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CLIENT	**QUALITY SHELTERS, CHENNAI**
PROJECT	**PROPOSED CONSTRUCTION OF RESIDENTIAL BUILDING (STILT+05) AT NO: 68, LAKSHMI APARTMENT, ANNA NAGAR WEST EXTENSION, CHENNAI**
TITLE	**GEOTECHNICAL INVESTIGATION REPORT**

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For Geo Mines Engineers Pvt. Ltd

Director

GEO MINES ENGINEERS (P) LTD. GMEPL Chennai

REV.	DATE	REPORT NUMBER	PREP. BY
0	02-05-2023	GMEPL/QUALITY SHELTERS/048/2023-24	

DISCLAIMER

We've been asked to look into the ground and identify and quantify everything that mother nature has put thereand predict how those materials will react to construction and long-term performance of a facility - and we may fall short of this lofty goal.

We have made reasonable and prudent conclusions but a cloud of uncertainty inherently looms over the project as per the pre and post facilities laid and their elemental behaviour on the mother soil.

Also, the variable nature of soil strata and it's varying characteristics may make the recommended foundation system disqualify and hence it's recommended that special care shall be taken by the owner during and after the construction is complete and during the run period of the building.

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CHAPTER-1

INTRODUCTION

1.0 Preamble

Quality Shelters, Chennai proposed to construct a **Residential Building (Stilt+05) at No: 68, Lakshmi Apartment, Anna Nagar West Extension, Chennai.**

For the purpose of designing the foundations, the responsibility of carrying out suitable soil investigation was entrusted to **M/s. Geo Mines ENGINEERS Pvt. Ltd., 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 Two Standard Soil investigation bore holes of 150mm diameter up to depth of 20.00m 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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CHAPTER-2

INVESTIGATION METHODOLOGY & TEST RESULTS

2.0 Field Testing:

2.1 Preamble:

Two 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 locations, 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.

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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 Fig.2.1 & 2.2.

2.6 Laboratory Testing:

2.6.1 Coarse Grained Samples:

2.6.1.1 Grain size Analysis Tests:

On the coarse-grained soil 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 & 2.2.

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 & 2.2.

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-2.3.

