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Soil Tests Analysis for Raft and Pile Foundations of a 5 Storey Building in Yenagoa, Bayelsa State, Nigeria

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Abstract

This work involved the designs and analyses of the foundation of a 5-storey building in Yenagoa, a water-logged area of Bayelsa State, (Nigeria), using both raft and pile foundations. Preliminary soil tests were carried out in order to determine the physical properties and the bearing capacity of the soil. These tests were Dutch cone penetrometer tests, Borehole characteristics test involving standard penetration test, particle size distribution tests, direct shear test, triaxial tests and consolidation tests. The Dutch cone penetrometer tests recorded resistance to cone penetration of 345-355kg/cm^2. The Borehole characteristic tests showed that the top soil was dry grayish mottled clay, followed by soft silty/sandy clay up to about 6m depth. Below 6-7m depth was sand. The clay end bearing minimum pressure was 54kN/m^2 and maximum pressure was 68kN/m^2. Sand end bearing minimum pressure was 416kN/m^2 and maximum was 697kN/m^2. The clay skin friction ranged from 10kN/m^2 to 13kN/m^2. The sand minimum skin friction was 77kN/m^2 and the maximum skin friction was 129kN/m^2.The allowable bearing capacity of the soil ranging from 64kN/m^{2}to 71kN/m^2 for a shallow depth of 1m – 2m and 177kN/m^2 to 517 kN/m^2 for a deep depth of 10m to 20m. The pile sizes ranged from 305mm to 500mm. Design of the structural elements (superstructure) as well as the design of the foundations (Raft and Pile) were executed with ultimate column axial load of 4138 kN and serviceability column axial load of 2164 kN. The cost analysis was also performed. From the cost analysis, the cost of the raft foundation was ₦78,884,505.00 (Seventy Eight Million, eight Hundred and eighty four Thousand, five Hundred and five Naira only) while the cost of the pile foundation was ₦117,551,700.00 (One Hundred and seventeen Million, five Hundred and Fifty one Thousand, Seven Hundred Naira only).

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This showed that the cost of the pile foundation was greater than that of the raft foundation by 39%. It is recommended that raft foundation be used on the area in order to minimize cost.

Keywords: Raft; Pile; Foundations; Shear; Designs.

1. Introduction

Foundations are appropriately described as a necessary evil. If a building is to be constructed on an outcrop of sound rock, no foundation is required. Hence, in contrast to the building itself which satisfies specific needs, appeals to the aesthetic sense, and fills its matters with pride, the foundation merely serve as a remedy for the deficiencies of whatever whimsical nature has provided for the support of the structure at the site which has been selected. On account of the fact that there is no glory attached to the foundations, and that the source of success or failures are hidden deep in the ground, building foundation have always been treated as step children; and their acts of revenge for lack of attention can be very embarrassing [15].The comments made by Terzaghi are very significant and should be taken seriously by all practicing architects and engineers. Since the substructures are as important as the superstructures, persons who are well qualified in the design of substructures should always be consulted [11].

All engineering construction resting on the earth are carried by some kind of interfacing element called a foundation. The term superstructure is commonly used to describe the engineered part of the system bringing load to the foundation, or substructure. The term superstructure has particular significance for buildings and bridges; however, foundation also may carry only machinery, support industrial equipment (pipes, towers, tanks), act as sign bases, and so on. For these reasons, it is better to describe a foundation as that part of engineered system that interfaces the load- carrying components to the ground. It is evident on the basis of this definition that a foundation is the most important part of the engineering system [2]. The function of any foundation is to safely sustain and transmit to the ground on which interests the combined dead, imposed and wind loads in such a manner as not to cause any settlement or other movement which would impair the stability or cause damage to any part of the building [8]. Research has shown that the two main types of foundation usually used in water-logged areas in which the soil is very weak and has a very low bearing capacity are raft and pile foundations and over the years, these foundations have imposed much concern and difficulties to engineers and clients in terms of their design and construction in water-logged areas [9] [1]. The aim is to design raft and pile foundations in a water logged area of Yenagoa for a five storey building and then compare both foundations and choose the one that is more effective in terms of safety and economy while taking into consideration the availability of materials.

2. Materials and Method

2.1 Materials

Preliminary soil tests were carried out in order to determine the physical properties and the bearing capacity of the soil in accordance with BS1377 [7]. These tests were Dutch cone penetration tests, Borehole characteristics test involving standard penetration test, particle size distribution tests, direct shear test, triaxial tests and consolidation tests.

2.1.1 Site Description

The proposed project site was situated along Tenbia Road, It located at about 2km from the proposed central processing facilities (CPF) are along the Crushed Rock Industries Road and about 500m of the Road. The area is topographically low lying seasonally flooded and located within dense vegetation

2.1.2 Field Work

The coordinates of the test location are presented in table 2.1

Table 2.1: Co-ordinates of Boreholes and CPT Test Positions

POINTS	NORTHING	EASTING
BH 1	110932	425821
BH 2	110983	425224
BH 3	110953	425138
BH 4	111004	425075
CPT 1	110953	425832
CPT 2	110880	425821
CPT 3	110969	425582
CPT 4	110911	425229
CPT 5	111025	425201
CPT 6	110985	425170
CPT 7	110899	425170
CPT 8	111031	425130
CPT 9	110956	425111
CPT 10	111027	425090
CPT 11	110940	425069
CPT 12	111060	425058

LEGEND: Bore Hole, Cone Penetration Test

2.2 Methods

2.2.1 Cone Penetration Test

The CPT data were acquired using mechanical static cone Penetrometer of the following specifications: cone base = $10cm^2$, apex angle = 60^o and friction sleeve = $150cm^2$. A total of twelve (12) Nos. Dutch Cone Tests (CPT) was performed with a 10 Ton Dutch Cone Penetrometer machine up to the depths at which the machine capacity or anchorage strength could allow. The cone and the sleeve are pushed into the ground for 25cm then the cone is pushed ahead of the sleeve for 3.5cm at a uniform rate of 2cm/sec.The Dutch Cone Penetrometer tests recorded resistance to penetration of the cone at intervals of 20cm by means of pressure gauges mounted on the hydraulic sounding head.

2.2.2 Bore Hole Characteristics/Standard Penetration Test

Four (4) Boreholes were drilled. A light cable percussion rig was used for the drilling operation. Representative samples were collected at 0.75m intervals of depths and also at changes in soil type. Undisturbed samples of suspected critical soils were also obtained from the clay layers in the boreholes. Standard penetration tests were performed in sandy layers at I .5m intervals of depths in each of the Boreholes. The number of blows required to drive the standard sampling spoon 300mm penetration after an initial 150mm penetration represents the SPT (N) value.

2.2.3 Particle Size Distribution Tests

Particle size analysis was carried out by wet sieving before dry sieving. Fine analysis was also carried out. Suspected soils were tested for organic content. The particle size analysis was carried out in accordance with BS1377 [7] — Methods of tests for soil for Civil Engineering purpose.

2.2.4 Direct Shear Tests

Quick unconsolidated undrained shear box test was performed on the soil samples to determine undrained strength all the direct shear box tests were performed in accordance with BS1377 [7].

2.2.5 Triaxial Tests

Quick unconsolidated undrained triaxial test was performed on the soil sample in accordance with BS1377 [7].

2.2.6 Consolidation Test

One dimensional Oedometer test was carried out on the undisturbed clay samples in order to determine the consolidation characteristics. The consolidation test was carried out in accordance with BS1377 [7].

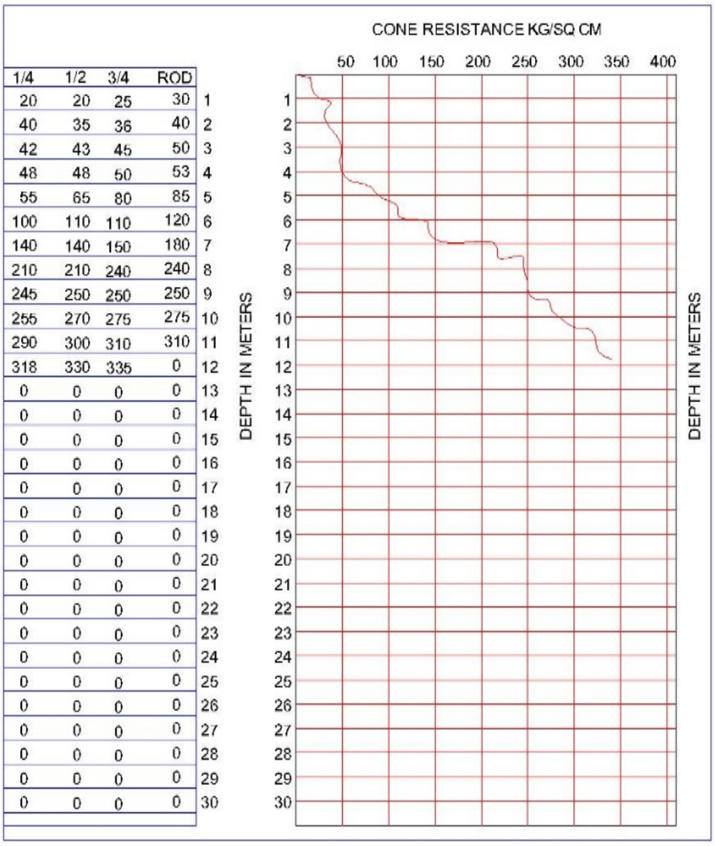
2.3 Design

Structural analysis and designs were carried out in accordance with BS 8110 – 1997[4], BS 6399 – 1984 [5], CP 1-3, 1972 and CP, 2004 [6]. For the purpose of estimation of forces and moments of the structure as well as the design of raft and pile foundations both at the serviceability and ultimate limit states, with the ultimate column axial load of 4138KN and serviceability column axial load of 2164KN [12,13,16].

3. Results and Discussions

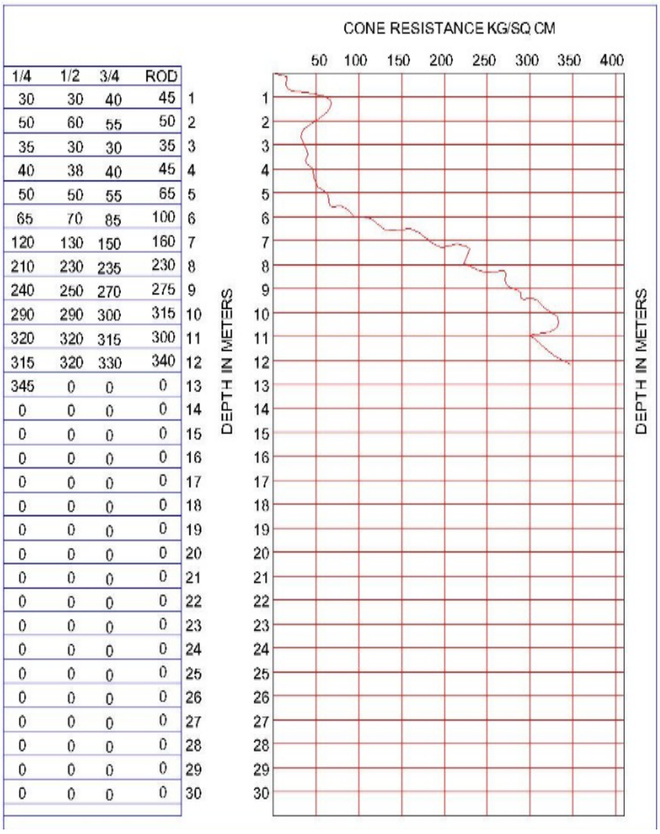
3.1 Cone Penetration Test Results

The Dutch Cone Penetrometer tests recorded resistance to penetration of the cone at intervals of 20cm by means of pressure gauges mounted on the hydraulic sounding head. The result are shown in fig. 3.1-3.12



