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CLIENT	M/s.BHAGGYAM CONSTRUCTION, CHENNAI
PROJECT	PROPOSED CONSTRUCTION OF RESIDENTIAL BUILDING (STILT+05) AT PLOT NO -24 OLD DOOR NOS: 26/1 TO 26/8 AND NEW DOOR NOS :51/1 TO 51/8, 4TH TRUST CROSS STREET, MANDAVELIPAKKAM, CHENNAI-600 028. COMPRISED IN R.S.NO: 4311/22, BLOCK NO.97, OF MYLAPORE VILLAGE, GREATER CHENNAI CORPORATION. DIVISION 126, ZONE -9.
TITLE	GEOTECHNICAL INVESTIGATION REPORT

REV.	DATE	REPORT NUMBER	REMARK
0	21.11.2023	BAG/ M/s.BHAGGYAM CONSTRUCTION /M-2617/23-24	

BOOSHNAM ASSOCIATES
Chennai-74.
Mobile: 9629631255
Email: booshnamassociates@gmail.com
GSTIN: 33BULPN7918Q1ZQ

Er. A. NIVEDHITHA M.Tech., (Ph.D)
Registered Geo Technical Engineer
CMDA-Reg. No : GTE/2022/04/55
No. 3/332, Ram 4th Street,
Shanmuga Nagar, Pozhichalur,
Chennai - 600 074. Ph: +91 96296 31255
Email: anivedhitha@gmail.com

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Geotechnical Engineer

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Geotechnical Engineer

CHAPTER-1

INTRODUCTION

1.0 Preamble

M/s.Bhaggyam Construction, Chennai proposed to construct a **Residential Building (Stilt+05) at Plot No -24 Old Door Nos: 26/1 To 26/8 And New Door Nos :51/1 To 51/8, 4th Trust Cross Street, Mandavelipakkam, Chennai-600 028. Comprised In R.S. No: 4311/22, Block No.97, Of Mylapore Village, Greater Chennai Corporation. Division 126, Zone -9.**

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 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)

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Geotechnical Engineer

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 were 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.

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Geotechnical Engineer

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 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.

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Geotechnical Engineer

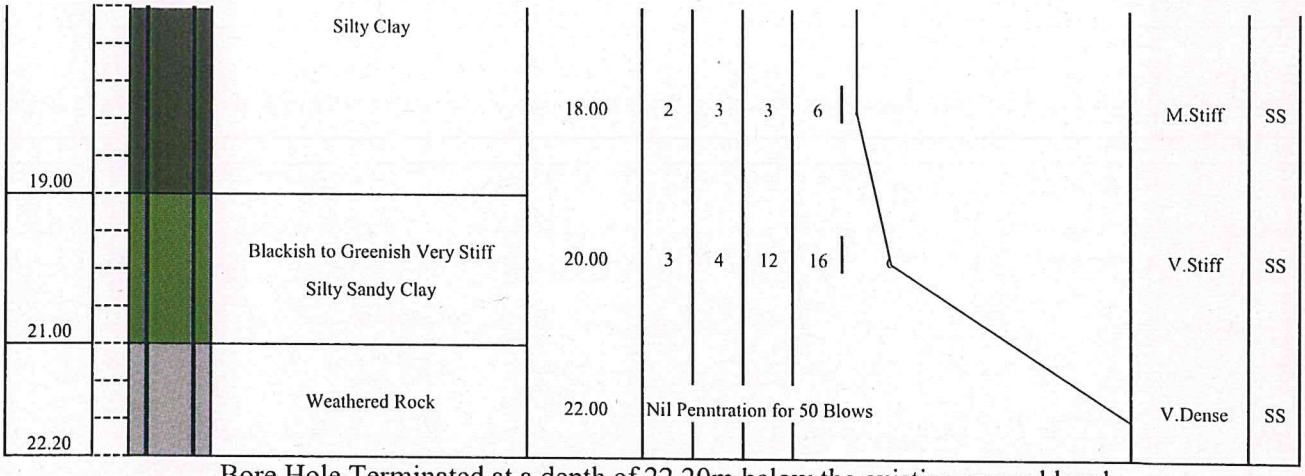
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Location: BH-01

