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GEOTECHNICAL INVESTIGATION REPORT

M/s. NEXA INFRA PROJECTS, CHENNAI

PROPOSED CONSTRUCTION OF RESIDENTIAL BUILDING (STILT+05) AT NO:3, A.N.A. ANNAMALAI AVENUE, ATHIPATTU, AMBATTUR, CHENNAI-53.

BAG/M/s. NEXA INFRA PROJECTS/M-2402/22-23

15th FEBRUARY 2023

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TITLE	GEOTECHNICAL INVESTIGATION REPORT

REV.	DATE	REPORT NUMBER	REMARK
0	15.02.2023	BAG/M/s. NEXA INFRA PROJECTS/M-2402/22-23	

For BOOSHNAM ASSOCIATES
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CHAPTER-1

INTRODUCTION

1.0 Preamble

M/s. Nexa Infra Projects, Chennai proposed to construct a **Residential Building (Stilt+05) at No:3, A.N.A. Annamalai Avenue, Athipattu, Ambattur, Chennai-53**. For the purpose of designing the foundations, the responsibility of carrying out suitable soil investigations was entrusted to **M/s. Booshnam Associates, Chennai.**

This report contains the field and laboratory test results along with Design computations and recommendations for suitable foundation systems.

1.1 Scope of Work

- Sinking Five Standard Soil investigation bore holes of 150mm diameter up to a depth of 22.00m below existing ground level as directed by the engineer-in-charge.
- Conducting Standard Penetration Test (SPT) at regular depth intervals.
- Collection of Split Spoon Samples or Disturbed Soil Samples
- Collection of water samples from each bore hole.
- Conducting relevant laboratory test results.

1.2 Structure of the Report

- Contents
- Introduction
- Investigation Methodology & Test Results
- Figures & Tables
- Sub-Surface Stratification
- Foundation Systems
- Recommendations
- Annexure (Design Computations)

CHAPTER-2

INVESTIGATION METHODOLOGY & TEST RESULTS

2.0 Field Testing:

2.1 Preamble:

Five standard soil investigation boreholes were put. The equipment used and the methodology adopted to carry out the fieldwork is described below.

2.2 Equipment Used and Method of Drilling:

2.2.1 Equipment Used

The equipment used for performing the drilling operations is a Calyx Rotary Drill Rig with direct mud circulation technique. The drill mud used was made out of Sodium Bentonite.

2.2.2 Methodology of drilling

In the soil strata, the drilling operations have been carried out using special drill bits and cutters coupled with direct mud circulation.

2.3 In-Situ Strength Tests:

2.3.1 Standard Penetration Test:

Standard penetration tests were conducted at the borehole location, in accordance with IS: 2131. The tests were conducted at every change of strata up to the depth of termination of the borehole as directed by the engineer-in-charge.

2.4. Collection of Samples:

2.4.1 Disturbed Soil Samples

The SPT-samples collected were used as disturbed soil samples. These samples were used for visual and physical identification and for conducting laboratory classification tests as per I.S.1498-1970.

2.4.2 Ground Water

For conducting suitable chemical tests, the ground water sample was collected from the respective boreholes.

2.5 Summary of Field Work

The locations of the boreholes are shown in site plan given in Fig.2.0. The soil profiles obtained at each location is shown in Figs.2.1 to 2.5.

2.6 Laboratory Testing:

2.6.1 Coarse Grained Samples:

2.6.1.1 Grain size Analysis Tests:

On the coarse grained samples, grain size distribution tests were conducted as per I.S.2720 (Part 4)-1985, to know the gradation characteristics and to classify them. These results are presented in Tables 2.1 to 2.5.

2.6.2 Fine Grained Samples:

2.6.2.1 Index Property – Free Swell Tests:

Atterberg Limits were carried out on fine grained soil samples to evaluate the limits of different consistency states. Generally Liquid limits, Plastic limits and Shrinkage Limits tests were conducted as per I.S.2720 (Part-5)-1985 and I.S.2720 (Part 6)-1972. On such type of soil strata encountered at the investigation locations, such tests were conducted and the test results are presented in Tables 2.1 to 2.5.

2.6.3 Chemical Analysis Tests:

2.6.3.1 Water Samples:

On representative water samples, chemical analysis tests were conducted to estimate pH, Chlorides and Sulphates. These results are presented in Table-2.6.