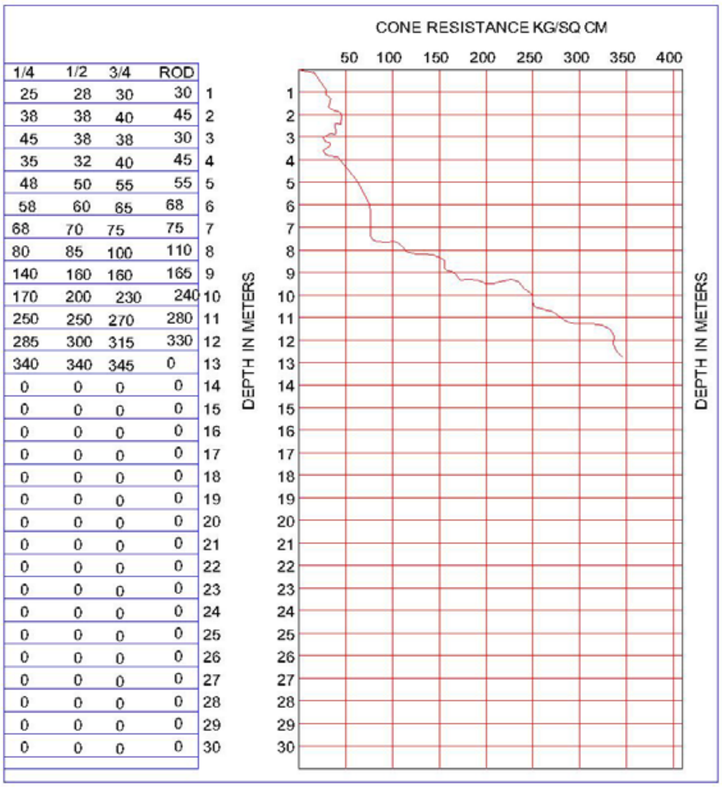
1/4	1/2	3/4	ROD	
20	20	25	30	1
40	35	36	40	2
42	43	45	50	3
48	48	50	53	4
55	65	80	85	5
100	110	110	120	6
140	140	150	180	7
210	210	240	240	8
245	250	250	250	9
255	270	275	275	10
290	300	310	310	11
318	330	335	0	12
0	0	0	0	13
0	0	0	0	14
0	0	0	0	15
0	0	0	0	16
0	0	0	0	17
0	0	0	0	18
0	0	0	0	19
0	0	0	0	20
0	0	0	0	21
0	0	0	0	22
0	0	0	0	23
0	0	0	0	24
0	0	0	0	25
0	0	0	0	26
0	0	0	0	27
0	0	0	0	28
0	0	0	0	29
0	0	0	0	30

Figure 3.1: ConePenetrometer



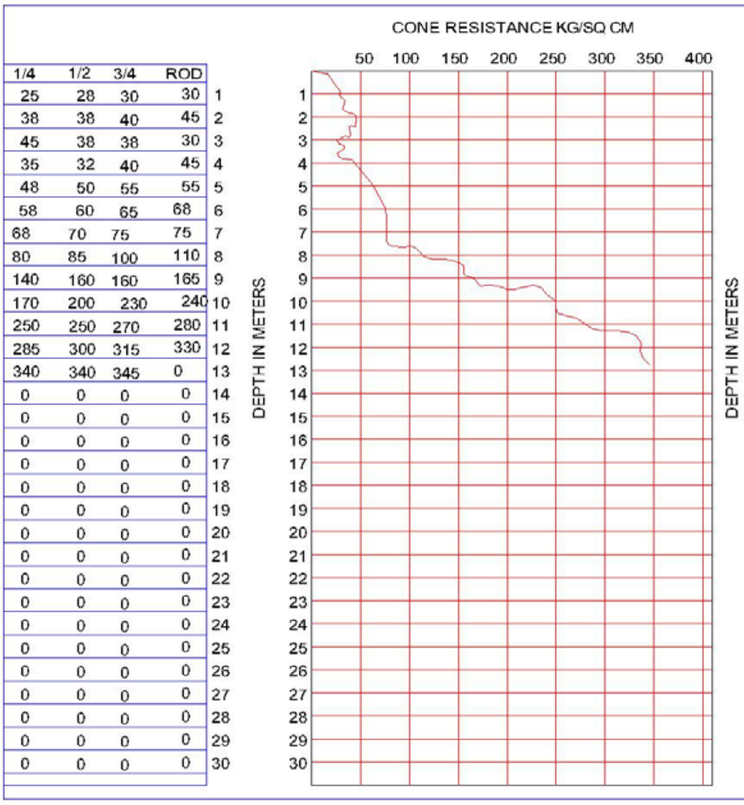
1/4	1/2	3/4	ROD	
30	30	40	45	1
50	60	55	50	2
35	30	30	35	3
40	38	40	45	4
50	50	55	65	5
65	70	85	100	6
120	130	150	160	7
210	230	235	230	8
240	250	270	275	9
290	290	300	315	10
320	320	315	300	11
315	320	330	340	12
345	0	0	0	13
0	0	0	0	14
0	0	0	0	15
0	0	0	0	16
0	0	0	0	17
0	0	0	0	18
0	0	0	0	19
0	0	0	0	20
0	0	0	0	21
0	0	0	0	22
0	0	0	0	23
0	0	0	0	24
0	0	0	0	25
0	0	0	0	26
0	0	0	0	27
0	0	0	0	28
0	0	0	0	29
0	0	0	0	30

Figure 3.2: ConePenetrometer Test 2



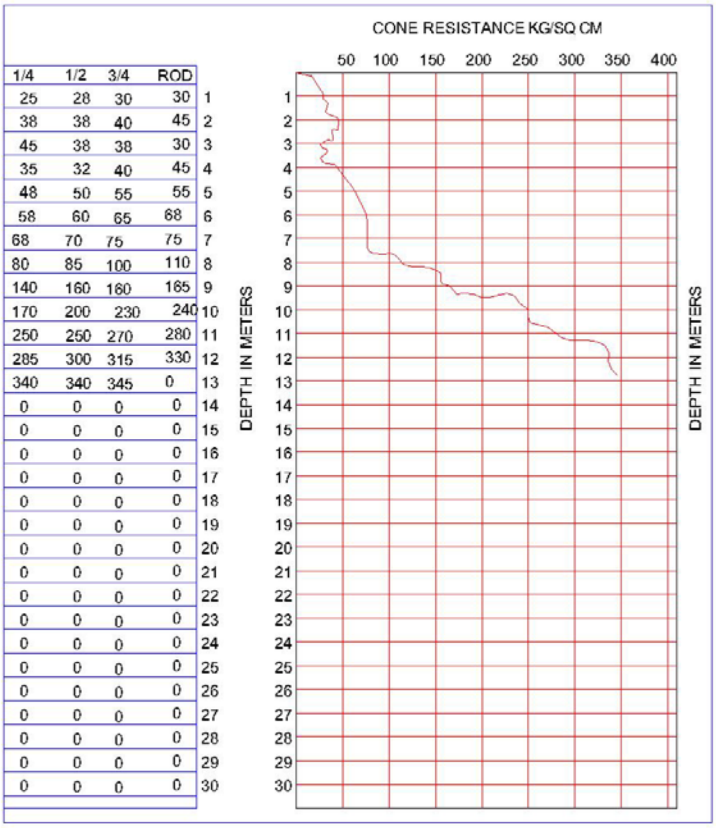
1/4	1/2	3/4	ROD	
25	28	30	30	1
38	38	40	45	2
45	38	38	30	3
35	32	40	45	4
48	50	55	55	5
58	60	65	68	6
68	70	75	75	7
80	85	100	110	8
140	160	160	165	9
170	200	230	240	10
250	250	270	280	11
285	300	315	330	12
340	340	345	0	13
0	0	0	0	14
0	0	0	0	15
0	0	0	0	16
0	0	0	0	17
0	0	0	0	18
0	0	0	0	19
0	0	0	0	20
0	0	0	0	21
0	0	0	0	22
0	0	0	0	23
0	0	0	0	24
0	0	0	0	25
0	0	0	0	26
0	0	0	0	27
0	0	0	0	28
0	0	0	0	29
0	0	0	0	30

Figure 3.3: Cone Penetrometer Test 3



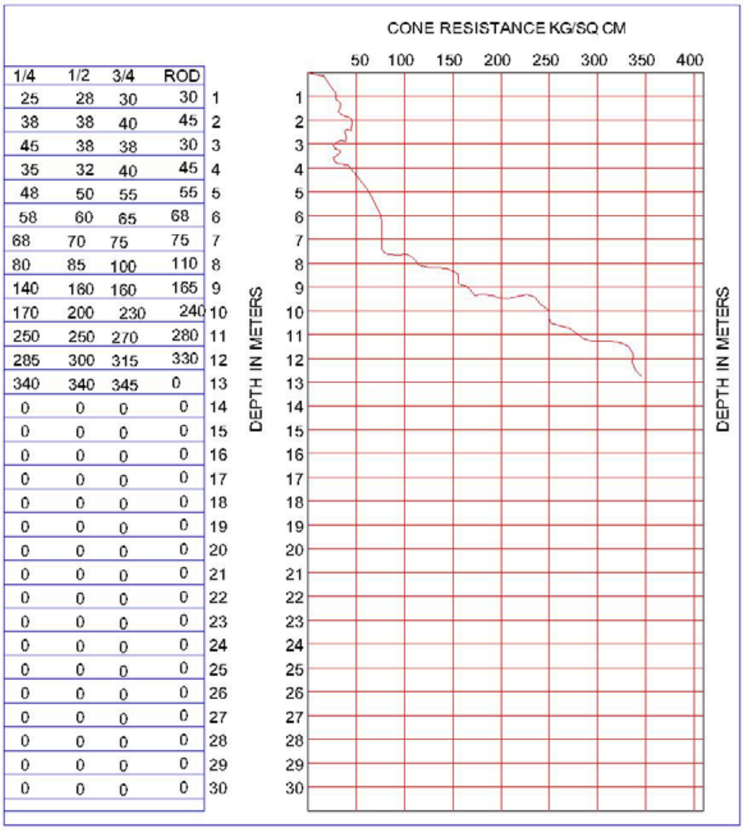
1/4	1/2	3/4	ROD	
25	28	30	30	1
38	38	40	45	2
45	38	38	30	3
35	32	40	45	4
48	50	55	55	5
58	60	65	68	6
68	70	75	75	7
80	85	100	110	8
140	160	160	165	9
170	200	230	240	10
250	250	270	280	11
285	300	315	330	12
340	340	345	0	13
0	0	0	0	14
0	0	0	0	15
0	0	0	0	16
0	0	0	0	17
0	0	0	0	18
0	0	0	0	19
0	0	0	0	20
0	0	0	0	21
0	0	0	0	22
0	0	0	0	23
0	0	0	0	24
0	0	0	0	25
0	0	0	0	26
0	0	0	0	27
0	0	0	0	28
0	0	0	0	29
0	0	0	0	30

Figure 3.4: Cone Penetrometer Test 4



1/4	1/2	3/4	ROD	
25	28	30	30	1
38	38	40	45	2
45	38	38	30	3
35	32	40	45	4
48	50	55	55	5
58	60	65	68	6
68	70	75	75	7
80	85	100	110	8
140	160	160	165	9
170	200	230	240	10
250	250	270	280	11
285	300	315	330	12
340	340	345	0	13
0	0	0	0	14
0	0	0	0	15
0	0	0	0	16
0	0	0	0	17
0	0	0	0	18
0	0	0	0	19
0	0	0	0	20
0	0	0	0	21
0	0	0	0	22
0	0	0	0	23
0	0	0	0	24
0	0	0	0	25
0	0	0	0	26
0	0	0	0	27
0	0	0	0	28
0	0	0	0	29
0	0	0	0	30