Started On : 16/11/2023; Ended On : 16/11/2023 G.W.T: 1.20m 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 Loose Silty Fine to Medium Coarse Sand	1.50	3	4	5	9		Loose	SS
2.00											
			Brownish Loose Silty Clayey Fine Sand	3.00	5	6	8	14		Loose	SS
4.00											
				4.50	6	8	10	18		M.Dense	SS
			Brownish Medium Dense Silty Clayey Fine Sand	6.00	6	9	11	20		M.Dense	SS
7.00											
				7.50	8	10	11	21		M.Dense	SS
			Brownish Medium Dense Silty Fine to Medium Coarse Sand	9.00	10	11	12	23		M.Dense	SS
10.00											
			Blackish Medium Dense Silty Fine to Medium Coarse Sand	10.50	10	13	14	27		M.Dense	SS
11.50											
			Blackish Medium Dense Silty Clayey Fine Sand	12.00	12	14	16	30		M.Dense	SS
13.00											
				14.00	2	2	3	5		M.Stiff	SS
			Blackish Medium Stiff	16.00	2	3	3	6		M.Stiff	SS

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Geotechnical Engineer



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

Fig. 2.1 Soil Profile at BH-01 Location

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Location: BH-02

Started On : 17/11/2023; Ended On : 17/11/2023 G.W.T: 1.20m 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 Loose Silty Fine to Medium Coarse Sand	1.50	4	5	6	11		Loose	SS
2.00											
			Brownish Loose Silty Clayey Fine Sand	3.00	6	6	7	13		Loose	SS
3.50											
			Brownish Medium Dense Silty Clayey Fine Sand	4.50	7	8	11	19		M.Dense	SS
5.00											
				6.00	7	10	10	20		M.Dense	SS
			Brownish Medium Dense Silty Fine to Medium Coarse Sand	7.50	9	11	12	23		M.Dense	SS
				9.00	11	13	14	27		M.Dense	SS
10.50				10.50	12	14	15	29		M.Dense	SS

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

Fig. 2.2 Soil Profile at BH-02 Location

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Geotechnical Engineer

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Location: BH-03

Started On : 17/11/2023; Ended On : 17/11/2023 G.W.T: 1.20m 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 Loose Silty Fine to Medium Coarse Sand	1.50	3	4	5	9		Loose	SS
2.00											
			Brownish Loose Silty Clayey Fine Sand	3.00	5	6	7	13		Loose	SS
3.50											
			Brownish Medium Dense Silty Clayey Fine Sand	4.50	6	9	10	19		M.Dense	SS
5.00											
				6.00	7	11	11	22		M.Dense	SS
			Brownish Medium Dense Silty Fine to Medium Coarse Sand	7.50	10	12	13	25		M.Dense	SS
				9.00	12	13	15	28		M.Dense	SS
10.50				10.50	13	15	15	30		M.Dense	SS

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

Fig. 2.3 Soil Profile at BH-03 Location

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Location: BH-04

Started On : 18/11/2023; Ended On : 18/11/2023 G.W.T: 1.20m 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 Loose Silty Fine to Medium Coarse Sand	1.50	4	6	6	12		Loose	SS
2.00				3.00	6	7	8	15		Loose	SS
			Brownish Loose Silty Clayey Fine Sand	4.50	6	7	7	14		Loose	SS
5.00				6.00	8	11	12	23		M.Dense	SS
			Brownish Medium Dense Silty Fine to Medium Coarse Sand	7.50	10	12	14	26		M.Dense	SS
				9.00	11	13	14	27		M.Dense	SS
10.50				10.50	12	14	16	30		M.Dense	SS

