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Geotechnical Indications of Bille Communnity in Niger Delta

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GEOTECHNICALINDICATIONSOFBILLECOMMUNNITYINNIGERDELTA

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Geotechnical Indications of Bille Communnity in Niger Delta

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Keywords: component; deep foundation; bearing capacity; foundation failures; niger delta; settlement.

I. Introduction

The area which is within the southern –most part of the Niger Delta, is located in the Transition or mangrove zone of the Niger Delta. 'Transition' Or Mangrove (Middle Delta) Zone coincides with the Mangrove brackish water zone with its numerous inter-tidal flats and mangrove vegetation. Sub-soils here are characterized by a typical fibrous, pervious clayey mud (that exhibits large values of compressibility and consolidation), underlain by silty sands which most often grade into poorly graded Sands and further downwards into well-graded sands and gravels. (Teme *et al* 2008).

Due to this characteristics, intolerable settlement (Total and Differential) of building is being observed within the area. Thereby making it unsafe for usage and results in the construction of building with low column loads. The study is about proposing bearing capacity for shallow foundation and work load for pile foundation within this area.

II. Site Description And Geology

Geologically, the site is underlain by the Coastal Plain sands of the Benin formation (short and stauble, 1967), which in this area is overlain by soft-firm silty clay sediments belonging to the Pleistocenic Formation (Nwankwoala, *et al*. 2014.) Morphologically the site is situated within the Salt water / Mangrove swamp zone of the Niger Delta. These are portions of the delta that are characterized by large saline-brackish water mangrove swamps. In these areas, there is less discharge of freshwater and there is a dominance of tidal influences. The zone which is rich in organic matter, consist of very soft peaty and bog soil, dark gray organic clay overlying fine sandy sequence. Water table is shallow in this zone as a result of the diurnal flooding and poor drainage. The elevation above mean sea level in this region ranges from 1 – 2m (Alaminiokuma, *et al 2016* , Nwankwoala, *et al*. 2014)

Fig. 1: Showing Location of Area

III. Methods Of Investigation

a) A 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 was 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.

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b) Bearing Capacity for Shallow Foundation

The conventional method of foundation design is based on the concept of bearing capacity or allowable bearing pressure of the soil. The bearing capacity is defined as the load or pressure developed under the foundation without introducing damaging movements in the foundation and in the superstructure supported on the foundation.

Damaging movements may result from foundation failure or excessive settlement. The two criteria used in the design of foundation are therefore:

i. Determination of bearing capacity of soil and the selection of adequate factor of safety, usually not less than 2.5
ii. Estimating the settlement under the expected load and comparison with the permissible settlement

Modified Terrzerghi Bearing Capacity equation (Murthy, 2007) was used in the calculation of the ultimate bearing capacity of the soil for rectangular foundations.

$$\mathbf{qu} = \mathbf{CNc}\,[\mathbf{1} + \mathbf{0.3BL}] + \boldsymbol{\gamma}\mathbf{Df\ Nq} + \mathbf{12}\boldsymbol{\gamma}\mathbf{BN}\boldsymbol{\gamma}\,[\mathbf{1} - \mathbf{0.2BL}] \quad (1)$$

Working Load for Pile (Bore) Foundation 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

$$Q_P = Q_S + Q_b + W_P \quad (2)$$

Where;

Q_P = *Ultimate Bearing Capacity of pile*

$W_P = weight\ \ of\ \ pile$

IV. Results and Discussion

a) 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 two primary zones.

Table 1: Showing Litholgy, bh1

Layers	Depth(m)	Thickness(m)	Lithology
1	0-12.0	12	Clay, soft Layer
2	12.0-13.5	13.5	Sand, gravelly
3	13.5- 14.5	1	Clay
4	14.5-20	5.5	Sand, Medium Dense Layer

Table 2: Showing Litholgy, bh2

Layers	Depth(m)	Thickness(m)	Lithology
1	0-10.5	10.5	Clay, soft-Layer
2	10.5-20	9.5	Sandy Medium Dense layer

Classification Test was done within Procedure Prescribe by BS 1377, Part 2, 1990 for Classification Test.

