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CLIENT	**M/s. BHAGGYAM CONSTRUCTIONS PVT LTD, CHENNAI**
PROJECT	**PROPOSED CONSTRUCTION OF RESIDENTIAL BUILDING (STILT+05) AT OLD DOOR NOS: 17 & 18/1, 18/2, 18/3 AND 18/4, NEW NOS: 42, 44/1, 44/2, 44/3 AND 44/4, VENKATARAMAN STREET, T. NAGAR, CHENNAI-600 017, COMPRISED in PLOT NO: 5 & 6 OLD S.NO:68, T.S.NO: 4871/2, 4871/3, 4871/4 BLOCK NO.113, IN T. NAGAR VILLAGE, GUINDY TALUK, GREATER CHENNAI CORPORATION. DIVISION 136, ZONE -10.**
TITLE	**GEOTECHNICAL INVESTIGATION REPORT**

REV.	DATE	REPORT NUMBER	REMARK
0	03.05.2023	BAG/M/s. BHAGGYAM CONSTRUCTIONS PVT LTD/M-1792/23-24	

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CHAPTER-1

INTRODUCTION

1.0 Preamble

M/s. Bhaggyam Constructions Pvt Ltd, Chennai proposed to construct a **Residential Building (Stilt+05) At Old Door Nos: 17 & 18/1, 18/2, 18/3 And 18/4, New Nos: 42, 44/1, 44/2, 44/3 And 44/4, Venkataraman Street, T. Nagar, Chennai-600 017, Comprised In Plot No: 5 & 6 Old S.No:68, T.S.No: 4871/2, 4871/3, 4871/4 Block No.113, In T. Nagar Village, Guindy Taluk, Greater Chennai Corporation. Division 136, Zone -10.**

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 Four Standard Soil investigation bore holes of 150mm diameter up to a depth of 23.00m 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:

Four 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 2.4.

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 2.4.

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 2.4.

2.6.3 Chemical Analysis Tests:

2.6.3.1 Water Samples:

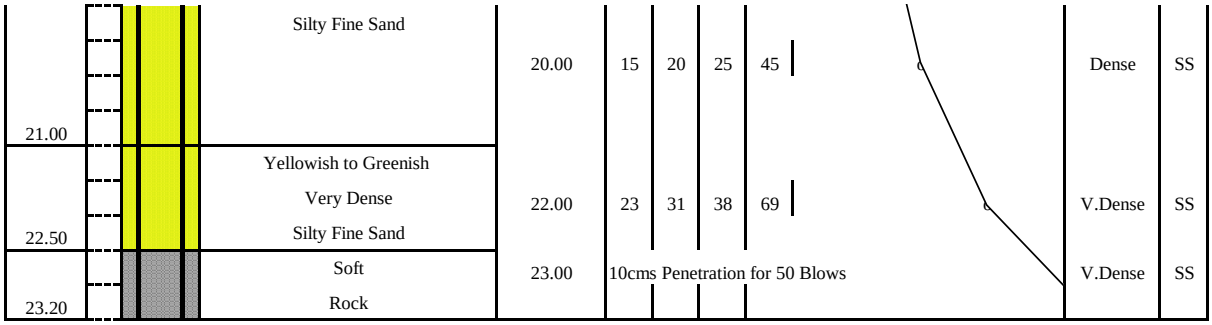
On representative water samples, chemical analysis tests were conducted to estimate pH, Chlorides and Sulphates. These results are presented in Table-2.5.

Project : Proposed Construction of Residential Building (Stilt+05) At Old Door Nos: 17 & 18/1, 18/2, 18/3 And 18/4, New Nos: 42, 44/1, 44/2, 44/3 And 44/4, Venkataraman Street, T. Nagar, Chennai-600 017, Comprised In Plot No: 5 & 6 Old S.No:68, T.S.No: 4871/2, 4871/3, 4871/4 Block No.113, In T. Nagar Village, Guindy Taluk, Greater Chennai Corporation. Division 136, Zone -10.

