study/research approach of the underlying geology of the area, these engineering and geologic structures ranges from buildings, infrastructures, roads to underground utilities(water-pipelines, Cables etc). Construction of structures without proper investigation of the geology of the area-topography, soil, rock, geologic setting, and hydrogeology influences the structural integrity of the structure negatively. Structural integrity is the capacity of a structure to hold together under a load, including its own weight without breaking or deforming excessively (R.A Collacott et al 1985). Soils with higher degree of susceptibility to increase in pore water pressure during rainfall should not be appreciated for construction purposes. Effective research on the mechanical and hydrogeology of the soil is relevant to addressing the Hydro-mechanical behavior of the ground surrounding civil engineering structures which is often ignored in Nibo, Awka. This study helps to bridge the gap between engineering structures and their failures with restriction to Nibo and its environs by collecting and analyzing different soil and rock samples. Many field geologists have done research works and published articles with vital information on the Anambra basin. This review covers the source of the sediments, the sequence stratigraphy of the formations within the basin and their tectonic evolution. According to Nwajide and Reijers (1996), it was noted that the study area occurs within the Anambra basin which is one of the major basins of Benue trough. The believed that the ironstone was derived from the overlaying ferruginous Nsukka Formation and was further described by Ibe And Adiuku-Brown (2000) as marking the transition between Ajali Formation and the Nsukka Formation. According to Orajaka (1992), while the correlation of the stratigraphic sequence in the southeastern Nigeria showed a relationship between the coal bearing sediments, they both pointed out that the coal bearing sediments, the both pointed out that coal did not occur in one formation but two distinct formations separated by a thick series of sandstone, the Ajali Sandstone.

From the field observation, the lithostratigraphy units found in the area belong to Ajali Sandstone (Upper Maastrichtian) and the Nsukka Formation (Upper Mastrichtian to Danian). The Ajali Sandstone consist of white but sometimes iron-stained, friable, and medium to coarse grained, cross-bedded, highly porous, permeable aquiferous units. The Nsukka Formation is younger than the Ajali Sandstone and therefore lies conformably above it. The lithostratigraphic units are described based on field studies of outcrops. The sand of Nsukka Formation is highly ferruginized which is described by Ibe and Adiuku-Brown (2000) as marking the transition between Ajali Formation and the Nsukka Formation. The Nanka Formation underlies the eastern part of the study area. It consists of a series of sand shale intercalation and highly fossiliferous greyish-green sandy-clay with white clays. Nanka sand is found in Okpuno-Awka, Amanuke and Urum. It has a similar texture and whitish colour to Ajali sand.

The most complex of erosion sites are underlain by poorly consolidated Nanka sand. Nanka sands forms hills filing and concave shaped sand depression in Imo shale. It is a regressive shallow marine deposit influenced by the late Eocene tectonic episode of positive movement. Since Nanka sand is underlain with aquitard shale, the major underground water reservoirs are found within it. The dry bulk density of Nanka sand is the highest of all the geological formation and it significantly different from coastal sand and Ajali sand. The dry bulk density increases with depth. The Anambra basin which is in the southern Benue Trough, being that the trough itself is a continental large scale intra-plate tectonic range structure, which is part of the mid-African rift system initiated in the latest Jurassic to early Cretaceous and is related to the opening of the central and South Atlantic Ocean (Murat, 1977). The southern Benue trough comprises the tectonically inverted Abakaliki Anticlinorium, Afikpo and Anambra basin flanking the Anticlinorium to the east and west respectively.

OUTCROP DESCRIPTION ECONOMIC GEOLOGY OF THE STUDY AREA

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For every field work, it is imperative that a detailed outcrop description of all exposures is made. This is a standard criterion for a comprehensive geologic report because in most cases it stands as a platform for proper explanation and characterization of identified features in the field. During the period of the geologic mapping within the study area, various observations were made at different stations or locations within the study area. These observations and outcrops were described and placed together to obtain the local geologic map of the area.

Station 1: Location at Amaenyi abandoned quarry site, opposite Anambra rice mill; Coordinate: LatitudeN6o 13’ 52’’, LongitudeE7o 6’38”, Elevation: 115m, Lithology: Sand and Shale.

This is concerned with earth materials that can be used for economic and/ or industrial purposes. The mapped area is endowed with deposits which are of economic importance to government, industries and individuals. Economic deposits found in the area include laterite, clay, coal, shale, sand, Ironstone and water. Laterite abounds in the study area. They are basically sandstone units that have been chemically weathered. They result from hydration and oxidation of soil and contain iron oxide. The chemical and geochemical characteristics make them harden on desiccation. They possess high resistance to weathering and also have high bearing capacity.