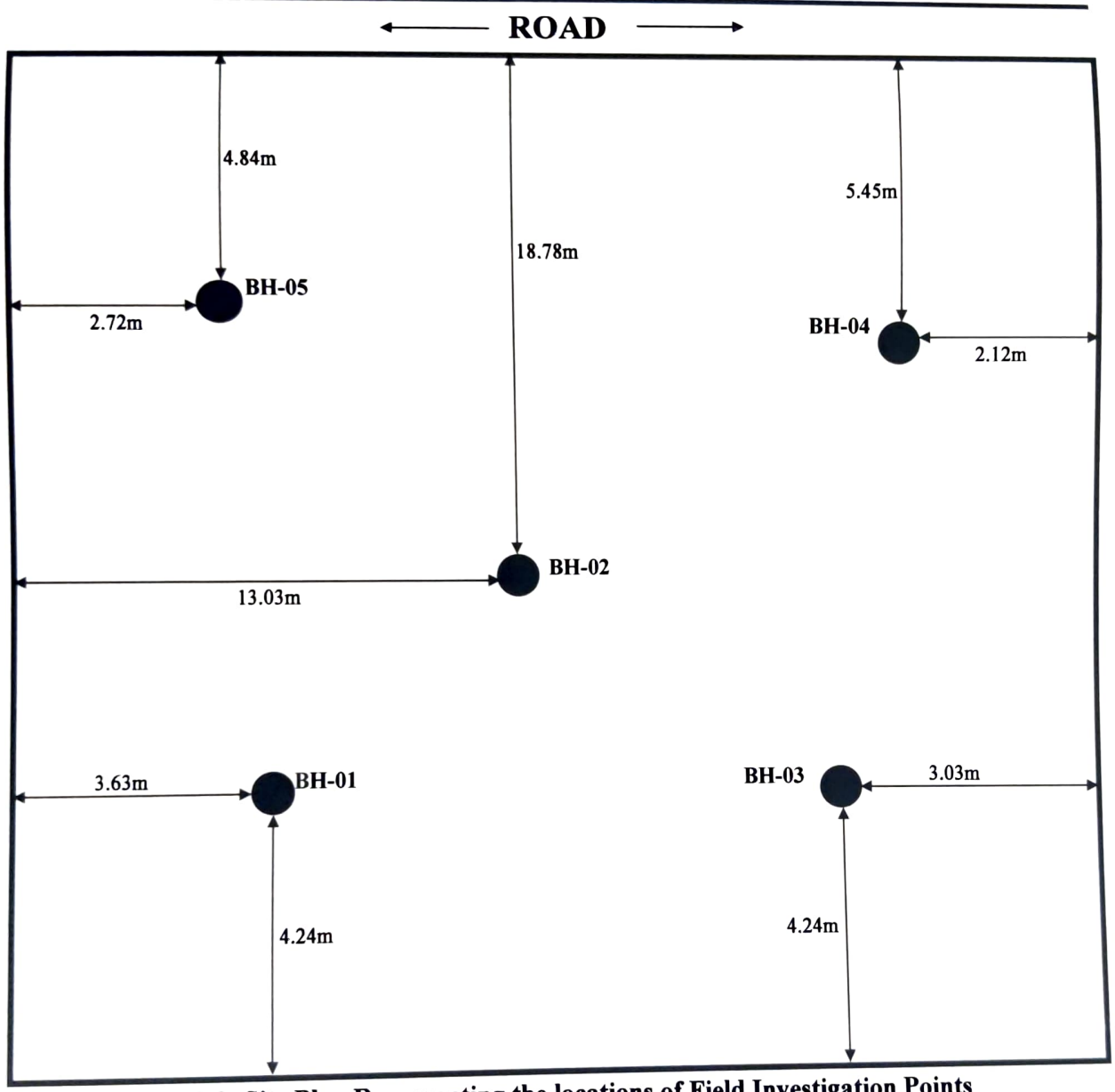


Fig. 2.0: Site Plan Representing the locations of Field Investigation Points

Project : Proposed Construction of Residential Building (Stilt+05) at No:3, A.N.A. Annamalai Avenue, Athipattu, Ambattur, Chennai-53.

Location: BH-01

Started On : 09/02/2023; Ended On : 09/02/2023 G.W.T: 2.00m below existing ground level

R.L of Layer (m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT below E.G.L (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Graphical Representation of SPT N-Value (0 10 20 30 40 50 60 70 80 90)	Relative Density/Consistency	Type of Sample
2.00	↓		Brownish Medium Stiff Silty Clay	1.50	2	3	3	6		M.Stiff	SS
5.00			Brownish Loose Silty Fine Sand	3.00	5	7	8	15		Loose	SS
				4.50	6	6	9	15		Loose	SS
7.00			Blackish Medium Stiff Silty Clay	6.00	2	2	3	5		M.Stiff	SS
9.50			Greyish Medium Dense Silty Fine Sand	7.50	7	9	11	20		M.Dense	SS
				9.00	9	12	16	28		M.Dense	SS
11.00			Greyish Dense Silty Fine Sand	10.50	17	17	21	38		Dense	SS
			Greyish Medium Stiff Silty Clay	12.00	2	3	5	8		M.Stiff	SS
15.00				14.00	3	4	4	8		M.Stiff	SS
16.20			Greyish Stiff Silty Clay	16.00	2	4	5	9		Stiff	SS

