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CLIENT	**M/s. M.P. DEVELOPERS, CHENNAI**
PROJECT	**PROPOSED CONSTRUCTION OF RESIDENTIAL BUILDING (STILT+05) AT SURVEY NO. 12/2B & 12/2C, MOONDRAMKATTALAI VILLAGE, KUNDRATHUR TALUK, KANCHEEPURAM DISTRICT.**
TITLE	**GEOTECHNICAL INVESTIGATION REPORT**

REV.	DATE	REPORT NUMBER	REMARK
0	10.08.2023	BAG/ M/s. M.P. DEVELOPERS /M-2321/23-24	

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CHAPTER-1

INTRODUCTION

1.0 Preamble

M/s. M.P. Developers, Chennai proposed to construct a **Residential Building (Stilt+05) at Survey no. 12/2B & 12/2C, Moondrankattalai village, Kundrathur taluk, Kancheepuram District.**

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 Six Standard Soil investigation bore holes of 150mm diameter up to a depth of 12.00m 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:

Six 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 2.6.

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 2.6.

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 2.6.

Project : Proposed Construction of Residential Building (Stilt+05) at Survey no. 12/2B & 12/2C, Moondrankattalai village, Kundrathur taluk, Kancheepuram District.

Location: BH-01

Started On : 06/08/2023; Ended On : 06/08/2023 G.W.T: 1.00m 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
	G.W.T		Brownish Medium Stiff Silty Clay	1.50	2	2	3	5		M.Stiff	SS
				3.00	3	2	4	6		M.Stiff	SS
4.00											
			Brownish Medium Dense Silty Fine Sand	4.50	9	12	14	26		M.Dense	SS
				6.00	11	13	15	28		M.Dense	SS
7.00											
			Brownish Dense Silty Fine to Medium Coarse Sand	7.50	14	16	18	34		Dense	SS
8.50											
			Brownish Very Dense Silty Fine to Medium Coarse Sand	9.00	19	22	35	57		V.Dense	SS
10.00											
			Weathered Rock	10.50	09cms Penetration for 50 Blows					V.Dense	SS
11.50				11.50	SPT Hammer Rebounded					V.Dense	SS

Bore Hole Terminated at a depth of 11.50m below the existing ground level

Fig. 2.1 Soil Profile at BH-01 Location

Project : Proposed Construction of Residential Building (Stilt+05) at Survey no. 12/2B & 12/2C, Moondrankattalai village, Kundrathur taluk, Kancheepuram District.

Location: BH-02

Started On : 07/08/2023; Ended On : 07/08/2023 G.W.T: 1.00m 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
G.W.T			Brownish Stiff Silty Clay	1.50	3	4	5	9		Stiff	SS
2.00			Brownish Medium Stiff Silty Clay	3.00	2	3	4	7		M.Stiff	SS
4.00			Brownish Medium Dense Silty Fine Sand	4.50	10	11	14	25		M.Dense	SS
5.50			Brownish Dense Silty Fine Sand	6.00	12	15	18	33		Dense	SS
7.00			Brownish Dense Silty Fine to Medium Coarse Sand	7.50	14	17	21	38		Dense	SS
8.50			Brownish Very Dense Silty Fine to Medium Coarse Sand	9.00	17	25	38	63		V.Dense	SS
10.00			Weathered Rock	10.50	10cms Penetration for 50 Blows					V.Dense	SS
10.70											

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

Fig. 2.2 Soil Profile at BH-02 Location

Project : Proposed Construction of Residential Building (Stilt+05) at Survey no. 12/2B & 12/2C, Moondrankattalai village, Kundrathur taluk, Kancheepuram District.
Location: BH-03

Started On : 07/08/2023; Ended On : 07/08/2023 G.W.T: 1.00m 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
G.W.T			Brownish Medium Stiff Silty Clay	1.50	2	3	3	6		M.Stiff	SS
2.00											
			Brownish Stiff Silty Clay	3.00	3	4	5	9		Stiff	SS
4.00											
			Brownish Medium Dense Silty Fine Sand	4.50	8	11	13	24		M.Dense	SS
				6.00	11	12	15	27		M.Dense	SS
7.00											
			Brownish Dense Silty Fine to Medium Coarse Sand	7.50	13	15	17	32		Dense	SS
8.50											
			Soft Disintegrated Rock	9.00	26	35	43	78		V.Dense	SS
10.00											
			Weathered Rock	10.50	11cms Penetration for 50 Blows					V.Dense	SS
12.00				12.00	SPT Hammer Rebounded					V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.3 Soil Profile at BH-03 Location

Project : Proposed Construction of Residential Building (Stilt+05) at Survey no. 12/2B & 12/2C, Moondrankattalai village, Kundrathur taluk, Kancheepuram District.

