Geotechnical Properties of Soils in Parts of Eleme, South-Southern Nigeria and its Suitability for Building Foundation

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Abstract: At Eteo Eleme, a geotechnical assessment was conducted to see if the soils were suitable for use as foundations. In compliance with applicable ASTM standards, laboratory tests such as bulk density, moisture content, particle size distribution, triaxial, and Atterberg limit were performed on 15 soil samples that were gathered between 0 and 2 meters below the surface. The soil profile and the parameters of the soil classification test were acquired by means of a thorough field and laboratory examination. The soil types at the three places were found to be Dark Brown silty clayey sand at the first location, Brown/Reddish silty clayey sand at the second location, and Dark/Gray clayey silty sand at the third location. This research was conducted in several areas of Eteo, Eleme. In all three (3) locations, the average natural moisture content of the soil is 10.72%, 14.62%, and 12.22%. The low moisture content measurements show that the soils have a high carrying capacity due to their strong shear strength. Locations 1, 2, and 3 have average bulk densities of 1278.00 kg/cm3, 1278.00 kg/cm3, and 1673.93 kg/m3, respectively. The bulk density value and the level of compaction increase with depth. To improve the soil's in-situ (natural state) stiffness and bearing capability, compaction is required. Compaction adds friction from the particles' interlocking, which raises the soils' shear strength. According to the Atterberg limit finding, Locations 1 and 2 have moderate plasticity with liquid limit average values of 32.05 and 35.85, respectively. Locations 1 and 2 have plastic limit average values of 24.07 and 25.86, respectively, indicating that the soil in these areas is readily distorted. site 1 has a low swelling potential, whereas site 2 has a medium swelling potential, as shown by the average plasticity index values of 10.07 and 17.41, respectively. According to the particle size result, the soils at site 2 (0.5 m) have a coefficient of uniformity of less than 5, which suggests that the soils there are poorly graded. The soil at site 3 (1.5 m and topsoil) has a coefficient of uniformity <5, which suggests that the soils there are not well graded. The soil's bearing capacity, as determined by the triaxial test conducted at position 2 at 1 m, is 30.09 kN/m2. This suggests that putting weights on the foundation that are greater than these values will cause settling.

Keywords: *Geotechnical, Index Properties, Bearing Capacity, Settlement, Foundation.*

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I. INTRODUCTION

In foundation studies, geotechnical soil analysis is crucial because if it is not done, building collapses might result in property and human casualties [10]. Poor soil geotechnical conditions are the primary cause of most foundation issues.

High temperatures due to climate change cause soil to shrink quickly, while higher precipitation rates induce abrupt changes in soil moisture. These aspects should therefore be taken into account in foundation studies.

The shallow foundation and the installation of raft/mat foundation are suggested as feasible choices in the region based on the evaluation of the foundation condition in Ubima, Ikwerre L.G.A. of Rivers State [5].

In order to improve development, civil structure construction has skyrocketed; government agencies and private citizens are building homes, lecture halls, and ultra-modern buildings to boost shelter and office complexes [3]. To gather geotechnical data on the region's subsurface at various depths, a comprehensive site investigation and laboratory examination are necessary. When building engineering projects, engineers looked for this knowledge.

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In order to appropriately assess and, if required, mitigate the consequences of projects on the environment and natural resources, geotechnical knowledge is helpful [4]. Particle size distribution, Atterberg Limits, Plasticity Limits, and Liquidity Limits are just a few of the physical, chemical, and geotechnical characteristics of soils that are closely linked to the physical conditions of the materials. These characteristics determine the instability of the material for the purposes of soil classification and construction. It has been discovered that soils develop in various sub climates and drainage environments.

By using their index qualities, soil may be readily detected, and appropriate engineering design can prevent foundation collapse [1].

The nation's alarmingly high rate of foundation failure, which has claimed many lives and damaged numerous properties, may be the result of ignorance of the geotechnical properties of the soil beneath the surface or of failure to take into account the engineering characteristics of soils under various stress and loading conditions. The geotechnical characteristics of the soil in Eteo Eleme will be updated and better understood thanks to this investigation, which will benefit local civil engineering projects.

II. LITERATURE REVIEW

The geotechnical characteristics of foundation subsoils in areas of Port Harcourt City, Obio/Akpor, and Ikwerre Local Government Area, Rivers State, Nigeria, were the subject of a study conducted by [11]. Field research and laboratory examination of soil samples taken from 0 to 20.25 meters below the surface were part of the study. The results showed a soil stratification, with a layer of light brown sandy clay on top and a layer of yellowish brown to light grey sand below. With shear strength values ranging from 40 to 60 kN/m2, the clays in the study region demonstrated low to intermediate plasticity (designated as CL-CI), demonstrating their capacity to support loads.

The geotechnical characteristics of sub-soils in the Escravos Estuary, which is situated in the Western Niger Delta of Nigeria, were studied by [5]. The geological features of this region and the environmental obstacles it presents for building projects—especially pipelines—make it noteworthy. Prior to starting building projects, it is essential to comprehend the subsurface characteristics in order to evaluate hazards and guarantee the stability of structures, particularly in regions with challenging ground conditions. As part of the study's methodology, soil samples were obtained using traditional boring techniques, which made it possible to gather the information required to assess the soil's geotechnical properties.

