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Bored Pile Designs Using Geotechnical Indications of Port Harcourt Metropolis

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ABSTRACT

With the observation of moderate bearing capacities in the Study area, deep foundation (pile) has become imperative for the construction high rise building . The study reveals pile characteristics and founding depth within the study area. Using critical Pile settlement computation, founding depths for piles were revealed and safe working Load of not greater than 1639kN were recorded for piles with diameter less than 0.6m . The study also reveals acceptable Factor of Safety values of 2.5 -3, as Factor of Safety value of 2 results in large settlement for large diameter piles.

KEYWORDS: Pile, Bored Piles, Settlement, Niger Delta, Safe Working Load.

INTRODUCTION

The need for Deep foundation has become imperative, due to the moderate bearing capacity values observed for shallow depths (<3m) within the Port Harcourt Metropolis. These values which are unsuitable for high rise building, necessitates the construction of multi- storey buildings using deep (pile) foundation. The need of Deep (pile) foundation for Heavy structures in the Niger Delta have been recognized by several authors (Teme *et al*, 2008) Piles are structures that transmit load to stable stratum (Das, 1994) The study aims at the design of Bored Piles within the Port Harcourt Metropolis. This involves calculating the work load for different sizes of piles and their anticipated settlement characteristics. The study involves determination of the stratigraphy of the deposit underlying the study area to a depth of 30m, determine relevant engineering characteristics of the deposits to enable appropriate pile foundation design of the structure.

Pile load test carried out by Akande et al. (2016) within the region recorded Pile Bearing capacity values of 4188kN/m^2 from a 406mm by 30m pile . Also Akpila et al, (2006), observed 1070kN as the Allowable Pile Working Load for a 406mm diameter pile within the Niger Delta region .

SITE DESCRIPTION AND GEOLOGY

The study area is located within G.R.A Phase 1, Port Harcourt, with Geographical Location, N 040 49’19.9” E 070 0’ 9.018”. Geologically, the site is underlain by the Coastal Plain sands, which in these areas are overlain by Alluvial Pleistocenic soft-firm silty clay sediments belonging to the Dry flat land and plain of the geomorphic units of the Niger Delta . The Niger Delta consist of three basic stratigraphic units, the Benin, Agbada, and the Akata Formations (Short and Stauble, 1967) . Generally geology of the areas 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 areas may be considered flat.

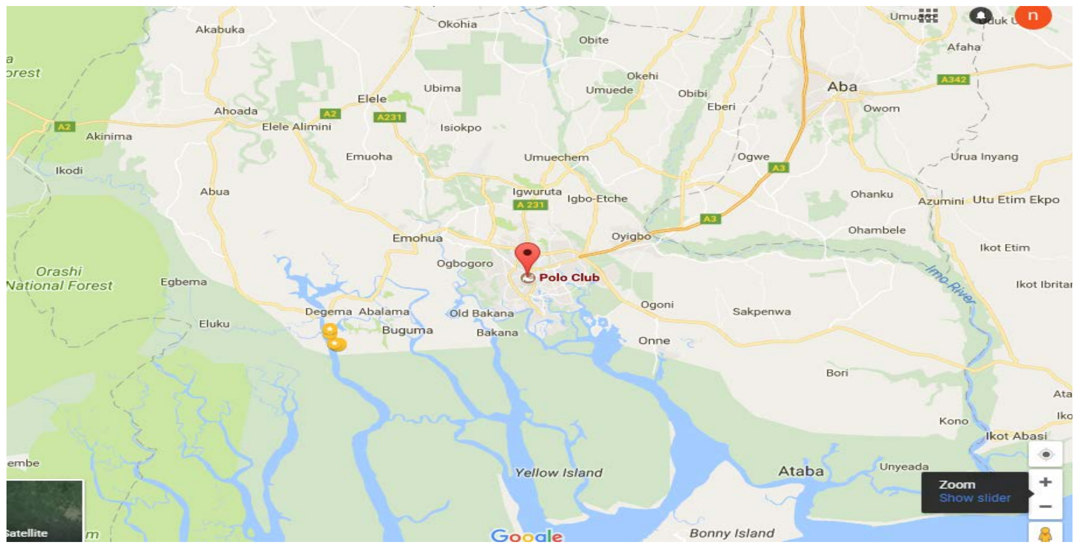

Figure 1: Location Map

METHODS

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. Undisturbed cohesive soil samples were retrieved from the boreholes with conventional open-tube sampler 100mm in diameter and 450mm in length. All samples recovered from the boreholes were examined, identified and roughly classified in the field. Standard Penetration Tests (SPT) was performed every 1.5m advance through cohesionless soils. The main objective of this test is to assess the relative densities of the cohesionless soils penetrated. The penetration resistance in blow counts with depth are indicated on the borehole logs.