Location: BH-04

Started On : 08/08/2023; Ended On : 08/08/2023 G.W.T: 1.00m below existing ground level

R.L of Layer (m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT below E.G.L (m)	SPT - Details 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
G.W.T			Brownish Medium Stiff Silty Clay	1.50	3	4	4	8		M.Stiff	SS
2.00											
			Brownish Stiff Silty Clay	3.00	3	5	6	11		Stiff	SS
4.00											
			Brownish to Blackish Medium Stiff Silty Clay	4.50	2	3	5	8		M.Stiff	SS
5.50											
			Brownish Medium Dense Silty Fine Sand	6.00	7	9	12	21		M.Dense	SS
7.00											
			Brownish Dense Silty Fine to Medium Coarse Sand	7.50	13	15	18	33		Dense	SS
8.50											
			Yellowish to Reddish Loose Silty Sandy Gravels	9.00	3	4	5	9		Loose	SS
10.00											
			Weathered Rock	10.50	10cms Penetration for 50 Blows					V.Dense	SS
10.70											

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

Fig. 2.4 Soil Profile at BH-04 Location

Project : Proposed Construction of Residential Building (Stilt+05) at Survey no. 12/2B & 12/2C, Moondrankattalai village, Kundrathur taluk, Kancheepuram District.

Location: BH-05

Started On : 07/08/2023; Ended On : 07/08/2023 G.W.T: 1.00m 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
G.W.T											
			Brownish Stiff Silty Clay	1.50	5	6	7	13		Stiff	SS
				3.00	4	5	5	10		Stiff	SS
				4.50	5	6	8	14		Stiff	SS
5.00											
			Brownish Dense Silty Fine Sand	6.00	14	18	19	37		Dense	SS
6.50											
			Brownish Dense Silty Fine to Medium Coarse Sand	7.50	13	15	20	35		Dense	SS
8.00											
			Yellowish to Reddish Loose Silty Sandy Gravels	9.00	4	5	6	11		Loose	SS
9.50											
			Weathered Rock	10.50	11cms Penetration for 50 Blows					V.Dense	SS
10.70											

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

Fig. 2.5 Soil Profile at BH-05 Location

Project : Proposed Construction of Residential Building (Stilt+05) at Survey no. 12/2B & 12/2C, Moondrankattalai village, Kundrathur taluk, Kancheepuram District.

Location: BH-06

Started On : 07/08/2023; Ended On : 07/08/2023 G.W.T: 1.00m 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
G.W.T			Brownish Medium Stiff Silty Clay	1.50	3	4	4	8		M.Stiff	SS
2.50				3.00	4	4	6	10		Stiff	SS
			Brownish Stiff Silty Clay	4.50	4	4	5	9		Stiff	SS
5.50				6.00	11	14	14	28		M.Dense	SS
			Brownish Medium Dense Silty Fine Sand	7.50	14	16	18	34		Dense	SS
7.00				9.00	23	35	41	76		V.Dense	SS
			Brownish Dense Silty Fine to Medium Coarse Sand	10.50	10cms Penetration for 50 Blows					V.Dense	SS
8.50				11.00	SPT Hammer Rebounded					V.Dense	SS
			Soft Disintegrated Rock								
10.00											
			Weathered Rock								
11.00											

Bore Hole Terminated at a depth of 11.00m below the existing ground level

Fig. 2.6 Soil Profile at BH-06 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 4.00	5	SS	Silty Clay	45	1.5	79	21	58	0.59	11	M.Stiff	0	0	0	0	15	85	CH
4.00 to 7.00	27	SS	Silty Fine Sand	-	1.8	-	-	-	-	-	M.Dense	0	0	0	79	21	0	SM
7.00 to 8.50	34	SS	Silty Fine to Medium Coarse Sand	-	1.9	-	-	-	-	-	Dense	0	12	22	48	18	0	SM
8.50 to 10.00	57	SS	Silty Fine to Medium Coarse Sand	-	2.0	-	-	-	-	-	V.Dense	0	14	23	45	18	0	SM
10.00 to 11.50	>100	SS	Weathered Rock	-	2.0	-	-	-	-	-	V.Dense	42	12	28	15	3	0	SDR