Location: BH-01

Started On : 29/04/2023; Ended On : 30/04/2023 G.W.T: 2.50m 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 Stiff Silty Sandy Clay	1.50	3	4	6	10		Stiff	SS
	G.W.T		Blackish Stiff Silty Sandy Clay	3.00	5	6	7	13		Stiff	SS
4.00											
5.50			Blackish Stiff Silty Clay	4.50	3	4	5	9		Stiff	SS
			Blackish Loose Silty Clayey Fine Sand	6.00	2	3	3	6		Loose	SS
8.50				7.50	3	3	4	7		Loose	SS
10.00			Blackish Medium Stiff Silty Clay	9.00	3	3	3	6		M.Stiff	SS
11.50			Blackish Loose Silty Clayey Fine Sand	10.50	2	2	3	5		Loose	SS
13.00			Greyish Very Loose Silty Fine Sand	12.00	2	2	2	4		V.Loose	SS
15.00			Greyish Loose Silty Fine Sand	14.00	3	3	4	7		Loose	SS
17.00			Greyish to Greenish Medium Dense Silty Fine Sand	16.00	11	13	15	28		M.Dense	SS
			Yellowish to Greenish Dense	18.00	12	15	18	33		Dense	SS



Bore Hole Terminated at a depth of 23.20m below the existing ground level

Fig. 2.1 Soil Profile at BH-01 Location

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Location: BH-02

Started On : 29/04/2023; Ended On : 29/04/2023 G.W.T: 2.50m 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
			Brownish Stiff Silty Sandy Clay	1.50	4	5	7	12		Stiff	SS
G.W.T	↓			3.00	5	6	7	13		Stiff	SS
4.00			Blackish Loose Silty Clayey Fine Sand	4.50	3	4	4	8		Loose	SS
5.50			Blackish Medium Stiff Silty Clay	6.00	3	2	4	6		M.Stiff	SS
7.00				7.50	2	3	4	7		Loose	SS
			Blackish Loose Silty Clayey Fine Sand	9.00	2	2	3	5		Loose	SS
10.50				10.50	3	3	4	7		Loose	SS

Bore Hole Terminated at a depth of 10.50m below the existing ground level

Fig. 2.2 Soil Profile at BH-02 Location

Project : Proposed Construction of Residential Building (Stilt+05) At Old Door Nos: 17 & 18/1, 18/2, 18/3 And 18/4, New Nos: 42, 44/1, 44/2, 44/3 And 44/4, Venkataraman Street, T. Nagar, Chennai-600 017, Comprised In Plot No: 5 & 6 Old S.No:68, T.S.No: 4871/2, 4871/3, 4871/4 Block No.113, In T. Nagar Village, Guindy Taluk, Greater Chennai Corporation. Division 136, Zone -10.

Location: BH-03

Started On : 30/04/2023; Ended On : 30/04/2023 G.W.T: 2.50m 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
			Brownish Stiff Silty Sandy Clay	1.50	4	4	6	10		Stiff	SS
G.W.T				3.00	4	6	8	14		Stiff	SS
4.00											
			Blackish Loose Silty Clayey Fine Sand	4.50	3	4	5	9		Loose	SS
5.50											
			Blackish Medium Stiff Silty Clay	6.00	3	2	4	6		M.Stiff	SS
7.00											
				7.50	2	3	5	8		Loose	SS
			Blackish Loose Silty Clayey Fine Sand	9.00	2	3	3	6		Loose	SS
10.50				10.50	3	3	5	8		Loose	SS

Bore Hole Terminated at a depth of 10.50m below the existing ground level

Fig. 2.3 Soil Profile at BH-03 Location

Project : Proposed Construction of Residential Building (Stilt+05) At Old Door Nos: 17 & 18/1, 18/2, 18/3 And 18/4, New Nos: 42, 44/1, 44/2, 44/3 And 44/4, Venkataraman Street, T. Nagar, Chennai-600 017, Comprised In Plot No: 5 & 6 Old S.No:68, T.S.No: 4871/2, 4871/3, 4871/4 Block No.113, In T. Nagar Village, Guindy Taluk, Greater Chennai Corporation. Division 136, Zone -10.