Piles Installation/ Pile Carrying Capacity

Piles installation in this study was done using Rotary Drilling under a Bentonite Slurry. Carrying capacity of non- displacement piles within the study area was done through the use of soil mechanics formula . The choice of non- displacement pile is imperative due to the cost effectiveness of installation and its non-impact to the environment . But these advantages is affected by the boring or drilling operations which eventually loosen cohesionless soils and thus lower the end resistance (Tomlinson, 1995). Thus Ø values used in the relevant equations should be representative of a loosed condition with exception of piles installation done under a bentonite slurry conditions . Tomlinson (1995), stated the carrying capacity of single pile using the Standard Penetrometer method. The Carry capacity in this study is obtained from the Skin friction and the End bearing. The Ultimate Bearing Capacity is as follows

$$Q_P = Q_S + Q_b + W_P \tag{1}$$

where ;

$Q_P = Ultimate\ Bearing\ Capacity\ of\ pile$

$W_P = weight\ \ of\ pile$

Due to the insignificance component of W_p, in relations to Q_p, this value is neglected in most scenarios. (Tomlinson, 1995). Workload for Pile Shaft for sand and clay are stated below

Pile shaft for sand

$$Q_S = q_s A_S \tag{2}$$

$$q_s = k_s \sigma_{vo} tan\delta \tag{3}$$

Pile Shaft for clay

$$Q_S = q_s A_s \tag{4}$$

$$q_s = \alpha \times c_u A_S \tag{5}$$

and Pile Base (sand) are given as;

$$Q_b = q_b A_B \tag{6}$$

$$q_b = N_Q \sigma'_{VO} \tag{7}$$

where;

Q_s = ultimate Shaft Resistance in skin friction

Q_B = ultimate Resistance of base

q_s = Design unit Skin Friction

q_b = Design unit base resistance

A_B = Base Area

A_S = Area of Shaft

N_Q = Bearing Capacity Factors

$\sigma'_{vo=}$ average effective overburden pressure

k_s = Coefficient of horizontal soil stress

δ = angle of wall friction (0.75∅)

α = adhesion factor

c_u = undrained cohesion

Bearing Capacity Values (Nq) based on the works of Berenzantsev were adopted (Berezantsev, 1961). These values takes into account the Depth to Width ratio and conform to field Criteria of most Pile Failures (Tomlinson, 1995). The ultimate Bearing Capacity can be described, as the load resulting in a settlement of one - tenth of the diameter of the pile (Vesic, 1970), though this rule excludes large diameter piles.

An average cu of less than 50kN/m^2 and average adhesion factor of 0.5 was considered in this study. This values corroborate research values on bored piles in study area (Skempton, 1959, Nwankwoala *et al***,** 2016, Ngerebara *et al*, 2014)

Settlement Analysis

The Settlement of piles at working load governs the final adoption of pile shaft and base diameter. Settlement calculations based on single pile is stated as follows;

$$p = \frac{(w_s+2w_b)L}{2A_S E_P} + \frac{\pi . w_b}{4A_b} . \frac{B(1-V^2)I_P}{E_b} \qquad 8$$

where;

w_s and w_b = loads on the pile shaft and base respectively
L = shaft lenght
A_s and A_b = cross sectional area of the shaft and base respectively
E_p = elastic modulus of the pile material
B = pile width
v = Poisson ratio of the soil
I_p = influence factor related to the ratio of L/B
E_b = deformation modulus of the soil beneath the pile base

With $v = 0.25$ and L/B > 5, I_p is taken as 0.5. A minimum value of 17000000kpa is assumed as the elastic Modulus of the concrete material. Derivation of the deformation modulus of the soil beneath pile base were made from Das 's assumption (Das, 1994).

Critical Depth for Settlement

Pile settlement can be reduced by increasing the depth of piles (Hull, 1987). Piles located beyond this critical depth has no effect on settlement amelioration. This Critical depth for settlement which is a factor of the Elastic modulus of the pile material and the soil beneath the pile base is stated as follows;

$$L_c/d = \{(\pi . E_p . A_p)/(E_s . d^2)\}\, 1/2$$

where;

L_c = Critical depth for settlement
A_p = cross sectional area of Pile
E_p = elastic modulus of the pile material
d = pile diameter
E_b = deformation modulus of the soil beneath the pile base

RESULTS

Soil Stratigraphy

The data from the soil sampling, and laboratory tests were carefully evaluated for the determination of the stratification of the underlying soils. The evaluation uncovered four primary soil zones beneath the site. A typical soil profile characterizing the site is described below.