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

Fig. 2.4 Soil Profile at BH-04 Location

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Geotechnical Engineer

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	9	SS	Silty Fine to Medium Coarse Sand	-	1.5	-	-	-	-	-	Loose	0	10	15	62	13	0	SM
2.00 to 4.00	14	SS	Silty Clayey Fine Sand	-	1.5	-	-	-	-	-	Loose	0	0	0	78	10	12	SM
4.00 to 7.00	19	SS	Silty Clayey Fine Sand	-	1.6	-	-	-	-	-	M.Dense	0	0	0	76	11	13	SM
7.00 to 10.00	22	SS	Silty Fine to Medium Coarse Sand	-	1.7	-	-	-	-	-	M.Dense	0	11	18	55	16	0	SM
10.00 to 11.50	27	SS	Silty Fine to Medium Coarse Sand	-	1.8	-	-	-	-	-	M.Dense	0	12	21	50	17	0	SM
11.50 to 13.00	30	SS	Silty Clayey Fine Sand	-	1.8	-	-	-	-	-	M.Dense	0	0	0	75	12	13	SM
13.00 to 19.00	5	SS	Silty Clay	44	1.5	70	23	47	0.55	-	M.Stiff	0	0	0	0	14	86	CH
19.00 to 21.00	16	SS	Silty Sandy Clay	28	1.8	66	24	42	0.9	-	V.Stiff	0	0	0	11	13	76	CI
21.00 to 22.20	>100	SS	Weathered Rock	-	2.0	-	-	-	-	-	V.Dense	39	12	25	20	4	0	SDR

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Geotechnical Engineer

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	11	SS	Silty Fine to Medium Coarse Sand	-	1.5	-	-	-	-	-	Loose	0	11	18	59	12	0	SM
2.00 to 3.50	13	SS	Silty Clayey Fine Sand	-	1.5	-	-	-	-	-	Loose	0	0	0	79	10	11	SM
3.50 to 5.00	19	SS	Silty Clayey Fine Sand	-	1.6	-	-	-	-	-	M.Dense	0	0	0	77	11	12	SM
5.00 to 10.50	23	SS	Silty Fine to Medium Coarse Sand	-	1.7	-	-	-	-	-	M.Dense	0	12	20	51	17	0	SM

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Er.A.NIVEDHITHA M.Tech
Geotechnical Engineer

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	9	SS	Silty Fine to Medium Coarse Sand	-	1.5	-	-	-	-	-	Loose	0	10	19	55	16	0	SM
2.00 to 3.50	13	SS	Silty Clayey Fine Sand	-	1.5	-	-	-	-	-	Loose	0	0	0	78	11	11	SM
3.50 to 5.00	19	SS	Silty Clayey Fine Sand	-	1.6	-	-	-	-	-	M.Dense	0	0	0	76	11	13	SM
5.00 to 10.50	25	SS	Silty Fine to Medium Coarse Sand	-	1.7	-	-	-	-	-	M.Dense	0	13	22	45	20	0	SM

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Geotechnical Engineer

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	12	SS	Silty Fine to Medium Coarse Sand	-	1.5	-	-	-	-	-	Loose	0	15	25	45	15	0	SM
2.00 to 5.00	14	SS	Silty Clayey Fine Sand	-	1.5	-	-	-	-	-	Loose	0	0	0	76	11	13	SM
5.00 to 10.50	25	SS	Silty Fine to Medium Coarse Sand	-	1.7	-	-	-	-	-	M.Dense	0	12	21	51	16	0	SM

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Er.A.NIVEDHITHA M.Tech
Geotechnical Engineer

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 Fine to Medium Coarse Sand
Colour	Brownish
Thickness of Layer	2.00m
SPT of the layer	09
Relative Density	Loose
Angle of Shearing Resistance, ϕ	29.80^0

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

Type of Strata	Silty Clayey Fine Sand
Colour	Brownish
Thickness of Layer	2.00m
SPT of the layer	14
Relative Density	Loose
Angle of Shearing Resistance, ϕ	31.20^0

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

Type of Strata	Silty Clayey Fine Sand
Colour	Brownish
Thickness of Layer	3.00m
SPT of the layer	19
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	32.70^0