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	9	SS	Silty Clay	33	1.7	60	20	40	0.68	8	Stiff	0	0	0	0	19	81	CH
2.00 to 4.00	7	SS	Silty Clay	34	1.6	79	24	55	0.82	-	M.Stiff	0	0	0	0	18	82	CH
4.00 to 5.50	25	SS	Silty Fine Sand	-	1.7	-	-	-	-	-	M.Dense	0	0	0	78	22	0	SM
5.50 to 7.00	33	SS	Silty Fine Sand	-	1.9	-	-	-	-	-	Dense	0	0	0	81	19	0	SM
7.00 to 8.50	38	SS	Silty Fine to Medium Coarse Sand	-	1.9	-	-	-	-	-	Dense	0	13	22	45	20	0	SM
8.50 to 10.00	63	SS	Silty Fine to Medium Coarse Sand	-	2.0	-	-	-	-	-	V.Dense	0	14	24	42	20	0	SM
10.00 to 10.70	>100	SS	Weathered Rock	-	2.0	-	-	-	-	-	V.Dense	44	11	18	25	2	0	SDR

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	6	SS	Silty Clay	41	1.5	66	24	42	0.60	4	M.Stiff	0	0	0	0	18	82	CH
2.00 to 4.00	9	SS	Silty Clay	32	1.7	69	28	41	0.90	-	Stiff	0	0	0	0	19	81	CH
4.00 to 7.00	25	SS	Silty Fine Sand	-	1.7	-	-	-	-	-	M.Dense	0	0	0	79	21	0	SM
7.00 to 8.50	32	SS	Silty Fine to Medium Coarse Sand	-	1.9	-	-	-	-	-	Dense	0	13	23	45	19	0	SM
8.50 to 10.00	78	SS	Soft Disintegrated Rock	-	2.0	-	-	-	-	-	V.Dense	48	10	12	21	9	0	SDR
10.00 to 12.00	>100	SS	Weathered Rock	-	2.0	-	-	-	-	-	V.Dense	40	12	24	18	6	0	SDR

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	8	SS	Silty Clay	35	1.6	62	22	40	0.68	8	M.Stiff	0	0	0	0	18	82	CH
2.00 to 4.00	11	SS	Silty Clay	30	1.7	64	24	40	0.85	-	Stiff	0	0	0	0	20	80	CH
4.00 to 5.50	8	SS	Silty Clay	34	1.6	66	25	41	0.78	-	M.Stiff	0	0	0	0	19	81	CH
5.50 to 7.00	21	SS	Silty Fine Sand	-	1.7	-	-	-	-	-	M.Dense	0	0	0	78	22	0	SM
7.00 to 8.50	33	SS	Silty Fine to Medium Coarse Sand	-	1.9	-	-	-	-	-	Dense	0	12	22	50	16	0	SM
8.50 to 10.00	9	SS	Silty Sandy Gravels	-	1.5	-	-	-	-	-	Loose	40	0	15	28	17	0	GP
10.00 to 10.70	>100	SS	Weathered Rock	-	2.0	-	-	-	-	-	V.Dense	42	11	21	19	7	0	SDR

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 5.00	12	SS	Silty Clay	29	1.7	59	28	31	0.97	9	Stiff	0	0	0	0	20	80	CH
5.00 to 6.50	37	SS	Silty Fine Sand	-	1.9	-	-	-	-	-	Dense	0	0	0	82	18	0	SM
6.50 to 8.00	35	SS	Silty Fine to Medium Coarse Sand	-	1.9	-	-	-	-	-	Dense	0	13	22	48	17	0	SM
8.00 to 9.50	11	SS	Silty Sandy Gravels	-	1.5	-	-	-	-	-	Loose	45	0	12	29	14	0	GP
9.50 to 10.70	>100	SS	Weathered Rock	-	2.0	-	-	-	-	-	V.Dense	39	21	15	22	3	0	SDR