Table 1: Showing Lithology

Layers	Depth(m)	Thickness (m)	Lithology
1	0-6	6	Clay, sandy, soft-firm Layer
2	6-11.5	5.5	Clay, sandy stiff layer
3	11.5-18	6.5	Sand, loosed,
4	18-30	12	Sand, Medium Densed

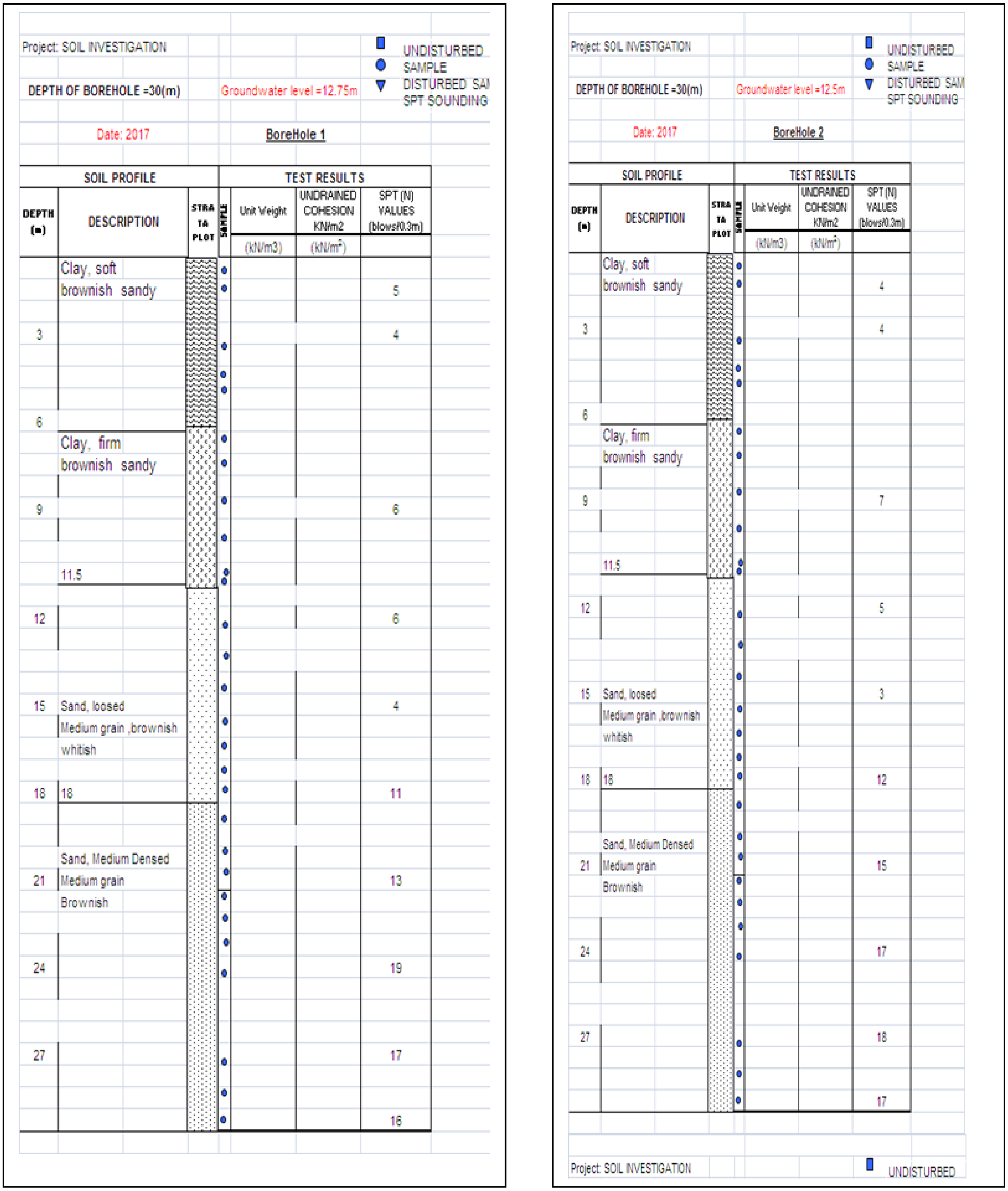

Figure 2: Showing Lithology for Bh 1 and Bh 2

Engineering Properties of the Soils

The investigation disclosed that the soil deposits within the depths explored are characterized by a near-surface deposit of Soft to stiff Clay layer . Beneath is a loosed Sand layer / Medium Densed sandy layer. The thickness of the most compressible zone is roughly 12m. The water table was encountered at 12m -12.5.m

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. Details of these are presented in tables at the end of this report.