Uses of lateritic sands include foundation materials for building, slope stabilization, road filling materials, making dwarf local barriers. Sandstone is another geologic material that is being exploited in the study area. Sandstone is used as concrete aggregate for block molding and other construction works. The exploitation of this material provides revenue for the government and at the same time serves as means of livelihood to some individuals in the area. It is a type of sedimentary rock that has a grain size between sand and clay. Its mineral constituent mainly comprises quartz and feldspar. It used in building and crop production, as well as in the production of Plaster of Paris (POP) for repairing broken bones. Shale is a type of fine-grained sedimentary rock with a thin, laminated and often friable structure. It can also contain organic matter and is usually greyish-white in colour. It can be used in making pots, cementing materials, tiles and refractory materials when it contains clay. Shale can also be used as filler in paint, plastic, roofing cement industries and as raw materials for bricks, landscaping and driveway material.

Table 1: Characteristics of the stratigraphic components of the Anambra basin.

LITHOSTRATIGRAPHIC UNIT	CHARACTERISTICS
Ogwashi-Asaba Formation (Oligocene)	Sucession of coarse grained sandstone, clay, and carbonaceous shale, containing continental lignite seam intercalations
Ameki Formation (Eocene)	Tidal-estuarine deposits comprising fossilferous grey-green sandyclays, calcareous concretions and white clayey sandstones. Displays rapid lateral facies changes.
Imo Formation (Paleocene)	Dark grey, fossilferous, marine shales with limestone, clayey sandstone and pebbly sands. Weathers into stiff clays.
Nsukka Formation (Maastrichtian-Paleocene)	Tidal-estuarine sandstones, dark shale/sandy shale with coal seams.
Ajali Sandstone (Maastrichtian)	Unconsolidated to poorly cemented, coarse to fine grained

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	sandstones, siltstones and carbonaceous and mud rocks, laterite on the surface. Mainly fluvial to marginal marine facies.
Mamu Formation (Maastrichtian)	Tidal-estuarine facies dominated by poorly consolidated carbonaceous sandstones, siltstone and mudrock with coal seams.
Nkporo Group (Campanian-Maastri\chtian)	Marine-tidal flat facies comprising carbonaceous shales, siltstones and poorly consolidated, coarse-medium grained.
Ezeaku Group (Turonian)	Hard, black fossilferousshales with limestone, calcareous siltstones and sandstones.
Asu-River Group (Albian)	Poorly bedded shales, occasionally sandy, and may contain lenses of sandstone and sandy limestone.

MATERIALS AND METHOD

Several materials were used with respect to the different analysis to be done in achieving the set goals. Material used for geologic field mapping survey and various laboratory analyses are essentially stated according to standard specifications including: Equipment for Geological Field Mapping ;Equipment for Laboratory Analysis; Equipment for grain size analysis; Atterberg Limit Test; Apparatus for Liquid Limit; Apparatus for Plastic Limit among others.

Main Grain Analaysis.

Equipment for Atterberg's limit test.

METHODOLOGY

Several methods and techniques were employed during the course of field work within the study area. Samples were collected using sample bags and laboratory analyses were later carried out on them in the laboratory. Generally, the method involved desk studies; reconnaissance survey; field investigation and sampling; laboratory tests; sample preparation; soil preparation; water preparation/digestion; sample analysis; sieve analysis. All these were done in accordance with procedures of the American Society for Testing Materials (ASTM). The next phase was to carry out the Atterberg limit tests as a measure of the response of clay or shale samples to stress as well as their settlement characteristics, texture and firmness. Atterberg's limit test involves the

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plastic limit test, liquid limit test and plasticity index in accordance with procedures of the American Society for Testing Materials (ASTM).

Table 2: Result of petro physical analysis of water samples from the study area

Parameters Mg/L	WHO Standard	Station three	Station four	Station five	Station six
Colour	15.Otcu	Colorless	Brown	Colorless	Brown
Copper	2.0	0.00	0.00	0.020	0.004
Magnesium	150	0.007	0.0004	1.742	0.989
Sodium	200	1.275	0.532	2.451	0.567
Calcium	200	0.059	0.055	0.178	0.027
Lead	0.01	0.00	0.00	0.00	0.00
pH	6.5-8.5	6.5	6.4	6.66	6.0
Conductivity (µs/cm)	1250	111.3	90.6	424	103.6
Alkalinity	100	37.5	27.5	112.5	15
Sulphate	100	106.667	97.778	136	114.667
Nitrate	45	19.67	21.009	20.154	15.789
Chloride	600	55	50	25	22
Temperature	24-30	28.3	28.2	28.9	28.3
Coliform	NIL	1.28×10^1	1.40×10^1	1.4×10^1	1.48×10^1