Figure 3.5: Cone Penetrometer Test 5



1/4	1/2	3/4	ROD	
25	28	30	30	1
38	38	40	45	2
45	38	38	30	3
35	32	40	45	4
48	50	55	55	5
58	60	65	68	6
68	70	75	75	7
80	85	100	110	8
140	160	160	165	9
170	200	230	240	10
250	250	270	280	11
285	300	315	330	12
340	340	345	0	13
0	0	0	0	14
0	0	0	0	15
0	0	0	0	16
0	0	0	0	17
0	0	0	0	18
0	0	0	0	19
0	0	0	0	20
0	0	0	0	21
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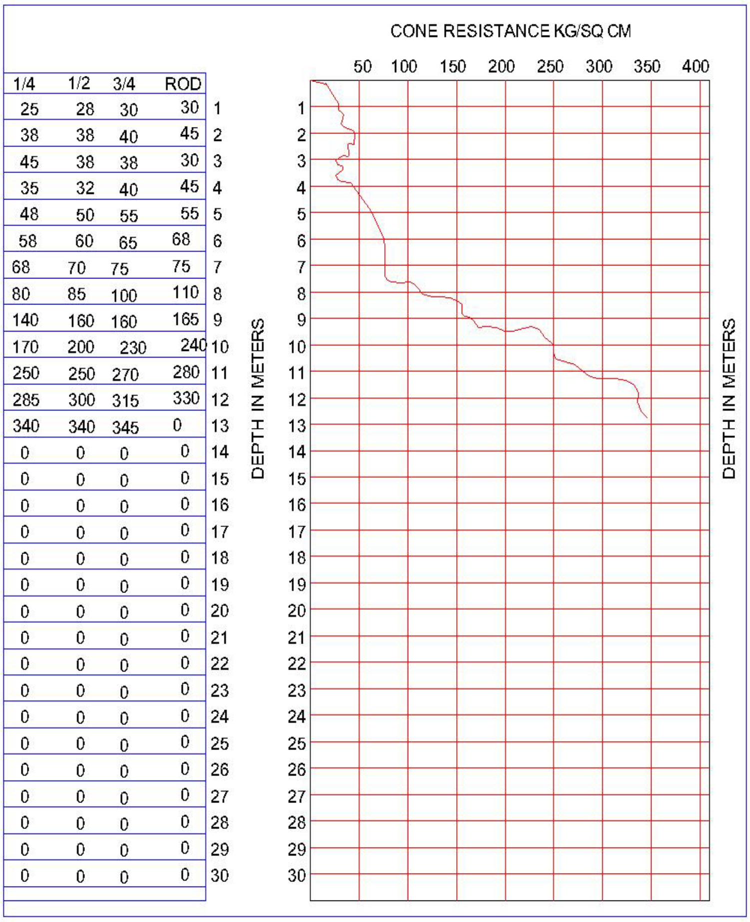
0	0	0	0	24
0	0	0	0	25
0	0	0	0	26
0	0	0	0	27
0	0	0	0	28
0	0	0	0	29
0	0	0	0	30

Figure 3.6: Cone Penetrometer Test 6



1/4	1/2	3/4	ROD	
25	28	30	30	1
38	38	40	45	2
45	38	38	30	3
35	32	40	45	4
48	50	55	55	5
58	60	65	68	6
68	70	75	75	7
80	85	100	110	8
140	160	160	165	9
170	200	230	240	10
250	250	270	280	11
285	300	315	330	12
340	340	345	0	13
0	0	0	0	14
0	0	0	0	15
0	0	0	0	16
0	0	0	0	17
0	0	0	0	18
0	0	0	0	19
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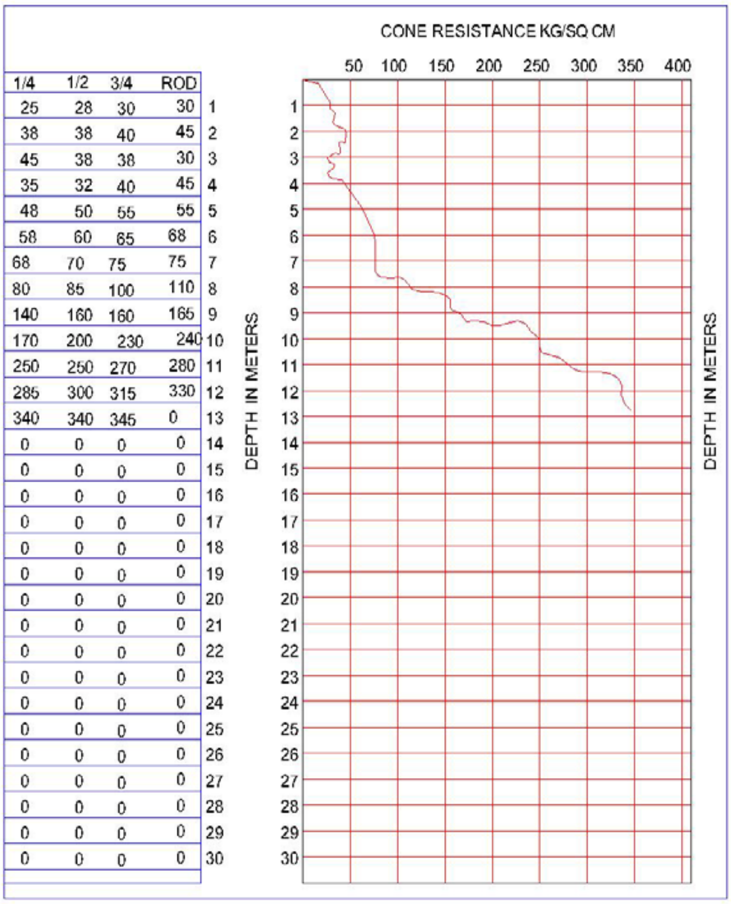
0	0	0	0	25
0	0	0	0	26
0	0	0	0	27
0	0	0	0	28
0	0	0	0	29
0	0	0	0	30

Figure 3.7: Cone Penetrometer Test 7



1/4	1/2	3/4	ROD	
25	28	30	30	1
38	38	40	45	2
45	38	38	30	3
35	32	40	45	4
48	50	55	55	5
58	60	65	68	6
68	70	75	75	7
80	85	100	110	8
140	160	160	165	9
170	200	230	240	10
250	250	270	280	11
285	300	315	330	12
340	340	345	0	13
0	0	0	0	14
0	0	0	0	15
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0	0	0	0	30