In order to evaluate the engineering geological qualities of the subsurface soils in Warri, Nigeria's Western Niger Delta, [6] used a combination of techniques, such as electrical resistivity surveys, borehole drilling, and in-situ testing. Three main sub-soil types were found in the region by the research: sand, clayey sand, and silty sand. Designing foundations for a variety of civil constructions requires a knowledge of the soils' load-bearing capacity, which these layers provide.

According to their observations, the top layer of silty sand's low thickness makes it typically unsuitable for major foundation construction. The underlying clayey/silty sand and sand layers, on the other hand, have more capacity to sustain medium-to-heavy buildings, which makes them more appropriate for construction. In order to guarantee that foundation designs are founded on accurate information, the study highlights the need of conducting sufficient subsurface studies prior to construction, especially in regions with diverse soil types and conditions.

III. LOCATION AND ACCESSIBILITY

Rivers State (Fig. 1) lies between latitude 4.7679° N and longitudes 7.1844°E. The site is accessible through the Eket-Port Harcourt express road in Rivers State.

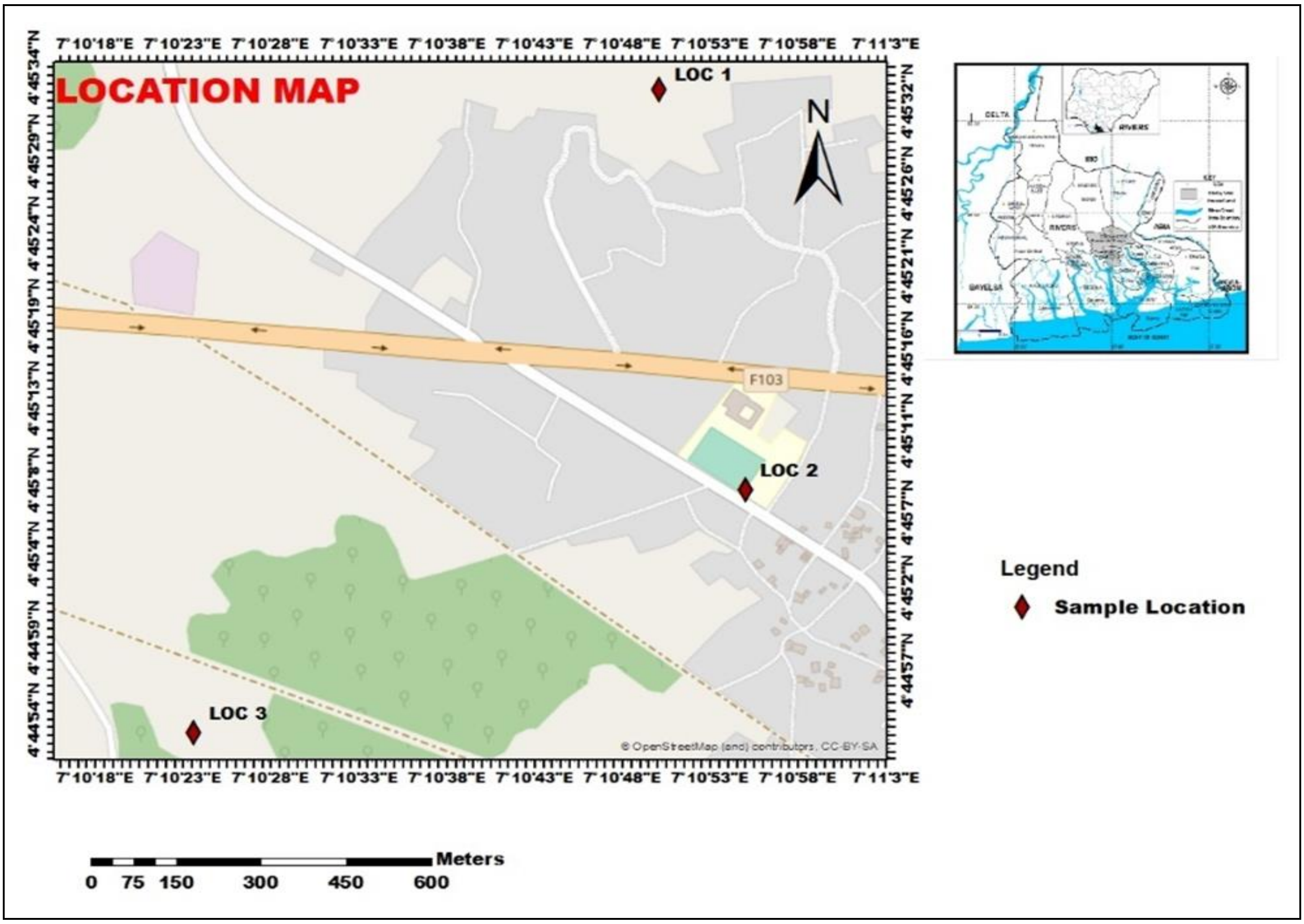

Fig 1 Location Map of Study Area

IV. MATERIALS AND METHODS

➢ *Field Investigation*

Using a hand auger, three boreholes were dug at various sites to a depth of two meters. Disturbed soil samples were taken at regular intervals of 0.5 meters. To stop moisture loss, the disturbed samples were removed from the cohesive soil layers and placed in a plastic zip-lock bag. Following field examination, identification, and detailed classification, the sample was packed and sent to the lab for further investigation. Latitudes 4° 45' 32.19" N, 4° 45' 7.93" N, and 4° 44' 53.16" N of the equator and longitudes 7° 10' 50.14" E, 7° 10' 55.02" E, and 7° 10' 23.65" E Greenwich meridian are where Locations 1, 2, and 3 are located, respectively.

