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GEOTECHNCIAL ASSESSMENT OF PART OF PORT HARCOURT, NIGER DELTA FOR STRUCTURAL ANALYSIS

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Abstract

The Study was carried out within Parts of Port Harcourt, Rivers State. investigations shows that the topsoil is underlain by a Firm to Stiff Sandy clay layer of low compressibility with cu > 50 KN/m2 (about 12m thick) with average Index Properties which indicates average shear resistance to shear deformations. Also Cone Values within this layer reflects values greater than 10kg/cm2 with friction ration > 3 at the top layer. This layer , overlies a well sorted ,Medium Dense sandy Layer (phi=300 - 310 ,) and average N Values of 12.. The allowable bearing capacity profile of the sub-surface shows average bearing Capacities characteristics(1.5m:133KN/m2 ,). Compressibility of the top soil under the influence of load from Pressure Bulb analysis , indicates Compression Index and Compression Ratio value less than 0.1.. Settlement predictions based on a loading >200KN/m2 indicates a tolerable settlement of <40mm.

Introduction

The Need for a thorough assessment of the sub-soil soil properties is very imperative for the structural analysis in the design of foundation in the Niger Delta (Warmate T and Nwakwola, 2014) . The study of this section of the Niger Delta, reveals the stratigraphy of the superficial deposit underlying the site to a depth of 20m and also determines relevant engineering characteristics of the deposits to enable appropriate foundation design and foundation recommendation of the structure within the study area.

Site description and geology

Geologically, the site is underlain by the Coastal Plain sands, which in this area is overlain by soft-firm silty clay sediments belonging to the Benin Formation of Pleistocenic age (short and stauble, 1967). The general geology of the area essentially reflects the influence of movements of rivers, in the Niger delta and their search for lines of flow to the sea with consequent deposition of transported sediments. In broad terms, the area may be considered flat. The surface deposits in this area comprises silty-clays. The near surface silty clays are subjected to mild desiccation during the dry season. Substantial seasonal variations in moisture are expected in the area. This could result in some false enhancement of strength in the dry season. The sandy layers underlying the top clay are predominantly medium to course in grain sizes, fairly well graded and found to exist in various states of compaction.

Fig 1. Site Location

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The Area is situated in Port Harcourt, within the Niger Delta. Close to the Airforce Base, Aba Road, Port Harcourt with coordinates. 4°50'32.7"N 7°01'00.2"E

Literature /Methods

Investigative procedures comprising 3nos borings, and 3nos cone Penetrometer, at a pre-determined locations at the proposed construction site.

Cone penetration testing (CPT)

Hydraulically operated, GMF type, static penetrometer of 100KN capacity was used in the cone resistance soundings. Mechanical mantle cone with friction jacket was used in the operation.

Soil borings

Conventional boring method which consists of the use of the light shell and auger hand rig was used in the boring operation. During the boring operations, disturbed samples were regularly collected at depths of 0.75m intervals and also when change of soil type is noticed. Standard Penetration Tests (SPT) was performed through cohesion less soils. The main objective of this test is to assess the relative densities of the cohesion less soils penetrated.

Choice of parameters

In clays the ultimate bearing capacity of spread foundation is calculated using total stress parameters. This gives the end-of-construction case, which is the worst condition, and allows the design to be based on undrained shear strength tests the bearing capacity analysis for the underlying soils is limited to the near surface sandy clay. In general, the sandy clay is partially saturated and when tested in unconsolidated and undrained conditions, exhibits both cohesion and angle of internal friction for its shear strength characteristics. However, the frictional component of shear strength is neglected for the clay encountered within normal founding depths for shallow foundations when estimating ultimate bearing pressures for the clay. . Modified Terrzerghi Bearing Capacity equation (Murthy, 2007) was used in the calculation of the ultimate bearing capacity of the soil for rectangular foundations.

$$\mathbf{q_u = CN_c \left[1 + 0.3\frac{B}{L}\right] + \gamma D_f\ N_q + \frac{1}{2}\gamma B N_\gamma \left[1 - 0.2\frac{B}{L}\right]} \qquad \mathbf{1}$$