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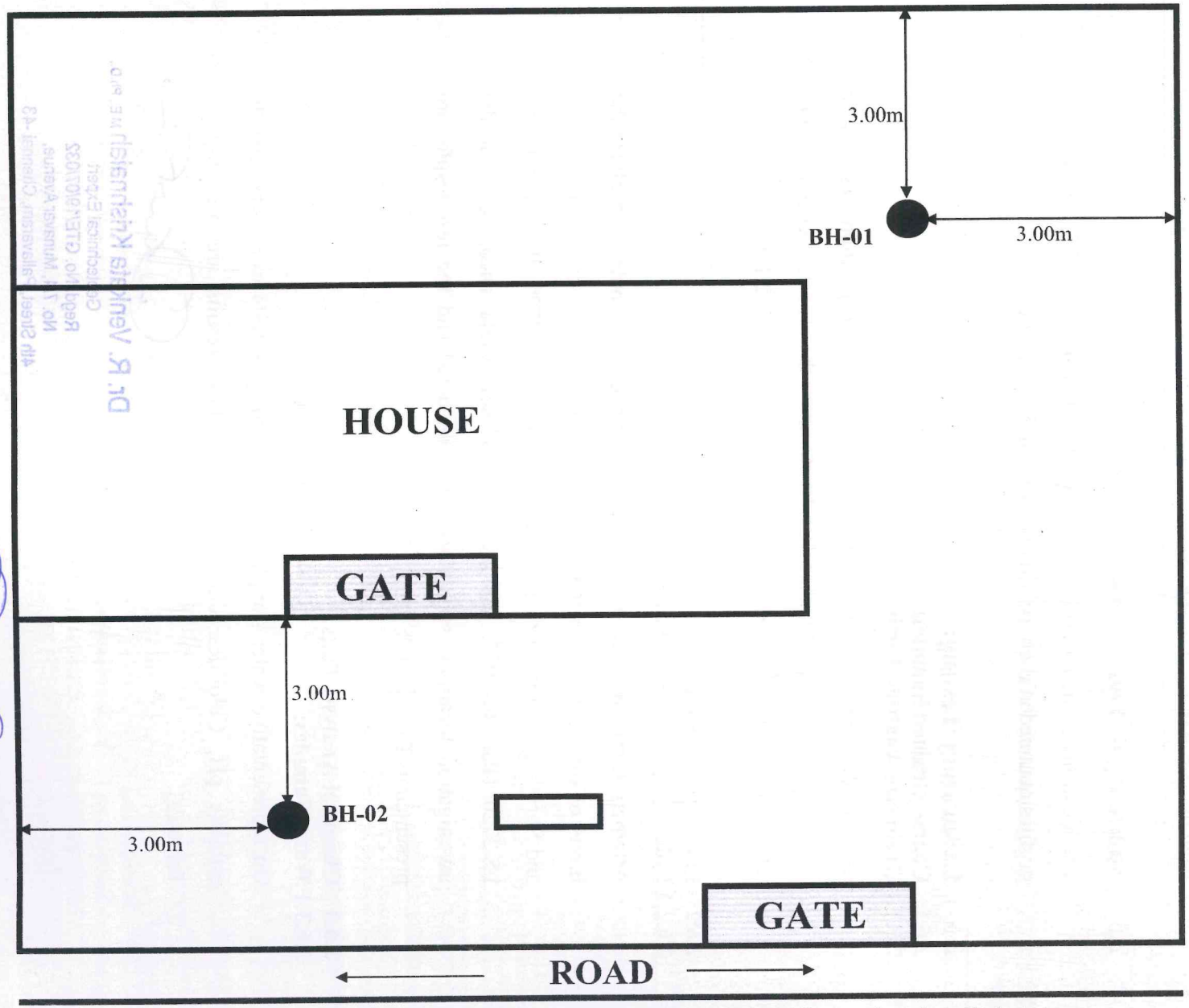


Fig. 2.0: Site Plan Representing the locations of Field Investigation Points

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Project : Proposed Construction of Residential Building (Stilt+05) at No: 68, Lakshmi Apartment, Anna Nagar West Extension, Chennai

Location: BH-01

Started On : 28/04/2023; Ended On : 28/04/2023 G.W.T: 1.50m 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	ical Representation ### 1 2 3 4 5 6 7 8 9	Relative Density/Consistency	Type of Sample
G.W.T	↓		Brownish Stiff Silty Clay	1.50	2	5	9	14	o	Stiff	SS
				3.00	3	4	6	10	o	Stiff	SS
5.00				4.50	4	6	8	14	o	Stiff	SS
			Blackish Very Stiff Silty Clay	6.00	3	7	9	16	o	V.Stiff	SS
7.00											
			Blackish Medium Stiff Silty Clay	7.50	2	4	3	7		M.Stiff	SS
8.50											
			Blackish Stiff Silty Clay	9.00	4	5	7	12	o	Stiff	SS
10.00				10.00	4	8	9	17	o	V.Stiff	SS
			Blackish Very Stiff Silty Clay	12.00	3	5	8	13	o	Stiff	SS
12.00											
			Blackish Stiff Silty Clay	14.00	2	2	4	6		M.Stiff	SS
14.00											
			Blackish Medium Stiff Silty Clay	16.00	3	4	6	10		Stiff	SS
15.50											
			Blackish Stiff Silty Clay	18.00	15	21	27	48	o	Dense	SS
17.00											
			Greyish Dense Cemented Sand	20.00	17	24	36	60	o	V.Dense	SS
19.00											
			Greyish Very Dense Cemented Sand								
20.20											

Bore Hole Terminated at a depth of 20.20m below the existing grou

Fig. 2.1 Soil Profile at BH-01 Location

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Project : Proposed Construction of Residential Building (Stilt+05) at No: 68, Lakshmi Apartment, Anna Nagar West Extension, Chennai