Table 2.6: Laboratory Test Result on the Soil Sample Collected from BH-06

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 2.50	8	SS	Silty Clay	32	1.6	62	20	42	0.71	9	M.Stiff	0	0	0	0	18	82	CH
2.50 to 5.50	9	SS	Silty Clay	32	1.7	69	25	44	0.84	-	Stiff	0	0	0	0	19	81	CH
5.50 to 7.00	28	SS	Silty Fine Sand	-	1.8	-	-	-	-	-	M.Dense	0	0	0	80	20	0	SM
7.00 to 8.50	34	SS	Silty Fine to Medium Coarse Sand	-	1.9	-	-	-	-	-	Dense	0	13	23	45	19	0	SM
8.50 to 10.00	76	SS	Soft Disintegrated Rock	-	2.0	-	-	-	-	-	V.Dense	45	12	22	15	6	0	SDR
10.00 to 11.00	>100	SS	Weathered Rock	-	2.0	-	-	-	-	-	V.Dense	42	22	18	12	6	0	SDR

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 4.00m depth)**

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	4.00m
SPT of the layer	05
Consistency	Medium Stiff
Un-drained Cohesion, Cu	33.33kPa

* **Layer-2 (from 4.00m to 7.00m depth)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	3.00m
SPT of the layer	27
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	35.10^0

* **Layer-3 (from 7.00m to 8.50m depth)**

Type of Strata	Silty Fine to Medium Coarse Sand
Colour	Brownish
Thickness of Layer	1.50m
SPT of the layer	34
Relative Density	Dense
Angle of Shearing Resistance, ϕ	37.10^0

* **Layer-4 (from 8.50m to 10.00m depth)**

Type of Strata	Silty Fine to Medium Coarse Sand

Colour	Brownish
Thickness of Layer	1.50m
SPT of the layer	57
Relative Density	Very Dense
Angle of Shearing Resistance, ϕ	42.05^0

* **Layer-5 (from 10.00m to 11.50m depth)**

Type of Strata	Weathered Rock
Colour	-
Thickness of Layer	1.50m
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 1.00m below the existing ground level during the second week of August 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	09
Consistency	Stiff
Un-drained Cohesion, Cu	60.00kPa

* **Layer-2 (from 2.00m to 4.00m 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-3 (from 4.00m to 5.50m depth)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	1.50m
SPT of the layer	25
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	34.50^0

* **Layer-4 (from 5.50m to 7.00m depth)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	1.50m
SPT of the layer	33
Relative Density	Dense
Angle of Shearing Resistance, ϕ	36.825^0

* **Layer-5 (from 7.00m to 8.50m depth)**

Type of Strata	Silty Fine to Medium Coarse Sand
Colour	Brownish
Thickness of Layer	1.50m
SPT of the layer	38
Relative Density	Dense
Angle of Shearing Resistance, ϕ	38.20^0

* **Layer-6 (from 8.50m to 10.00m depth)**

Type of Strata	Silty Fine to Medium Coarse Sand
Colour	Brownish
Thickness of Layer	1.50m
SPT of the layer	63
Relative Density	Very Dense
Angle of Shearing Resistance, ϕ	42.50^0

* **Layer-7 (from 10.00m to 10.70m depth)**

Type of Strata	Weathered 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 1.00m below the existing ground level during the second week of August 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	06
Consistency	Medium Stiff
Un-drained Cohesion, Cu	40.00kPa

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

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	2.00m
SPT of the layer	09
Consistency	Stiff
Un-drained Cohesion, Cu	60.00kPa

* **Layer-3 (from 4.00m to 7.00m depth)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	3.00m
SPT of the layer	25
Relative Density	Medium Dense

Angle of Shearing Resistance, ϕ	34.50^0

* **Layer-4 (from 7.00m to 8.50m depth)**

Type of Strata	Silty Fine to Medium Coarse Sand
Colour	Brownish
Thickness of Layer	1.50m
SPT of the layer	32
Relative Density	Dense
Angle of Shearing Resistance, ϕ	36.55^0

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

Type of Strata	Soft Disintegrated Rock
Colour	-
Thickness of Layer	1.50m
SPT of the layer	78
Relative Density	Very Dense
Angle of Shearing Resistance, ϕ	42.50^0

* **Layer-6 (from 10.00m to 12.00m depth)**

Type of Strata	Weathered Rock
Colour	-
Thickness of Layer	2.00m
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 1.00m below the existing ground level during the second week of August 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	08
Consistency	Medium Stiff
Un-drained Cohesion, Cu	53.33kPa