Bore Hole Terminated at a depth of 16.20m below the existing ground level

Fig. 2.1 Soil Profile at BH-01 Location

M/s. Booshnam Associates, Chennai

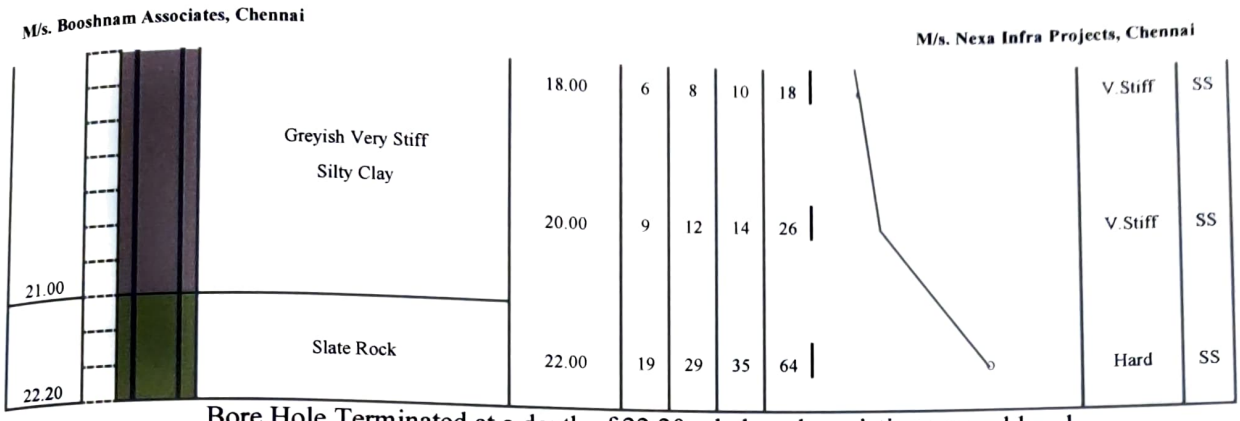
M/s. Nexa Infra Projects, Chennai

Project : Proposed Construction of Residential Building (Stilt+05) at No:3, A.N.A. Annamalai Avenue, Athipattu, Ambattur, Chennai-53.

Location: BH-02

Started On : 10/02/2023; Ended On : 13/02/2023 G.W.T: 2.00m below existing ground level

R.L. of Layer (m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT below E.G.L (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Graphical Representation of SPT N-Value (0 10 20 30 40 50 60 70 80 90)	Relative Density/Consistency	Type of Sample
2.00	▼		Brownish Soft Silty Clay	1.50	1	2	2	4		Soft	SS
			Brownish Loose Silty Fine Sand	3.00	4	4	5	9		Loose	SS
5.00				4.50	5	7	8	15		Loose	SS
			Greyish Medium Stiff Silty Clay	6.00	1	3	3	6		M.Stiff	SS
7.00				7.50	6	9	14	23		M.Dense	SS
8.50			Greyish Medium Dense Silty Fine Sand	9.00	8	15	17	32		Dense	SS
			Greyish Dense Silty Fine Sand	10.50	18	21	24	45		Dense	SS
11.00				12.00	2	4	4	8		M.Stiff	SS
			Greyish Medium Stiff Silty Clay	14.00	1	3	4	7		M.Stiff	SS
15.00				16.00	3	4	6	10		Stiff	SS
			Greyish Stiff Silty Clay								
17.00											



Bore Hole Terminated at a depth of 22.20m below the existing ground level

Fig. 2.2 Soil Profile at BH-02 Location

M/s. Booshnam Associates, Chennai

M/s. Nexa Infra Projects, Chennai

Project : Proposed Construction of Residential Building (Stilt+05) at No:3, A.N.A. Annamalai Avenue, Athipattu, Ambattur, Chennai-53.

Location: BH-03

Started On : 11/02/2023; Ended On : 11/02/2023 G.W.T: 2.00m below existing ground level

R.L of Layer (m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT below E.G.L (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Graphical Representation of SPT (0 10 20 30 40 50 60 70 80 90)	Relative Density/Consistency	Type of Sample
2.00	▼		Brownish Medium Stiff Silty Clay	1.50	2	2	3	5		M.Stiff	SS
5.00			Brownish Medium Dense Silty Fine Sand	3.00	8	7	9	16		M.Dense	SS
				4.50	7	9	11	20		M.Dense	SS
7.00			Blackish Medium Stiff Silty Clay	6.00	1	2	4	6		M.Stiff	SS
9.50			Greyish Medium Dense Silty Fine Sand	7.50	5	7	9	16		M.Dense	SS
				9.00	6	9	14	23		M.Dense	SS
10.70			Greyish Dense Silty Fine Sand	10.50	17	19	24	43		Dense	SS

Bore Hole Terminated at a depth of 10.70m below the existing ground level

Fig. 2.3 Soil Profile at BH-03 Location

M/s. Booshnam Associates, Chennai

M/s. Nexa Infra Projects, Chennai

Project : Proposed Construction of Residential Building (Stilt+05) at No:3, A.N.A. Annamalai Avenue, Athipattu, Ambattur, Chennai-53.

Location: BH-04

Started On : 11/02/2023; Ended On : 11/02/2023 G.W.T: 2.00m below existing ground level

R.L of Layer (m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT below E.G.L (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Graphical Representation of SPT N-Value (0 10 20 30 40 50 60 70 80 90)	Relative Density/Consistency	Type of Sample
2.00	▼		Brownish Medium Stiff Silty Clay	1.50	2	3	4	7		M.Stiff	SS
3.50			Brownish Loose Silty Fine Sand	3.00	6	6	8	14		Loose	SS
5.00			Brownish Medium Dense Silty Fine Sand	4.50	8	9	12	21		M.Dense	SS
7.00			Blackish Medium Stiff Silty Clay	6.00	2	2	3	5		M.Stiff	SS
9.50			Greyish Medium Dense Silty Fine Sand	7.50	6	8	9	17		M.Dense	SS
				9.00	9	11	13	24		M.Dense	SS
10.70			Greyish Dense Silty Fine Sand	10.50	16	18	22	40		Dense	SS

Bore Hole Terminated at a depth of 10.70m below the existing ground level

Fig. 2.4 Soil Profile at BH-04 Location

M/s. Booshnam Associates, Chennai

M/s. Nexa Infra Projects, Chennai

Project : Proposed Construction of Residential Building (Stilt+05) at No:3, A.N.A. Annamalai Avenue, Athipattu, Ambattur, Chennai-53.