b) 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 Clay layer with high compressibility. Beneath is a Medium Densed sandy layer. The thickness of the most compressible zone is roughly 14.5m. The water table was encountered at 0.3m

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.

i. *Soft Clay*

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

	Min	Max
Natural moisture content (%)	38	47
Liquid limit (%)	33	33
Plastic limit (%)	7	9
Plasticity index (%)	24	26
Unit weight (kN/m^3)	18	
Undrained cohesion (kPa)	14	
Angle of internal friction (^{o})	0.5	0.7
Modulus of Elasticity (KN/m^2)		

For design purposes, undrained cohesion of 14kPa, angle of internal friction of zero and Saturated unit weight of 18kN/m^3 are suggested for this layer

ii. *Medium densed Sandy Layer*

Underlying the clay layer is a layer of predominantly Well graded, Medium densed sand. About 6m of the sand deposit was proved. The uniformity Coefficient reveals the sand as a well graded sand with cu>4.0 The ranges of variations in the relevant engineering parameters of the sand are given below:-

	(BH1, 20m)
Effective particle size d_{10} (mm)	0.3
Mean particle size d_{50} (mm)	1.5
Coefficient of uniformity Cu,	5.6
Coefficient of curvature Cc,	2.7
SPT (N-value)	11
Elastic Modulus ((Kpa)	22000