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

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	2.00m
SPT of the layer	11
Consistency	Stiff
Un-drained Cohesion, Cu	73.33kPa

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

Type of Strata	Silty Clay
Colour	Brownish to Blackish
Thickness of Layer	1.50m
SPT of the layer	08

Consistency	Medium Stiff
Un-drained Cohesion, Cu	53.33kPa

* **Layer-4 (from 5.50m to 7.00m 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-5 (from 7.00m to 8.50m depth)**

Type of Strata	Silty Fine to Medium Coarse Sand
Colour	Brownish
Thickness of Layer	1.50m
SPT of the layer	33
Relative Density	Dense
Angle of Shearing Resistance, ϕ	36.825^0

* **Layer-6 (from 8.50m to 10.00m depth)**

Type of Strata	Silty Sandy Gravels
Colour	Yellowish to Reddish
Thickness of Layer	1.50m
SPT of the layer	09
Relative Density	Loose
Angle of Shearing Resistance, ϕ	29.80^0

* **Layer-7 (from 10.00m to 10.70m depth)**

Type of Strata	Weathered 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 1.00m below the existing ground level during the second week of August 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 5.00m depth)**

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	5.00m
SPT of the layer	12
Consistency	Stiff
Un-drained Cohesion, Cu	80.00kPa

* **Layer-2 (from 5.00m to 6.50m depth)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	1.50m

SPT of the layer	37
Relative Density	Dense
Angle of Shearing Resistance, ϕ	37.925^0

* **Layer-3 (from 6.50m to 8.00m depth)**

Type of Strata	Silty Fine to Medium Coarse Sand
Colour	Brownish
Thickness of Layer	1.50m
SPT of the layer	35
Relative Density	Dense
Angle of Shearing Resistance, ϕ	37.375^0

* **Layer-4 (from 8.00m to 9.50m depth)**

Type of Strata	Silty Sandy Gravels
Colour	Yellowish to Reddish
Thickness of Layer	1.50m
SPT of the layer	11
Relative Density	Loose
Angle of Shearing Resistance, ϕ	30.30^0

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

Type of Strata	Weathered Rock
Colour	-
Thickness of Layer	1.20m
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 1.00m below the existing ground level during the second week of August 2023.

3.1.6 Soil Profile at BH-06 Location
(At BH-06 Location, as presented in Site plan)

* **Layer-1 (from E.G.L to 2.50m depth)**

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	2.50m
SPT of the layer	08
Consistency	Medium Stiff
Un-drained Cohesion, Cu	53.33kPa

* **Layer-2 (from 2.50m to 5.50m depth)**

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	3.00m
SPT of the layer	09
Consistency	Stiff
Un-drained Cohesion, Cu	60.00kPa

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

Type of Strata	Silty Fine Sand
Colour	Brownish

Thickness of Layer	1.50m
SPT of the layer	28
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	35.40^0

* **Layer-4 (from 7.00m to 8.50m depth)**

Type of Strata	Silty Fine to Medium Coarse Sand
Colour	Brownish
Thickness of Layer	1.50m
SPT of the layer	34
Relative Density	Dense
Angle of Shearing Resistance, ϕ	37.10^0

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

Type of Strata	Soft Disintegrated Rock
Colour	-
Thickness of Layer	1.50m
SPT of the layer	76
Relative Density	Very Dense
Angle of Shearing Resistance, ϕ	42.50^0

* **Layer-6 (from 10.00m to 11.00m depth)**

Type of Strata	Weathered Rock
Colour	-
Thickness of Layer	1.00m
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 1.00m below the existing ground level during the second week of August 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 varying shear strength characteristics along the depth of borehole.

It can further be 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 column loads in the range of 650kN to 750kN respectively.

If fine-grained soil 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 soil 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-04) are within their safe bearing capacity limits.