Location: BH-04

Started On : 30/04/2023; Ended On : 30/04/2023 G.W.T: 2.50m 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
			Brownish Stiff Silty Sandy Clay	1.50	3	5	6	11		Stiff	SS
G.W.T				3.00	5	6	8	14		Stiff	SS
4.00											
			Blackish Loose Silty Clayey Fine Sand	4.50	3	5	5	10		Loose	SS
5.50											
			Blackish Medium Stiff Silty Clay	6.00	3	2	4	6		M.Stiff	SS
7.00											
				7.50	3	3	5	8		Loose	SS
			Blackish Loose Silty Clayey Fine Sand	9.00	3	3	4	7		Loose	SS
10.50				10.50	3	4	4	8		Loose	SS

Bore Hole Terminated at a depth of 10.50m below the existing ground level

Fig. 2.4 Soil Profile at BH-04 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	10	SS	Silty Sandy Clay	32	1.7	62	21	41	0.73	10	Stiff	0	0	0	10	12	78	CH
2.00 to 4.00	13	SS	Silty Sandy Clay	31	1.7	66	24	42	0.83	-	Stiff	0	0	0	12	14	74	CH
4.00 to 5.50	9	SS	Silty Clay	33	1.7	64	22	42	0.74	-	Stiff	0	0	0	9	11	80	CH
5.50 to 8.50	6	SS	Silty Clayey Fine Sand	-	1.5	-	-	-	-	-	Loose	0	0	0	80	8	12	SM
8.50 to 10.00	6	SS	Silty Clay	44	1.5	78	23	55	0.62	-	M.Stiff	0	0	0	0	18	82	CH
10.00 to 11.50	5	SS	Silty Clayey Fine Sand	-	1.5	-	-	-	-	-	Loose	0	0	0	78	10	12	SM
11.50 to 13.00	4	SS	Silty Fine Sand	-	1.4	-	-	-	-	-	V.Loose	0	0	0	75	25	0	SM
13.00 to 15.00	7	SS	Silty Fine Sand	-	1.5	-	-	-	-	-	Loose	0	0	0	76	24	0	SM
15.00 to 17.00	28	SS	Silty Fine Sand	-	1.8	-	-	-	-	-	M.Dense	0	0	0	79	21	0	SM
17.00 to 21.00	39	SS	Silty Fine Sand	-	1.9	-	-	-	-	-	Dense	0	0	0	83	17	0	SM
21.00 to 22.50	69	SS	Silty Fine Sand	-	2.0	-	-	-	-	-	V.Dense	0	0	0	0	86	14	SM
22.50 to 23.20	>100	SS	Soft Rock	-	2.0	-	-	-	-	-	V.Dense	100	0	0	0	0	0	SR

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 4.00	12	SS	Silty Sandy Clay	31	1.7	66	25	41	0.85	12	Stiff	0	0	0	11	13	76	CH
4.00 to 5.50	8	SS	Silty Clayey Fine Sand	-	1.5	-	-	-	-	-	Loose	0	0	0	78	10	12	SM
5.50 to 7.00	6	SS	Silty Clay	42	1.5	79	21	58	0.64	-	M.Stiff	0	0	0	0	17	83	CH
7.00 to 10.50	6	SS	Silty Clayey Fine Sand	-	1.5	-	-	-	-	-	Loose	0	0	0	79	8	13	SM

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 4.00	12	SS	Silty Sandy Clay	30	1.7	64	22	42	0.81	15	Stiff	0	0	0	17	12	71	CH
4.00 to 5.50	9	SS	Silty Clayey Fine Sand	-	1.5	-	-	-	-	-	Loose	0	0	0	77	11	12	SM
5.50 to 7.00	6	SS	Silty Clay	40	1.5	78	24	54	0.70	-	M.Stiff	0	0	0	0	18	82	CH
7.00 to 10.50	7	SS	Silty Clayey Fine Sand	-	1.5	-	-	-	-	-	Loose	0	0	0	78	10	12	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 4.00	12	SS	Silty Sandy Clay	29	1.7	59	28	31	0.97	11	Stiff	0	0	0	11	13	76	CH
4.00 to 5.50	10	SS	Silty Clayey Fine Sand	-	1.5	-	-	-	-	-	Loose	0	0	0	79	10	11	SM
5.50 to 7.00	6	SS	Silty Clay	41	1.5	79	21	58	0.66	-	M.Stiff	0	0	0	0	17	83	CH
7.00 to 10.50	7	SS	Silty Clayey Fine Sand	-	1.5	-	-	-	-	-	Loose	0	0	0	80	9	11	SM

Table 2.5: Chemical Analysis Results conducted on Water Samples collected from BH-01 to BH-04