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

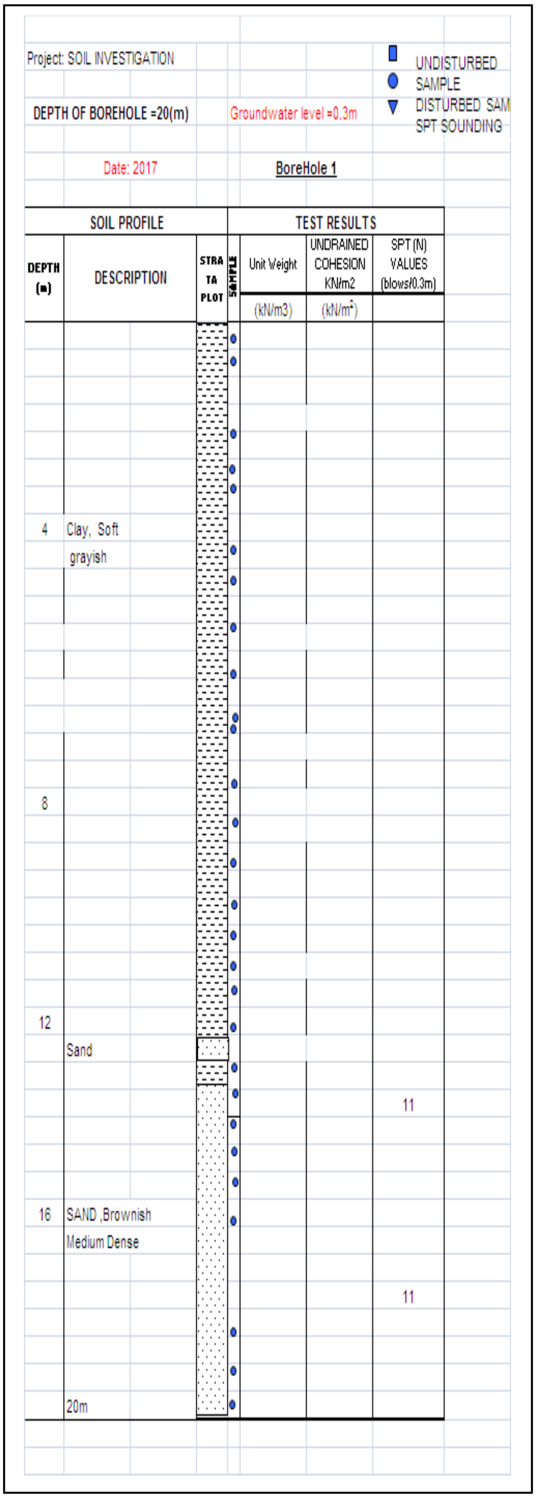

Fig. 2: CPT Profile

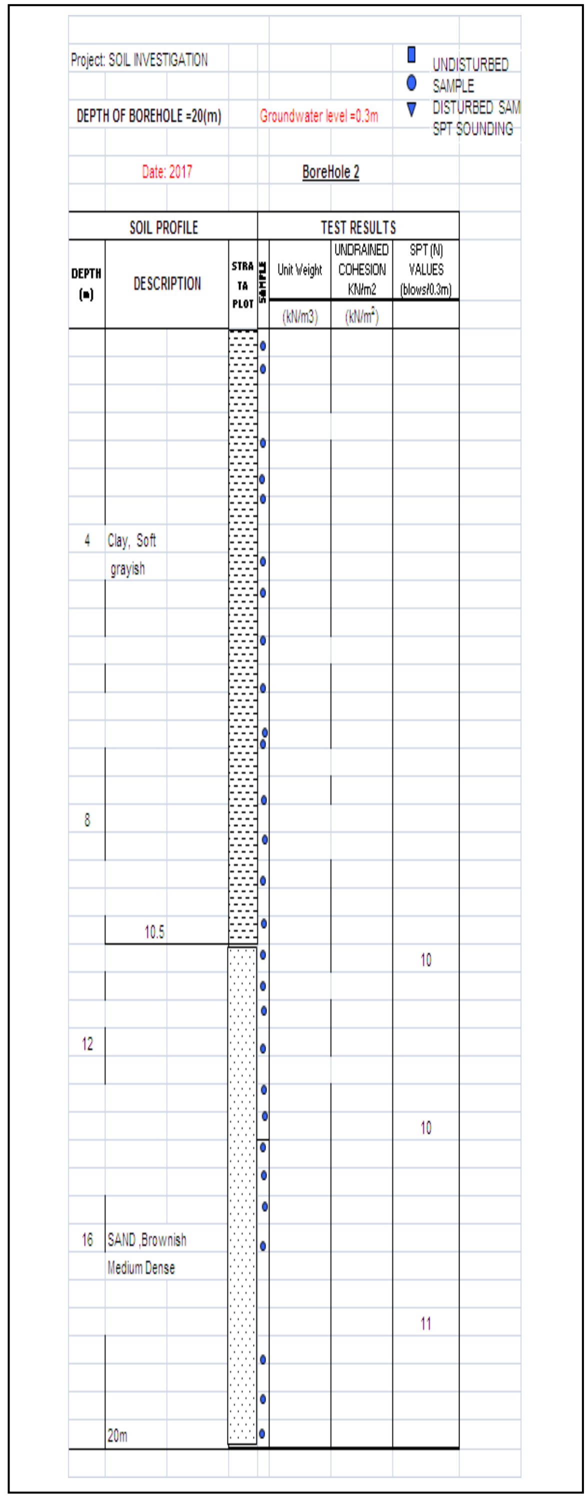

Fig. 3: Soil Lithology

Table 3: Showing Bearing Capacity for Both Areas

Foundation Depth (m)	Width (m)	Undrained Shear Strength (KN/m²)	Ultimate Bearing Pressure (KN/m²)			Allowable Bearing Pressure (KN/m²)		
			L/B =1	L/B= 1.5	L/B = 5	L/B=1	L/B=1.5	L/B=5
1	1	14	121.812	113.838	102.6744	40.60	37.95	34.22
1	1.5	14	121.848	113.877	102.7176	40.62	37.96	34.24
1	2	14	121.884	113.916	102.7608	40.63	37.97	34.25
1	2.5	14	121.92	113.955	102.804	40.64	37.99	34.27
1	5	14	122.1	114.15	103.02	40.70	38.05	34.34
1	10	14	122.46	114.54	103.452	40.82	38.18	34.48
1.5	1	14	130.812	122.838	111.6744	43.60	40.95	37.22
1.5	1.5	14	130.848	122.877	111.7176	43.62	40.96	37.24
1.5	2	14	130.884	122.916	111.7608	43.63	40.97	37.25
1.5	2.5	14	130.92	122.955	111.804	43.64	40.99	37.27
1.5	5	14	131.1	123.15	112.02	43.70	41.05	37.34
1.5	10	14	131.46	123.54	112.452	43.82	41.18	37.48
2	1	14	139.812	131.838	120.6744	46.60	43.95	40.22
2	1.5	14	139.848	131.877	120.7176	46.62	43.96	40.24
2	2	14	139.884	131.916	120.7608	46.63	43.97	40.25
2	2.5	14	139.92	131.955	120.804	46.64	43.99	40.27
2	5	14	140.1	132.15	121.02	46.70	44.05	40.34
2	10	14	140.46	132.54	121.452	46.82	44.18	40.48