RESULTS, DISCUSSIONS AND INTERPRETATIONS

The study area is basically of Nanka sand which is Eocene in age and the Imo shale which is of Paleocene in age. The Nanka sand is highly friable, the sand unit is poorly sorted and well graded, the grain size ranges from fine-medium-coarse grain. The friable nature makes them very prone to erosion. (Implications of hydro geophysical investigation of the Agulu-Nanka gullies of Anambra State by A.G. Onwuemesi; B.C.E Egboka; J.P Orajaka and E.A Emenike). Next in the geological sequence, is the Ameki formation, which includes the Nanka sands laid down in the Eocene. Its rock type is sandstone, calcareous shale, and shaleylimestione in the band. Outcrop of the sandstones occurs at various places on the higher cuesta, such as Abagana and Nsugbe

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where they are quarried for construction purposes. Nanka sands outcrop mainly at Nanka and Oko in the Orumba North Local Government Area.

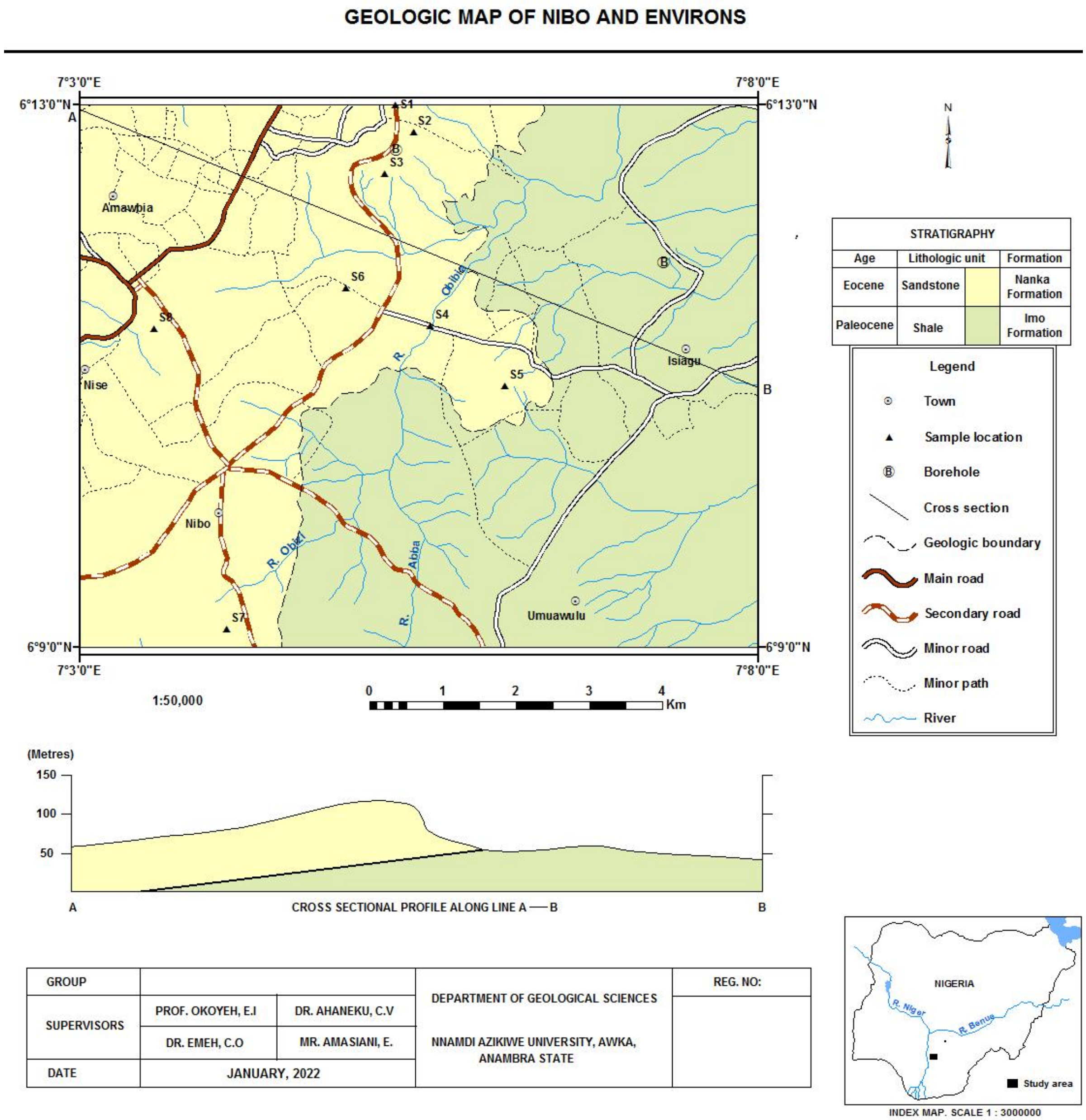

Fig 1: Geologic map of Nibo. Source: Google Earth.

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Fig.2: Station 1 showing sparse vegetation

SIEVE ANALYSIS RESULTS AND INTERPRETATION.

Four samples were collected from the study area and subjected to sieve analysis to determine their sorting, grading and strength characteristics. Results obtained from the sieve analysis were recorded and plotted accordingly on a log probability graph following the method of Folk, 1974.

Table 3: Sieve analysis for sample obtained at location 1

Sieve size (mm)	Wt. of empty sieve (g)	Wt. of sieve + sample retained (g)	Mass retained (g)	Corrected weight of sample retained (g)	Toal retained (%)	Cumulative retained (%)	% Passing
2.36	416.53	426.77	10.24	10.24	3.4133	3.4133	98.5867
1.18	481.71	531.28	49.57	49.7375	16.5792	19.9925	80.0075
0.600	352.13	477.95	125.82	125.9875	41.9958	61.9883	38.0117
0.425	329.07	393.21	64.14	64.3075	21.4358	83.4241	16.5759
0.300	324.36	350.65	26.29	26.4575	8.8192	92.2433	7.7567