Consolidation tests were carried out to provide information for settlement analysis. Method proposed by Pacheco Silva (1970) was used to determine the Preconsolidation Pressure graphically. Similar to Casagrande's (1936) method, Pacheco Silva's method uses an empirical construction from the e – log p ′ curve, where e is the void ratio and p ′ is the vertical effective stress. Settlement Analysis based on Normal and Over consolidated soils are stated as follows(Coduto D.P, 2007)

$$s = \sum \frac{c_c}{1 + e_o} H log \left[\frac{\sigma'_{zf}}{\sigma'_{zo}}\right] \qquad \mathbf{2}$$

$$s = \sum \frac{c_r}{1 + e_o} H log \left[\frac{\sigma'_{zf}}{\sigma'_{zo}}\right] \qquad \mathbf{3}$$

Where:
s= settlement
e_o= void ratio
H= height of Clay
σ'_{zf}=final vertical effective stress
σ'_{zo} = Initial vertical effective stress
c_c= compression index
c_r = recompression Index

Results of geotechnical studies

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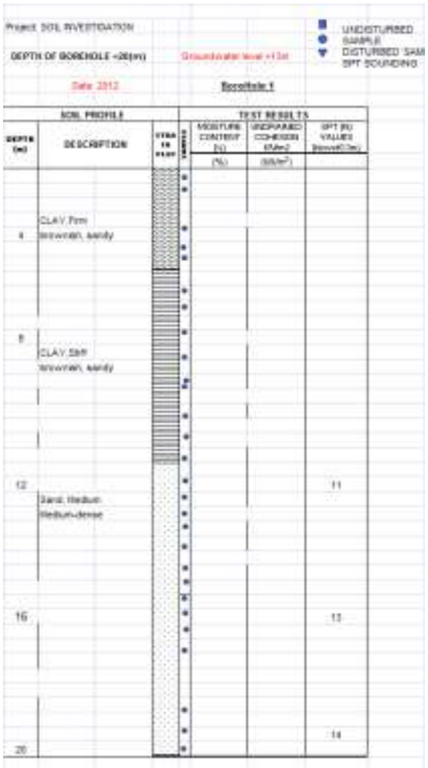
Soil stratigraphy

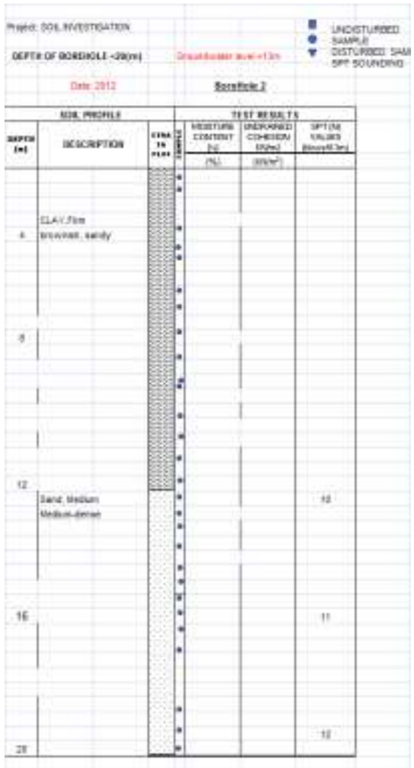
The data from the soil sampling, standard penetration tests, and laboratory tests were carefully evaluated for the determination of the stratification of the underlying soils. The evaluation uncovered two primary soil zones beneath the site from the three Bore-holes.

A typical soil profile characterizing the site is described below.

Table 1 : Soil Profile

layer	Lithology	Thickness(Min),m	Thickness(Max),m
1	Firm to stiff Sandy Clay	11	12
2	Medium Dense Sandy Layer	8	9