Location: BH-05

Started On : 13/02/2023; Ended On : 13/02/2023 G.W.T: 2.00m below existing ground level

R.L of Layer (m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT below E.G.L (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Graphical Representation of SPT N-Value (0 10 20 30 40 50 60 70 80 90)	Relative Density/Consistency	Type of Sample
2.00	2.00		Brownish Medium Stiff Silty Clay	1.50	3	3	4	7		M.Stiff	SS
3.50			Brownish Loose Silty Fine Sand	3.00	5	7	8	15		Loose	SS
5.00			Brownish Medium Dense Silty Fine Sand	4.50	7	10	14	24		M.Dense	SS
7.00			Blackish Soft Silty Clay	6.00	1	2	2	4		Soft	SS
9.50			Greyish Medium Dense Silty Fine Sand	7.50	5	9	12	21		M.Dense	SS
				9.00	7	9	15	24		M.Dense	SS
10.70			Greyish Dense Silty Fine Sand	10.50	14	19	25	44		Dense	SS

Bore Hole Terminated at a depth of 10.70m below the existing ground level

Fig. 2.5 Soil Profile at BH-05 Location

***Table 2.1*: Laboratory Test Result on the Soil Sample Collected from BH-01**

Depth of Sample below E.G.L. (m)	SPT of Sample	Type of Sample	Engineering Description of Soil	NMC(%)	Natural Density (g/cc)	Clay					Relative Density/ Consistency	Sieve Analysis						IS-Classification
						LL (%)	PL (%)	PI	I_c	FS		Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	
0.00 to 2.00	6	SS	Silty Clay	42	1.5	79	21	58	0.64	-	M.Stiff	0	0	0	0	17	83	CH
2.00 to 5.00	15	SS	Silty Fine Sand	-	1.5	-	-	-	-	-	Loose	0	0	0	76	24	0	SM
5.00 to 7.00	5	SS	Silty Clay	43	1.5	60	20	40	0.43	-	M.Stiff	0	0	0	0	18	82	CH
7.00 to 9.50	24	SS	Silty Fine Sand	-	1.7	-	-	-	-	-	M.Dense	0	0	0	78	22	0	SM
9.50 to 11.00	38	SS	Silty Fine Sand	-	1.9	-	-	-	-	-	Dense	0	0	0	82	18	0	SM
11.00 to 15.00	8	SS	Silty Clay	38	1.6	66	24	42	0.67	-	M.Stiff	0	0	0	0	19	81	CH
15.00 to 16.20	9	SS	Silty Clay	33	1.7	69	25	44	0.82	-	Stiff	0	0	0	0	20	80	CH

Table 2.2: Laboratory Test Result on the Soil Sample Collected from BH-02

Depth of Sample below E.G.L. (m)	SPT of Sample	Type of Sample	Engineering Description of Soil	NMC(%)	Natural Density (g/cc)	Clay					Relative Density/ Consistency	Sieve Analysis						IS-Classification
						LL (%)	PL (%)	PI	I_c	FS		Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	
0.00 to 2.00	4	SS	Silty Clay	55	1.4	80	19	61	0.41	40	Soft	0	0	0	0	14	86	CH
2.00 to 5.00	12	SS	Silty Fine Sand	-	1.5	-	-	-	-	-	Loose	0	0	0	76	24	0	SM
5.00 to 7.00	6	SS	Silty Clay	40	1.5	78	23	55	0.69	-	M.Stiff	0	0	0	0	17	83	CH
7.00 to 8.50	23	SS	Silty Fine Sand	-	1.7	-	-	-	-	-	M.Dense	0	0	0	78	22	0	SM
8.50 to 11.00	38	SS	Silty Fine Sand	-	1.9	-	-	-	-	-	Dense	0	0	0	83	17	0	SM
11.00 to 15.00	7	SS	Silty Clay	33	1.6	62	22	40	0.73	-	M.Stiff	0	0	0	0	19	81	CH
15.00 to 17.00	10	SS	Silty Clay	31	1.7	66	24	42	0.83	-	Stiff	0	0	0	0	20	80	CH
17.00 to 21.00	22	SS	Silty Clay	25	1.9	59	28	31	1.10	-	Soft	0	0	0	0	22	78	Cl
21.00 to 22.20	64	SS	Slate Rock	17	2.0	44	33	11	2.45	-	M.Stiff	0	0	0	0	24	76	Cl

Table 2.3: Laboratory Test Result on the Soil Sample Collected from BH-03

Depth of Sample below E.G.L. (m)	SPT of Sample	Type of Sample	Engineering Description of Soil	NMC(%)	Natural Density (g/cc)	Clay					Relative Density/ Consistency	Sieve Analysis						IS-Classification
						LL (%)	PL (%)	PI	I_c	FS		Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	
0.00 to 2.00	5	SS	Silty Clay	41	1.5	79	21	58	0.66	40	M.Stiff	0	0	0	0	16	84	CH
2.00 to 5.00	18	SS	Silty Fine Sand	-	1.6	-	-	-	-	-	M.Dense	0	0	0	77	23	0	SM
5.00 to 7.00	6	SS	Silty Clay	40	1.5	78	23	55	0.69	-	M.Stiff	0	0	0	0	17	83	CH
7.00 to 9.50	19	SS	Silty Fine Sand	-	1.6	-	-	-	-	-	M.Dense	0	0	0	78	22	0	SM
9.50 to 10.70	43	SS	Silty Fine Sand	-	1.9	-	-	-	-	-	Dense	0	0	0	84	16	0	SM