Location	Depth of Sample below E.G.L. (m)	pH	Chlorides (ppm)	Sulphates (ppm)
BH-01	2.50	6.71	335.21	377.11
BH-02	2.50	6.72	331.15	372.54
BH-03	2.50	6.70	319.25	359.15
BH-04	2.50	6.71	311.44	350.37

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 Sandy Clay
Colour	Brownish
Thickness of Layer	2.00m
SPT of the layer	10
Consistency	Stiff
Un-drained Cohesion, Cu	66.66kPa

* **Layer-2 (from 2.00m to 4.00m depth)**

Type of Strata	Silty Sandy Clay
Colour	Blackish
Thickness of Layer	2.00m
SPT of the layer	13
Consistency	Stiff
Un-drained Cohesion, Cu	86.66kPa

* **Layer-3 (from 4.00m to 5.50m depth)**

Type of Strata	Silty Clay
Colour	Blackish
Thickness of Layer	1.50m
SPT of the layer	09
Consistency	Stiff
Un-drained Cohesion, Cu	60.00kPa

* **Layer-4 (from 5.50m to 8.50m depth)**

Type of Strata	Silty Clayey Fine Sand
Colour	Blackish
Thickness of Layer	3.00m

SPT of the layer	06
Relative Density	Loose
Angle of Shearing Resistance, ϕ	29.20^0

* **Layer-5 (from 8.50m to 10.00m depth)**

Type of Strata	Silty Clay
Colour	Blackish
Thickness of Layer	1.50m
SPT of the layer	06
Consistency	Medium Stiff
Un-drained Cohesion, Cu	40.00kPa

* **Layer-6 (from 10.00m to 11.50m depth)**

Type of Strata	Silty Clayey Fine Sand
Colour	Blackish
Thickness of Layer	1.50m
SPT of the layer	05
Relative Density	Loose
Angle of Shearing Resistance, ϕ	29.00^0

* **Layer-7 (from 11.50m to 13.00m depth)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	04
Relative Density	Very Loose
Angle of Shearing Resistance, ϕ	28.80^0

* **Layer-8 (from 13.00m to 15.00m depth)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	2.00m
SPT of the layer	07
Relative Density	Loose
Angle of Shearing Resistance, ϕ	29.40^0

* **Layer-9 (from 15.00m to 17.00m depth)**

Type of Strata	Silty Fine Sand
Colour	Greyish to Greenish
Thickness of Layer	2.00m
SPT of the layer	28
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	35.40^0

* **Layer-10 (from 17.00m to 21.00m depth)**

Type of Strata	Silty Fine Sand
Colour	Yellowish to Greenish
Thickness of Layer	4.00m
SPT of the layer	39
Relative Density	Dense
Angle of Shearing Resistance, ϕ	38.475^0

* **Layer-11 (from 21.00m to 22.50m depth)**

Type of Strata	Silty Fine Sand
Colour	Yellowish to Greenish
Thickness of Layer	1.50m
SPT of the layer	69

Relative Density	Very Dense
Angle of Shearing Resistance, ϕ	42.50^0

* **Layer-12 (from 22.50m to 23.20m depth)**

Type of Strata	Soft Rock
Colour	-
Thickness of Layer	0.70m
SPT of the layer	>100
Relative Density	Very Dense
Angle of Shearing Resistance, ϕ	42.50^0

Ground Water

Ground water table was encountered at a depth of 2.50m below the existing ground level during the last week of April 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 4.00m depth)**

Type of Strata	Silty Sandy Clay
Colour	Brownish
Thickness of Layer	4.00m
SPT of the layer	12
Consistency	Stiff
Un-drained Cohesion, Cu	80.00kPa

* **Layer-2 (from 4.00m to 5.50m depth)**

Type of Strata	Silty Clayey Fine Sand
Colour	Blackish
Thickness of Layer	1.50m
SPT of the layer	08
Relative Density	Loose
Angle of Shearing Resistance, ϕ	29.60^0

* **Layer-3 (from 5.50m to 7.00m depth)**

Type of Strata	Silty Clay
Colour	Blackish
Thickness of Layer	1.50m
SPT of the layer	06
Consistency	Medium Stiff
Un-drained Cohesion, Cu	40.00kPa

* **Layer-4 (from 7.00m to 10.50m depth)**

Type of Strata	Silty Clayey Fine Sand
Colour	Blackish
Thickness of Layer	3.50m
SPT of the layer	06
Relative Density	Loose
Angle of Shearing Resistance, ϕ	29.20^0