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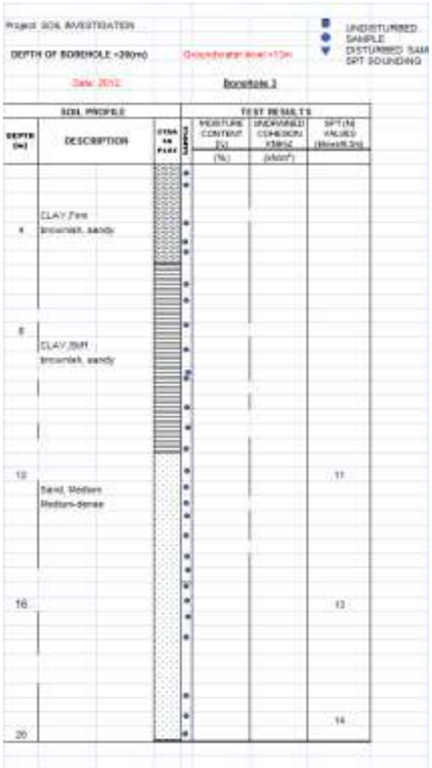


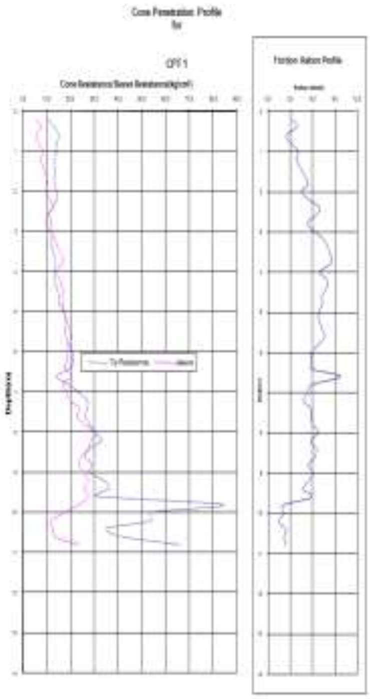
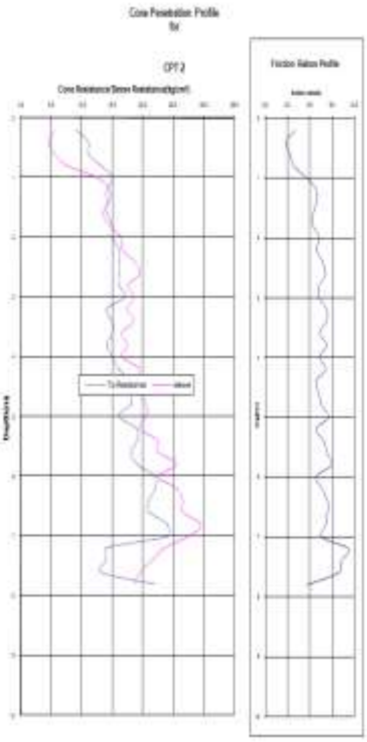


Fig 2 showing lithology and CPT Profile



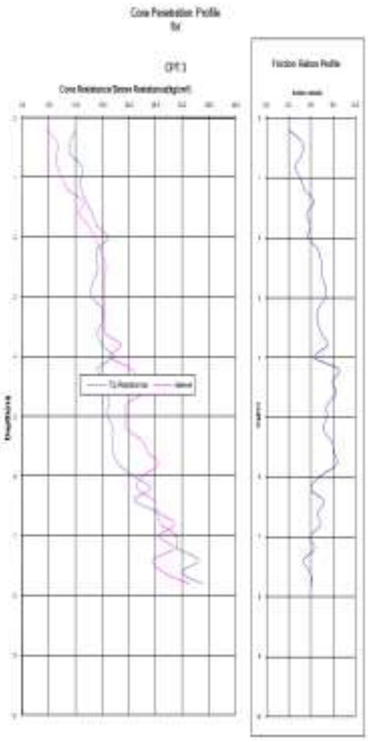


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Fig 3, Showing CPT Profile

Engineering properties of the soils

Classification, strength and compressibility characteristics of the soils were determined from the laboratory and in-situ tests. The relevant index and engineering parameters of the soils are summarized below.