Table 2.4: Laboratory Test Result on the Soil Sample Collected from BH-04

Depth of Sample below E.G.L. (m)	SPT of Sample	Type of Sample	Engineering Description of Soil	NMC(%)	Natural Density (g/cc)	Clay					Relative Density/ Consistency	Sieve Analysis						IS-Classification
						LL (%)	PL (%)	PI	I_c	FS		Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	
0.00 to 2.00	7	SS	Silty Clay	33	1.6	66	24	42	0.79	20	M.Stiff	0	0	0	0	18	82	CH
2.00 to 3.50	14	SS	Silty Fine Sand	-	1.5	-	-	-	-	-	Loose	0	0	0	76	24	0	SM
3.50 to 5.00	21	SS	Silty Fine Sand	-	1.7	-	-	-	-	-	M.Dense	0	0	0	78	22	0	SM
5.00 to 7.00	5	SS	Silty Clay	35	1.5	70	22	48	0.73	-	M.Stiff	0	0	0	0	17	83	CH
7.00 to 9.50	20	SS	Silty Fine Sand	-	1.6	-	-	-	-	-	M.Dense	0	0	0	77	23	0	SM
9.50 to 10.70	40	SS	Silty Fine Sand	-	1.9	-	-	-	-	-	Dense	0	0	0	85	15	0	SM

Table 2.5: Laboratory Test Result on the Soil Sample Collected from BH-05

Depth of Sample below E.G.L. (m)	SPT of Sample	Type of Sample	Engineering Description of Soil	NMC(%)	Natural Density (g/cc)	Clay					Relative Density/ Consistency	Sieve Analysis						IS-Classification
						LL (%)	PL (%)	PI	I_c	FS		Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	
0.00 to 2.00	7	SS	Silty Clay	31	1.6	69	25	44	0.86	15	M.Stiff	0	0	0	0	18	82	CH
2.00 to 3.50	15	SS	Silty Fine Sand	-	1.5	-	-	-	-	-	Loose	0	0	0	75	25	0	SM
3.50 to 5.00	24	SS	Silty Fine Sand	-	1.7	-	-	-	-	-	M.Dense	0	0	0	77	23	0	SM
5.00 to 7.00	4	SS	Silty Clay	55	1.4	71	22	49	0.33	-	Soft	0	0	0	0	15	85	CH
7.00 to 9.50	22	SS	Silty Fine Sand	-	1.7	-	-	-	-	-	M.Dense	0	0	0	78	22	0	SM
9.50 to 10.70	44	SS	Silty Fine Sand	-	1.9	-	-	-	-	-	Dense	0	0	0	85	15	0	SM

Table 2.6: Chemical Analysis Results conducted on Water Samples collected from BH-01 to BH-05

Location	Depth of Sample below E.G.L. (m)	pH	Chlorides (ppm)	Sulphates (ppm)
BH-01	2.00	6.60	345.11	388.24
BH-02	2.00	6.62	322.51	362.82
BH-03	2.00	6.61	318.44	358.24
BH-04	2.00	6.60	319.25	359.15
BH-05	2.00	6.61	308.38	346.92

CHAPTER-3

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole location, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(At BH-01 Location, as presented in Site plan)

* **Layer-1 (from E.G.L to 2.00m depth)**	
Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	2.00m
SPT of the layer	06
Consistency	Medium Stiff
Un-drained Cohesion, Cu	**40.00**kPa
* **Layer-2 (from 2.00m to 5.00m depth)**	
Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	3.00m
SPT of the layer	15
Relative Density	Loose
Angle of Shearing Resistance, ϕ	31.50^0
* **Layer-3 (from 5.00m to 7.00m depth)**	
Type of Strata	Silty Clay
Colour	Blackish
Thickness of Layer	2.00m
SPT of the layer	05
Consistency	Medium Stiff
Un-drained Cohesion, Cu	33.33kPa
* **Layer-4 (from 7.00m to 9.50m depth)**	
Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	2.50m

SPT of the layer	24
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	34.20^0
* **Layer-5 (from 9.50m to 11.00m depth)**	
Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	38
Relative Density	Dense
Angle of Shearing Resistance, ϕ	38.20^0
* **Layer-6 (from 11.00m to 15.00m depth)**	
Type of Strata	Silty Clay
Colour	Greyish
Thickness of Layer	4.00m
SPT of the layer	08
Consistency	Medium Stiff
Un-drained Cohesion, Cu	53.33kPa
* **Layer-7 (from 15.00m to 16.20m depth)**	
Type of Strata	Silty Clay
Colour	Greyish
Thickness of Layer	1.20m
SPT of the layer	09
Consistency	Stiff
Un-drained Cohesion, Cu	**60.00**kPa

Ground Water

Ground water table was encountered at a depth of 2.00m below the existing ground level during the second week of February 2023.

3.1.2 Soil Profile at BH-02 Location
(At BH-02 Location, as presented in Site plan)

* **Layer-1 (from E.G.L to 2.00m depth)**	
Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	2.00m
SPT of the layer	04
Consistency	Soft
Un-drained Cohesion, Cu	**26.66**kPa
* **Layer-2 (from 2.00m to 5.00m depth)**	
Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	3.00m
SPT of the layer	12
Relative Density	Loose
Angle of Shearing Resistance, ϕ	**30.60**^{0}
* **Layer-3 (from 5.00m to 7.00m depth)**	
Type of Strata	Silty Clay
Colour	Greyish
Thickness of Layer	2.00m