Figure 3.8: Cone Penetrometer Test 8

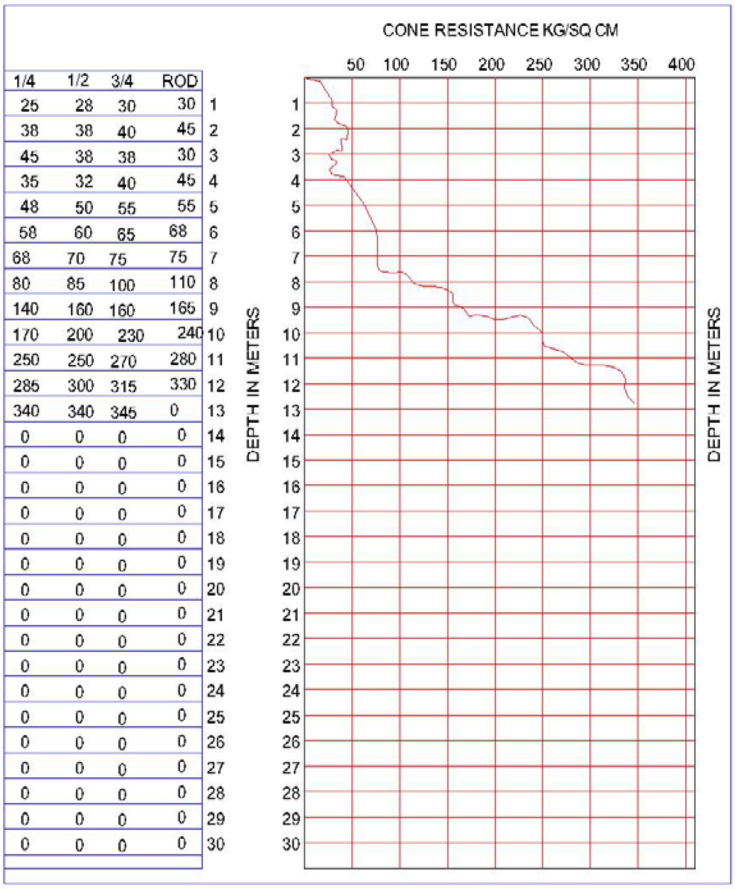


Figure 3.9: Cone Penetrometer Test 9

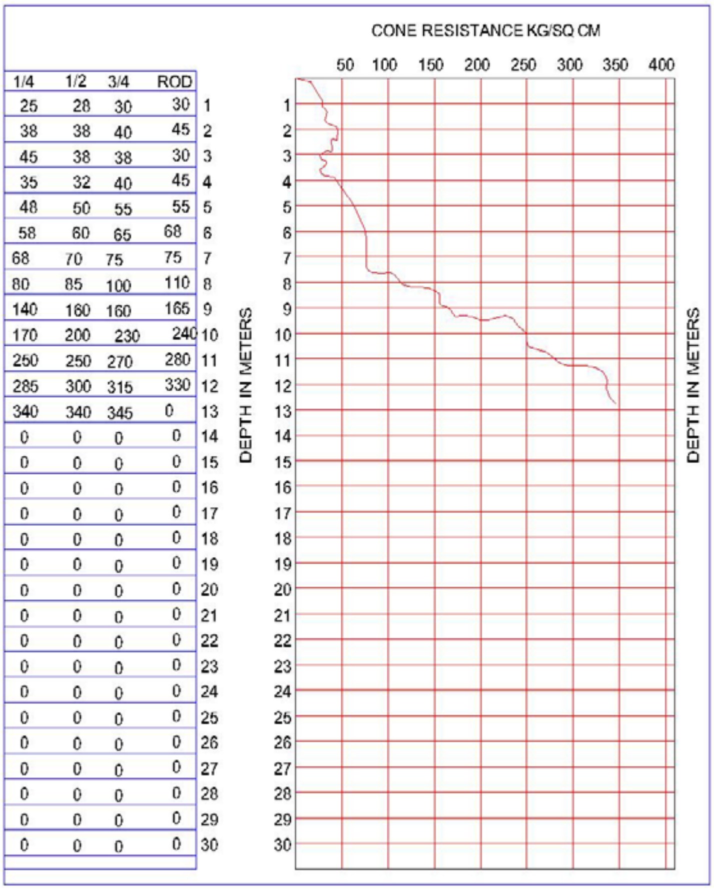


Figure 3.10: Cone Penetrometer Test

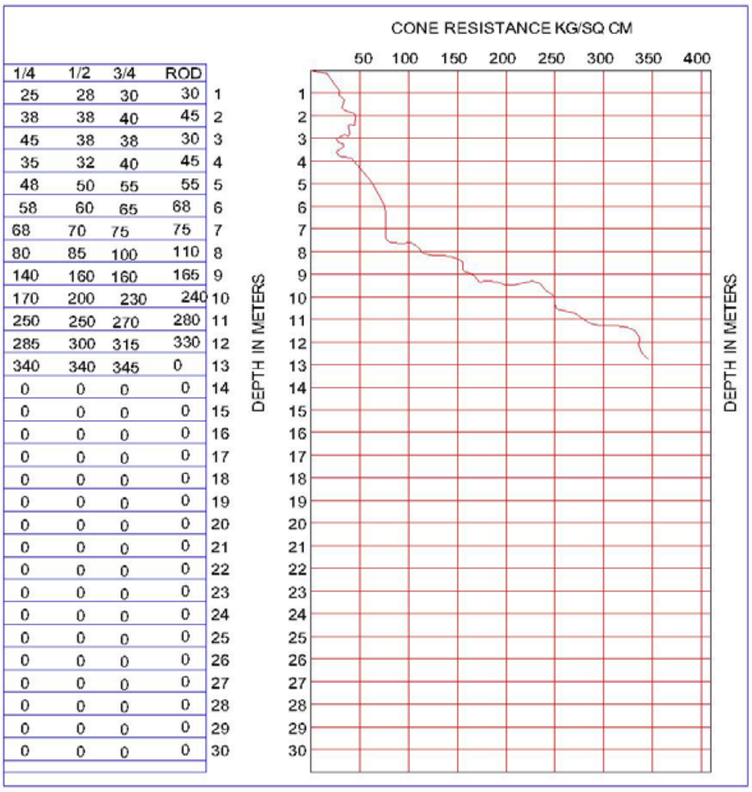


Figure 3.11: Cone Penetrometer Test 11

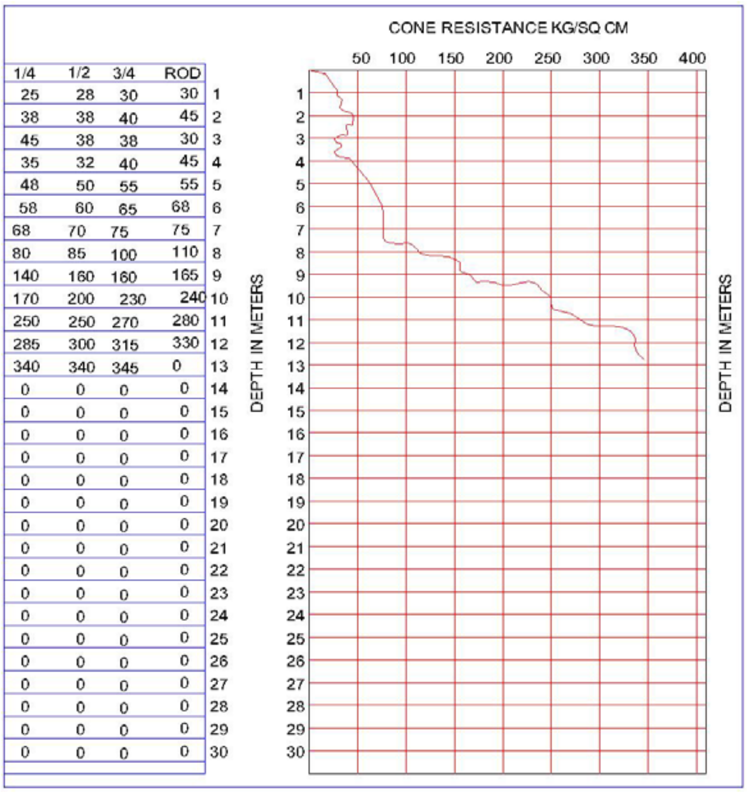


Figure 3.12: Cone Penetrometer Test 12

3.2 Bore Hole Characteristics/Standard Penetration Test Results

The results of the bore hole characteristics/standard penetration test are shown in figures 3.13 to 3.16. The tests showed that the top soil was dry grayish mottled clay, followed by soft silty/ sandy clay up to 6m depth. Below 6 to 7m was sand. The clay end bearing minimum pressure was 54kN/m^2 and its maximum pressure was 68kN/m^2. The sand end bearing minimum pressure was 416kN/m^2 and its maximum bearing pressure - 697kN/m^2. The clay skin friction ranged from 10 – 13kN/m^2. The sand minimum skin friction was 77kN/m^2 and the maximum was 129kN/m^2. The allowable bearing capacity of the soil ranged from 64kN/m^2 to 71kN/m^2 for a shallow depth of 1m – 2m and 177kN/m^2 – 517kN/m^2 for a deep depth of 10m – 20m. The soil water quality is shown in table 3.1

Table 3.1: Water Quality

Borehole No	Temperature (^{o}C)	pH	Sulphate (mg/I)	Chloride (mg/I)
1	27.6	6.1	142	10.4
2	27.6	*5.9*	145	8.9
3	*27.5*	6.0	144	11.5
4	27.4	6.0	140	11.2

Soil Water Quality

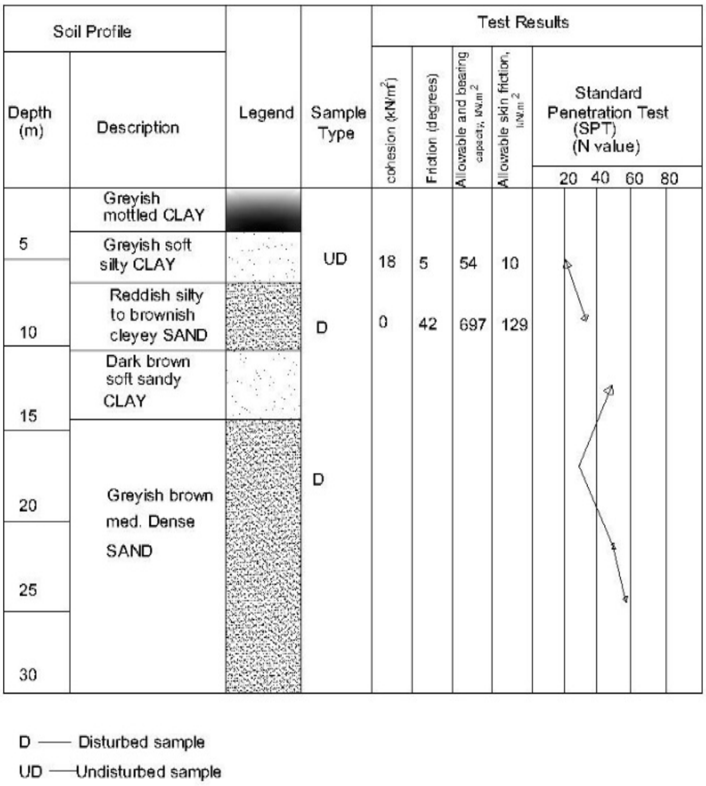


Figure 3.13: Bore Hole No.1 Characteristics With Ground Water Depth 9.5m

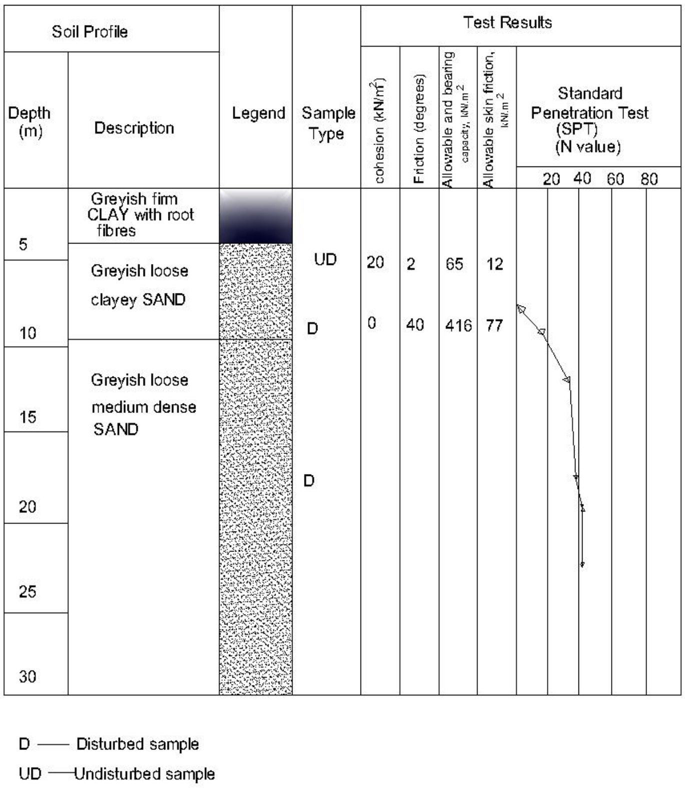


Figure 3.14: Bore Hole No.1 Characteristics With Ground Water Depth 8.5m

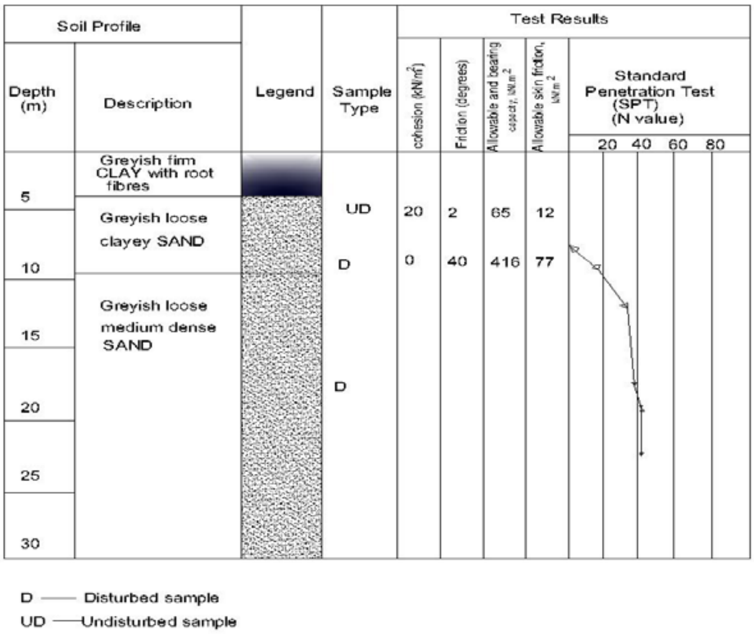


Figure 3.15: Bore Hole No.1 Characteristics With Ground Water Depth 9.0m

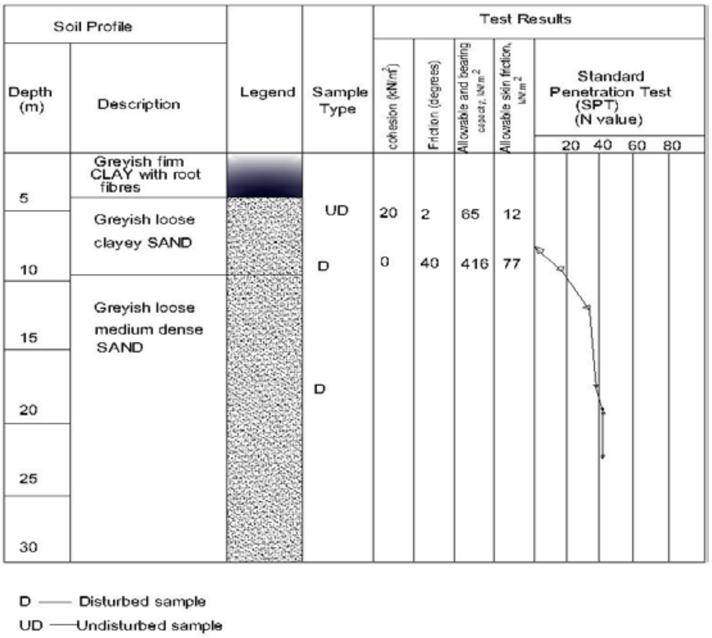


Figure 3.16: Bore Hole No.1 Characteristics With Ground Water Depth 9.2m

3.3 Particle Size Analysis

The results of the particle size analysis are summarized in Table 3.1 and presented below in figs. 3.17 to 3.32. The sands classify as poor graded material (mfc). Organic matters identified were mainly root fibers varying from 0% to 3% in content.