0.212	412.71	425.12	12.41	12.5775	4.1925	96.4358	3.5642
0.150	305.57	312.21	6.64	6.8075	2.2692	98.7050	1.2950
0.063	298.02	301.04	3.02	3.1875	1.0625	99.7675	0.2325
Pan	370.26	370.79	0.53	0.6975	0.2325	100	0
TOTAL			298.66	300	100		

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Table.4: Sieve analysis for sample obtained at location 2

Sieve size (mm)	Wt. of empty sieve (g)	Wt. of sieve + sample retained (g)	Mass retained (g)	Corrected weight of sample retained (g)	Toal retained (%)	Cumulative retained (%)	% Passing
2.36	416.56	461.82	45.26	45.26	15.09	15.09	84.91
1.18	481.77	569.69	81.92	82.0825	27.36	42.45	57.55
0.600	352.22	438.27	86.05	86.2125	28.74	71.19	28.81
0.425	329.08	358.63	29.55	29.7125	9.90	81.09	18.91
0.300	325.82	343.24	17.37	17.5325	5.84	86.93	13.07
0.212	412.78	426.57	13.79	13.9525	4.65	91.58	8.42
0.150	305.67	314.31	8.64	8.8025	2.93	94.51	5.49
0.063	298.06	304.83	6.77	6.9325	2.31	96.82	3.18
Pan	370.27	379.62	9.35	9.5125	3.17	100	0
TOTAL			298.70	300	100		

SIEVE ANALYSIS INTERPRETATION

Effective grain size: This is the grain size corresponding to the percentage finer point on the curve of the graph e.g. D_{10}.
Uniform coefficient (Cu): This is the measure of the uniformity of the grain size of the soil; it is defined as the ratio of 60% finer size to the10% finer size.
Mathematically,
$Cu = D_{60} / D_{10}$.
Coefficient of gradient of the curve (Cc): Also known as the coefficient of curvature. It is the value that can be used to identify a poorly graded soil.
Mathematically,
$Cc = (D_{30})^2 / D_{60} \times D_{10}$
Gradation based on Cu and Cc parameters (U.S Department of Transportation, FHWA, Publication No. NHI-06-088, December 2006)
Gradation Gravels Sands
Well graded $Cu \geq 4$ and $1 < Cc < 3$ $Cu \geq 6$ and $1 < Cc < 3$
Poorly graded $Cu < 4$ and $1 < Cc < 3$ Cu 6 and $1 < Cc < 3$
Gap graded* Cc not between 1 and 3 Cc not between 1 and 3
*Gap graded soils may be well graded or poorly graded. In addition to the Cc value it is recommended that the shape of the GSD be the basis for definition of gap graded.