SPT of the layer	06
Consistency	Medium Stiff
Un-drained Cohesion, Cu	**40.00**kPa
* **Layer-4 (from 7.00m to 8.50m depth)**	
Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	23
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	**33.90**^{0}
* **Layer-5 (from 8.50m to 11.00m depth)**	
Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	2.50m
SPT of the layer	38
Relative Density	Dense
Angle of Shearing Resistance, ϕ	**38.20**^{0}
* **Layer-6 (from 11.00m to 15.00m depth)**	
Type of Strata	Silty Clay
Colour	Greyish
Thickness of Layer	4.00m
SPT of the layer	07
Consistency	Medium Stiff
Un-drained Cohesion, Cu	**46.66**kPa
* **Layer-7 (from 15.00m to 17.00m depth)**	
Type of Strata	Silty Clay
Colour	Greyish
Thickness of Layer	2.00m
SPT of the layer	10
Consistency	Stiff
Un-drained Cohesion, Cu	**66.66**kPa
* **Layer-8 (from 17.00m to 21.00m depth)**	
Type of Strata	Silty Clay
Colour	Greyish
Thickness of Layer	4.00m
SPT of the layer	22
Consistency	Very Stiff
Un-drained Cohesion, Cu	**146.66**kPa
* **Layer-9 (from 21.00m to 22.20m depth)**	
Type of Strata	Slate Rock
Colour	-
Thickness of Layer	1.20m
SPT of the layer	64
Consistency	Hard
Un-drained Cohesion, Cu	**426.66**kPa

Ground Water

Ground water table was encountered at a depth of 2.00m below the existing ground level during the second week of February 2023.

3.1.3 Soil Profile at BH-03 Location
(At BH-03 Location, as presented in Site plan)

* **Layer-1 (from E.G.L to 2.00m depth)**

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	2.00m
SPT of the layer	05
Consistency	Medium Stiff
Un-drained Cohesion, Cu	33.33kPa

* **Layer-2 (from 2.00m to 5.00m depth)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	3.00m
SPT of the layer	18
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	32.40^0

* **Layer-3 (from 5.00m to 7.00m depth)**

Type of Strata	Silty Clay
Colour	Blackish
Thickness of Layer	2.00m
SPT of the layer	06
Consistency	Medium Stiff
Un-drained Cohesion, Cu	40.00kPa

* **Layer-4 (from 7.00m to 9.50m depth)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	2.50m
SPT of the layer	19
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	32.70^0

* **Layer-5 (from 9.50m to 10.70m depth)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.20m
SPT of the layer	43
Relative Density	Dense
Angle of Shearing Resistance, ϕ	39.425^0

Ground Water

Ground water table was encountered at a depth of 2.00m below the existing ground level during the second week of February 2023.

3.1.4 Soil Profile at BH-04 Location
(At BH-04 Location, as presented in Site plan)

* **Layer-1 (from E.G.L to 2.00m depth)**

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	2.00m
SPT of the layer	07

Consistency	Medium Stiff
Un-drained Cohesion, Cu	46.66kPa
* **Layer-2 (from 2.00m to 3.50m depth)**	
Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	1.50m
SPT of the layer	14
Relative Density	Loose
Angle of Shearing Resistance, ϕ	31.20^0
* **Layer-3 (from 3.50m to 5.00m depth)**	
Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	1.50m
SPT of the layer	21
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.30^0
* **Layer-4 (from 5.00m to 7.00m depth)**	
Type of Strata	Silty Clay
Colour	Blackish
Thickness of Layer	2.00m
SPT of the layer	05
Consistency	Medium Stiff
Un-drained Cohesion, Cu	33.33kPa
* **Layer-5 (from 7.00m to 9.50m depth)**	
Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	2.50m
SPT of the layer	20
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.00^0
* **Layer-6 (from 9.50m to 10.70m depth)**	
Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.20m
SPT of the layer	40
Relative Density	Dense
Angle of Shearing Resistance, ϕ	38.75^0

Ground Water

Ground water table was encountered at a depth of 2.00m below the existing ground level during the second week of February 2023.

3.1.5 Soil Profile at BH-05 Location

(At BH-05 Location, as presented in Site plan)

* **Layer-1 (from E.G.L to 2.00m depth)**	
Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	2.00m
SPT of the layer	07

	Consistency	Medium Stiff
	Un-drained Cohesion, Cu	**46.66**kPa
*	**Layer-2 (from 2.00m to 3.50m depth)**	
	Type of Strata	Silty Fine Sand
	Colour	Brownish
	Thickness of Layer	1.50m
	SPT of the layer	15
	Relative Density	Loose
	Angle of Shearing Resistance, ϕ	**31.50^0**
*	**Layer-3 (from 3.50m to 5.00m depth)**	
	Type of Strata	Silty Fine Sand
	Colour	Brownish
	Thickness of Layer	1.50m
	SPT of the layer	24
	Relative Density	Medium Dense
	Angle of Shearing Resistance, ϕ	**34.20^0**
*	**Layer-4 (from 5.00m to 7.00m depth)**	
	Type of Strata	Silty Clay
	Colour	Blackish
	Thickness of Layer	2.00m
	SPT of the layer	04
	Consistency	Soft
	Un-drained Cohesion, Cu	**26.66**kPa
*	**Layer-5 (from 7.00m to 9.50m depth)**	
	Type of Strata	Silty Fine Sand
	Colour	Greyish
	Thickness of Layer	2.50m
	SPT of the layer	22
	Relative Density	Medium Dense
	Angle of Shearing Resistance, ϕ	**33.60^0**
*	**Layer-6 (from 9.50m to 10.70m depth)**	
	Type of Strata	Silty Fine Sand
	Colour	Greyish
	Thickness of Layer	1.20m
	SPT of the layer	44
	Relative Density	Dense
	Angle of Shearing Resistance, ϕ	**39.65^0**

Ground Water

Ground water table was encountered at a depth of 2.00m below the existing ground level during the third week of February 2023.