➢ *Equipments used in the Field Includes:*

- hand auger
- maxing tape
- marker
- pen
- book
- zip lock bag
- camera
- G.P.S (Global Positioning System)

➢ *Laboratory Investigation*

Every soil sample that was collected in the field was examined and described in more depth in the lab. For a number of laboratory tests, representative samples were then extracted from each soil sample.

British standard BS 5930 (1990) was used when conducting test procedures for field investigations, while British standard BS 1377 (1990) was followed when conducting test procedures for laboratory investigations. The following tests are conducted as part of the laboratory investigations:

➢ *Index Property of the Soil*

- Natural moisture content
- Bulk Density

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- Liquid and plastic limits
- Particle size distribution analysis

> *Engineering Properties*

- Triaxial Test

> *Index Property*

- *Natural Moisture Content*

The quantity of absorbed water in a soil is referred to as its moisture (water) content. It is defined as the weight of dry solid soil matter divided by the weight of water contained, given as a percentage.

Materials for determining the natural moisture content Oven, weighing scale, soil sample, and crucible.

- *Method of Testing*

Weighing and recording m1 was done on the five dry and clean crucibles that were utilized. A few moist samples were added to the crucible, weighed, and measured in millimeters (m2). For 12 to 18 hours, the crucible with the moist soil was left in an oven set between 105 and 110 degrees Celsius to dry. After taking the crucibles out of the oven and letting them cool, the crucible and dry soil were weighed to determine their mass in cubic meters.

✓ *Formulas*

$$\text{Moisture (water) content} = \frac{\text{mass of water}}{\text{mass of solid soil}} \times 100$$

$$\therefore \text{ m or w} = \frac{m_2 - m_3}{m_3 - m_1} \times 100$$

Where:

m_1 = mass of empty can

m_2 = mass of can and wet soil sample

m_3 = mass of can and dry soil sample

> *Bulk Density*

The density of a moist soil sample is measured by its bulk density. It's the mass of the soil divided by the volume of the container it's put in.

To get bulk density is $\frac{m}{v}$

Where M = mass of soil

V = volume= $\pi r^2 h$

Material used for Bulk density determination soil sample, weighing balance, ruler, and cylindrical cutter.

> *Method of Testing*

Using the formula r2h, the cylindrical cutter's length and internal diameter were measured in order to calculate its volume. The cylindrical cutter's empty weight was measured and noted as m1.

After inserting the cutter into the earth, a sample of dirt was placed inside; the combined weight of the cutter and soil was measured and recorded as m2.

- *Formulas*

$$\text{Bulk density} = \frac{\text{mass of wet soil}}{\text{internal volume of cylindrical mould}}$$

$$\text{Bulk density (P)} = \frac{m_2 - m_1}{V}$$

The bulk density is measured in kg/m^3.

Atterberg Limit/Consistency Limit (ASTMD 427 And D4318)

By performing the Liquid Limit, Plastic Limit, and Shrinkage Limit tests, the Atterberg limit test is achieved. The moisture content of a soil at the boundaries between states is known as the Atterberg (consistency) limit. Depending on the water concentration, cohesive soil may exist in four different states: solid, semi-solid, plastic, and liquid.

The difference between a soil's liquid and plastic limits is known as its plasticity index (IP). It is the water content at which, when properly rolled out to a diameter of 3 mm, a thread of soil simply crumbles; if it collapses at a diameter less than 3 mm, the soil is too wet; if it crumbles at a diameter larger than 3 mm, the soil is too dry.

PI = LL-PL

PI = plasticity index

LL = liquid limit

PL = plastic limit

> *Materials used for Liquid Limit Determination*

Spatula, wash bottle, oven, weighing balance, crucible, mortar pestle, glass plate, soil sample, washing pan, liquid limit device, grooving tool.

- *Test Procedures*

✓ *Liquid Limit*

Five crucibles were weighed to determine their mass. A sample of soil was spread out on a glass plate, and to create a consistent paste, distilled water was periodically added and thoroughly mixed with the soil. The liquid limit device's cup was filled with a part of the paste, and the surface was smoothed down to a maximum depth of 1 cm.

To create a groove, the grooving tool was pulled through the sample along the cup's symmetrical axis. The number of blows required to seal the dirt groove over a distance of 10 mm was recorded while the handle of the liquid limit device was rotated at a rate of around two revolutions per second. After this was accomplished, a sample of soil was taken close to the closed groove, put in a crucible, weighed as crucible + wet dirt to be m2, and dried in an oven. After returning the sample in the liquid limit capsule to the glass plate, more water was added, mixed, and the above procedures were carried out five times. The water content and the number of blows were plotted.