Soft Clay

The thickness of this deposit, as confirmed by the borings varies within 6m. The clay is mainly of Modertae to high compressibilty and *Brownish* in colour. .The ranges of variations in the relevant index and engineering parameters of the clay are summarized below:-

	Min	Max	Av
Natural moisture content (%)	22.3	23	
Liquid limit (%)	36	43	
Plastic limit (%)	18	20	
Plasticity index (%)	16	25	
unit weight (kN/m^3)	18		
Undrained cohesion (kPa)	31	33	
Angle of internal friction (^{o})	3	4	
Modulus of Elasticity (KN/m^2)			

For design purposes, undrained cohesion of **31kPa**, angle of internal friction of **zero** and Satur8ated unit weight of **18kN/m^3** are suggested for this layer

Firm Clay

The thickness of this deposit, as confirmed by the borings varies within 5.5m -6m. The clay is mainly of Modertae to high compressibilty and *Brownish* in colour. .The ranges of variations in the relevant index and engineering parameters of the clay are summarized below:-

	Min	Max	Av
Natural moisture content (%)	22.8	30.1	
Liquid limit (%)	37	45	
Plastic limit (%)	19	24	
Plasticity index (%)	14	26	
unit weight (kN/m^3)	18		
Undrained cohesion (kPa)	40	40	
Angle of internal friction (^{o})	4	4	
Modulus of Elasticity (kN/m^2)			

For design purposes, undrained cohesion of **40kPa**, angle of internal friction of **zero** and Saturated unit weight of **18kN/m^3** are suggested for this layer

Loose Sandy Layer

Underlying the clayey layer is a layer of predominantly Poorly sorted, loosed sandy layer. About 6m of the sand deposit was proved. The ranges of variations in the relevant engineering parameters of the sand are given below:-

	Average (BH1, 15.75m)
Effective particle size d_{10} (mm)	0.17
Mean particle size d_{50} (mm)	0.35
Coefficient of uniformity $Cu = \frac{d_{60}}{d_{10}}$	2.4
Coefficient of curvature $Cc = \frac{d^2_{30}}{d_{10}*d_{60}}$	0.9
SPT (N-value)	4

For design purposes, mean angle of internal friction of 28 o and cohesion zero are suggested for the sand layer. Unit weight of **18kN/m^3** are suggested for this layer

Medium dense Sandy Layer

Underlying the loosed layer is a layer of predominantly Poorly sorted, Medium densed sand. About 12m of the sand deposit was proved. The ranges of variations in the relevant engineering parameters of the sand are given below:-

	Average
Effective particle size d_{10} (mm)	0.2
Mean particle size d_{50} (mm)	0.5
Coefficient of uniformity $Cu = \frac{d_{60}}{d_{10}}$	3
Coefficient of curvature $Cc = \frac{d^2_{30}}{d_{10}*d_{60}}$	1
SPT (N-value)	11
Elastic Modulus ((kPa)	25730

For design purposes, mean angle of internal friction of **31 ^{o}** and cohesion **zero** are suggested for the sand layer. Unit weight of **20kN/m^3** are suggested for this layer

Pile Work Load

Pile Work calculations were made using relevant equation stated above

Table 2: Pile Load Calculations for Deep Foundation for 19m

							Pile work Load Calculation							
					Unit	Over burden	Effective	cum. Effect					Pile shaft	End
	0			Cohesion	weight	stress	stress	stress	bearing factors		Ka	α	load,kpa	load,kpa
Layers	Bottom	Thickness(m)	phi	kpa	KN/cu.m	KN/cu.m	KN/cu.m	KN/cu.m	Nc	Nq				
1-Cl	6	6		31	18	108	108	108	9			0.5	15.5	
2-Cl	12	6		40	18	108	108	216	9			0.5	20	
3-Sp	18	6	28		20	120	60	276	0		0.7		37.08126578	
4- sp	19	1	31		20	20	10	286	0		0.7		43.00635399	
	Total	19					286					Total		
					Diameter(m)								0.4	0.45
					Nq								21.3	18.97
					shaft Load (KN)		1						116.808	131.409
					shaft Load (KN)		2						150.72	169.56
					shaft Load (KN)		3						279.444419	314.3749713
					shaft Load (KN)		4						54.01598061	60.76797818
					Total shaft Load (KN)								600.9883996	676.1119495
					End Load (KN)								766.104768	863.5369743
					Total Load (KN)								1367.093168	1539.648924
					Safe Load, SF		3						455.6977225	513.2163079
					Safe Load, SF		2.5						546.837267	615.8595695
					Safe Load, SF		2						683.5465838	769.8244619
		k= earth pressure												
		α=Adhesion Factor												
		Qs=∑Af +∑Acuα												
		f= frictional resistance												
		Qb=∑cNc+qNq												