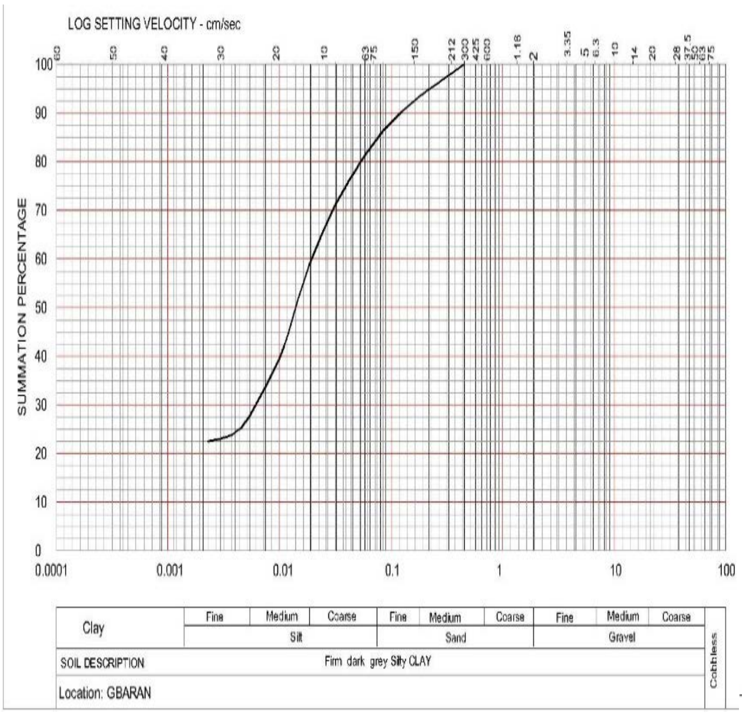


Figure 3.17: Bore Hole No. Particles Size Distribution At Depth 2m

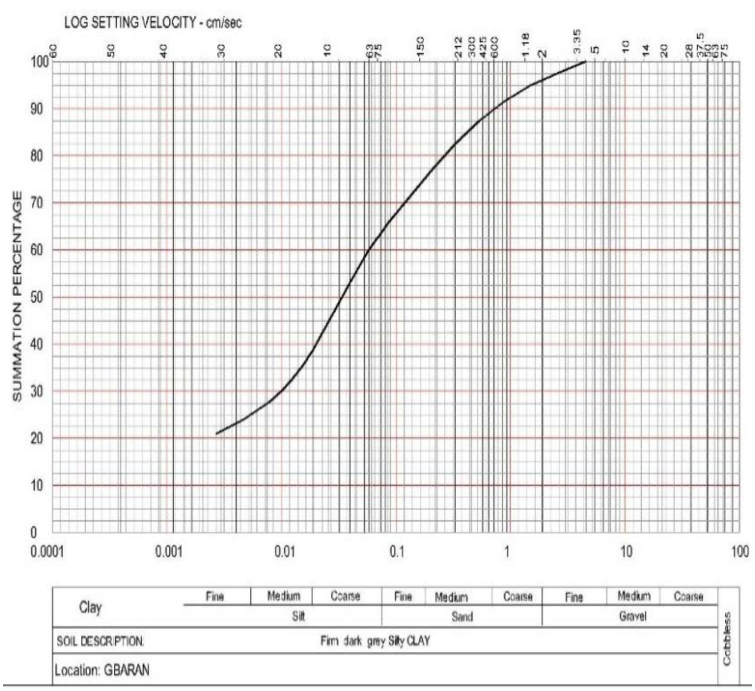


Figure 3.18: Bore Hole No. Particles Size Distribution At Depth 3.25m

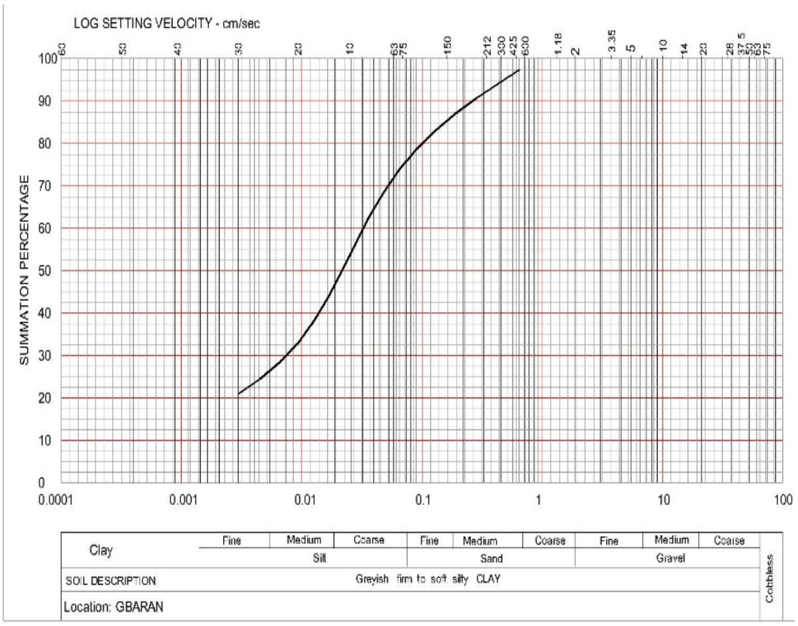


Figure 3.19: Bore Hole No. Particles Size Distribution At Depth 4m

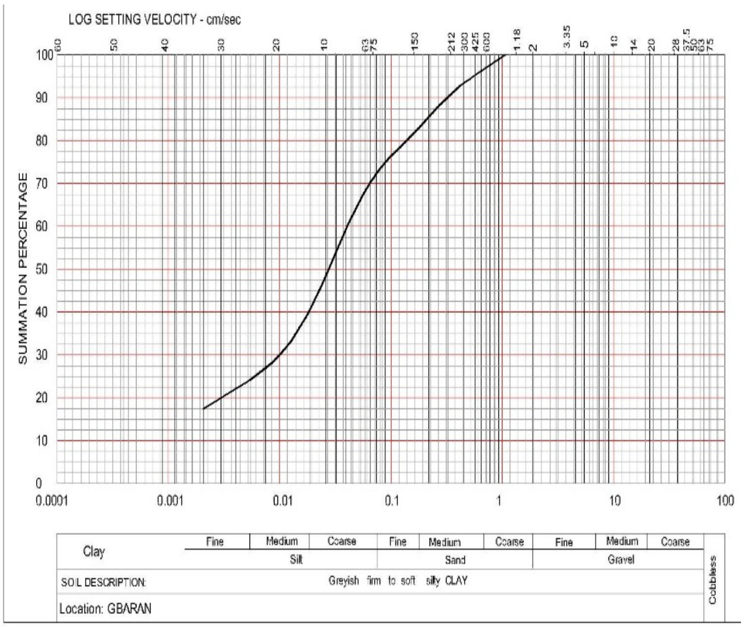


Figure 3.20: Bore Hole No. Particles Size Distribution At Depth 6.2m

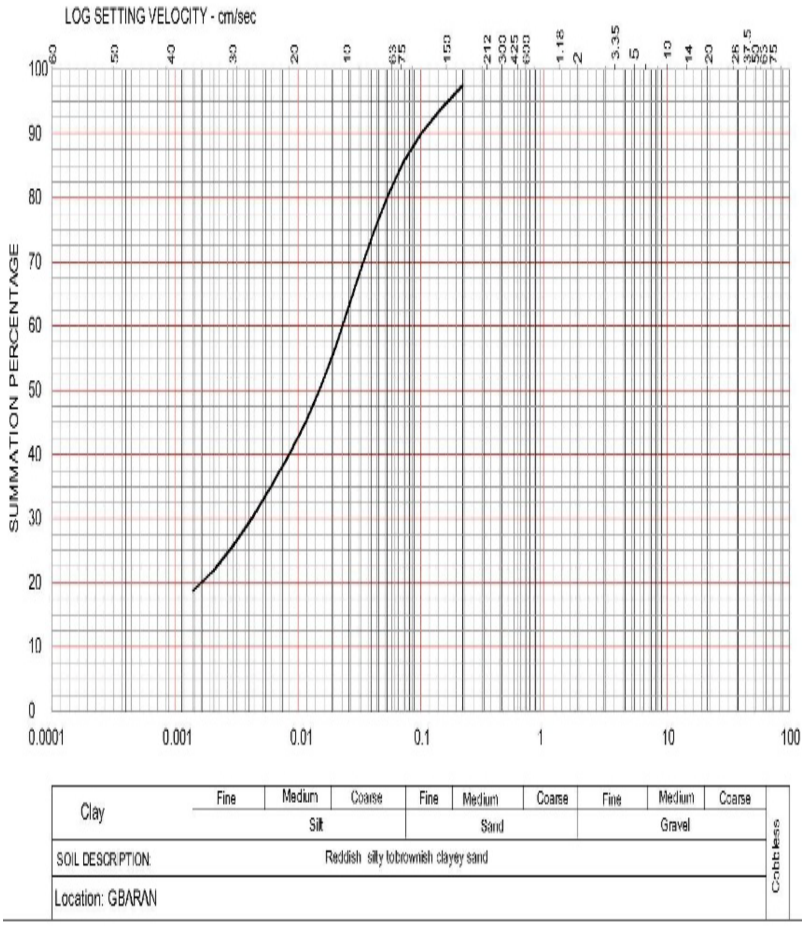


Figure 3.21: Bore Hole No. Particles Size Distribution At Depth 6.75m

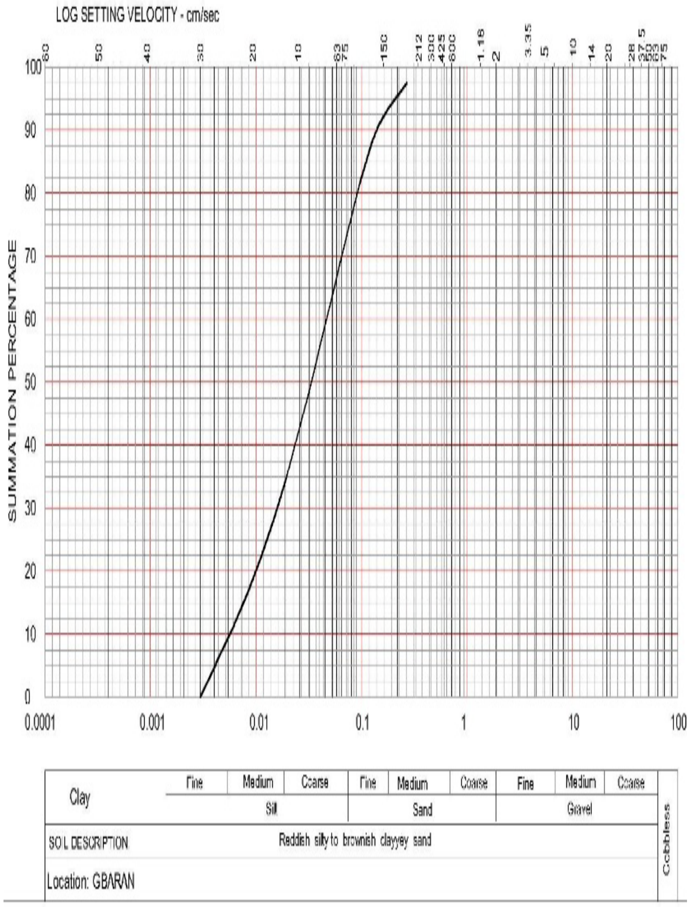


Figure 3.22: Bore Hole No. Particles Size Distribution At Depth 7.5m

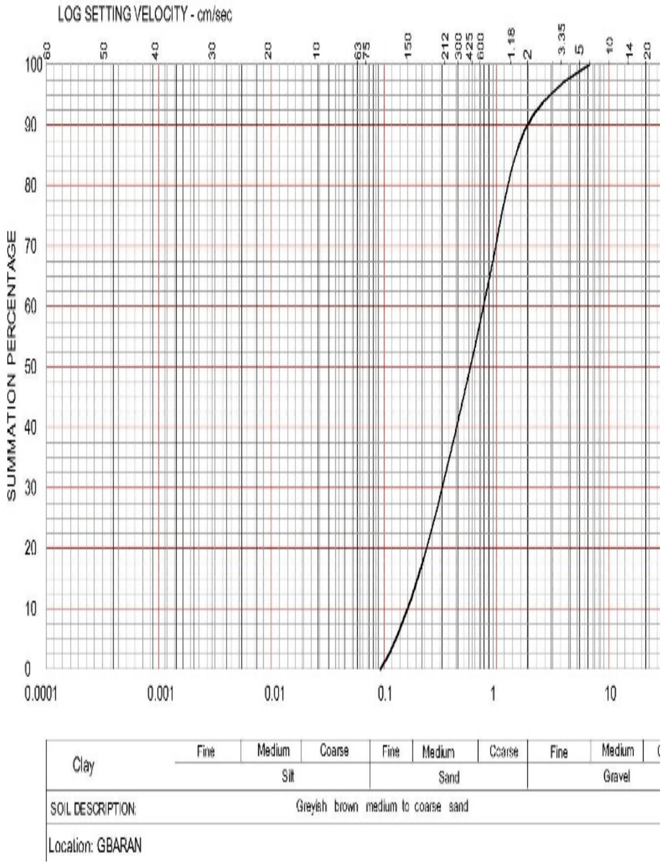


Figure 3.25: Bore Hole No. Particles Size Distribution At Depth 12.75m

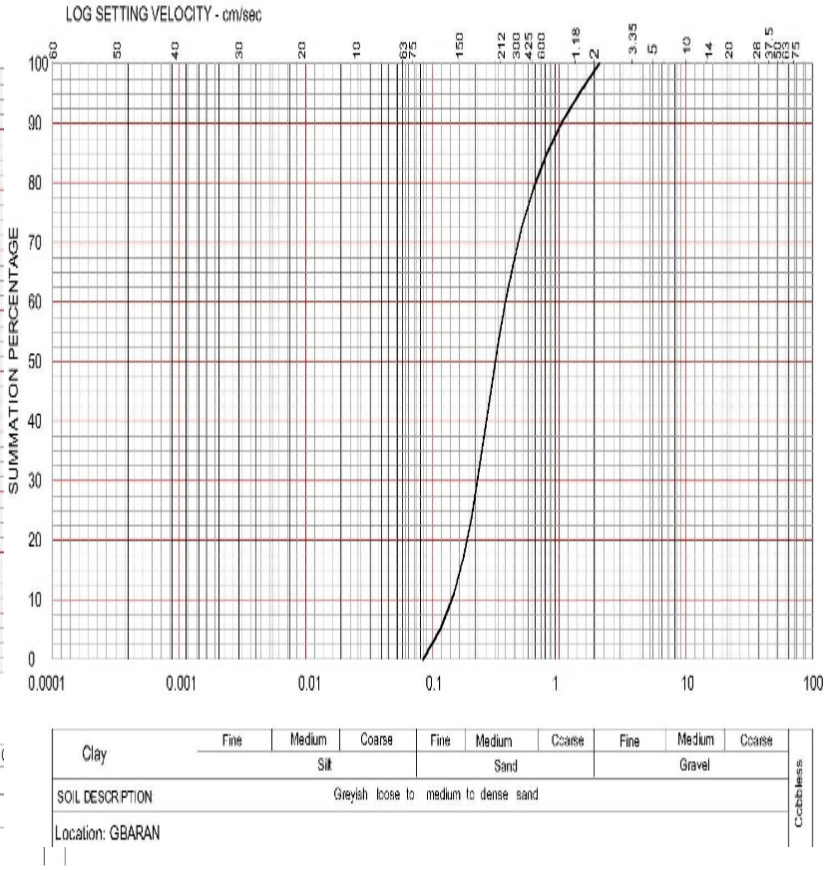


Figure 3.26: Bore Hole No. Particles Size Distribution At Depth 16m

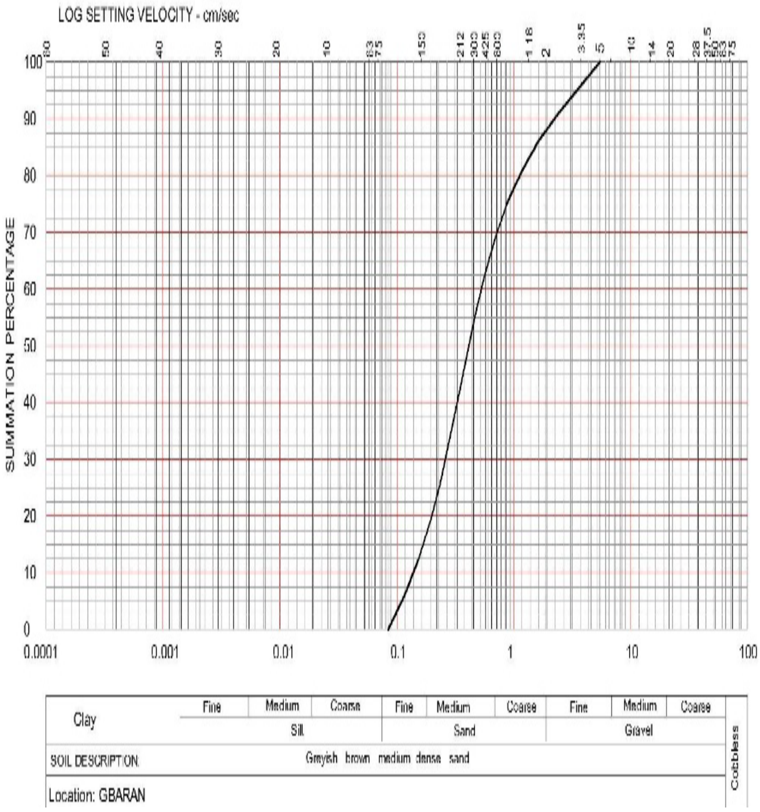


Figure 3.27: Bore Hole No. Particles Size Distribution At Depth 15m

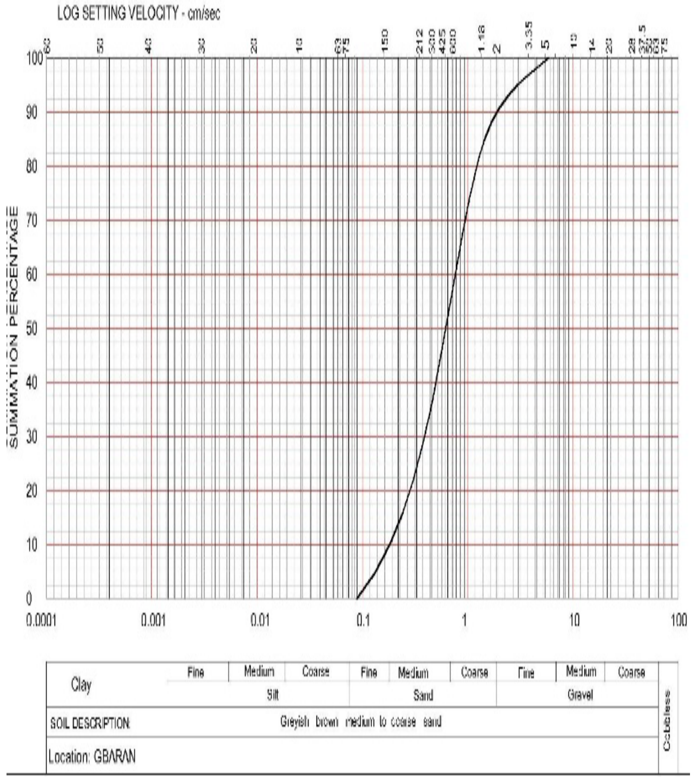


Figure 3.28: Bore Hole No. Particles Size Distribution At Depth 15.25m

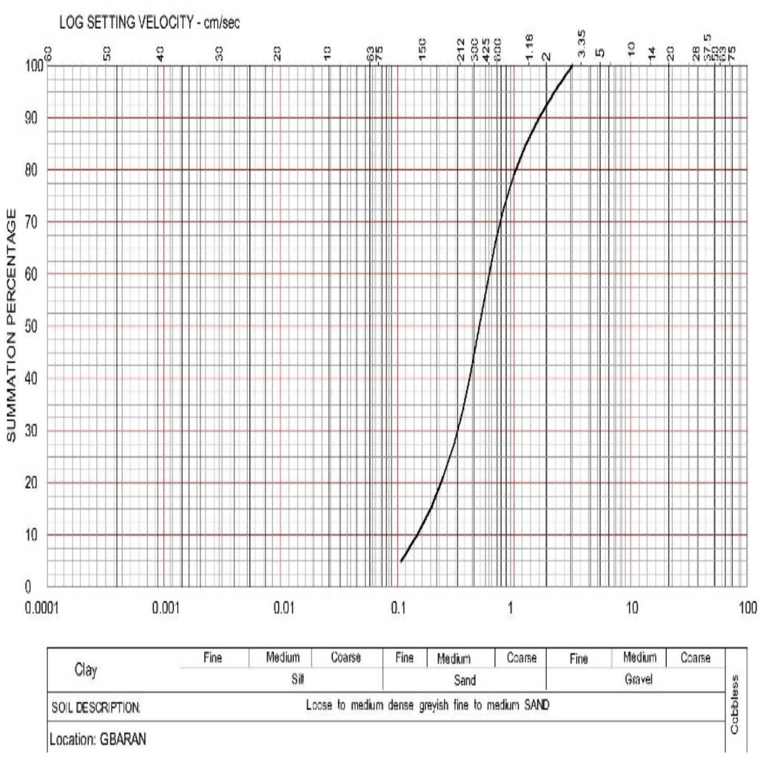


Figure 3.31: Bore Hole No. Particles Size Distribution at Depth 25.25m

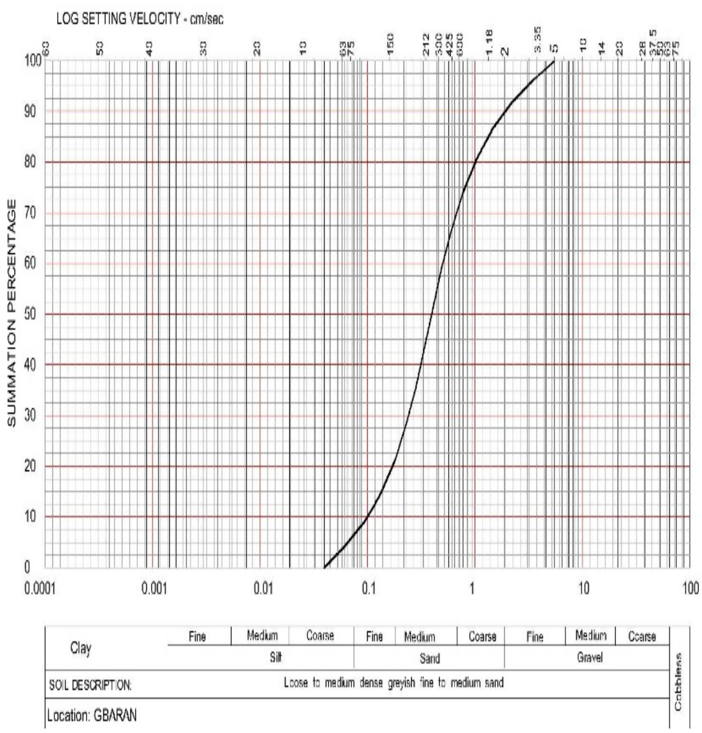


Figure 3.32: Bore Hole No. Particles Size Distribution at Depth 27.25m

3.4 Shear Box Test Results

The results from the shear box test are shown in Table 3.2 (soil characteristics) and table 3.3 (summary of soil properties). The direct shear tests graphs are shown