* **Layer-4 (from 7.00m to 10.00m depth)**

Type of Strata	Silty Fine to Medium Coarse Sand

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Colour	Brownish
Thickness of Layer	3.00m
SPT of the layer	22
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.60^0
* **Layer-5 (from 10.00m to 11.50m depth)**	
Type of Strata	Silty Fine to Medium Coarse Sand
Colour	Blackish
Thickness of Layer	1.50m
SPT of the layer	27
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	35.10^0
* **Layer-6 (from 11.50m to 13.00m depth)**	
Type of Strata	Silty Clayey Fine Sand
Colour	Blackish
Thickness of Layer	1.50m
SPT of the layer	30
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	36.00^0
* **Layer-7 (from 13.00m to 19.00m depth)**	
Type of Strata	Silty Clay
Colour	Blackish
Thickness of Layer	6.00m
SPT of the layer	05
Consistency	Medium Stiff
Un-drained Cohesion, Cu	33.33kPa
* **Layer-8 (from 19.00m to 21.00m depth)**	
Type of Strata	Silty Sandy Clay
Colour	Blackish to Greenish
Thickness of Layer	2.00m
SPT of the layer	16
Consistency	Very Stiff
Un-drained Cohesion, Cu	106.66kPa
* **Layer-9 (from 21.00m to 22.20m 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 1.20m below the existing ground level during the third week of November 2023.

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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 Fine to Medium Coarse Sand
Colour	Brownish
Thickness of Layer	2.00m
SPT of the layer	11
Relative Density	Loose
Angle of Shearing Resistance, ϕ	30.30^0

* **Layer-2 (from 2.00m to 3.50m depth)**

Type of Strata	Silty Clayey Fine Sand
Colour	Brownish
Thickness of Layer	1.50m
SPT of the layer	13
Relative Density	Loose
Angle of Shearing Resistance, ϕ	30.90^0

* **Layer-3 (from 3.50m to 5.00m depth)**

Type of Strata	Silty Clayey Fine Sand
Colour	Brownish
Thickness of Layer	1.50m
SPT of the layer	19
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	32.70^0

* **Layer-4 (from 5.00m to 10.50m depth)**

Type of Strata	Silty Fine to Medium Coarse Sand
Colour	Brownish
Thickness of Layer	5.50m
SPT of the layer	23
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.90^0

Ground Water

Ground water table was encountered at a depth of 1.20m below the existing ground level during the third week of November 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 Fine to Medium Coarse Sand
Colour	Brownish
Thickness of Layer	2.00m
SPT of the layer	09
Relative Density	Loose
Angle of Shearing Resistance, ϕ	29.80^0

* **Layer-2 (from 2.00m to 3.50m depth)**

Type of Strata	Silty Clayey Fine Sand

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Colour	Brownish
Thickness of Layer	1.50m
SPT of the layer	13
Relative Density	Loose
Angle of Shearing Resistance, ϕ	30.90^0

* **Layer-3 (from 3.50m to 5.00m depth)**

Type of Strata	Silty Clayey Fine Sand
Colour	Brownish
Thickness of Layer	1.50m
SPT of the layer	19
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	32.70^0

* **Layer-4 (from 5.00m to 10.50m depth)**

Type of Strata	Silty Fine to Medium Coarse Sand
Colour	Brownish
Thickness of Layer	5.50m
SPT of the layer	25
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	34.50^0

Ground Water

Ground water table was encountered at a depth of 1.20m below the existing ground level during the third week of November 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 Fine to Medium Coarse Sand
Colour	Brownish
Thickness of Layer	2.00m
SPT of the layer	12
Relative Density	Loose
Angle of Shearing Resistance, ϕ	30.60^0

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

Type of Strata	Silty Clayey Fine Sand
Colour	Brownish
Thickness of Layer	3.00m
SPT of the layer	14
Relative Density	Loose
Angle of Shearing Resistance, ϕ	31.20^0

* **Layer-3 (from 5.00m to 10.50m depth)**

Type of Strata	Silty Fine to Medium Coarse Sand
Colour	Brownish
Thickness of Layer	5.50m
SPT of the layer	25
Relative Density	Medium Dense

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

Angle of Shearing Resistance, ϕ	34.50^0

Ground Water

Ground water table was encountered at a depth of 1.20m below the existing ground level during the third week of November 2023.