Location: BH-02

Started On : 29/04/2023; Ended On : 29/04/2023 G.W.T: 1.50m 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	ical Representation of 0 1 2 3 4 5 6 7 8 9	Relative Density/Consistency	Type of Sample
G.W.T	↓		Brownish Stiff Silty Clay	1.50	3	5	8	13	o	Stiff	SS
3.50				3.00	4	6	6	12	o	Stiff	SS
5.00			Brownish Very Stiff Silty Clay	4.50	5	9	10	19	o	V.Stiff	SS
8.00			Blackish Very Stiff Silty Clay	6.00	7	11	13	24	o	V.Stiff	SS
				7.50	7	6	12	18	o	V.Stiff	SS
9.50			Blackish Stiff Silty Clay	9.00	4	6	9	15	o	Stiff	SS
10.20			Blackish Medium Stiff Silty Clay	10.00	3	4	4	8	o	M.Stiff	SS

Bore Hole Terminated at a depth of 10.20m below the existing grou

Fig. 2.2 Soil Profile at BH-02 Location

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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 5.00	12	SS	Silty Clay	31	1.7	54	28	26	0.88	13	Stiff	0	0	0	0	19	81	CH
5.00 to 7.00	16	SS	Silty Clay	29	1.8	49	29	20	1.00	-	V.Stiff	0	0	0	0	22	78	CI
7.00 to 8.50	7	SS	Silty Clay	36	1.6	63	23	40	0.68	-	M.Stiff	0	0	0	0	17	83	CH
8.50 to 10.00	12	SS	Silty Clay	30	1.7	54	27	27	0.89	-	Stiff	0	0	0	0	20	80	CH
10.00 to 12.00	17	SS	Silty Clay	26	1.8	47	28	19	1.11	-	V.Stiff	0	0	0	0	23	77	CI
12.00 to 14.00	13	SS	Silty Clay	28	1.7	50	26	24	0.92	-	Stiff	0	0	0	0	21	79	CI
14.00 to 15.50	6	SS	Silty Clay	37	1.5	65	22	43	0.65	-	M.Stiff	0	0	0	0	18	82	CH
15.50 to 17.00	10	SS	Silty Clay	33	1.7	57	27	30	0.80	-	Stiff	0	0	0	0	19	81	CH
17.00 to 19.00	48	SS	Cemented Sand	-	1.9	-	-	-	-	-	Dense	0	23	19	34	12	12	SM
19.00 to 20.20	60	SS	Cemented Sand	-	2.0	-	-	-	-	-	V.Dense	0	20	14	38	9	19	SM

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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 3.50	12	SS	Silty Clay	33	1.7	56	29	27	0.85	14	Stiff	0	0	0	0	19	81	CH
3.50 to 5.00	19	SS	Silty Clay	28	1.8	47	30	17	1.12	-	V.Stiff	0	0	0	0	22	78	CI
5.00 to 8.00	21	SS	Silty Clay	26	1.9	44	29	15	1.20	-	V.Stiff	0	0	0	0	24	76	CI
8.00 to 9.50	15	SS	Silty Clay	30	1.7	50	30	20	1.00	-	Stiff	0	0	0	0	21	79	CI
9.50 to 10.20	8	SS	Silty Clay	36	1.6	63	27	36	0.75	-	M.Stiff	0	0	0	0	17	83	CH

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Table 2.3: Chemical Analysis Results conducted on Water Samples collected from BH-01 & BH-02

Location	Depth of Sample below E.G.L. (m)	pH	Chlorides (ppm)	Sulphates (ppm)
BH-01	3.00	6.77	244.82	275.42
BH-02	3.00	6.76	248.93	280.04

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CHAPTER-3

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, 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 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 7.00m depth)**

Type of Strata	Silty Clay
Colour	Blackish
Thickness of Layer	2.00m
SPT of the layer	16
Consistency	Very Stiff
Un-drained Cohesion, Cu	106.66kPa

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

Type of Strata	Silty Clay
Colour	Blackish
Thickness of Layer	1.50m
SPT of the layer	07
Consistency	Medium Stiff
Un-drained Cohesion, Cu	46.66kPa