Table 3: Pile Load Calculations for Deep Foundation for 21m

Pile work Load Calculation

Layers	Bottom	Thickness(m)	phi	Cohesion kpa	Unit weight KN/cu.m	Over burden stress KN/cu.m	Effective stress KN/cu.m	cum. Effect stress KN/cu.m	bearing factors Nc	Nq	Ka	α	Pile shaft load,kpa	End load,kpa
	0													
1-CI	6	6		31	18	108	108	108	9			0.5	15.5	
2-CI	12	6		40	18	108	108	216	9			0.5	20	
3-Sp	18	6	28		20	120	60	276	0		0.7		37.08126578	
4- sp	21	3	31		20	60	30	306	0		0.7		46.01379133	
	Total	21					306					Total		
					Diameter(m)								0.4	0.45
					Nq								16.64	18.22
					shaft Load (KN)		1						116.808	131.409
					shaft Load (KN)		2						150.72	169.56
					shaft Load (KN)		3						279.444419	314.3749713
					shaft Load (KN)		4						173.3799657	195.0524614
					Total shaft Load (KN)								720.3523847	810.3964328
					End Load (KN)								640.3497984	887.3958078
					Total Load (KN)								1360.702183	1697.792241
					Safe Load, SF		3						453.5673944	565.9307469
					Safe Load, SF		2.5						544.2808732	679.1168962
					Safe Load, SF		2						680.3510915	848.8961203

k=earth pressure

α=Adhesion Factor

$Q_s=\sum Af+\sum Acu\alpha$

f=frictional resistance

$Q_b=\sum cN_c+qN_q$

Table 4: Pile Load Calculations for Deep Foundation for 23m

Column1	Column2	Column3	Column4	Column5	Column6	Column7	Column8	Column82	Column9	Column10	Column11	Column12	Column13	Column14
						Pile work Load Calculation								
					Unit	Over burden	Effective	cum. Effect					Pile shaft	End
	0			Cohesion	weight	stress	stress	stress	bearing factors		Ka	α	load,kpa	load,kpa
Layers	Bottom	Thickness(m)	phi	kpa	KN/cu.m	KN/cu.m	KN/cu.m	KN/cu.m	Nc	Nq				
1-Cl	6	6		31	18	108	108	108	9			0.5	15.5	
2-Cl	12	6		40	18	108	108	216	9			0.5	20	
3-Sp	18	6	28		20	120	60	276	0		0.7		37.08126578	
4- sp	23	5	32		20	100	50	326	0		0.7		50.80059299	
	Total	23					326					Total		
					Diameter(m)								0.4	0.45
					Nq								18.79	20.88
					shaft Load (KN)		1						116.808	131.409
					shaft Load (KN)		2						150.72	169.56
					shaft Load (KN)		3						279.444419	314.3749713
					shaft Load (KN)		4						319.027724	358.9061895
					Total shaft Load (KN)								866.000143	974.2501608
					End Load (KN)								770.3479104	1083.417055
					Total Load (KN)								1636.348053	2057.667216
					Safe Load, SF		3						545.4493511	685.889072
					Safe Load, SF		2.5						654.5392213	823.0668864
					Safe Load, SF		2						818.1740267	1028.833608
		k=earth pressure												
		α=Adhesion Factor												
		Qs=∑Af +∑Acuα												
		f=frictional resistance												
		Qb=∑cNc+qNq												