However, the refusal soil (SPT>50) strata encountered below 10.00m 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 Open Foundation System (BH-04) -Raft Footing

Considering the high plasticity of fine-grained soil strata encountered at shallow depths, their shear strength characteristics and presence of underlying relatively weak soil strata encountered at 4.00m below existing ground level, open foundation system of ***Isolated Column Footing/ Raft*** *located at a design depth of 2.00m below present existing ground level over 0.30m thick 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 **Raft** footing below Present Existing Ground Level (m)	Safe Bearing Capacity (MT/m^2)	Elastic Settlements (mm)
Isolated Column Footing/ Raft Footing	**2.80**	**0.30**	**2.50**	**12**	**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 strata encountered at 4.00m depths below existing ground level (SPT @ 4.50m is 08, Ref. BH-04) i.e. 1.20m distant apart from the bottom level of raft.

4.2.2 Deep Foundation System-10.50m Long Bored Cast-in-Situ Friction cum End Bearing Piles-(Critical-BH-04)

Considering the weak shear strength characteristics of sub-soil strata encountered at shallow depths, deep foundation system consisting of 10.50m 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 10.50m 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	10.50	400	50	24
2			450	60	27
3			500	70	30
4			550	80	33

The computations of safe load carrying capacity for 400mm diameter and 10.50m 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. Safe bearing capacity of open foundation system is computed considering any rise in the ground water table up to or above the level of strips.
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-04) i.e. 1.20m distant apart from the bottom level of raft.

Open Foundation Depths & Restricted Least Dimension of Isolated Column Footing / Raft

5. Depth of open excavations below present existing ground level shall be 2.80m.
6. Back-fill Thickness with well compacted CNS soil shall be 0.30m.
7. Depth of Raft below present existing ground level will be 2.50m.

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 CNS soil layer is recommended to be sand-witched in between.**

Deep Foundation System.

10. *Care shall be taken so that the ultimate end bearing soil strata are none other than recommended "Weathered Rock" type. The same shall be reaffirmed by our Geotechnical Engineer during foundation laying works are under progress.*

11. Suitable pile load tests (as per I.S: 2911, part-IV) shall be performed to confirm the presented safe load carrying capacities **(Mandatory)**.
12. Pile cap can be located over 0.30m thick well compacted ground replaced CNS (Cohesive Non-Swelling) soil surface.
13. **CNS can be non-plastic clean river sand or quarry dust or fly-ash or sand-gravels mix.**
14. Piles shall be grouped according to the column design load requirements.
15. Safe load carrying capacities of piles shall be limited to their structural capacities.

General

16. 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-04)

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1.1 Geometrical Data :

Isolated Column Footing

Type of Foundation System:	Raft	
R.L of the top of Borehole (m):	0.00	m
Total Depth of Excavations below Natural Ground Level (m) :	2.80	m
Recommended Thickness of Back-Fill (m):	0.30	m
Effective Depth of Foundation below natural ground level (D_f):	2.50	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 Clay	
Design SPT-value of the Bearing Strata :	11	
(considered based upon the density of the strata)		
Type of Shear Failure:	General	
Undrained Cohesion, Cu:	73.33	kPa

1.3 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	16.00	kN/m^3
Effective Overburden pressure at foundation level (q)	15.00	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

I_γ = N/A

1.4 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 376.93 kPa

1.5 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 150.77 kPa

Recommended Safe Bearing Capacity: 120.00 kPa

Safe bearing capacity presented above is restricted considering the presence of underlying relaltively weak soil layer encountered at 4.00m depths below existing ground level i.e. 1.20m distant apart from the bottom level of footing/ raft.

1.6 Settlements

Since, the bearing strata are medium stiff fine-grained type, the settlements under the allowable safe bearing pressure 120kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 120kPa and average SPT of 11 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 footing or 70mmraft as per I.S:1904.

Depth of fixity of Pile

Length of Pile — L_1 = 0 cm
[since the pile cast at ground level with fixed head]

Characteristic strength of Concrete — f_{ck} = 30 N/mm^2

Diameter of Pile — D = 40 cm

Modulas of Elasticity of Concrete (E) — $5000 \times \sqrt{f_{ck}} = 5000 \times \sqrt{30}$ N/mm^2
[As per IS 456 :2000 pg. no : 16]

= 273861.28 Kg/cm^2

Moment of Inertia of Pile (I) — $\frac{\pi \times D^4}{64} = \frac{3.14 \times 40^4}{64}$ cm^4

= 125600.0 cm^4

K_2 (constant) = 97.750 Kg/cm^2
[As per IS : 2911 (Part 1 / Sec 1) - appendix-B]

R (constant) = $\sqrt[4]{\frac{(E \times I)}{K_2}}$
[As per IS : 2911 (Part 1 / Sec 1) - appendix-B, Cl.5.5.2]