Allowable Bearing Capacities for shallow foundations (Water depth > foundation Depth)

Table 4: Pile Load Calculations for Deep Foundation for 15m

							Pile work Load Calculation							
					Unit	Over burde	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-CH	13.5	13.5		14	18	243	108	108	9			0.5	7	
2-SP	15	1.5	31		20	30	15	123	0		0.7		18.4957397	
	Total	15					123					Total		
					Diameter(m)								0.3	0.35
					Nq								17.24	18.84
					shaft Load (KN)		1						89.019	103.8555
					shaft Load (KN)		2						26.1344801	30.4902268
					Total shaft Load (KN)								115.15348	134.345727
					End Load (KN)								150.005585	223.123156
					Total Load (KN)								265.159065	357.468883
					Safe Load, SF		3						88.386355	119.156294
					Safe Load, SF		2.5						106.063626	142.987553
					Safe Load, SF		2						132.579532	178.734442
		k= earth pressure												
		α=Adhesion Factor												
		Qs=∑Af +∑Acuα												
		f= frictional resistance												
		Qb=∑cNc+qNq												

Table 5: Pile Load Calculations for Deep Foundation for 15m

						Pile work Load Calculation								
					Unit	Over burde	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-CH	13.5	13.5		13	18	243	108	108	9			0.5	6.5	
2-SP	15	1.5	31		20	30	15	123	0		0.7		18.4957397	
	Total	15					123					Total		
					Diameter(m)								0.4	0.45
					Nq								19.86	20.53
					shaft Load (KN)		1						110.214	123.99075
					shaft Load (KN)		2						34.8459735	39.2017202
					Total shaft Load (KN)								145.059974	163.19247
					End Load (KN)								307.204013	401.921866
					Total Load (KN)								452.263986	565.114337
					Safe Load, SF		3						150.754662	188.371446
					Safe Load, SF		2.5						180.905595	226.045735
					Safe Load, SF		2						226.131993	282.557168
		k= earth pressure												
		α=Adhesion Factor												
		Qs=∑Af +∑Acuα												
		f= frictional resistance												
		Qb=∑cNc+qNq												

iii. *Settlement Characteristics for Shallow Foundation*

Table 6: Consolidation (One –Dimensional) Compressibility Parameter

Bore-Hole Nos	Depth (m)	Pressure Range (Kpa)	Coefficient of Consolidation Cv(m^2/yr)	Coefficient of Volume Compressibility Mv (M^2/MN)	Coefficient of Permeabilty K 10^{-8}cm/s
	1.5m				
		0-12.5	1.314	6.712000	2.74E-7
		12.5-50	1.441161	0.925663	4.15E-8
		25-50	1.441161	4.262838	1.91E-7
		50-100	1.441161	1.199011	5.37E-8
		100-200	1.441161	0.928337	4.16E-8
		200-400	1.540551	0.355124	1.7E-08