Firm to stiff sandy clay

The thickness of this deposit, as confirmed by the borings cone Resistance varies within 11-12m. The clay is mainly of low compressibilty and Brownish in colour..The ranges of variations in the relevant index and engineering parameters of the clay are summarized below:-

Table 2: Soil Properties

	BH1		BH2		BH3	
	Min	Max	Min	Max	Min	Max
Natural moisture content (%	19	24	19	19.1	20	22
Liquid limit (%)	33	41	27	42	29	21
Plastic limit (%)	20	21	17.9	20	17.8	21
Plasticity index (%)	13	21	13	22	13.1	15
unit weight (kN/m^3)	19.7	19.9	15.9	20	19.7	21.1
Undrained cohesion (kPa)	53	70	50	60	50	52
Angle of internal friction (°)	4	5	4	5	3	4

Medium – dense sand

Underlying the sandy clay layer is a layer of predominantly well sorted, medium-dense sand. About 8-9m of the sand deposit was proved. The ranges of variations in the relevant parameters of the sand are given below:-

Table 3: Showing Sandy Properties

	BH1	BH 2	BH 3
Effective particle size d_{10} (mm)	0.2	0.25	0.4
Mean particle size d_{50} (mm)	0.5	0.55	0.54
Coefficient of uniformity Cu,	3.0	2.6	2.61
SPT penetration resistance N values (blows/0.3m)	13	11	11

Table 4: Triaxial

BH 1, 3m

Minor Principal Stress	100KN/m^2	300KN/m^2
Deviator Stress	121KN/m^2	145KN/m^2
Major Principal Stress	221KN/m^2	445KN/m^2

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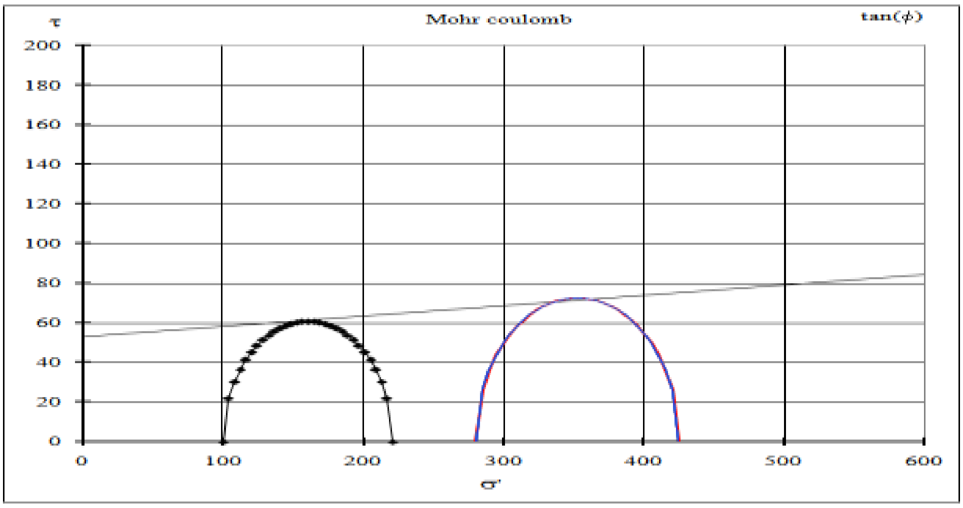

Fig 4: Mohr Circle Diagram for BH 1,3m

Table 5 : UU Test: BH 3, 3m

Minor Principal Stress	100KN/m^2	300KN/m^2
Deviator Stress	164KN/m^2	191KN/m^2
Major Principal Stress	264KN/m^2	491KN/m^2