= 136.96 cm

Hence L_1 / R = $\frac{L_1}{R}$
[As per IS : 2911 (Part 1 / Sec 1) - appendix-B, Cl.5.5.2]

= 0.0E+00

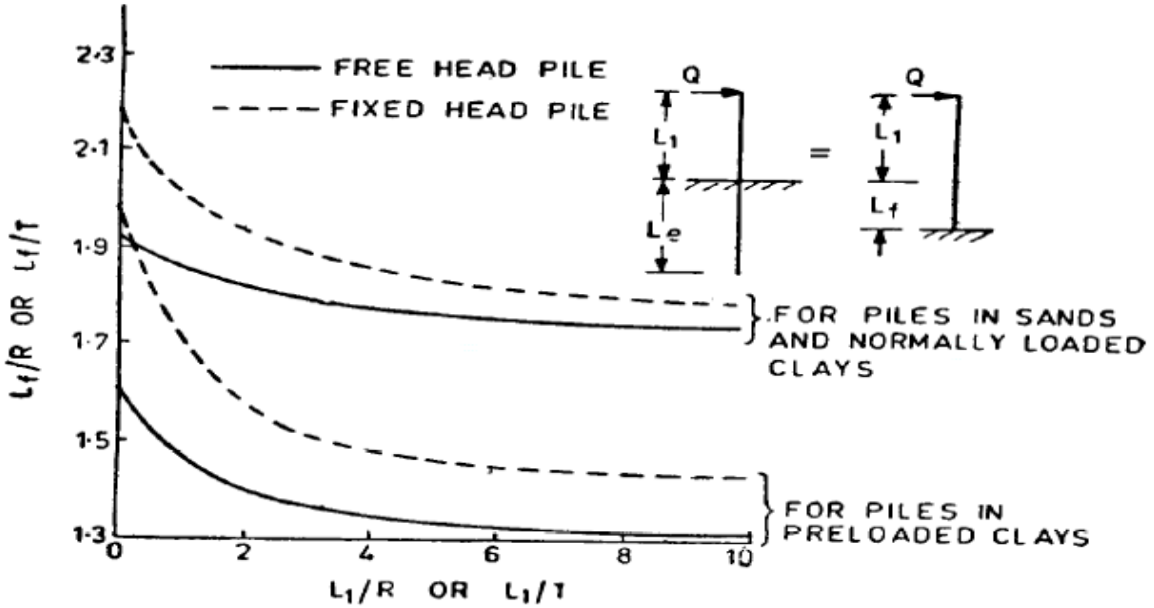


FIG. 2 DETERMINATION OF DEPTH FIXITY

For fixed head pile $\frac{L_1}{R} = 2.2$ [As per IS : 2911 (Part 1 / Sec 1) - appendix-B, Cl.5.5.2 fig 2]

Length of fixity L_f = 301.32 cm [As per IS : 2911 (Part 1 / Sec 1) - appendix-B, Cl.5.5.2]
= 3.01 m

Embedded Length Le > 4 x R [As per IS : 2911 (Part 1 / Sec 1) - appendix-B, Cl.5.5.2]
> 5.5 m

Calculation of Lateral capacity of pile

(From IS:2911, Part 1 / Sec. 1, Cl.5.5.2 - Appendix A)

Lateral capacity , Q = $\frac{12 E I Y}{(L_1 + L_f)^3}$ for Fixed Head Pile

Where ,

Y = Lateral deflection of pile = 5 mm (As per IS2911, part1 / sec.1)

Modulas of Elasticity of Concrete (E) = 273861.28 Kg/cm2

Moment of Inertia of Pile (I) = 125600.0 cm4

L1 + Lf = 0 + 301.32
= 301.3 cm
= 3.01 m

Safe Lateral Load Carrying Capacity $Q = \frac{12 \times 273861.28 \times 125600.0 \times 0.05}{301.3 \times 301.3 \times 301.3 \times 2.5}$

= 3.0 MT

= 30 kN

S.No	Diameter of Pile (mm)	Depth of Fixity of Pile below Ground Level (m)	Safe Lateral Load Carrying Capacity (MT)
1	400	3.01	3.00
2	450	3.39	3.40
3	500	3.77	3.80
4	550	4.14	4.10



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