CHAPTER-4

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the overall stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole locations is presented in the subsequent sections.

4.1 Bearing Strata Characteristics

From field investigations, it can be observed that the sub-soil strata encountered at shallow depths are weak from both shear strength characteristics and deformation considerations and hence cannot be considered as bearing strata for proposed impending loads from structure.

However, the refusal soil (SPT>50) strata encountered below 21.00m depths from existing ground level can be considered as end bearing strata for proposed impending loads from structure.

Considering the above, suitable foundation system is presented below.

4.2 Foundation System

4.2.1 Deep Foundation System-22.00m Long Bored Cast-in-Situ Friction cum End Bearing Piles

Considering the weak shear strength characteristics of sub-soil strata encountered at shallow depths, deep foundation system consisting of 22.00m long bored cast-in-situ Friction cum End Bearing Piles can be adopted.

Piles shall be drilled through DMC (direct mud circulation) technique.

For four different diameters, the safe load carrying capacities of 22.00m long bored cast-in-situ Friction cum End Bearing Piles are computed and presented below which can be adopted for foundation design purposes.

S. No	Type of Installation of Pile	Length of Pile below Existing Ground Level (m)	Diameter of Pile (mm)	Safe Load Carrying Capacity (MT)	Safe Pull Out Capacity (MT)
1	Bored Cast-in-Situ	22.00	450	70	48
2			500	80	54
3			550	90	59
4			600	100	65

The computations of safe load carrying capacity for 450mm diameter and 22.00m long bored cast-in-situ Friction cum End Bearing Piles are annexed to this report.

CHAPTER-5

CONCLUSIONS & RECOMMENDATIONS

1. Deep foundation system presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
2. *Care shall be taken so that the ultimate end bearing soil strata are none other than recommended "Slate Rock" type. The same shall be reaffirmed by our Geotechnical Engineer during foundation laying works are under progress.*
3. Suitable pile load tests (as per I.S: 2911, part-IV) shall be performed to confirm the presented **theoretical** safe load carrying capacities and the same shall be taken as **allowable/design** load carrying capacities of piles under consideration and attached to detailed project report.
4. Pile cap can be located over 0.30m thick well compacted ground replaced CNS (Cohesive Non-Swelling) soil surface.
5. **CNS can be non-plastic clean river sand or quarry dust or fly-ash or sand-gravels mix.**
6. Piles shall be grouped according to the column design load requirements.
7. Safe load carrying capacities of piles shall be limited to their structural capacities.
8. As the chlorides and sulphates present in the collected water samples are within the permissible limits, no special steel or cement is recommended to be used for foundation construction purposes.

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For BOOSHNAM ASSOCIATES
Er.A.NIVEDHITHA M.Tech
Geotechnical Engineer

DESIGN OF PILE FOUNDATION (Ref. BH-02)

Refer, IS:2911(Part I/Sec 2)-1979, Reaffirmed 1997

1.0 Type of Installation of Pile — **Bored Cast in Situ**

1.1 Geometrical Data

Assumed Diameter of pile(D):	**450.0**	mm
Assumed R.L of E.G.L:	0.000	m
Length of pile below E.G.L.(l) :	**22.000**	m
R.L. of Bot. of Pile	-22.00	m

1.2 Design of Pile for Vertical Compression

1.2.1 Computation of Skin Resistance:

1.2.1.1

Layer-I

Type of Strata:	Silty Clay	
Average SPT of the strata,N:	4	
Bulk Density of the strata,γ:	14	kN/m^3
Undrained Cohesion, Cu:	26.67	kPa
R.L of top of Strata:	0.00	m
R.L of bottom of Strata:	-2.00	m
Average Thickness of Strata,I_c:	2.00	m
Effective overburden pressure over the top of strata,σ_{top}:	0.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	8.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	4.00	kN/m^2
Adhesion Factor, α:	1.00	
Negative Skin Resistance of the pile,q_s:	**-75.40**	**kN**
(q_s:α*Cu*pi()*d*Ic)		

1.2.1.2

Layer-II

Type of Strata:	Silty Fine Sand	
Average SPT of the strata,N:	12	
Bulk Density of the strata,γ:	15	kN/m^3
Angle of Shearing Resistance,ϕ:	30.6	Deg.
R.L of top of Strata:	-2.00	m
R.L of bottom of Strata:	-5.00	m
Average Thickness of Strata,I_c:	3.00	m
Effective overburden pressure over the top of strata,σ_{top}:	8.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	23.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	15.50	kN/m^2
Coeff. Of Earth Pressure, k:	1.00	
Skin Resistance of the pile,q_s:	38.88	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		

.2.1.3

Layer-III

Type of Strata:	Silty Clay	
Average SPT of the strata,N:	6	
Bulk Density of the strata,γ:	15	kN/m^3
Undrained Cohesion, Cu:	40.00	kPa
R.L of top of Strata:	-5.00	m

R.L of bottom of Strata: -7.00 m
Average Thickness of Strata,I_c: 2.00 m
Effective overburden pressure over the top of strata,σ_{top}: 23.00 kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}: 33.00 kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}: 28.00 kN/m^2
Adhesion Factor, α: 0.70
Skin Resistance of the pile,q_s: 79.17 kN
(q_s:α*Cu*pi()*d*Ic)