Ground Water

Ground water table was encountered at a depth of 2.50m below the existing ground level during the last week of April 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 4.00m depth)**

Type of Strata	Silty Sandy Clay
Colour	Brownish
Thickness of Layer	4.00m
SPT of the layer	12
Consistency	Stiff
Un-drained Cohesion, Cu	80.00kPa

* **Layer-2 (from 4.00m to 5.50m depth)**

Type of Strata	Silty Clayey Fine Sand
Colour	Blackish
Thickness of Layer	1.50m
SPT of the layer	09
Relative Density	Loose
Angle of Shearing Resistance, ϕ	29.80^0

* **Layer-3 (from 5.50m to 7.00m depth)**

Type of Strata	Silty Clay
Colour	Blackish
Thickness of Layer	1.50m
SPT of the layer	06
Consistency	Medium Stiff
Un-drained Cohesion, Cu	40.00kPa

* **Layer-4 (from 7.00m to 10.50m depth)**

Type of Strata	Silty Clayey Fine Sand
Colour	Blackish
Thickness of Layer	3.50m
SPT of the layer	07
Relative Density	Loose
Angle of Shearing Resistance, ϕ	29.40^0

Ground Water

Ground water table was encountered at a depth of 2.50m below the existing ground level during the last week of April 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 4.00m depth)**

Type of Strata	Silty Sandy Clay
Colour	Brownish
Thickness of Layer	4.00m
SPT of the layer	12
Consistency	Stiff
Un-drained Cohesion, Cu	80.00kPa

* **Layer-2 (from 4.00m to 5.50m depth)**

Type of Strata	Silty Clayey Fine Sand
Colour	Blackish
Thickness of Layer	1.50m
SPT of the layer	10

Relative Density	Loose
Angle of Shearing Resistance, ϕ	30.00^0

* **Layer-3 (from 5.50m to 7.00m depth)**

Type of Strata	Silty Clay
Colour	Blackish
Thickness of Layer	1.50m
SPT of the layer	06
Consistency	Medium Stiff
Un-drained Cohesion, Cu	40.00kPa

* **Layer-4 (from 7.00m to 10.50m depth)**

Type of Strata	Silty Clayey Fine Sand
Colour	Blackish
Thickness of Layer	3.50m
SPT of the layer	07
Relative Density	Loose
Angle of Shearing Resistance, ϕ	29.40^0

Ground Water

Ground water table was encountered at a depth of 2.50m below the existing ground level during the last week of April 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 uniformly stratified from type but possess non-uniform shear strength characteristics, BH-01 being relatively weak from deformation considerations and hence shall be considered as design borehole to determine the bearing strata and its safe bearing capacity.

Considering BH-01 as design borehole, it can be further envisaged that the highly plastic fine-grained soil strata encountered at shallow depths will hold good to act as bearing strata from shear strength characteristics and deformation considerations for nominal column loads in the range of 650kN to 750kN respectively.

If fine-grained strata encountered at shallow depths are considered as bearing strata, the safe bearing capacity of open foundation system will be a function of un-drained cohesive strength of the bearing strata.

Care shall be taken in locating the foundation system on such type of highly plastic fine-grained strata so that ordinate pressures resulting from its volumetric change phenomenon during variations in seasonal moisture content variations do not impact on the structural system of foundation.

Care shall also be taken in regulating the safe bearing capacity of open foundation system so that the dispersed open foundation stresses on the

underlying relatively weak soil layer encountered at 4.00m depths from present existing ground level (SPT @ 4.50m is 08, Ref. BH-02) are within their safe bearing capacity limits.

However, the refusal soil (SPT>50) strata encountered below 22.50m depths from existing ground level can be considered as end bearing strata for proposed impending loads from structure.

Considering the above, suitable foundation systems are presented below.

4.2 Foundation System

4.2.1 Open Foundation System (BH-01)

Considering the uniformity in sub-soil stratifications at shallow depths, shear strength, presence of underlying relatively weak soil layer at 4.00m depths from existing ground level, highly plastic characteristics of fine-grained soil strata encountered at shallow depths, open foundation system of ***Isolated Column Footing*** *type located at a design depth of 1.70m below present existing ground level over 0.30m thick well compacted CNS (Cohesive Non-Swelling) soil can be adopted.*

The safe bearing capacity of such type of open foundation system is presented below which can be adopted for foundation design purposes.