The liquid limit of a certain soil is the water content that, on the flow curve, equals 25 blows.

- ✓ *Formula*

$$\text{Moisture (water) content} = \frac{\text{mass of water}}{\text{mass of solid soil}} \times 100$$

$$\therefore \text{ m or w} = \frac{m_2 - m_3}{m_3 - m_1} \times 100$$

- ➢ *Materials used for Plastic Limit Determination*

Weighing balance, Crucible, soil sample, oven, wash bottle, spatula, glass plate.

- *Plastic Limit*

The weight of five empty crucibles was noted as m1. A piece of the wet soil was rolled into a thread on a glass plate after the dirt and distilled water had been combined. When a fracture appeared, the thread was rolled until it reached a diameter of 3 mm. After being measured in m2, the cracked dirt was put in the empty crucible and dried in an oven. After drying, the mass of the dry soil and crucible was measured and reported as m3. This procedure was carried out five times. After calculating the moisture content, the plastic limit is calculated by dividing the total moisture content by five.

- *Analysis of Particle Size Distribution*

The division of soil particles into fractions, each of which contains grains or particles of about the same size, is known as particle size distribution. The proportion of different grain sizes found in a soil as established by sifting and sedimentation is known as the particle size distribution.

- ➢ *Material for Determining the Particle Size Distribution*

Pen, book, graph, weighing scale, and sieve set.

- *Method of Testing*

Weighing the soil sample in a container and recording the result as m1 was done. A pan was at the bottom of a set of sieves that were positioned in decreasing aperture diameter order. Weighing and recording were done on each sieve. The soil sample was then placed in the uppermost sieve and sealed with a lid. The entire set of sieves was vibrated for approximately ten minutes in order to sieve the soil. After that, each sieve containing the particles was weighed and its contents noted.

- *Properties of Engineering*

- ✓ *Triaxial Examination*

To ascertain a soil's bearing ability to sustain stresses placed on the ground, a triaxial test is used. The maximum average contact pressure between the soil and the foundation that should prevent shear failure in the soil is known as the bearing capacity of the soil. Allowable bearing capacity is calculated by dividing the ultimate bearing capacity by a safety factor. Ultimate bearing capacity is the utmost pressure that may be maintained theoretically without failing. Large settlements on loaded foundations without actual shear failure may sometimes happen on soft soil sites; in these situations, the maximum permitted settlement serves as the basis for the allowable bearing capacity.

There are three forms of failure that restrict bearing capacity: general shear failure, local shear failure, and punched shear failure. It relies upon the shear strength of soil as well as form, size, depth and kind of foundation.

The first person to provide a thorough theory for determining the eventual bearing capacity of rough, shallow foundations was Karl von Terzaghi. According to this notion, a foundation is considered shallow if its depth is equal to or less than its breadth. But according to further research, a foundation may be considered shallow if its depth, measured from the ground surface, is three to four times its breadth.

To get Ultimate bearing capacity $Qu = CN_c + ɣ\ D_f\ N_q + 0.5\ ɣ\ B\ N_ɣ$

Where

γ = unit weight

D_f = Depth of foundation

B = Breath of foundation

C = Cohesion

f.s = factor of safety

To get Allowable bearing

Capacity QA = Qu/f. s

- ➢ *Material used for Triaxial Test*

Triaxial cell, base, pressure system, dial gauge or digital transducer assembly, platen adaptors, and a load frame with a 50 KN capacity.

- ➢ *Procedure for Testing*

A suitable mold is used in the laboratory to create the cylindrical soil sample. The cylindrical soil sample is positioned between two porous discs at the top and bottom

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ends and vertically sealed within a thin rubber membrane. After that, the cylindrical soil sample is set up within a triaxial pressure chamber on a pedestal between loading plates. Water or fluid is poured into the pressure chamber, applying fluid pressure on the cylindrical soil sample's sidewalls.

V. RESULTS AND DISCUSSION

The result of the tests carried out to determine the geotechnical properties of the soil are presented below

Table 1 Soil Description

SOIL DISCRIPTION				
Location	**Depth(m)**	**Soil type**	**Colour**	**Texture**
1. Eta-mbionwi	Topsoil	Silty clay sand	Dark brown	Medium-fine
	0.5	Silty clay sand	Dark brown	Medium-fine
	1.0	Silty clay sand	Reddish brown	Medium-fine
	1.5	Silty clay sand	Reddish brown	Medium-fine
	2.0	Silty clay sand	Reddish brown	Medium-fine
2. Eteo Community Secondary School	Topsoil	Silty clay sand	Dark brown	Medium-fine
	0.5	Silty clay sand	Reddish brown	Medium-fine
	1.0	Silty clay sand	Reddish brown	Medium-fine
	1.5	Silty clay sand	Reddish brown	Medium-fine
	2.0	Silty clay sand	Reddish brown	Medium-fine
3. Ogbere-okee	Topsoil	Clay silty sand	Dark	Medium-fine
	0.5	Clay silty sand	Dark	Medium-fine
	1.0	Clay silty sand	Grey	Medium-fine
	1.5	Clay silty sand	White	Medium-fine
	2.0	Clay silty sand	White	Course-Medium-fine