1.2.1.4 **Layer-IV**

Type of Strata: Silty Fine Sand
Average SPT of the strata,N: 23
Bulk Density of the strata,γ: 17 kN/m^3
Angle of Shearing Resistance,ϕ: 33.9 Deg.
R.L of top of Strata: -7.00 m
R.L of bottom of Strata: -8.50 m
Average Thickness of Strata,I_c: 1.50 m
Effective overburden pressure over the top of strata,σ_{top}: 33.00 kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}: 43.50 kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}: 38.25 kN/m^2
Coeff. Of Earth Pressure, k: 1.50
Skin Resistance of the pile,q_s: 81.76 kN
(q_s:σ*k*tanϕ*pi()*d*Ic)

1.2.1.5 **Layer-V**

Type of Strata: Silty Fine Sand
Average SPT of the strata,N: 38
Bulk Density of the strata,γ: 19 kN/m^3
Angle of Shearing Resistance,ϕ: 38.2 Deg.
R.L of top of Strata: -8.50 m
R.L of bottom of Strata: -11.00 m
Average Thickness of Strata,I_c: 2.50 m
Effective overburden pressure over the top of strata,σ_{top}: 43.50 kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}: 66.00 kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}: 54.75 kN/m^2
Coeff. Of Earth Pressure, k: 2.00
Skin Resistance of the pile,q_s: 304.54 kN
(q_s:σ*k*tanϕ*pi()*d*Ic)

1.2.1.6 **Layer-VI**

Type of Strata: Silty Clay
Average SPT of the strata,N: 7
Bulk Density of the strata,γ: 16 kN/m^3
Undrained Cohesion, Cu: 46.67 kPa
R.L of top of Strata: -11.00 m
R.L of bottom of Strata: -15.00 m
Average Thickness of Strata,I_c: 4.00 m
Effective overburden pressure over the top of strata,σ_{top}: 66.00 kN/m^2

Effective overburden pressure over the bottom of strata, σ_{bottom}:	90.00	kN/m^2
Effective overburden pressure at the middle of the strata, σ_{middle}:	78.00	kN/m^2
Adhesion Factor, α:	0.60	
Skin Resistance of the pile, q_s:	158.34	kN

(q_s:α*Cu*pi()*d*Ic)

.1.7 Layer-VII

Type of Strata:	Silty Clay	
Average SPT of the strata,N:	10	
Bulk Density of the strata,γ:	17	kN/m^3
Undrained Cohesion, Cu:	66.67	kPa
R.L of top of Strata:	-15.00	m
R.L of bottom of Strata:	-17.00	m
Average Thickness of Strata, I_c:	2.00	m
Effective overburden pressure over the top of strata, σ_{top}:	90.00	kN/m^2
Effective overburden pressure over the bottom of strata, σ_{bottom}:	104.00	kN/m^2
Effective overburden pressure at the middle of the strata, σ_{middle}:	97.00	kN/m^2
Adhesion Factor, α:	0.40	
Skin Resistance of the pile, q_s:	75.40	kN

(q_s:α*Cu*pi()*d*Ic)

.1.8 Layer-VIII

Type of Strata:	Silty Clay	
Average SPT of the strata,N:	22	
Bulk Density of the strata,γ:	19	kN/m^3
Undrained Cohesion, Cu:	146.67	kPa
R.L of top of Strata:	-17.00	m
R.L of bottom of Strata:	-21.00	m
Average Thickness of Strata, I_c:	4.00	m
Effective overburden pressure over the top of strata, σ_{top}:	104.00	kN/m^2
Effective overburden pressure over the bottom of strata, σ_{bottom}:	140.00	kN/m^2
Effective overburden pressure at the middle of the strata, σ_{middle}:	122.00	kN/m^2
Adhesion Factor, α:	0.40	
Skin Resistance of the pile, q_s:	331.75	kN

(q_s:α*Cu*pi()*d*Ic)

.1.9 Layer-IX

Type of Strata:	Slate Rock	
Average SPT of the strata,N:	60	
Bulk Density of the strata,γ:	20	kN/m^3
Undrained Cohesion, Cu:	400.00	kPa
R.L of top of Strata:	-21.00	m
R.L of bottom of Strata:	-22.00	m
Average Thickness of Strata, I_c:	1.00	m
Effective overburden pressure over the top of strata, σ_{top}:	140.00	kN/m^2
Effective overburden pressure over the bottom of strata, σ_{bottom}:	150.00	kN/m^2
Effective overburden pressure at the middle of the strata, σ_{middle}:	145.00	kN/m^2
Adhesion Factor, α:	0.40	

Skin Resistance of the pile,q_s: 226.19 kN
(q_s:α*Cu*pi()*d*Ic)

Ultimate Skin Resistance,q_s: 1220.63 kN

1.2.2 Computation of End Bearing Resistance:

Type of Bearing Strata Slate Rock
Cross-Sectional Area of pile,Ap: 0.159 m^2
R.L of bottom of pile: -22.00
Minimum SPT-value of the Bearing Strata 60
Un-drained Cohesion, Cu: 400.00 kPa
Bearing Capacity Factor(Nc) 9.00
Ultimate End Bearing Resistance (Qp) 572.6 kN
(Qp=Ap*q*Nq)

1.3.0 Ultimate Load Carrying Capacity (Qu=Qs+Q_p) 1793.2 kN
Safe Load Carrying Capacity (Qsafe =Qu/2.50) 717.3 kN
However, limit Q_{safe} to the structural capacity of pile: 700.0 kN

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