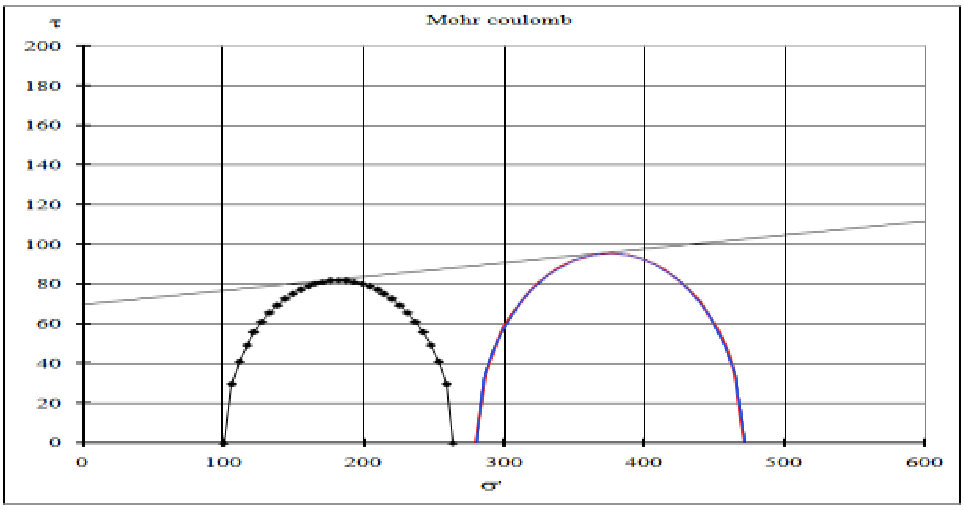

Fig 5: Mohr Circle Diagram for BH 3,3m

Table 6: UU Test BH 2, 6m

Minor Principal Stress	100KN/m^2	300KN/m^2
Deviator Stress	154KN/m^2	199KN/m^2
Major Principal Stress	254KN/m^2	499KN/m^2

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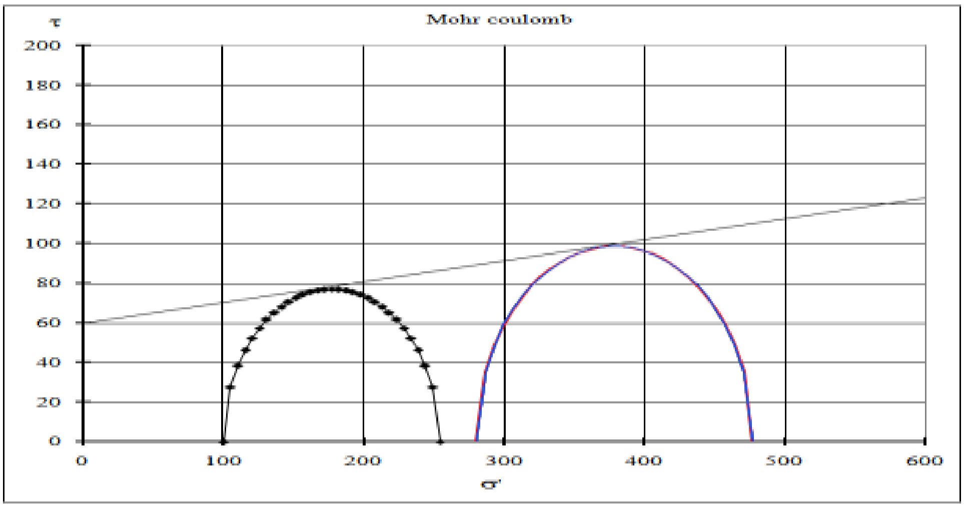

Fig 6: Mohr Circle Diagram for BH 2,6m

Bearing capacity

Undrained cohesion of 50kPa and angle of internal friction of zero are adopted for the bearing capacity analysis. This Values least within the area tested.

Table 6: Bearing Capacity

Foundation Depth (m)	Width (m)	Undrained Shear Strength (KN/m^2)	Ultimate Bearing Pressure (KN/m^2)			Allowable Bearing Pressure (KN/m^2)		
			L/B =1	L/B= 1.5	L/B = 5	L/B=1	L/B=1.5	L/B=5
1	1	50	388.572	360.078	320.1864	129.52	120.03	106.73
1	1.5	50	388.608	360.117	320.2296	129.54	120.04	106.74
1	2	50	388.644	360.156	320.2728	129.55	120.05	106.76
1	2.5	50	388.68	360.195	320.316	129.56	120.07	106.77
1	5	50	388.86	360.39	320.532	129.62	120.13	106.84
1	10	50	389.22	360.78	320.964	129.74	120.26	106.99
1.5	1	50	397.572	369.078	329.1864	132.52	123.03	109.73
1.5	1.5	50	397.608	369.117	329.2296	132.54	123.04	109.74
1.5	2	50	397.644	369.156	329.2728	132.55	123.05	109.76
1.5	2.5	50	397.68	369.195	329.316	132.56	123.07	109.77
1.5	5	50	397.86	369.39	329.532	132.62	123.13	109.84
1.5	10	50	398.22	369.78	329.964	132.74	123.26	109.99