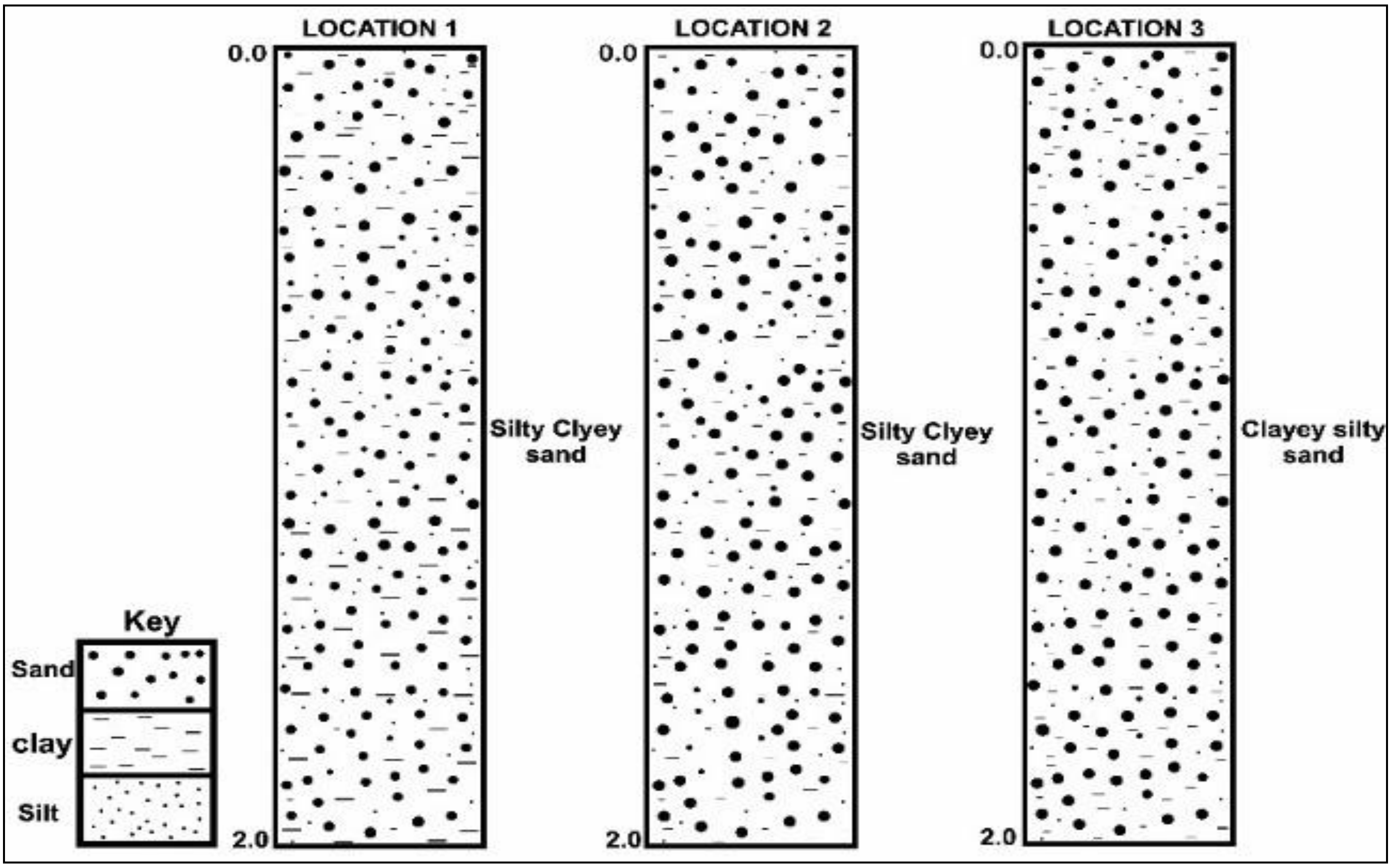

Fig 2 Lithology Description of the Sample

The soils in the study area at Eta-mbionwi (Location 1) and Eteo Community Secondary School (Location 2) are primarily composed of sand with clay and minute silt (Silty Clayey Sand), according to the soil description (Fig. 2), whereas Ogbere-okee (Location 3) is primarily composed of sand with silt and minute clay (Clayey Silty Sand).

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Table 2 Summary of Moisture Content Result

Location	BH	Depth (M)	Moisture content
Eta-mbionwi	1	Topsoil	8.66
		0.5	14.60
		1.0	17.22
		1.5	17.27
		2.0	18.75
		Range	8.66-18.75
		Average	10.72
Eteo Community secondary school	2	Topsoil	7.45
		0.5	11.84
		1.0	17.16
		1.5	18.04
		2.0	18.63
		Range	7.45-18.63
		Average	14.62
Ogbere-okee	3	Topsoil	7.19
		0.5	10.16
		1.0	11.96
		1.5	14.83
		2.0	16.97
		Range	7.19-16.97
		Average	12.22

Table 2 displays the findings of the soils' Natural Moisture Content. At site 1, Eta-mbionwi, values range from 8.66 to 18.75 percent with an average of 10.72 percent; at location 2, Eteo Community secondary school, values range from 7.45 to 18.63 percent with an average of 14.62 percent; and at location 3, Ogbere-okee, values range from 7.19 to 16.97 percent with an average of 12.22 percent. Emesiobi (2000) states that the natural moisture content of gravel and sand may vary from less than 5 to 50%. A soil's shear strength decreases as its moisture content increases because it tends to act more like a liquid. A soil's density and shear strength improve with decreasing moisture content. The soil has a high shear strength, suggesting solid foundation potential, while the moisture content value obtained is modest.