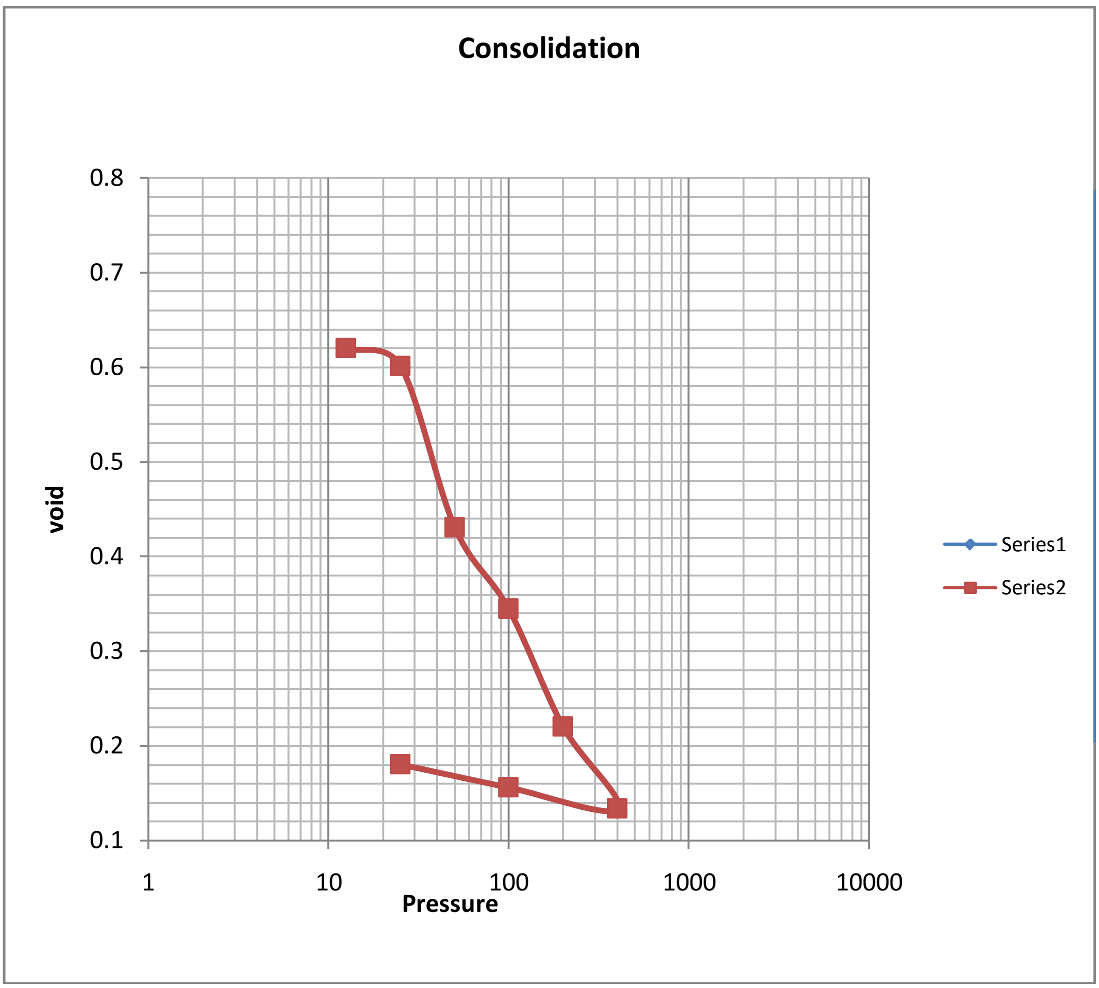

Fig. 3: Void Ratio / Pressure Plot

Table 7: Settlements Parameter, Bh 1 depth =1.5m

Clay	Normally consolidated OCR <1
e_o	0.62
Preconsolidation Pressure	20
Cc	0.35
Soil Compressibility based on CC and e_o	0.1
P_i (elastic)	
Pc (Primary)	

Computed Rate of Settlements (Pressure Range : 200-400 KPa)

Rate of Settlements	Years
T50	
T90	

Table 8: Showing Settlement variation for shallow foundation For Bh 1

Pressure (KPA)	50	100	150	200	250	400	600
Settlement (mm)	57.4	103.6	142.1	175.2	204.2	274.4	343.9