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2	1	50	406.572	378.078	338.1864	135.52	126.03	112.73
2	1.5	50	406.608	378.117	338.2296	135.54	126.04	112.74
2	2	50	406.644	378.156	338.2728	135.55	126.05	112.76
2	2.5	50	406.68	378.195	338.316	135.56	126.07	112.77
2	5	50	406.86	378.39	338.532	135.62	126.13	112.84
2	10	50	407.22	378.78	338.964	135.74	126.26	112.99

Settlement of shallow foundation

Settlement of shallow foundation for net foundation load of $\Delta\sigma$ **=200**kPa can be calculated.

Table 8: Consolidation Paramater

Bore-Hole Nos	Depth (m)	Pressure Range (Kpa)	Coefficient of Consolidation Cv(m^2/yr)	Coefficient of Volume Compressibility (MN/m2) Mv 10^{-4}	Coefficient of Permeabilty K 10^{-8}cm/s
2	**6m**	0-25	12.41	2.800000	1.08E-7
		25-50	17.45156	3.423968	1.86E-7
		50-100	18.615	2.336211	1.35E-7
		100-200	18.615	1.644399	9.51E-8
		200-400	17.45156	0.992685	5.38E-8
		400-800	17.8704	0.586354	3.26E-8
1	**3**	0-25	17.18307	5.000000	2.67E-7
		25-50	17.18307	4.455696	2.33E-9
		50-100	17.52	2.867384	1.56E-7
		100-200	17.8704	1.766234	9.81E-8
		200-400	17.65849	1.057641	5.8E-08
		400-800	18.615	0.729335	4.22-08
3	**3**	0-25	18.615	3.600000	2.08E-7
		25-50	18.615	4.439960	2.57E-7
		50-100	17.8704	2.857143	1.59E-7
		100-200	17.8704	1.966874	1.09E-7
		200-400	17.18307	1.055966	5.64E-8
		400-800	18.615	0.660734	3.82E-8

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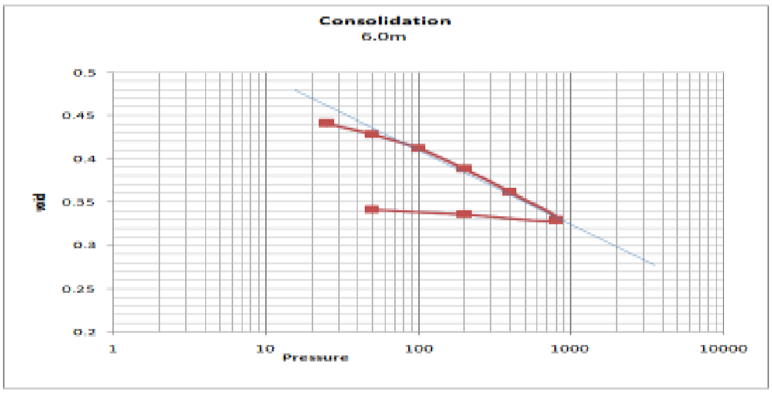