Table 5: Pile Load Calculations for Deep Foundation for 25m

						Pile work Load Calculation								
					Unit	Over burden	Effective	cum. Effect					Pile shaft	End
	0			Cohesion	weight	stress	stress	stress	bearing factors		Ka	α	load,kpa	load,kpa
Layers	Bottom	Thickness(m)	phi	kpa	KN/cu.m	KN/cu.m	KN/cu.m	KN/cu.m	Nc	Nq				
1-Cl	6	6		31	18	108	108	108	9			0.5	15.5	
2-Cl	12	6		40	18	108	108	216	9			0.5	20	
3-Sp	18	6	28		20	120	60	276	0		0.7		37.08126578	
4- sp	25	7	32		20	140	70	346	0		0.7		53.91719379	
	Total	25					346					Total		
					Diameter(m)								0.4	0.45
					Nq								17.06	19.44
					shaft Load (KN)		1						116.808	131.409
					shaft Load (KN)		2						150.72	169.56
					shaft Load (KN)		3						279.444419	314.3749713
					shaft Load (KN)		4						474.0399678	533.2949638
					Total shaft Load (KN)								1021.012387	1148.638935
					End Load (KN)								742.3310976	1070.58199
					Total Load (KN)								1763.343484	2219.220925
					Safe Load, SF		3						587.7811615	739.7403082
					Safe Load, SF		2.5						705.3373937	887.6883699
					Safe Load, SF		2						881.6717422	1109.610462

k=earth pressure

α=Adhesion Factor

Qs=∑Af +∑Acuα

f=frictional resistance

Qb=∑cNc+qNq

Table 6: Showing Pile Settlement variation

Pile Settlement Calculations

s/n	depth (B)m	diameter (m)	shaft area (As)m2	base area(Ab) m2	shaft load (Ws)KN	base load(Wb)KN	Ep(kpa)	Es(kpa)	influence factor " I"	F.S	Expected Settlement (P) mm	Allowable Settlement (P) mm
1	19	0.4	23.8944	0.12576	300	383	17000000	25730	0.5	2	44.53977668	40
2	19	0.4	23.8944	0.12576	240	306.4	17000000	25730	0.5	2.5	28.50546106	40
2	19	0.4	23.8944	0.12576	200	255.3	17000000	25730	0.5	3	19.79029365	40

P (settlement) =(Ws+2Wb)L/2AsEp+3.144Wb/4Ab *0.5Wb/BEs

Ep (Elastic Modulus for Pile)=17 000,000Kpa

Es (Elastic Modulus for base soil)

FS (factor of Safty)

Poisson Ratio , v, =0.25

Column1 Column2 Column3 Column4 Column5 Column6 Column7 Column8 Column9 Column10 Column11 Column12 Column13 Column14 Column15

Pile Settlement Calculations

s/n	depth (B)m	diameter (m)	shaft area (As)m2	base area(Ab) m2	shaft load (Ws)KN	base load(Wb)KN	Ep(kpa)	Es(kpa)	influence factor " I"	F.S	Expected Settlement (P) mm	Allowable Settlement (P) mm
1	21	0.4	26.4096	0.12576	360.2	320.15	17000000	25730	0.5	2	31.12128946	40
2	21	0.4	26.4096	0.12576	288.16	256.12	17000000	25730	0.5	2.5	19.917629	40
2	21	0.4	26.4096	0.12576	240.133333	213.433333	17000000	25730	0.5	3	13.8316894	40

P (settlement) =(Ws+2Wb)L/2AsEp+3.144Wb/4Ab *0.5Wb/BEs

Ep (Elastic Modulus for Pile)=17 000,000Kpa

Es (Elastic Modulus for base soil)

FS (factor of Safty)

Poisson Ratio , v, =0.25

Column1	Column2	Column3	Column4	Column5	Column6	Column7	Column8	Column9	Column10	Column11	Column12	Column13	Column14	Column15
						Pile Settlement Calculations								
											Expected	Allowable		
			shaft	base	shaft	base			influence		Settlement (P)	Settlement (P)		
s/n	depth (B)m	diameter (m)	area (As)m2	area(Ab) m2	load (Ws)KN	load(Wb)KN	Ep(kpa)	Es(kpa)	factor " I"	F.S	mm	mm		
1	23	0.4	28.9248	0.12576	433	385.15	17000000	25730	0.5	2	45.04123809	40		
2	23	0.4	28.9248	0.12576	346.4	308.12	17000000	25730	0.5	2.5	28.82639688	40		
2	23	0.4	28.9248	0.12576	288.666667	256.766667	17000000	25730	0.5	3	20.01833429	40		

P (settlement) =(Ws+2Wb)L/2AsEp +3.144Wb/4Ab *0.5Wb/BEs

Ep (Elastic Modulus for Pile)=17 000,000Kpa

Es (Elastic Modulus for base soil)

FS (factor of Safty)