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SIEVE ANALYSIS INTERPRETATION

Sample two is a well graded sample containing particle range from silt to gravel but predominantly sand, it'll have low void ratio, high shear strength and hence suitable for engineering works. Samples one and three are poorly graded and not suitable for civil

ATTERBERG'S LIMIT TEST RESULT

Six samples were collected and subjected to plastic and liquid limit test otherwise known as the consistency limit test to determine their compressive strength. The samples used were plastic, cohesive and have swelling potentials.

Table 5: Results obtained from plastic limit test for sample 1

Location 1: Off Old Road, Amaenyi
Latitude: 6^0 13^1 8^{11}
Longitude: 7^0 5^1 38^{11}
Plastic limit result

Determination	1	2	3
Dish	C	H	K
Wt of dish + wet soil	49.46	50.07	49.40
Wt of dish + dry soil	48.8	49.28	48.72
Wt of moisture	0.66	0.79	0.68
Wt of dish	46.17	46.14	46.05
Wt of dry soil	2.63	3.14	2.67
Moisture content	25.40	25.16	25.47

Plastic Limit: 25.40+25.16+25.47= 25.34%i.e 25%

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LIQUID LIMIT RESULT

Determination	1	2	3	4
Dish	I	12	59	D
No of blows	45	35	25	15
Wt of dish + wet soil	50.70	50.74	51.73	51.06
Wt of dish + dry soil	49.18	49.13	49.75	49.18
Wt of moisture	1.52	1.66	1.98	1.88
Wt of dish	45.99	46.00	46.13	46.03
Wt of dry soil	3.19	3.13	3.60	3.15
Moisture content	47.65	51.44	55.00	59.68

Liquid Limit at 25 Blows = 55%, Plasticity Index: LL-PL, 55 – 25 = 30

Table 6: Showing results obtained from liquid limit test for sample 2

Location 1: Off Old Road, Amaenyi
Latitude: $6^0\ 13^1\ 8^{11}$
Longitude: $7^0\ 5^1\ 38^{11}$
Plastic limit result

Determination	1	2	3
Dish	3	6	9
Wt of dish + wet soil	18.40	18.72	19.63
Wt of dish + dry soil	18.23	18.50	18.79
Wt of moisture	0.17	0.22	0.24
Wt of dish	16.28	16.37	16.37

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Wt of dry soil	1.95	2.13	2.42
Moisture content	8.72	10.33	9.92

Plastic Limit: 8.72+10.33+9.92= 9.66%i.e 10%, Liquid Limit at 25 Blows =20%, Plasticity Index: LL-PL, 20 – 10= 10

Table 7: Showing results obtained from liquid limit test for sample 2

Location 3: Ring Road Nkwelle, Awka
Latitude: 6^0 12^1 30^{11}
Longitude: 7^0 $5^1 15^{11}$
Plastic limit result

Determination	1	2	3
Dish	A23	40	I
Wt of dish + wet soil	50.88	51.49	51.76
Wt of dish + dry soil	50.10	50.65	50.92
Wt of moisture	0.78	0.84	0.84
Wt of dish	45.63	45.95	46.23
Wt of dry soil	4.47	4.70	4.69
Moisture content	17.45	17.87	17.91

Plastic Limit: 17.45+17.87+17.91= 17.74%i.e 18%

Liquid Limit at 25 Blows =32%, Plasticity Index: LL-PL, 32 – 18= 14

Table 8: Results obtained from plastic limit test for sample 2

Location 4: Off Isiagu Road
Latitude: 6^0 11^1 22^{11}
Longitude: 7^0 $5^1 35^{11}$
Plastic limit result

Determination	1	2	3
Dish	A23	X	Z
Wt of dish + wet soil	50.98	50.69	51.11
Wt of dish + dry soil	50.13	49.93	50.34
Wt of moisture	0.85	0.76	0.77
Wt of dish	45.64	45.75	46.25
Wt of dry soil	4.49	4.18	4.09
Moisture content	18..93	18.18	18.83

Plastic Limit: 18.93+18.18+18.83= 18.65%i.e 19%

CONCLUSION AND RECOMMENDATION

The geologic map generated for the study area clearly shows the distribution of the distinct and conformable two lithostratigraphic units with the sandstone being the dominant lithology. Laboratory analysis of clay and sand samples such as Atterberg's limit and sieve analysis were also carried out to determine their suitability for engineering works and it showed that three of the clay samples are suitable for foundation and for construction works. Hydro-geochemical analysis of the water in the study area showed that the water in the study area has different degree of impurities which do not meet the required standard for consumption in accordance with the World Health Organization (WHO).

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