Fig 7 : Showing Void Ratio Pressure for Bh 2

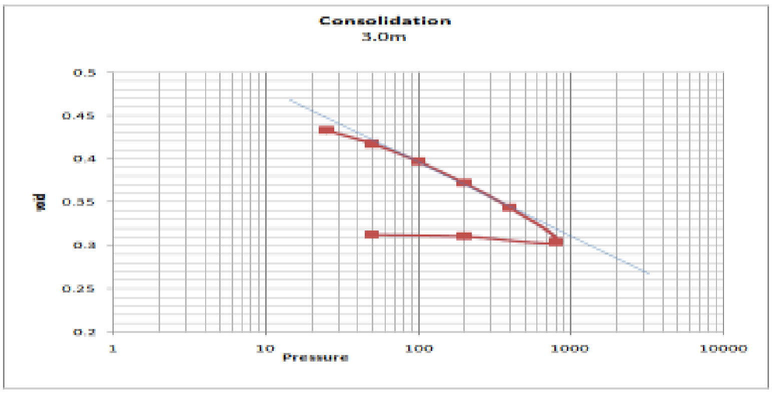

Fig 8 : Showing Void Ratio Pressure for Bh 1

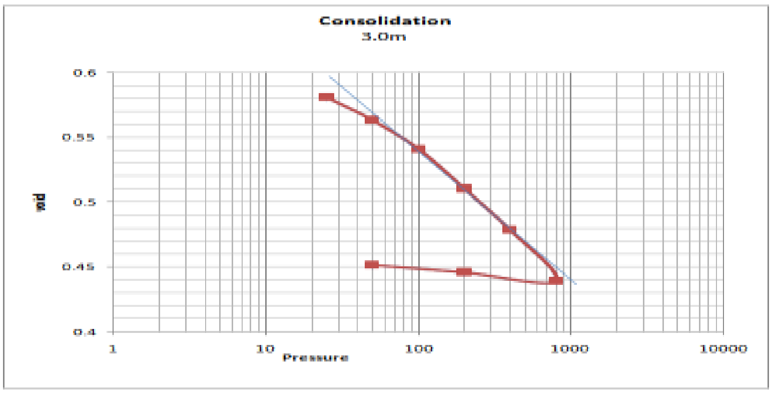

Fig 9: Showing Void Ratio Pressure for Bh 3

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Table 9 Settlement Parameter

BH, Depth	BH 3, 3m	BH1,3	BH2,6
Sample	**Normally Consolidated**	**Normally Consolidated**	**Normally Consolidated**
e_o	**0.055**	**0.450**	**0.451**
Preconsolidation Pressure	**22**	**39**	**39**
Cc	**0.055**	**0.088**	**0.088**
Compression ratio	**0.034**	**0.06**	**0.06**
P_i (elastic)	**3**	**4**	**4**
Pc (Primary)	**22**	**39**	**39**

Computed rate of settlements

Rate of Settlements	**Years**	**Years**	**Years**
T50	**0.02**	**0.026**	**0.026**
T90	**0.1**	**0.11**	**0.1125**