Table 3 Summary of Bulk Density Result

Location	BH	Depth (M)	Bulk density (kg/cm^3)
Eta-mbionwi	1	Topsoil	1183.17
		0.5	1174.41
		1.0	1235.75
		1.5	1237.51
		2.0	1273.44
		Range	1174.41-1273.44
		Average	1220.86
Eteo Community secondary school	2	Range	1255.92
		0.5	1195.44
		1.0	1230.49
		1.5	1381.24
		2.0	1326.91
		Range	1195.44-1381.24
		average	1278.00
Ogbere-okee	3	Topsoil	1456.31
		0.5	1360.00
		1.0	1520.74
		1.5	1952.33
		2.0	2080.31
		Range	1360.00-2080.31
		average	1673.938

The bulk density values at site 1 (Eta-mbionwi) vary from 1174.41-1273.44 kg/cm3 with an average of 1278.00 kg/cm3, position 2 (Eteo Community secondary school) range from 1195.44-1381.24 kg/cm3 with an average of 1278.00 kg/cm3, and location 3 (Ogbere-okee) range from

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1360.00-2080.31 kg/cm3 with an average of 1673.93 kg/m3. (Table 3)

A sturdy working platform is provided by the increased bulk density and compaction that occur with increasing depth. To improve the soil's in-situ (natural state) stiffness and bearing capability, compaction is required. Compaction adds friction from the particles' interlocking, which raises the soils' shear strength.

By making the soil denser and more rigid, voids are eliminated and future soil settling is decreased.

Table 4 Summary of Atterberg Limit Result

Location	Depth(M)	Liquid Limit (LL)%	Plastic Limit (PL)%	Plasticity Index (PI)
BH1	0.5	35.2	26.28	8.92
	1.0	39.9	41.202	1.302
	1.5	45	24.512	20.488
	2.0	48	28.37	19.63
	Range	35.2-48.0	24.51-28.37	1.3-20.48
	Average	35.2-48.0	24.07	10.068
BH2	0.5	-	-	-
	1.0	_-	-_	_-
	1.5	39.7	24.512	15.188
	2.0	32	27.2	19.63
	Range	32.0-39.7	24.512-27.0	15.188-19.63
	Average	35.85	25.856	17.409

According to the results, the soils' liquid limits in locations 1 and 2 range from 35.2-48.0% with an average of 32.05% and 32.0-39.7% with an average of 32.85%, respectively. The soils in this location have intermediate plasticity because the liquid limit values obtained fall within the range of 35–50%, which is the range specified by the code of practice for site investigation (BSS5930, 20019). (Table 4)

Locations 1 and 2 have plastic limits ranging from 24.51% to 28.07% with an average of 24.06% and 24.51% to 28.07% with an average of 25.06%. The soil in the area is plastic because the plastic limit value obtained is within the range of 16–35% of plastic stipulated in the code of practice for site inspection (BSS5930, 20019).

Locations 1 and 2 have plasticity index values ranging from 1.3 to 20.48 percent with an average of 10.07 percent and 15.188 to 19.63 percent with an average of 17.41 percent, respectively. Plasticity values range from 0 to 15% for location one and 15 to 25% for location two, indicating that location one has a low swelling potential and position two has a medium swelling potential, in accordance with the code of practice for site research (BSS5930, 20019).

General Classification	Granular Materials (35% or Less Passing 0.075 mm)			Silt-Clay Materials (More than 35% Passing 0.075 mm)			
Group Classification	A-1	A-3ª	A-2	A-4	A-5	A-6	A-7
Sieve analysis, percent passing:							
2.00 mm (No. 10)	—	—	—	—	—	—	—
0.425 mm (No. 40)	50 max.	51 min.	—	—	—	—	—
0.075 mm (No. 200)	25 max.	10 max.	35 max.	36 min.	36 min.	36 min.	36 min.
Characteristics of fraction passing 0.425 mm (No. 40)							
Liquid limit	—	—		40 max.	41 min.	40 max.	41 min.
Plasticity index	6 max.	N.P.	b	10 max.	10 max.	11 min.	11 min.
General rating as subgrade	Excellent to good			Fair to poor			