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* **Layer-4 (from 8.50m to 10.00m depth)**	
Type of Strata	Silty Clay
Colour	Blackish
Thickness of Layer	1.50m
SPT of the layer	12
Consistency	Stiff
Un-drained Cohesion, Cu	80.00kPa
* **Layer-5 (from 10.00m to 12.00m depth)**	
Type of Strata	Silty Clay
Colour	Blackish
Thickness of Layer	2.00m
SPT of the layer	17
Consistency	Very Stiff
Un-drained Cohesion, Cu	113.33kPa
* **Layer-6 (from 12.00m to 14.00m depth)**	
Type of Strata	Silty Clay
Colour	Blackish
Thickness of Layer	2.00m
SPT of the layer	13
Consistency	Stiff
Un-drained Cohesion, Cu	86.66kPa
* **Layer-7 (from 14.00m to 15.50m 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-8 (from 15.50m to 17.00m depth)**	
Type of Strata	Silty Clay
Colour	Blackish
Thickness of Layer	1.50m
SPT of the layer	10
Consistency	Stiff
Un-drained Cohesion, Cu	66.66kPa
* **Layer-9 (from 17.00m to 19.00m depth)**	
Type of Strata	Cemented Sand
Colour	Greyish
Thickness of Layer	2.00m
SPT of the layer	48
Consistency	Dense
Angle of Shearing Resistance, ϕ	40.55^0
* **Layer-10 (from 19.00m to 20.20m depth)**	
Type of Strata	Cemented Sand
Colour	Greyish
Thickness of Layer	1.20m
SPT of the layer	60
Consistency	Very Dense
Angle of Shearing Resistance, ϕ	42.50^0

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Ground Water

Ground water table was encountered at a depth of 1.50m 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 3.50m depth)**

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	3.50m
SPT of the layer	12
Consistency	Stiff
Un-drained Cohesion, Cu	80.00kPa

* **Layer-2 (from 3.50m to 5.00m depth)**

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	1.50m
SPT of the layer	19
Consistency	Very Stiff
Un-drained Cohesion, Cu	126.66kPa

* **Layer-3 (from 5.00m to 8.00m depth)**

Type of Strata	Silty Clay
Colour	Blackish
Thickness of Layer	3.00m
SPT of the layer	21
Consistency	Very Stiff
Un-drained Cohesion, Cu	140.00kPa

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

Type of Strata	Silty Clay
Colour	Blackish
Thickness of Layer	1.50m
SPT of the layer	15
Consistency	Stiff
Un-drained Cohesion, Cu	100.00kPa

* **Layer-5 (from 9.50m to 10.20m depth)**

Type of Strata	Silty Clay
Colour	Blackish
Thickness of Layer	0.70m
SPT of the layer	08
Consistency	Medium Stiff
Un-drained Cohesion, Cu	53.33kPa

Ground Water

Ground water table was encountered at a depth of 1.50m below the existing ground level during the last week of April 2023.

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CHAPTER-4

FOUNDATION SYSTEM

4.0 Preamble

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

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

4.1 Bearing Strata Characteristics

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

However, the Refusal strata in the form of "Very Dense Cemented Sand" (SPT>60) encountered below 19.00m depths from present existing ground level (Ref. Bh-01) can be considered as good end bearing strata for proposed impending loads from structure.

Considering the above, suitable foundation system is presented below.

4.2 Foundation System

4.2.1 Deep Foundation System-20.00m long Bored Cast-in-Situ Friction cum End Bearing Piles

As the sub-soil strata encountered at shallow depths are weak from shear strength characteristics and deformation considerations, deep foundation system consisting of 20.00m long bored cast-in-situ Friction cum End Bearing Piles can be adopted.

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

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For four different diameters, the safe load carrying capacities of 20.00m long bored cast-in-situ Friction cum End Bearing Piles are computed and presented below which can be adopted for foundation design purposes.