Type of Open Foundation System	Total Depth of Excavations below existing ground level (m)	Backfill with well compacted CNS (m)	Depth of **Isolated Column Footing** below Existing Ground Level (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
Isolated Column Footing	**2.00**	**0.30**	**1.70**	**08**	**42**

The computations for above are annexed to this report.

Notes

Safe Bearing Capacity of open foundation system is restricted considering the presence of underlying relatively weak soil layer encountered at 4.00m depths from existing ground level i.e. 2.00m distant apart from the bottom level of footing.

4.2.2 Deep Foundation System-23.00m Long Bored Cast-in-Situ Friction cum End Bearing Piles

In case, the safe bearing capacity of open foundation system presented above in Clause 4.2.1 is lower than the foundation stresses, deep foundation system consisting of 23.00m long bored cast-in-situ Friction cum End Bearing Piles can also be adopted.

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

For four different diameters, the safe load carrying capacities of 23.00m 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	Type 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	Fixed Head Pile	23.00	450	140	108
2				500	160	121
3				550	180	133
4				600	200	145

The computations of safe load carrying capacity for 400mm diameter and 23.00m long bored cast-in-situ Friction cum End Bearing Piles are annexed to this report.

CHAPTER-5

CONCLUSIONS & RECOMMENDATIONS

1. Foundation systems presented in Clause 4.2.1 & 4.2.2, Chapter-IV can be adopted for foundation design purposes.

Open Foundation System

2. The safe bearing capacity of open foundation system is computed considering rise in the ground water table up to or above the level of footing.
3. In case, ground water table is encountered within recommended depth of foundation system, provision shall be made to continuously bail the water out of the foundation pits to keep the surfaces of pit consolidated dry.
4. Safe Bearing Capacity of open foundation system is restricted considering the presence of underlying relatively weak soil strata encountered at 4.00m depths below existing ground level (SPT @ 4.50m is 08, Ref. BH-02) i.e. 2.00m distant apart from the bottom level of footing.

Open Foundation Depths

5. Depth of open excavations below present existing ground level shall be 2.00m.
6. Back-fill Thickness with well compacted CNS soil shall be 0.30m.
7. Depth of Isolated Column Footing below present existing ground level will be 1.70m.

Usage of Excavated Earth

8. **Excavated highly plastic fine-grained soil encountered at shallow depths shall be in no case used for back filling purposes.**
9. **No structural units can be in direct contact of highly plastic fine-grained soil strata encountered at shallow depths. A 0.30m thick well compacted and non-plastic CNS is recommended to be sand-witched in between.**

Deep Foundation System

10. Suitable pile load tests (as per I.S: 2911, part-IV) shall be performed to confirm the presented **theoretical** safe load carrying capacities and arrive at the design safe load capacity of piles. (**Mandatory**).
11. *Care shall be taken so that the ultimate end bearing soil strata are none other than recommended "Soft Rock" type. The same shall be reaffirmed by our Geotechnical Engineer during foundation laying works are under progress.*

12. Recommended length of pile shall be taken from its cut-off level.
13. As the sub-soil strata encountered up to the investigated depths are stable, pile liner is not required to be provided while casting the piles.
14. Pile cap can be located over 0.30m thick well compacted existing ground to be replaced soil surface. Ground replacement can be carried out with CNS (cohesive non-swelling) soil.
15. Piles shall be grouped according to the column design load requirements.
16. Safe load carrying capacities of piles shall be limited to their structural capacities.

General

17. **CNS can be well graded coarse-grained soil like quarry dust or clean river sand or sand: gravels mix (1:2) or fly-ash.**
18. 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**.**

DESIGN OF OPEN FOUNDATION SYSTEM (Ref. BH-01)

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1.1 Geometrical Data :

Type of Foundation System:	Isolated Column Footing	
R.L of the top of Borehole (m):	0.00	m
Total Depth of Excavations below Existing Ground Level (m) :	2.00	m
Recommended Thickness of CNS Back-Fill (m):	0.30	m
Effective Depth of Foundation below existing ground level (D_f):	1.70	m
Design Width of Foundation (B):	1.00	m
Thickness of Foundation (T) :	0.20	m