Fig 3 Soil and Soil-Aggregate Classification Mixtures by the AASHTO System

Table 5 Summary of Particle Size Distribution

Loc/BH	Depth(M)	%passing sieve Diameter(mm)						%fine	%sand	cu
1		2	1	0.425	0.25	0.015	0.063			
	Top	100	98.44	82.69	67.18	56.23	51.27	51.27	48.73	
	0.5	100	97.07	79.85	62.91	50.95	45.53	51.27	54.47	
	1.0	100	98.30	80.40	63.59	50.51	45.02	45.02	54.98	
	1.5	100	98.09	79.42	62.15	49.83	44.26	44.26	55.74	
	2.0	99.94	97.24	79.14	62.64	50.55	45.64	45.7	54.3	
2	Top	99.72	98.3.4	85.98	71.58	53.74	46.37	46.65	53.35	
	0.5	100	96.1	70.0	41.9	23.0	21.8	21.8	78.2	9

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	1.0	99.94	98.27	82.52	66.33	53.27	47.95	48.01	51.99	
	1.5	100	98.03	81.79	64.75	52.41	46.03	46.03	53.97	
	2.0	100	98.03	83.96	69.61	57.78	52.14	52.14	47.86	
3	Top	100	98.3	78.1	63.4	45.3	29.8	29.8	70.2	2.9
	0.5	99.93	97.72	80.62	54.85	38.69	34.34	34.41	65.59	
	1.0	99.81	96.90	86.65	74.34	60.18	74.34	74.53	25.47	
	1.5	99.8	89.1	63.3	50.2	30.2	25.2	25.4	74.6	4.9
	2.0	99.55	94.37	77.17	53.30	37.52	32.26	32.71	67.29	

The coefficient of uniformity of the soils at position 2 at a depth of 0.5 meters is larger than 5 (>5), indicating that the soils at this location are poorly graded, according to the particle size result (Table 5, fig. 3). Because of the varying proportions of soil particle size, the area will have a high carrying capacity.

The fact that the soil at position 3 for Topsoil and 1.5 m has a coefficient of uniformity below (<5) suggests that the soils there are not well graded.

G = Gravel, S = Sand, M = Silt, C = Clay, O = Organic

Major division			Group symbol	Typical name	Classification criteria	
Coarse-grained soils (More than 50% retained on No. 200 ASTM sieve)	Gravels 50% or more of coarse fraction retained on No. 4 ASTM sieve	Clean gravels	GW	Well-graded gravels and gravel-sand mixtures, little or no fines.		$U = D_{60}/D_{10}$ greater than 4 $C_c = D^2_{30}/(D_{60} \times D_{20})$ between 1 and 3.
			GP	Poorly-graded gravels and gravel-sand mixtures, little or no fines.	Classification on the basis of percentage of fines. Less than 5% passing No. 200 ASTM sieve—GW, GP, SW, SP. More than 12% passing No. 200 ASTM sieve— GM, GC, SM, SC. 5% to 12% passing No. 200 ASTM sieve—Border-line classification requiring use of dual symbols.	Not meeting both criteria for GW.
		Gravels with fines	GM	Silty gravels, gravel-sand-silt mixtures.		Atterberg limits plot below A-line or plasticity index less than 4.
			GC	Clayey gravels, gravel-sand-clay mixtures.		Atterberg limits plot above A-line or plasticity index less than 4.
	Sands More than 50% of coarse fraction passes No. 4 ASTM sieve	Clean sands	SW	Well-graded sands and gravelly sands, little or no fines.		U greater than 6 C_c between 1 and 3.
			SP	Poorly-graded sands and gravelly sands, little or no fines.		Not meeting both criteria for SW.
		Sands with fines	SM	Silty sands, and-silt mixtures.		Atterberg limits plot below A-line or plasticity index less than 4.
			SC	Clayey sands, sand-clay mixtures.		Atterberg limits plot above A-line or plasticity index greater than 7.
Fine-grained soils (50% or more passes No. 200 ASTM Sieve)	Silts and Clays (Liquid limit 50% or less)		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands.	Check Plasticity Chart	
			CL	Inorganic clays or low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.		
			OL	Organic silts and organic silty clays of low plasticity.		
	Silts and clays (Liquid limit greater than 50%)		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts.		
			CH	Inorganic clays of high plasticity, fat clays.		
			OH	Organic clays of medium to high plasticity.		
Highly organic clays			P_t	Peat, muck and other highly organic soils.	Fibrous organic matter, will char, burn, or glow. Readily identified by colour, odour, spongy feel, and fibrous texture.	

Fig 4 Unified Soil Classification System Designation

Table 6 Summary of Triaxial Test Result

Undrained cohesion (kN/m^2)	**Angle of internal friction**	**Moisture content**	**Bulk unit weight (kN/m^2)**	**Dry unit weight (kN/m^2)**
4.3	8	20.4	18.1	15.0

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According to Table 6's results, the soil's bearing capacity at site 2 (Eteo Community Secondary School) at a depth of one meter is 30.09 kN/m2. Weak soils that cannot sustain large loads from structures without experiencing excessive settlement or shear failure, such as loose clay, peat, or soft silts, are indicated by this soil bearing capacity rating (Das, 2016).

Unless deep foundations or ground improvement are used, it is often inappropriate for heavy industrial or multi-story buildings (Coduto et al., 2011).

Unless a foundation that distributes the weight sufficiently is used, light constructions may nevertheless have uneven or prolonged settling [9].