S. No	Type of Installation of Pile	Length of Pile below Existing Ground Level (m)	Diameter of Pile (mm)	Safe Load Carrying Capacity (MT)	Safe Pull Out Capacity (MT)
1	Bored Cast-in-Situ	20.00	500	120	84
2			550	130	92
3			600	140	100
4			650	150	109

The computations of safe load carrying capacity for 500mm diameter and 20.00m long bored cast-in-situ Friction cum End Bearing Pile are annexed to this report.

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CHAPTER5

CONCLUSIONS & RECOMMENDATIONS

1. Deep foundation system presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
2. *Care shall be taken so that the ultimate end bearing soil strata are none other than recommended "Cemented Sand" type. The same shall be reaffirmed by our Geotechnical Engineer during foundation laying works are under progress.*
3. Suitable pile load tests (as per I.S: 2911, part-IV) shall be performed to confirm the presented **theoretical** safe load carrying capacities and shall be used as **allowable/design** load capacities on the pile under considerations. **(Note)**.
4. Piles shall be installed though DMC (direct mud circulation) technique only.
5. Pile cap can be located over 0.30m thick well compacted existing ground surface.
6. Piles shall be grouped according to the column design load requirements.
7. Safe load carrying capacities of piles shall be limited to their structural capacities.

General

8. *As the chlorides and sulphates present in the collected water samples from shallow levels are within the permissible limits, no special steel or cement is recommended to be used for foundation construction purposes at such depths. However, it is advised to sample the water at different levels from the borewell or open well and test chemical parameters as per the usage and requirements.*

For Geo Mines Engineers Pvt. Ltd

Director

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DESIGN OF PILE FOUNDATION (Refer-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):	**500.0**	mm
Assumed R.L of E.G.L:	0.000	m
Length of pile below E.G.L.(l) :	**20.000**	m
R.L. of Bot. of Pile	-20.00	m

1.2 Design of Pile for Vertical Compression

1.2.1 Computation of Skin Resistance:

1.2.1.1 **Layer-I**

Type of Strata:	Silty Clay	
Average SPT of the strata,N:	12	
Bulk Density of the strata,γ:	17	kN/m^3
Undrained Cohesion, Cu:	80	kPa
R.L of top of Strata:	0.00	m
R.L of bottom of Strata:	-5.00	m
Average Thickness of Strata,l_c:	5.00	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}:	35.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	17.50	kN/m^2
Adhesion Factor, α:	0.40	
Skin Resistance of the pile,q_s:	251.33	kN
(q_s:α*Cu*pi()*d*lc)		

1.2.1.2 **Layer-II**

Type of Strata:	Silty Clay	
Average SPT of the strata,N:	16	
Bulk Density of the strata,γ:	18	kN/m^3
Undrained Cohesion, Cu:	106.67	kPa
R.L of top of Strata:	-5.00	m
R.L of bottom of Strata:	-7.00	m
Average Thickness of Strata,l_c:	2.00	m
Effective overburden pressure over the top of strata,σ_{top}:	35.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	51.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	43.00	kN/m^2
Adhesion Factor, α:	0.40	
Skin Resistance of the pile,q_s:	134.04	kN
(q_s:α*Cu*pi()*d*Ic)		

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1.2.1.3 **Layer-III**

Type of Strata:	Silty Clay	
Average SPT of the strata,N:	7	
Bulk Density of the strata,γ:	16	kN/m^3
Undrained Cohesion, Cu:	46.67	kPa
R.L of top of Strata:	-7.00	m
R.L of bottom of Strata:	-8.50	m
Average Thickness of Strata,I_c:	1.50	m
Effective overburden pressure over the top of strata,σ_{top}:	51.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	60.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	55.50	kN/m^2
Adhesion Factor, α:	0.60	
Skin Resistance of the pile,q_s:	65.97	kN
(q_s:α*Cu*pi()*d*Ic)		

1.2.1.4 **Layer-IV**

Type of Strata:	Silty Clay	
Average SPT of the strata,N:	12	
Bulk Density of the strata,γ:	17	kN/m^3
Undrained Cohesion, Cu:	80	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}:	60.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	70.50	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	65.25	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)		