Table 3.2: Soil Characteristics (Shear/ Consolidation Test Result)

BH NO	Depth **(m)**	**Moisture** content **(%)**	Bulk unit weight *(*KN/m^3*)*	Dry unit weight (KN/m^3)	Friction (Degree)	Cohesion (Direct shear) (KN/m^2)	Compression Index	Coeff. Of consolidation (Cm^2/Sec)	Coeff of Vol. Comp (m^2/kN)
1.	*4.5*	41	17.76	12.60	7	17	0.17	1.1x10^{-3}	6.2x10^{-4}
	16.0	17	18.21	15.56	44	0	-	-	-
2.	3.0	38	16.22	11.75	*5*	19	0.13	1.4x10^{-3}	5.0x10^{-4}
	11.0	20	17.72	14.77	43	0	-	-	-
3	4.0	43	15.52	*10.85*	2	20	0.41	0.28x10^{-3}	7.8x10^{-4}
	14.0	22	18.87	15.47	43	0	-	-	-
4.	2.0	44	*15.29*	10.62	3	19	0.17	1.0x10^{-3}	6.1x10^{-4}
	12.0	21	18.36	15.17	44	0	-	-	-

Table 3.3: Summary of Soil Properties (Shear/ Consolidation Test Result)

	Clay			Silty Sand		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Friction (degrees)	2	7	4	43	44	44
Cohesion (kN/m^2)	17	20	19	0	0	0
Bulk density (kN/m^3)	15.29	17.76	16.20	17.21	18.87	18.16
Dry density(kN/m^3)	10.62	12.6	11.46	14.77	15.56	15.24
Moisture content **(%)**	38	41	42	17	22	20
Liquid limit **(%)**	36	65	45	-	-	-
Plasticity Index **(%)**	14	34	20	-	-	-
Compression index	0.13	0.41	0.22	-	-	-
Coeff of Comp (m^2/kN)	$5.0x10^{-4}$	$7.8x 10^{-4}$	$6.3x10^{-4}$	-	-	-
Coeff Of consol (cm^2/sec)	$0.28x10^{-3}$	$1.4x10^{-3}$	$0.95x10^{-3}$	-	-	-
Specific gravity	2.58	2.61	2.60	2.61	2.62	2.62
%Passing200	25	30	28	1	5	3
Coeff Of curvature				0.07	1.3	0.8
Coeff Of uniformity				0.38	4.0	2.8