VI. CONCLUSION

The soil types at the three places are Dark Brown silty clayey sand for the first location, Brown/Reddish silty clayey sand for the second location, and Dark/Gray clayey silty sand for the third location, according to the research of the soils in various areas of Eteo, Eleme. In all three (3) locations, the average natural moisture content of the soil is 10.72%, 14.62%, and 12.22%. The low moisture content values show that the soils have a high carrying capacity due to their strong shear strength. Locations 1, 2, and 3 have average bulk densities of 1278.00 kg/cm3, 1278.00 kg/cm3, and 1673.93 kg/m3, respectively. The bulk density value and the level of compaction increase with depth. To improve the soil's in-situ (natural state) stiffness and bearing capability, compaction is required. Compaction adds friction from the particles' interlocking, which raises the soils' shear strength. According to the Atterberg limit finding, Locations 1 and 2 have moderate plasticity with liquid limit average values of 32.05 and 35.85, respectively. Locations 1 and 2 have plastic limit average values of 24.07% and 25.86%, respectively, indicating that the soil in these areas is readily distorted. site 1 has a low swelling potential, whereas site 2 has a medium swelling potential, as shown by the average plasticity index values of 10.07% and 17.41, respectively. According to the particle size result, the soils at site 2 (0.5 m) have a coefficient of uniformity of less than 5, which suggests that the soils there are poorly graded.

The soil at site 3 (1.5 m and topsoil) has a coefficient of uniformity <5, which suggests that the soils there are not well graded.

The triaxial test, which was conducted at position 2 at a depth of 1 m, indicates that the soil's bearing capacity is 30.09 kN/m2. Weak soils that cannot sustain large loads from structures without experiencing excessive settlement or shear failure, such as loose clay, peat, or soft silts, are indicated by this soil bearing capacity rating [13]

Unless deep foundations or ground improvement are used, it is often inappropriate for heavy industrial or multi-story buildings [12]

Without a foundation that distributes the weight sufficiently, light constructions may nevertheless experience uneven or persistent settling.

RECOMMENDATIONS

➢ *It is Advised to use the Following Foundation Types Due to the Limited Soil Bearing Capacity:*

- A raft foundation, which lessens the strain on the earth underneath by distributing the structural load across a wide region. When the SBC is less than 75 kN/m2, it works well in fragile soils [8].
- To shift the weight to deeper, more capable strata, piles may be driven or drilled if the weak soil reaches a significant depth.

REFERENCES

[1]. Akpokodje, E. G. 1986. The Engineering Geology Characteristics and Classification of the Major Superficial Soil of the Niger Delta. Engineering Geology Vol. 23, pp. 193-211.

[2]. Akpokodje, E. G. 2001. Introduction to Engineering Geology. Pam Unique Publication Co. Ltd. Port Harcourt 272pp.

[3]. Nnurum, E. U., Ugwueze, C. U., Tse, A. C., & Udom, G. J. 2021. Soil Gradation Distribution across Port Harcourt, South-eastern Nigeria. IJRES: 9, 11: 25-33

[4]. Nwankwoala HO, Youdowei PO (2009) Assessment of Some environment problems associated with Road construction in the Eastern Niger Delta. Afr J Environ Pollut Health 8: 1-7.

[5]. Nwankwoala, H. O., Amadi, A. N., Warmate, T., & Jimoh, M. O. (2015). Geotechnical Properties of Sub-Soils in Escravos Estuary, Western Niger Delta, Nigeria. American Journal of Civil Engineering and Architecture, 3(1), 8–14. https://doi.org/10.12691/AJCEA-3-1-2

[6]. Oghenero, E., Enuvie, G. A., & Akaha, T. (2014). Geotechnical Properties of Subsurface Soils in Warri, Western Niger Delta, Nigeria. http://www.scienpress.com/Upload/GEO/Vol%204_1_8.pdf

[7]. Terzaghi, K. and Peck, R.B. 1967. Soil Mechanics in Engineering Practice. John Wiley and Sons. New York. 356pp.

[8]. Tomlinson, M., & Woodward, J. (2015). Foundation Design and Construction (7th ed.). CRC Press.

[9]. Tse, A. C. 2006. Engineering Geology Properties of Foundation Soil in Part of the Mangrove Swamps of the Eastern Niger Delta, Nigeria. Unpublished Ph. D Dissertation, Department of Geology, University of Port Harcourt, 300pp.

[10]. Udoh, G. C., Udom, G. J., & Nnurum, E. U. (2023). Suitability of soils for Foundation Design, Uruan, South Southern Nigeria. International Journal of Multidisciplinary Research and Growth Evaluation, 4(4):962-972

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may2065

[11]. Udom, G. J., & John, P. N. (2023). Geotechnical Properties of Foundation Subsoils in Parts of Port Harcourt City, Obio/Akpor and Ikwerre Local Government Area, Rivers State, Nigeria. British Journal of Earth Sciences Research. https://doi.org/10.37745/bjesr.2013/vol11n4119
[12]. Coduto, D. P., Yeung, M. C., & Kitch, W. A. (2011). Geotechnical Engineering: Principles and Practices (2nd ed.). Pearson Education.
[13]. Das, B. M. (2016). Principles of Foundation E3gineering (8th ed.). Cengage Learning.