Poisson Ratio , v, =0.25

Column1	Column2	Column3	Column4	Column5	Column6	Column7	Column8	Column9	Column10	Column11	Column12	Column13	Column14	Column15
						Pile Settlement Calculations								
											Expected	Allowable		
			shaft	base	shaft	base			influence		Settlement (P)	Settlement (P)		
s/n	depth (B)m	diameter (m)	area (As)m2	area(Ab) m2	load (Ws)KN	load(Wb)KN	Ep(kpa)	Es(kpa)	factor " I"	F.S	mm	mm		
1	25	0.4	31.44	0.12576	510.505	371.15	17000000	25730	0.5	2	41.82630289	40		
2	25	0.4	31.44	0.12576	408.404	296.92	17000000	25730	0.5	2.5	26.76883854	40		
2	25	0.4	31.44	0.12576	340.336667	247.433333	17000000	25730	0.5	3	18.58947446	40		

P (settlement) =(Ws+2Wb)L/2AsEp +3.144Wb/4Ab *0.5Wb/BEs

Ep (Elastic Modulus for Pile)=17 000,000Kpa

Es (Elastic Modulus for base soil)

FS (factor of Safty)

Poisson Ratio , v, =0.25

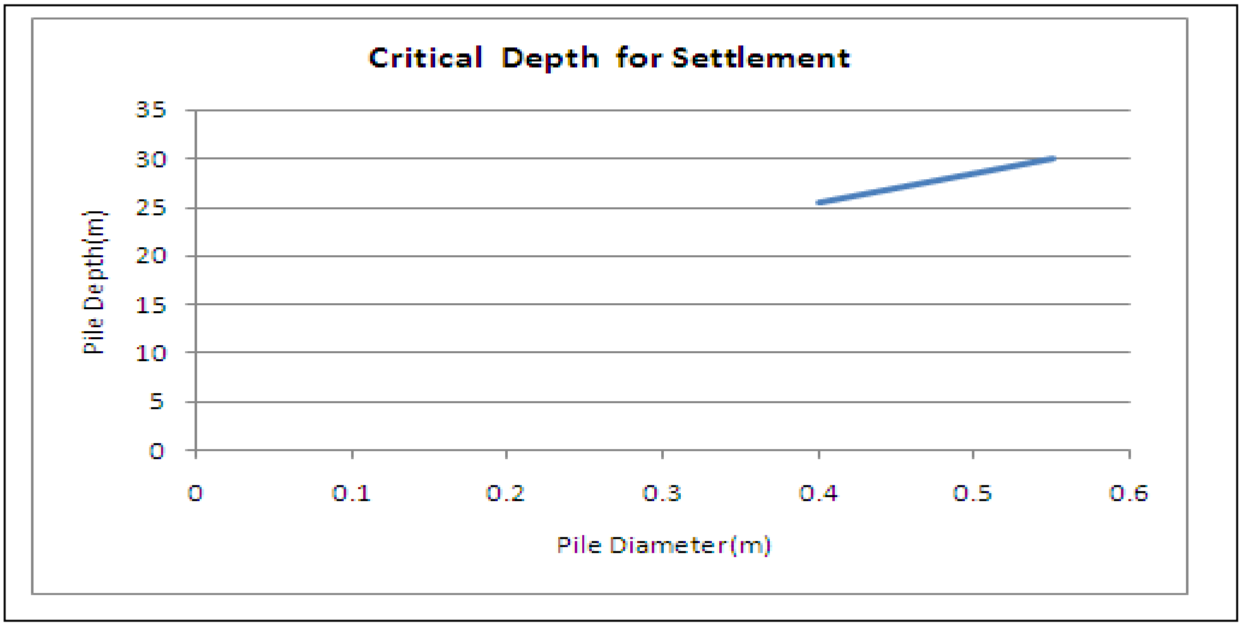

Figure 3: Critical Depth analysis plot

Table 7: Summary of Pile Characteristics

Pile Depth (m)	Pile Diameter (m)	Ultimate Pile Capacity kN	Factor of Safety	Allowable Pile Bearing Capacity kN	Expected Settlement (mm)	Allowable Settlement (mm)
			3	455.6977225	19.79029365	
19	0.4	1367.093168	2.5	546.837267	28.50546106	40
			2	683.5465838	44.53977668	
			3	513.2163079	17.66750653	
19	0.45	1539.648924	2.5	615.8595695	25.44120541	45
			2	769.8244619	39.7518772	
			3	620.7632431	21.32477063	
19	0.5	1862.289729	2.5	744.9158918	30.70766525	50
			2	931.1448647	47.98072	
			3	736.2717034	24.80448855	
19	0.55	2208.81511	2.5	883.526044	35.71845863	55
			2	1104.407555	55.81008397	
			3	453.5673944	13.8316894	
21	0.4	1360.702183	2.5	544.2808732	19.917629	40
			2	680.3510915	31.12128946	
			3	565.9307469	18.6590459	
21	0.45	1697.792241	2.5	679.1168962	26.8690218	45
			2	848.8961203	41.98283984	
			3	681.1642569	22.57077792	
21	0.5	2043.492771	2.5	817.3971083	32.50191543	50
			2	1021.746385	50.78423541	