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

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 coarse-grained type and good from both shear strength characteristics and deformation considerations to act as bearing strata for proposed impending loads form structure.

If coarse-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 least dimension of footing and effective surcharge over the bearing strata.

Care shall also be taken in designing the open foundation system so that the dispersed open foundation stresses on the underlying relatively weak soil layer encountered at 13.00m depths from existing ground level (SPT @ 14.00m is 05, Ref. BH-01) are within its safe bearing capacity limits.

Further, the refusal soil strata (SPT>60) encountered below 21.00m depths from existing ground level can also be considered as good end bearing strata for proposed impending loads from structure.

Considering the above, suitable foundation systems are presented below.

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Er.A.NIVEDHITHA M.Tech
Geotechnical Engineer

4.2 Foundation System

4.2.1 Open Foundation System (BH-01)

Considering the shear strength characteristics of coarse-grained soil strata encountered at shallow depths and presence of underlying relatively weak soil strata encountered at 13.00m below existing ground level, open foundation system of ***Isolated Column Footing*** *located at a design depth of 2.50m below present existing ground level 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	Depth of Isolated Column Footing below Existing Ground Level (m)	Observed Thickness of Fill (m)	Depth of Isolated Column Footing below Natural Ground Level (m)	Type of Bearing Strata	Safe Bearing Capacity (MT/m^2)	Elastic Settlements <=50mm (mm)
Isolated Column Footing	2.50	0.00	2.50	Silty Clayey Fine Sand	14	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 13.00m depths from existing ground level i.e. 10.50m distant apart from the bottom level of footing.

4.2.2 Deep Foundation System-22.00m 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 impending foundation stresses, deep foundation system consisting of 22.00m 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 BOOSHNAM ASSOCIATES
Er.A.NIVEDHITHA M.Tech
Geotechnical Engineer

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	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	22.00	450	90	57
2				500	105	63
3				550	120	70
4				600	135	76

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

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

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. Open foundation System of isolated column footing type located at shallow depths over coarse-grained strata can be adopted for foundation design purposes.
3. Care shall be taken so that the ultimate bearing strata are none other than coarse-grained **Silty Clayey Fine Sand** type.
4. 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.
5. Safe Bearing Capacity of open foundation is restricted considering the presence of underlying relatively weak soil layer encountered at a depth of 13.00m below existing ground level i.e. 10.50m distant apart from the bottom level of footing.
6. Excavated coarse-grained soil encountered at shallow depths can only be used for back filling purposes.

Open Foundation Depths

7. Depth of open excavations below present existing ground level shall be 2.50m.
8. Observed Thickness of filled up soil @ Site is 0.00m.
9. Depth of Isolated Column Footing below natural ground level will be 2.50m.

Other Recommendations

10. It is recommended to connect the grade beams so that the structure can act as a single unit against any differential settlements in between the individual footings.
11. Special provisions to contain any lateral collapse of soil from the walls excavated foundation pits are required up to the recommended depths of open foundation system.

Deep Foundation System

BOOSHNAM ASSOCIATES
Chennai-74.
Mobile: 9629631255
Email: booshnamassociates@gmail.com
GSTIN: 33BULPN7918Q1ZQ

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

12. *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.*
13. Suitable pile load tests (as per I.S: 2911, part-IV) shall be performed to confirm the presented safe load carrying capacities.
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.

BOOSHNAM ASSOCIATES
Chennai-74.
Mobile: 9629631255
Email: booshnamassociates@gmail.com
GSTIN: 33BULPN7918Q1ZQ

Er. A. NIVEDHITHA M.Tech., (Ph.D)
Registered Geo Technical Engineer
CMDA-Reg. No : GTE/2022/04/55
No. 3/332, Ram 4th Street,
Shanmuga Nagar, Pozhichalur,
Chennai - 600 074. Ph: +91 96296 31255
Email: arumugamnivedhitha@gmail.com

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
Depth of Foundation below existing ground level (D_f):	2.50	m
Observed Thickness of fill at site:	0.00	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) :	0.25	m

1.2 Soil Data :

Type of Bearing Strata :	Silty Clayey Fine Sand	
Design SPT-value of the Bearing Strata : (considered based upon the density of the strata)	14	
Type of Shear Failure:	General	
Angle of Shearing Resistance - Limited to a Maximum of:	31.20	Deg.