1.2 Soil Data :

Type of Bearing Strata :	Silty Sandy Clay	
Design SPT-value of the Bearing Strata : (considered based upon the density of the strata)	7	
Type of Shear Failure:	General	
Undrained Cohesion, Cu:	46.67	kPa

1.3 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	17.00	kN/m^3
Effective Overburden pressure at foundation level (q)	11.90	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = 5.14

N_q = N/A

N_γ = N/A

Shape Factors:

S_c = 1.00

S_q = N/A

S_γ = N/A

Depth Factors :

D_c = 1.00

D_q = N/A

D_γ = N/A

Inclination Factor:

I_c = 1.00

I_q = N/A

N/A

1.4 Ultimate Bearing Capacity (Qu) :

Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*γ*Nγ*Sγ*Dγ*Ig*w'

Q_u = 239.87 kPa

1.5 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 95.95 kPa

Recommended Safe Bearing Capacity: 80.00 kPa

Restricted considering the presence of underlying relatively weak soil strata encountered at 4.00m depths from existing ground level i.e. 2.00m distant apart from the bottom level of footing.

1.6 Settlements

Since, the bearing strata are stiff fine-grained type, the settlements under the allowable safe bearing pressure 80kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 80kPa and average SPT of 07 considering extent of pressure bulb below bottom level of footing are computed to be in the order of 42mm which is within the permissible limits of 50mm for isolated column footings as per I.S:1904.

DESIGN OF PILE FOUNDATION (Ref. BH-01)

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) :	**23.000**	m
R.L. of Bot. of Pile	-23.00	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 Sandy 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:	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}:	14.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	7.00	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)		

1.2.1.2 Layer-II

Type of Strata:	Silty Sandy Clay	
Average SPT of the strata,N:	13	
Bulk Density of the strata,γ:	17	kN/m^3
Undrained Cohesion, Cu:	86.67	kPa
R.L of top of Strata:	-2.00	m
R.L of bottom of Strata:	-4.00	m
Average Thickness of Strata,I_c:	2.00	m
Effective overburden pressure over the top of strata,σ_{top}:	14.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	28.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	21.00	kN/m^2
Adhesion Factor, α:	0.40	
Skin Resistance of the pile,q_s:	98.02	kN
(q_s:α*Cu*pi()*d*Ic)		

1.2.1.3 Layer-III

Type of Strata:	Silty Clay	
Average SPT of the strata,N:	9	
Bulk Density of the strata,γ:	17	kN/m^3
Undrained Cohesion, Cu:	60.00	kPa
R.L of top of Strata:	-4.00	m

R.L of bottom of Strata:	-5.50	m
Average Thickness of Strata,I_c:	1.50	m
Effective overburden pressure over the top of strata,σ_{top}:	28.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	38.50	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	33.25	kN/m^2
Adhesion Factor, α:	0.40	
Skin Resistance of the pile,q_s:	50.89	kN
(q_s:α*Cu*pi()*d*Ic)		

1.2.1.4 Layer-IV

Type of Strata:	Silty Clayey Fine Sand	
Average SPT of the strata,N:	6	
Bulk Density of the strata,γ:	15	kN/m^3
Angle of Shearing Resistance,ϕ:	29.2	Deg.
R.L of top of Strata:	-5.50	m
R.L of bottom of Strata:	-8.50	m
Average Thickness of Strata,I_c:	3.00	m
Effective overburden pressure over the top of strata,σ_{top}:	38.50	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	53.50	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	46.00	kN/m^2
Coeff. Of Earth Pressure, k:	1.00	
Skin Resistance of the pile,q_s:	109.03	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		

1.2.1.5 Layer-V

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:	-8.50	m
R.L of bottom of Strata:	-10.00	m
Average Thickness of Strata,I_c:	1.50	m
Effective overburden pressure over the top of strata,σ_{top}:	53.50	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	61.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	57.25	kN/m^2
Adhesion Factor, α:	0.70	
Skin Resistance of the pile,q_s:	59.38	kN
(q_s:α*Cu*pi()*d*Ic)		