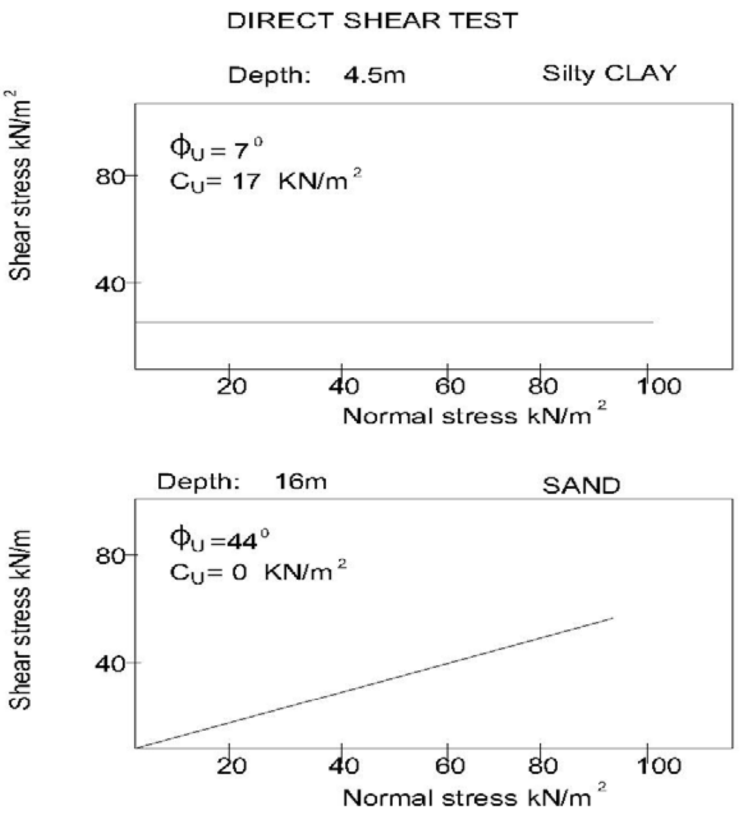


Figure 3.33: Shear Box Test For Borehole No.1

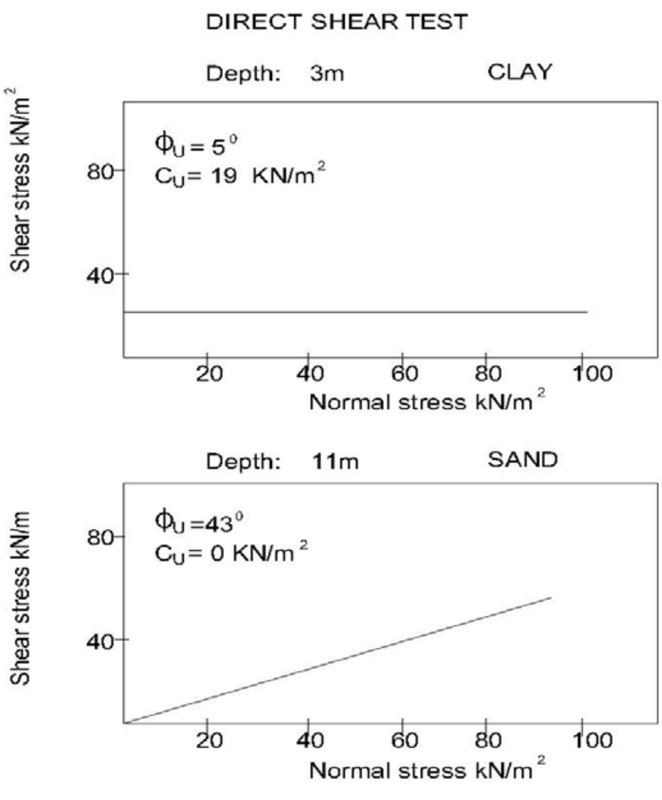


Figure 3.34: Shear Box Test For BoreholeNo.2

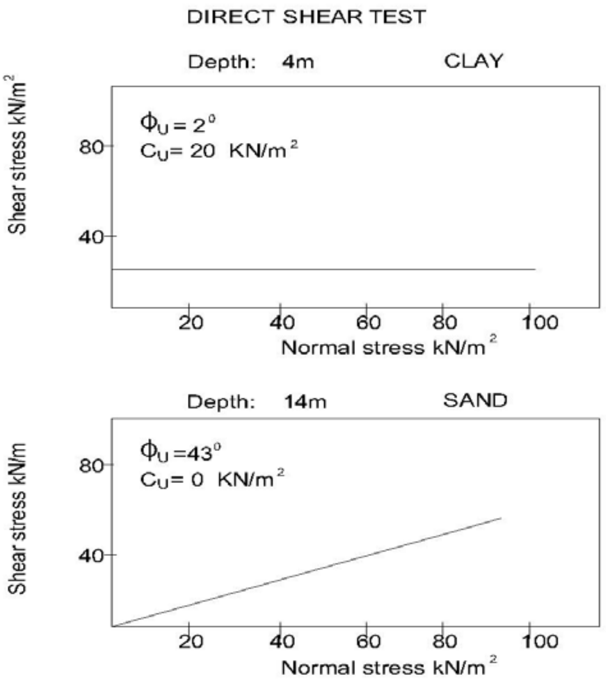


Figure 3.35: Shear Box Test For BoreholeNo.3

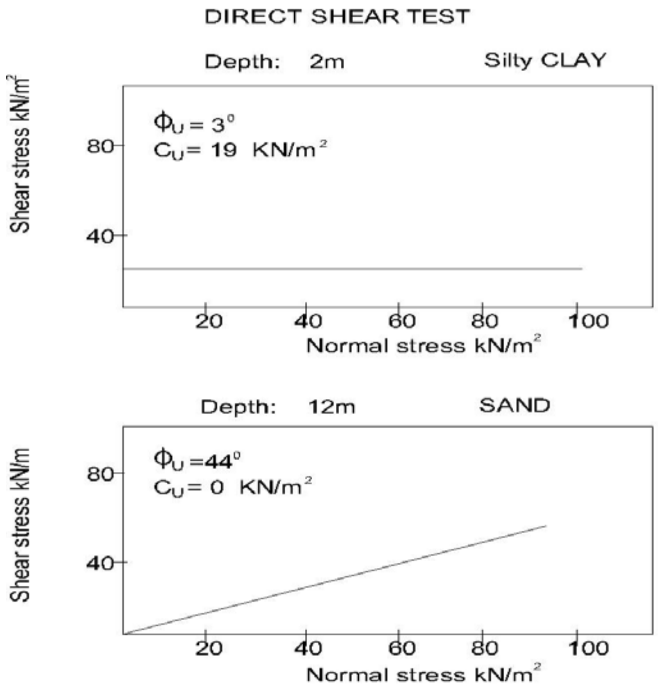


Figure 3.36: Shear Box Test For BoreholeNo.4

3.3 Triaxial Test Results

The results obtained are presented against their corresponding soil layers in each of the Boreholes. The data were analyzed following Mohr — Coulomb failure criterion, as shown in figs. 3.37 to 3.40.

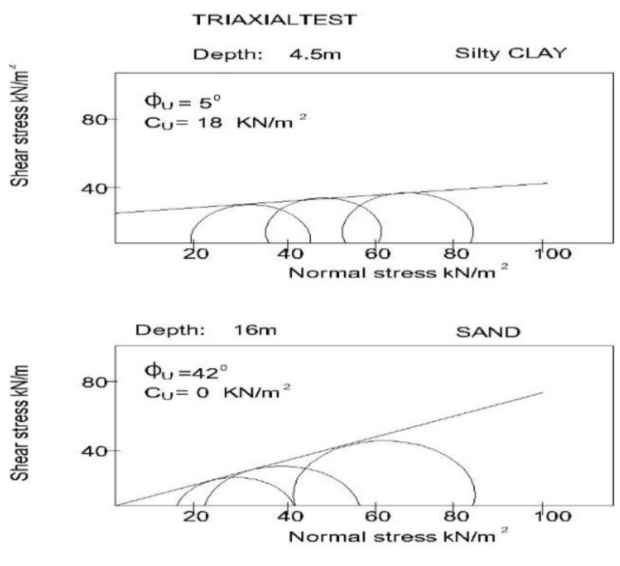


Figure 3.37: Triaxial Test for Borehole No.1

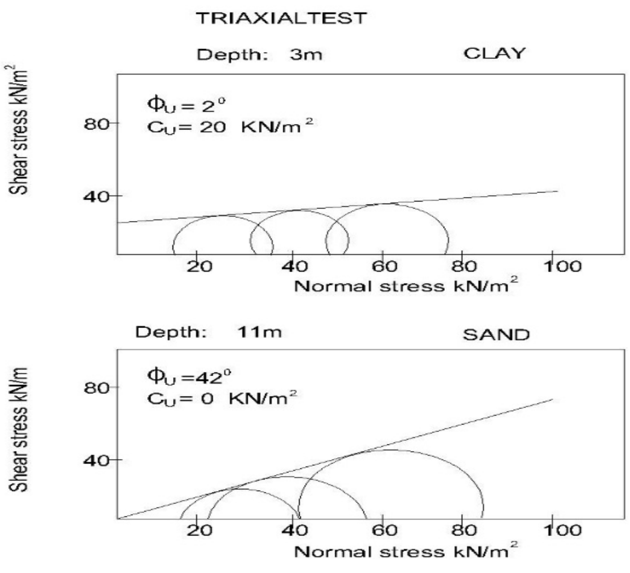


Figure 3.38: Triaxial Test for Borehole No.2

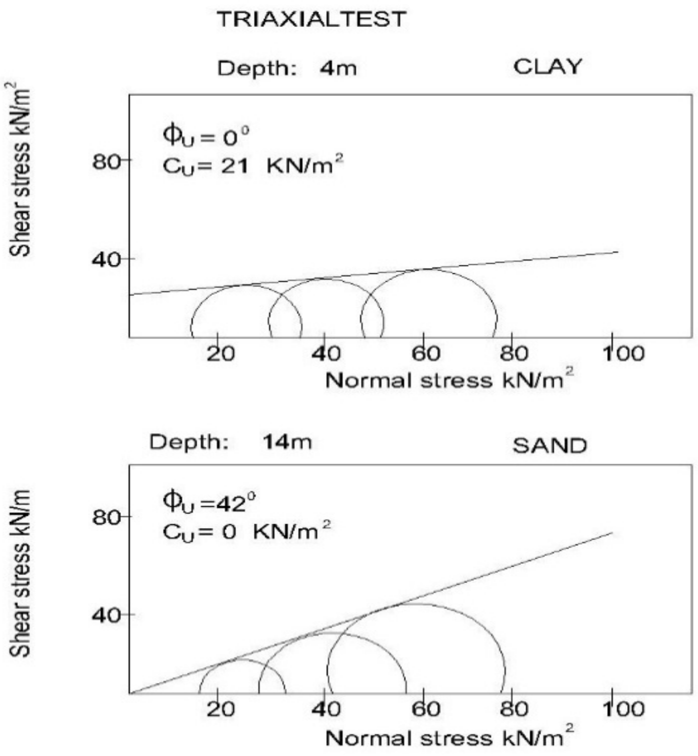


Figure 3.39: Triaxial Test for BoreholeNo.3

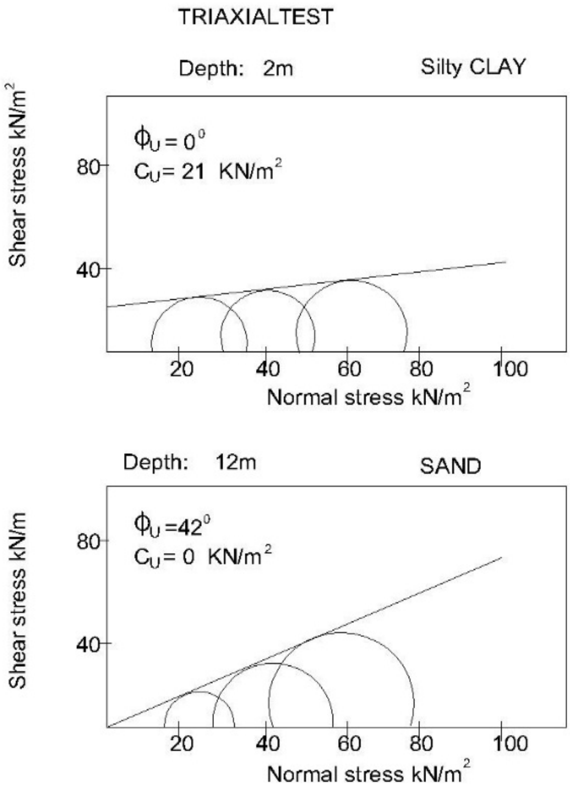
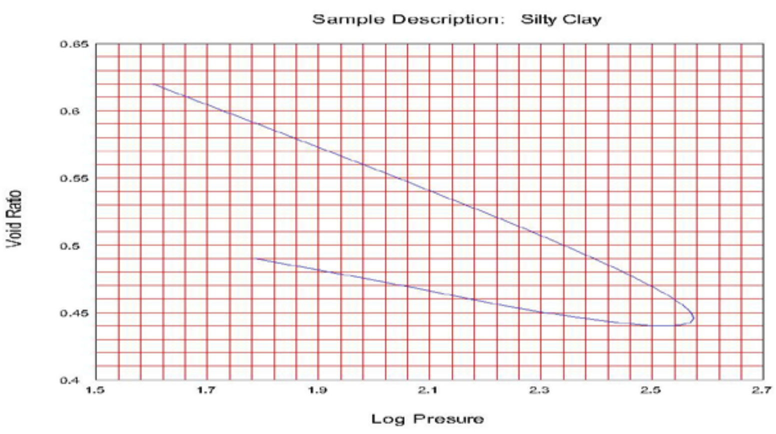