1.3 Design Parameters:

Bulk Density of Soil above the foundation depth (γ_{bulk})	15.00	kN/m^3
Effective Overburden pressure at foundation level (q)	12.50	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 21.98

N_γ = 28.55

Shape Factors:

S_c = N/A

S_q = 1.61

S_γ = 0.60

Depth Factors :

D_c = N/A

D_q = 1.00

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

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

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 = 505.30 kPa

1.5 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 202.12 kPa

Recommended Safe Bearing Capacity: 140.00 kPa

Restricted considering the presence of underlying relatively weak soil layer encountered at 13.00m depths from existing ground level i.e. 10.50m distant apart from the bottom level of footing.

1.6 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure 140kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 140kPa and average SPT of 14 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 as per I.S:1904.

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

DESIGN OF PILE FOUNDATION (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) :	**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 Fine to Medium Coarse Sa	
Average SPT of the strata,N:	9	
Bulk Density of the strata,γ:	15	kN/m^3
Angle of Shearing Resistance,ϕ:	29.8	Deg.
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}:	10.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	5.00	kN/m^2
Coeff. Of Earth Pressure, k:	1.00	
Skin Resistance of the pile,q_s:	8.10	kN

(q_s:σ*k*tanϕ*pi()*d*Ic)

1.2.1.2 **Layer-II**

Type of Strata:	Silty Clayey Fine Sand	
Average SPT of the strata,N:	14	
Bulk Density of the strata,γ:	15	kN/m^3
Angle of Shearing Resistance,ϕ:	31.2	Deg.
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}:	10.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	20.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	15.00	kN/m^2
Coeff. Of Earth Pressure, k:	1.00	
Skin Resistance of the pile,q_s:	25.69	kN

(q_s:σ*k*tanϕ*pi()*d*Ic)

1.2.1.3 **Layer-III**

Type of Strata:	Silty Clayey Fine Sand	
Average SPT of the strata,N:	19	
Bulk Density of the strata,γ:	16	kN/m^3
Angle of Shearing Resistance,ϕ:	32.7	Deg.
R.L of top of Strata:	-4.00	m

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R.L of bottom of Strata: -7.00 m
Average Thickness of Strata,I_c: 3.00 m
Effective overburden pressure over the top of strata,σ_{top}: 20.00 kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}: 38.00 kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}: 29.00 kN/m^2
Coeff. Of Earth Pressure, k: 1.50
Skin Resistance of the pile,q_s: 118.44 kN
(q_s:σ*k*tanϕ*pi()*d*Ic)

1.2.1.4 **Layer-IV**

Type of Strata: Silty Fine to Medium Coarse S
Average SPT of the strata,N: 22
Bulk Density of the strata,γ: 17 kN/m^3
Angle of Shearing Resistance,ϕ: 33.6 Deg.
R.L of top of Strata: -7.00 m
R.L of bottom of Strata: -10.00 m
Average Thickness of Strata,I_c: 3.00 m
Effective overburden pressure over the top of strata,σ_{top}: 38.00 kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}: 59.00 kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}: 48.50 kN/m^2
Coeff. Of Earth Pressure, k: 1.50
Skin Resistance of the pile,q_s: 205.00 kN
(q_s:σ*k*tanϕ*pi()*d*Ic)

1.2.1.5 **Layer-V**

Type of Strata: Silty Fine to Medium Coarse S
Average SPT of the strata,N: 27
Bulk Density of the strata,γ: 18 kN/m^3
Angle of Shearing Resistance,ϕ: 35.1 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}: 59.00 kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}: 71.00 kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}: 65.00 kN/m^2
Coeff. Of Earth Pressure, k: 1.50
Skin Resistance of the pile,q_s: 145.31 kN
(q_s:σ*k*tanϕ*pi()*d*Ic)