Table 9: Showing Pile Settlement variation

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	15	0.3	14.148	0.07074	57.5	75	17000000	22000	0.5	2	4.734854955	30		
2	15	0.3	14.148	0.07074	46	60	17000000	22000	0.5	2.5	3.030308207	30		
2	15	0.3	14.148	0.07074	38.3333333	50	17000000	22000	0.5	3	2.104381418	30		
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	15	0.35	16.506	0.096285	67	111.5	17000000	22000	0.5	2	6.590121719	35		
2	15	0.35	16.506	0.096285	53.6	89.2	17000000	22000	0.5	2.5	4.21767914	35		
2	15	0.35	16.506	0.096285	44.6666667	74.3333333	17000000	22000	0.5	3	2.928944709	35		
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	15	0.4	18.864	0.12576	72.5	153.5	17000000	22000	0.5	2	8.367285154	40		
2	15	0.4	18.864	0.12576	58	122.8	17000000	22000	0.5	2.5	5.355063919	40		
2	15	0.4	18.864	0.12576	48.3333333	102.333333	17000000	22000	0.5	3	3.718795374	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	15	0.45	21.222	0.159165	81.5	201	17000000	22000	0.5	2	10.07632879	45		
2	15	0.45	21.222	0.159165	65.2	160.8	17000000	22000	0.5	2.5	6.448852037	45		
2	15	0.45	21.222	0.159165	54.3333333	134	17000000	22000	0.5	3	4.478370587	45		
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														

Table 10: Particle Size Distribution

Borehole No	Depth(m)	Effective particle	d_{30}	Mean particle size d_{50}(mm)	d_{60}	Coefficient of uniformity	Coefficient of curvature
1	15	0.3	1.2	1.5	1.7	5.66666667	2.823529412
1	20	0.22	0.6	1.2	1.5	6.81818182	1.090909091
1	18	0.23	0.7	1.2	1.6	6.95652174	1.331521739

c) Bearing Capacity Calculations for Shallow Foundation

Undrained cohesion of 18 kPa, Unit weight of 18kN/m^3 and angle of internal friction of 0 were adopted for the bearing capacity analysis, adopting methods from BS 1377, Part 7 1990: 8. Table 2., indicates low values of allowable bearing capacities with different L/B ratios.

d) Settlement of Shallow Foundation

Laboratory Consolidation Test was performed on selected Cohesive sample to determine the compressibility Parameter. The Test was carried out in accordance with Procedure Recommended in BS 1377, Part 5, 1990:3. Method proposed by Pacheco Silva (1970) was used to determine the Preconsolidation Pressure graphically. Settlement Analysis based on Normally consolidated soils are stated as follows (Coduto D.P, 2007)

$$s = \Sigma cc1 + eoHlog\,[\sigma zf/\sigma zo\,] \qquad (3)$$

Where:
s= settlement
eo= void ratio
H= height of Clay
σzf =final vertical effective stress
σzo= Initial vertical effective stress
cc= compression index

V. Conclusion

The Study Reveals that the surface within these area is underlain by a Normally Consolidated soft clay of High compressibility (about 14.5m thick) . Beneath this layer is a medium dense, well graded Sandy Layer(with Phi value > 30^0). Moisture Content, Liquid Limit, compessional Index and Plasticity Index Shows high Values, indicating high Compressibility. Drainage Characteristics is expected to be low at the site as indicated by the K values.

An average Cu=18KN/m^2 and Phi =0 was considered within depth of 1m-2m The allowable bearing capacity profile of the sub-surface shows Low bearing Capacities characteristics (1.5m: 43KN/m^2,). Settlement predictions based on a loading of 250KN/m^2 indicated a settlement > 200 mm within the clay layer. The differential and total settlement is expected to be within intolerable limits. Due to the highly anticipated settlement values, Due to this layer, which depicts low allowable bearing capacities, Deep (Pile) foundation with depth greater than 15m is recommended for higher column loads. Pile calculations on table 4 and 5, shows working load of different diameter between 0.3m-0.45m . Working load for 0.3m diameter bored pile with depth of 15m, shows values 132.1KN and 106.1 KN for F.S values of 2 and 2.5 respectively . Also, Working load for 0.35m diameter bored pile with depth of 15m, shows values 179KN and 143 KN for F.S values of 2 and 2.5 respectively . 0.4m diameter by 15m Depth Pile shows working load of 226KN and 180KN for F.S values of 2 and 2.5 respectively, while 282KN and 226KN with F.S 2 and 2.5 respectively are working loads for 0.45m by 15m depth pile.

Settlement calculations on table 9 for deep foundation shows expected settlement lower the Allowable settlement, this imp[lies calculated work load for the different pile diameter is adequate and will not result in foundation failures.

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