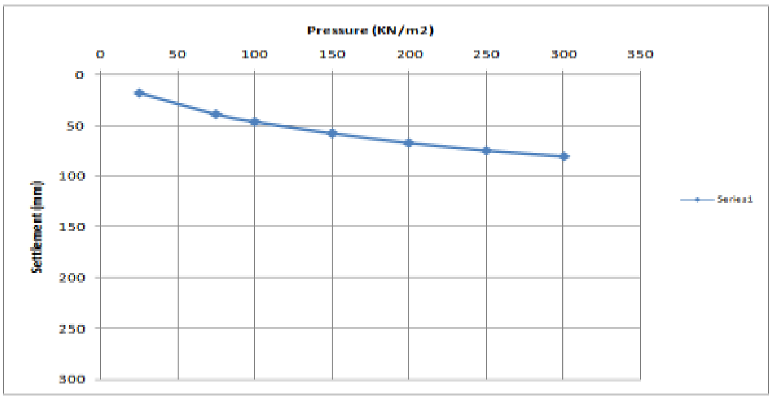

Fig 10. Showing settlement-Pressure variation for Bh 2

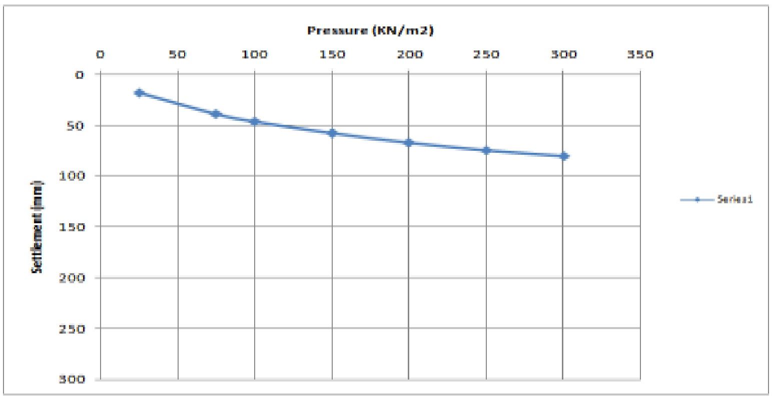

Fig 11. Showing settlement-Pressure variation for Bh 1

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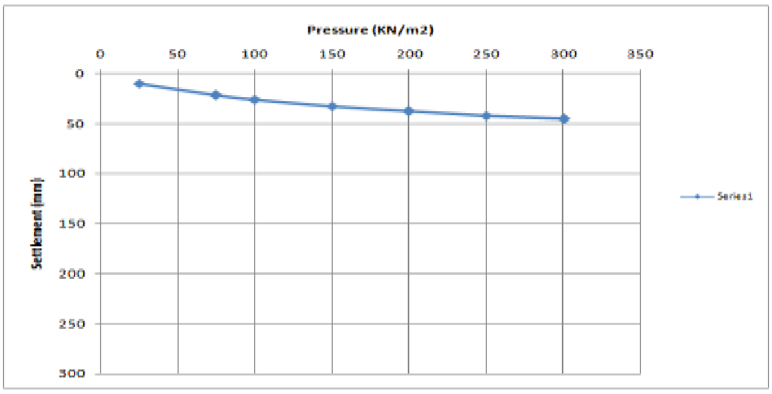

Fig 12. Showing settlement-Pressure variation for Bh 3

Discussion

Field and Laboratory investigations shows that the topsoil is underlain by a Firm to Stiff Sandy clay layer of low compressibility with cu > 50 KN/m2 (about 12m thick) with average Moisture content , Liquid limit and Plastic Limit which indicates average shear resistance to shear deformations. Also cone Values within this layer reflects values greater than 10kg/cm2 with friction ration > 3 at the top layer. For design purposes, undrained cohesion of 53kPa, angle of internal friction of zero and unit weight of 18kN/m3 are suggested for this layer.

This layer , overlies a well sorted ,Medium Dense sandy Layer (phi=300 - 310 ,) and average N Values of 12. For design purposes, mean angle of internal friction of 31o and cohesion zero are suggested for the sand layer.

The allowable bearing capacity profile of the sub-surface shows average bearing Capacities characteristics(1.5m:133KN/m2 ,).

Compressibility of the top soil under the influence of load from Pressure Bulb analysis , indicates Compression Index and Compression Ratio value less than 0.1. Moderate Permeabilty is expected as indicated by the K Values. Settlement predictions based on a loading >200KN/m2 indicates a tolerable settlement of <40mm.

Conclusions

The Study was conducted with the principal intention to determine the prevailing subsoil conditions at the area of study and also to provide foundation recommendations. It was observed that a shallow foundation with bearing capacity of 133KN/m2 within depth <2 m can be adopted with low settlement characteristics expected. The final Depth and the dimension of the footing should be determined by the structural engineer based on the expected column load. The water table was at 13m, this implies it will not pose any serious challenge during excavation.

References

1. *Casagrande, A (. 1936). The determination of the pre-consolidation load and its practical*
2. *Significance. In Proceedings of the 1st International Soil Mechanics and Foundation Engineering Conference, Cambridge, Mass., 22–26 June 1936. Edited by A. Casagrande. Graduate School of Engineering, Harvard University, Cambridge, Mass. Vol. 3, pp. 60–64.*
3. *Coduto D.P, (2007). Geotechnical Engineering: Principle and Practices. Prentice Hall of Indian Private Limited. New Delhi*
4. *Murthy, V.N.S (2007) Soil Mechanics and Foundation Engineering. CBS Publishers and Distributors Pvt Ltd, New Delhi*
5. *Pacheco Silva, F. (1970). A new graphical construction for determination of the pre- consolidation stress of a soil sample. In Proceedings of the 4th Brazilian conference on Soil Mechanics and Foundation Engineering, Rio de Janeiro, Brazil. Vol. 2, No.1,*
6. *Short and Stauble (1967). Outline of Geology of the Niger Delta. Am Assoc. of Petroleum Geologists Bull Vol 51, 761-779*

Global Journal of Engineering Science and Research Management

7. *Nwankwoala, H.O and Warmate, T (2014.) Geotechnical Assessment of Foundation Conditions of a Site in Ubima, Ikwerre Local Government Area, Rivers State, Nigeria. International Journal of Engineering Research and Development IJERD 98: 50 63.*