1.2.1.6 **Layer-VI**

Type of Strata: Silty Clayey Fine Sand
Average SPT of the strata,N: 30
Bulk Density of the strata,γ: 18 kN/m^3
Angle of Shearing Resistance,ϕ: 36 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}: 71.00 kN/m^2

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Geotechnical Engineer

Effective overburden pressure over the bottom of strata, σ_{bottom}: 83.00 kN/m^2
Effective overburden pressure at the middle of the strata, σ_{middle}: 77.00 kN/m^2
Coeff. Of Earth Pressure, k: 1.50
Skin Resistance of the pile, q_s: 177.95 kN
(q_s:σ*k*tanϕ*pi()*d*Ic)

1.2.1.7 **Layer-VII**

Type of Strata: Silty Clay
Average SPT of the strata,N: 5
Bulk Density of the strata,γ: 15 kN/m^3
Undrained Shear Strength, C_u: 33.33 kPa
R.L of top of Strata: -13.00 m
R.L of bottom of Strata: -19.00 m
Average Thickness of Strata, I_c: 6.00 m
Effective overburden pressure over the top of strata, σ_{top}: 83.00 kN/m^2
Effective overburden pressure over the bottom of strata, σ_{bottom}: 113.00 kN/m^2
Effective overburden pressure at the middle of the strata, σ_{middle}: 98.00 kN/m^2
Adhesion,α: 0.70
Skin Resistance of the pile, q_s: 197.92 kN
(q_s:α*Cu*pi()*d*Ic)

1.2.1.8 **Layer-VIII**

Type of Strata: Silty Sandy Clay
Average SPT of the strata,N: 16
Bulk Density of the strata,γ: 18 kN/m^3
Undrained Shear Strength, C_u: 106.67 kPa
R.L of top of Strata: -19.00 m
R.L of bottom of Strata: -21.00 m
Average Thickness of Strata, I_c: 2.00 m
Effective overburden pressure over the top of strata, σ_{top}: 113.00 kN/m^2
Effective overburden pressure over the bottom of strata, σ_{bottom}: 129.00 kN/m^2
Effective overburden pressure at the middle of the strata, σ_{middle}: 121.00 kN/m^2
Adhesion,α: 0.40
Skin Resistance of the pile, q_s: 120.64 kN
(q_s:α*Cu*pi()*d*Ic)

1.2.1.9 **Layer-IX**

Type of Strata: Weathered Rock
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: -22.00 m
Average Thickness of Strata, I_c: 1.00 m
Effective overburden pressure over the top of strata, σ_{top}: 129.00 kN/m^2
Effective overburden pressure over the bottom of strata, σ_{bottom}: 139.00 kN/m^2
Effective overburden pressure at the middle of the strata, σ_{middle}: 134.00 kN/m^2
Coeff. Of Earth Pressure, k: 2.50

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Er.A.NIVEDHITHA M.Tech
Geotechnical Engineer

Skin Resistance of the pile,q_s:	433.97	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		
Ultimate Skin Resistance,q_s:	**1433.01**	**kN**

1.2.2 Computation of End Bearing Resistance:

Type of Bearing Strata	Weathered 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	
Angle of Shearing Resistance(ASR)	42.50	Degrees
Bearing Capacity Factor(Nq)	220.00	
Effecitve Over Burden Pressure at the bottom of pile (q)	27.00	kPa
Ultimate End Bearing Resistance (Qp)	**944.7**	**kN**
(Qp=Ap*q*Nq)		

1.3.0	**Ultimate Load Carrying Capacity ($Qu=Qs+Q_p$)**	**2377.7**	**kN**
	Safe Load Carrying Capacity (Qsafe =Qu/2.50)	**951.1**	**kN**
	However, limit Q_{safe} to the structural capacity of pile:	**900.0**	**kN**

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

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Chennai, India

hello@verified.realestate
+91 9996 12 9996
www.verified.realestate