Figure 3.40: Triaxial Test for BoreholeNo.4

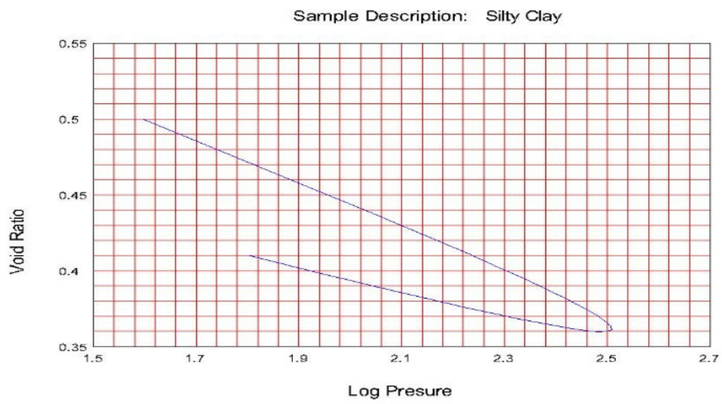
3.4 Consolidation Test Results

The void ratio versus load curves of the consolidation test are shown Figs. 3.41 to 3.44.



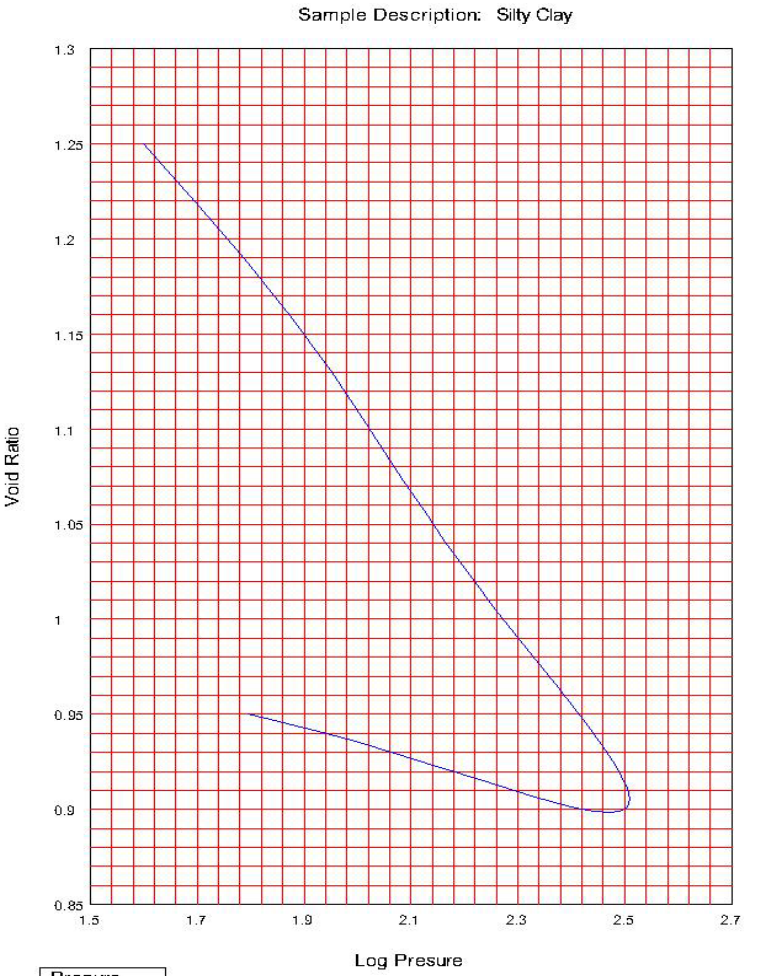
Presure KN/m^2	Compression index C_c	Coff. Of Compressibility M_v m^2/kN	Coeff. of Consolidation C_v cm^2/sec
40			
80	0.18	6.2×10^{-4}	1.1×10^{-3}
160		5.5×10^{-4}	1.4×10^{-3}
320		3.0×10^{-4}	2.4×10^{-3}

Figure 3.41: Borehole 1. Consolidation test at depth, 4.5m



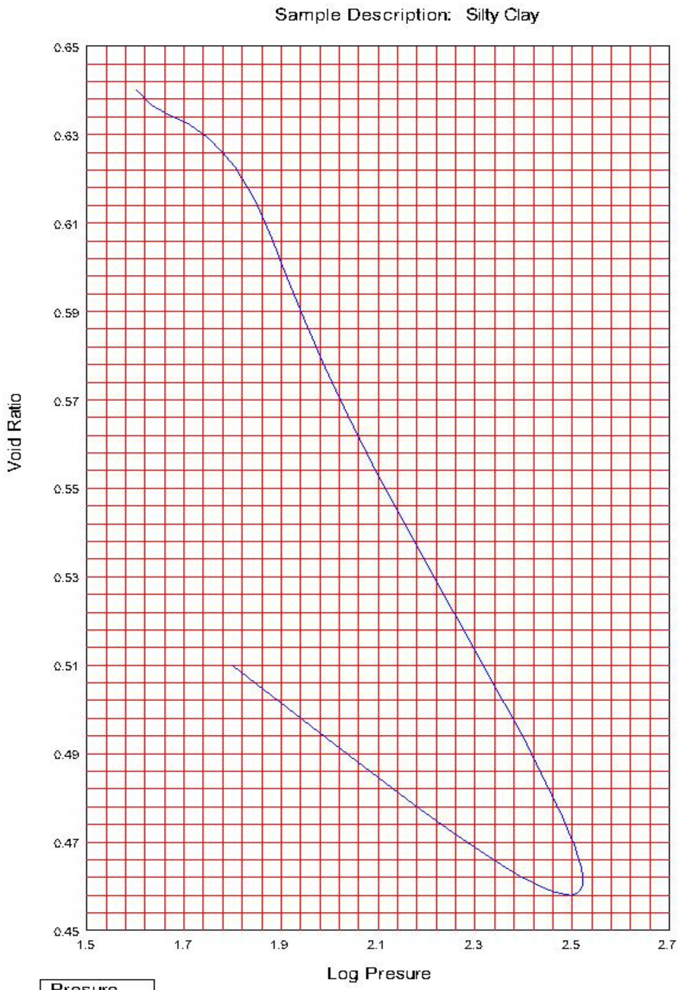
Presure KN/m^2	Compression index C_c	Coff. Of Compressibility M_v m^2/kN	Coeff. of Consolidation C_v cm^2/sec
40			
80	0.13	5.0×10^{-4}	1.4×10^{-3}
160		4.0×10^{-4}	2.5×10^{-3}
320		3.0×10^{-4}	2.9×10^{-3}

Figure 3.42: Borehole 2. Consolidation test at depth, 3m



Presure KN/m²	Compression index C_c	Coff. Of Compressibility M_v m²/kN	Coeff. of Consolidation C_v cm²/sec
40			
80	0.41	$7.8x10^{-1}$	$0.28x10^{-3}$
160		$5.4x10^{-1}$	$1.3x10^{-3}$
320		$3.5x10^{-1}$	$1.9x10^{-3}$

Figure 3.43: Borehole 3. Consolidation test at depth, 3.75m



Presure KN/m²	Compression index C_c	Coff. Of Compressibility M_v m²/kN	Coeff. of Consolidation C_v cm²/sec
40			
80	0.18	$6.1x10^{-1}$	$1.0x10^{-3}$
160		$5.0x10^{-1}$	$1.4x10^{-3}$
320		$2.7x10^{-1}$	$2.5x10^{-3}$

Figure 3.44: Borehole 4. Consolidation test at depth, 2m

3.5 Quantities and Cost Analysis of Raft Foundation

The quantities and cost analysis of the raft foundation based on Building and Engineering Standard Method of Measurement (BESMM3), 1998. Is presented in table 3.4.

Table 3.4: Bills of Quantities for the Raft Foundation

S/N	Description	Qty	Unit	Rate (₦)	Amount (₦)
	Element No. 1				
	Excavation and Filling				
A.	Excavate foundation starting from the top level to a depth not exceeding 5.00metres.	5240	m^3	2,000.00	10,480,000.00
B.	Remove surplus excavated materials from site.	5240	m^3	1,000.00	5,240,000.00
	In Situ Concrete				
C.	Plain in situ concrete (1:2:4-19mm aggregate) for building.	629	m^3	25,000.00	15,725,000.00
	In Situ Concrete				
D.	Reinforced concrete raft foundation with thin form thickness of 600mm mix ratio (1:1:2).	629	m^3	30,000.00	18,870,000.00
	Form Work				
E.	Sawn form work at the edges of bed 600mm.	286	m	850.00	243,100.00
	Reinforcement				
F.	12mm diameter high tensile reinforcement to BS 4449.	63	Ton	390,000.00	24,570,000.00
	SUB TOTAL				**75,128,100.00**
	ADD 5% Contingencies				**3,756,405.00**
	GRAND TOTAL				**78,884,505.00**

3.6 Quantities and Cost Analysis of Pile Foundation

The quantities and cost analysis of the pile foundation based on Building and Engineering Standard Method of measurement (BESMM3), [14] 1998.

Table 3.5: Bills of Quantities for the Pile Foundation

S/N	Description	Qty	Unit	Rate (₦)	Amount (₦)
	Element No. 1 **Concrete Work** **In Situ Concrete**				
A.	Reinforced concrete pile foundation with 6 piles in a cap, each pile is 15m deep. 36 numbers of pile caps. Concrete mix (1:1:2).	250	m^3	30,000.00	7,500,000.00
	Form Work				
B.	Sawn form work to reinforced concrete pile foundation to vertical sides of pile cap 36 numbers.	720	m^3	850.00	612,000.00
	Reinforcement 16mm diameter high tensile reinforcement to BS 4449.				
C.	12mm diameter high tensile reinforcement to BS 4449.	15	Ton	390,000.00	5,850,000.00
D.	**Pilling** 6 pile in a cap, 15m deep.	12	Ton	390,000.00	4,680,000.00
E.		36	Nr	2,592,000.00	93,312,000.00
	SUB TOTAL				**111,954,000.00**
	ADD 5% Contingencies				**5,597,700.00**
	GRAND TOTAL				**117,551,700.00**

4. Limitations

The limitations of the research include:

1. Difficulty in obtaining permission from the local community leaders before carrying out soil

investigation.

2. It also involves a lot of financial implications to get suitable equipment to work on swampy environment

4. Conclusion

From the cost analysis, the cost of the raft foundation was N78,884,505.00 (Seventy Eight Million, eight Hundred and eighty four Thousand, five Hundred and five Naira only) while the cost of the pile foundation was N117,551,700.00 (One Hundred and seventeen Million, five Hundred and Fifty one Thousand, Seven Hundred Naira only). This showed that the cost of the pile foundation was greater than that of the raft foundation by 39%. It is recommended that raft foundation be used on the area in order to minimize cost.

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