			3	807.9265006	26.66086269	
21	0.55	2423.779502	2.5	969.5118008	38.39163703	55
			2	1211.889751	59.98692465	
			3	545.4493511	20.01833429	
23	0.4	1636.348053	2.5	654.5392213	28.82639688	40
			2	818.1740267	45.04123809	
			3	685.889072	27.79120774	
23	0.45	2057.667216	2.5	823.0668864	40.01933393	45
			2	1028.833608	62.5302011	
			3	838.9270629	35.53513696	
23	0.5	2516.781189	2.5	1006.712475	51.17059131	50
			2	1258.390594	79.95403968	
			3	1003.830916	43.02062358	
23	0.55	3011.492748	2.5	1204.597099	61.94969139	55
			2	1505.746374	96.79638252	
			3	587.7811615	18.58947446	
25	0.4	1763.343484	2.5	705.3373937	26.76883854	40
			2	881.6717422	41.82630289	
			3	739.7403082	27.15337861	
25	0.45	2219.220925	2.5	887.6883699	39.10085973	45
			2	1109.610462	61.09508478	
			3	906.3306878	35.9525797	
25	0.5	2718.992063	2.5	1087.596825	51.77170884	50
			2	1359.496032	80.8932858	
			3	1086.061075	44.62311862	
25	0.55	3258.183224	2.5	1303.27329	64.25728385	55
			2	1629.091612	100.4019951	

DISCUSSIONS

Field and Laboratory investigations show that the area of study is underlain by an over consolidated soft sandy Clay layer (about 6m thick) overlying a stiff sandy clay . Beneath this clay layer is a loosed Medium grain Poorly sorted sandy layer (with minimum Phi= 28^0), overlying a poorly sorted medium densed sandy layer (about 12m thick.) with minimum Phi= 31^0.

Critical depth for settlement analysis were made using equation described (eqn 8) above. This is to ascertain the depth beyond which there will be no further reduction of settlement. Figure 3, indicates depth less than 30m for piles diameter under consideration (0.4m-0.55m). Thus, pile depths are located within less than 30m on stable (Medium dense) layers.. Lithology of the subsurface shows clayey / sandy formation with the medium dense sand layer indicative from depth > 18m. This implies that for a pile which is anticipated to be mostly an end bearing pile, this layer is appropriate for founding. This is also corroborated by works of Teme *et al* (2008) in the Niger Delta. Pile Work load calculations (Table 2-5) carried out within this layer indicates piles founded at 19m with diameter 0.4m-0.55m has safe working load within the range of 455 – 931kN. Piles located within depth of 21m with diameter of 0.4m-0.55m indicates safe working load of 453-1212kN. Also piles located within depth of 23m and 25m with different diameters show safe working load of 654-1506kN and 587-1629kN, respectively. This implies that columns load from superstructure not greater than 1630kN can be accommodated by bored piles within these depth with diameter less than 0.6m.

Settlement calculations (Table 6) indicates high percentage of anticipated settlement values are less than the allowable values (using the one tenth criterion). Global factor of safety values of 2-3 were adopted for the ultimate bearing capacities values. Derivatives of Safe Working Load with FS value of 2, indicates high settlement values greater than the accepted criterion for most piles . This implies FS values of 2 is inappropriate for work load calculations for large diameter piles.

Generally, Settlement observation (Table 7), indicates that Safe working Loads less than 931kN, resulted in settlement <50mm. Also Safe Working Loads less than 1212 KN, resulted in settlement <59mm, while Safe Working Loads less than 1505kN and 1629kN indicates settlement less than 97mm and 100mm respectively. Thus, safe working load with settlement values greater than the one-tenth criterion should not be part of designs considerations.

CONCLUSIONS

With C_u values less than 50 kN/m^2, shallow allowable bearing capacity profile of the sub-surface is expected to be low-moderate thereby limiting the loads of superstructures. Hence a Deep foundation is imperative for the construction of high rising building . The study of the subsurface reveals founding depths within the medium dense layers (depths >19m), using critical depth for settlement analysis. Pile Bearing capacity calculations reveals safe working load not greater than 1630kN for pile diameter less than 0.6m. Settlement analysis indicates values less than the accepted criterion, though using FS value of 2 in pile bearing capacity calculations reveals high settlement values (Values greater thn the acceptable criterion). Hence, the used of FS value of 2 should not be prioritize in large pile diameter computations.

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