1.2.1.6 Layer-VI

Type of Strata:	Silty Clayey Fine Sand	
Average SPT of the strata,N:	5	
Bulk Density of the strata,γ:	15	kN/m^3
Angle of Shearing Resistance,ϕ:	29	Deg.
R.L of top of Strata:	-10.00	m
R.L of bottom of Strata:	-11.50	m
Average Thickness of Strata,I_c:	1.50	m
Effective overburden pressure over the top of strata,σ_{top}:	61.00	kN/m^2

Effective overburden pressure over the bottom of strata,σ_{bottom}:	68.50	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	64.75	kN/m^2
Coeff. Of Earth Pressure, k:	1.00	
Skin Resistance of the pile,q_s:	76.11	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		

1.2.1.7 Layer-VII

Type of Strata:	Silty Fine Sand	
Average SPT of the strata,N:	4	
Bulk Density of the strata,γ:	14	kN/m^3
Angle of Shearing Resistance,ϕ:	28.8	Deg.
R.L of top of Strata:	-11.50	m
R.L of bottom of Strata:	-13.00	m
Average Thickness of Strata,I_c:	1.50	m
Effective overburden pressure over the top of strata,σ_{top}:	68.50	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	74.50	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	71.50	kN/m^2
Coeff. Of Earth Pressure, k:	1.00	
Skin Resistance of the pile,q_s:	83.35	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		

1.2.1.8 Layer-VIII

Type of Strata:	Silty Fine Sand	
Average SPT of the strata,N:	7	
Bulk Density of the strata,γ:	15	kN/m^3
Angle of Shearing Resistance,ϕ:	29.4	Deg.
R.L of top of Strata:	-13.00	m
R.L of bottom of Strata:	-15.00	m
Average Thickness of Strata,I_c:	2.00	m
Effective overburden pressure over the top of strata,σ_{top}:	74.50	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	84.50	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	79.50	kN/m^2
Coeff. Of Earth Pressure, k:	1.00	
Skin Resistance of the pile,q_s:	126.66	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		

1.2.1.9 Layer-IX

Type of Strata:	Silty Fine Sand	
Average SPT of the strata,N:	28	
Bulk Density of the strata,γ:	18	kN/m^3
Angle of Shearing Resistance,ϕ:	35.4	Deg.
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}:	84.50	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	100.50	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	92.50	kN/m^2
Coeff. Of Earth Pressure, k:	1.50	

Skin Resistance of the pile,q_s:	278.80	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		

1.2.1.10 Layer-X

Type of Strata:	Silty Fine Sand	
Average SPT of the strata,N:	39	
Bulk Density of the strata,γ:	19	kN/m^3
Angle of Shearing Resistance,ϕ:	38.475	Deg.
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}:	100.50	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	136.50	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	118.50	kN/m^2
Coeff. Of Earth Pressure, k:	2.00	
Skin Resistance of the pile,q_s:	1065.09	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		

1.2.1.11 Layer-XI

Type of Strata:	Silty Fine Sand	
Average SPT of the strata,N:	60	
Bulk Density of the strata,γ:	20	kN/m^3
Angle of Shearing Resistance,ϕ:	42.5	Deg.
R.L of top of Strata:	-21.00	m
R.L of bottom of Strata:	-22.50	m
Average Thickness of Strata,I_c:	1.50	m
Effective overburden pressure over the top of strata,σ_{top}:	136.50	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	151.50	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	144.00	kN/m^2
Coeff. Of Earth Pressure, k:	2.50	
Skin Resistance of the pile,q_s:	699.53	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		

Ultimate Skin Resistance,q_s: 2722.26 kN

1.2.2 Computation of End Bearing Resistance:

Type of Bearing Strata	Soft Rock	
Cross-Sectional Area of pile,Ap:	0.159	m^2
R.L of bottom of pile:	-23.00	
Minimum SPT-value of the Bearing Strata	60	
Angle of Shearing Resistance(ASR)	42.50	Degrees
Bearing Capacity Factor(Nq)	220.00	
Effecitve Over Burden Pressure at the bottom of pile (q)	30.00	kPa
Ultimate End Bearing Resistance (Qp)	**1049.7**	**kN**
(Qp=Ap*q*Nq)		

1.3.0 Ultimate Load Carrying Capacity ($Qu=Qs+Q_p$)	**3771.9**	**kN**
Safe Load Carrying Capacity (Qsafe =Qu/2.50)	**1508.8**	**kN**
However, limit Q_{safe} to the structural capacity of pile:	**1400.0**	**kN**



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