1.2.1.5 **Layer-V**

Type of Strata:	Silty Clay	
Average SPT of the strata,N:	17	
Bulk Density of the strata,γ:	18	kN/m^3
Undrained Cohesion, Cu:	113.33	kPa
R.L of top of Strata:	-10.00	m
R.L of bottom of Strata:	-12.00	m
Average Thickness of Strata,I_c:	2.00	m
Effective overburden pressure over the top of strata,σ_{top}:	70.50	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	86.50	kN/m^2

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Effective overburden pressure at the middle of the strata,σ_{middle}:	78.50	kN/m^2
Adhesion Factor, α:	0.40	
Skin Resistance of the pile,q_s:	142.42	kN
(q_s:α*Cu*pi()*d*Ic)		

1.2.1.6 **Layer-VI**

Type of Strata:	Silty 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:	-12.00	m
R.L of bottom of Strata:	-14.00	m
Average Thickness of Strata,I_c:	2.00	m
Effective overburden pressure over the top of strata,σ_{top}:	86.50	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}:	93.50	kN/m^2
Adhesion Factor, α:	0.40	
Skin Resistance of the pile,q_s:	108.91	kN
(q_s:α*Cu*pi()*d*Ic)		

1.2.1.7 **Layer-VII**

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	kPa
R.L of top of Strata:	-14.00	m
R.L of bottom of Strata:	-15.50	m
Average Thickness of Strata,I_c:	1.50	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}:	108.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	104.25	kN/m^2
Adhesion Factor, α:	0.70	
Skin Resistance of the pile,q_s:	65.97	kN
(q_s:α*Cu*pi()*d*Ic)		

1.2.1.8 **Layer-VIII**

Type of Strata:	Silty Clay	
Average SPT of the strata,N:	10	
Bulk Density of the strata,γ:	17	kN/m^3
Undrained Cohesion, Cu:	66.67	kPa
R.L of top of Strata:	-15.50	m
R.L of bottom of Strata:	-17.00	m

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Average Thickness of Strata,I_c:	1.50	m
Effective overburden pressure over the top of strata,σ_{top}:	108.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	118.50	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	113.25	kN/m^2
Adhesion Factor, α:	0.40	
Skin Resistance of the pile,q_s:	62.83	kN
(q_s:α*Cu*pi()*d*Ic)		

1.2.1.9 **Layer-IX**

Type of Strata:	Cemented Sand	
Average SPT of the strata,N:	48	
Bulk Density of the strata,γ:	19	kN/m^3
Angle of Shearing Resistance,ϕ:	40.55	Deg.
R.L of top of Strata:	-17.00	m
R.L of bottom of Strata:	-19.00	m
Average Thickness of Strata,I_c:	2.00	m
Effective overburden pressure over the top of strata,σ_{top}:	118.50	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}:	127.50	kN/m^2
Coeff. Of Earth Pressure, k:	2.00	
Skin Resistance of the pile,q_s:	685.42	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		

1.2.1.10 **Layer-X**

Type of Strata:	Cemented 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:	-19.00	m
R.L of bottom of Strata:	-20.00	m
Average Thickness of Strata,I_c:	1.00	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}:	146.50	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	141.50	kN/m^2
Coeff. Of Earth Pressure, k:	2.50	
Skin Resistance of the pile,q_s:	509.18	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		

Ultimate Skin Resistance,q_s: 2101.5 kN

1.2.2 Computation of End Bearing Resistance:

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Type of Bearing Strata	Cemented Sand	
Cross-Sectional Area of pile,Ap:	0.196	m^2
R.L of bottom of pile:	-20.00	
Minimum SPT-value of the Bearing Strata	60	
Angle of Shear Resistance, ϕ:	42.50	Deg.
Effective Overburden Pressure, q:	27.00	kPa
Bearing Capacity Factor(Nq)	220.00	
Ultimate End Bearing Resistance (Qp)	**1166.3**	**kN**
(Qp=Ap*q*Nq)		

1.3.0	**Ultimate Load Carrying Capacity ($Qu=Qs+Q_p$)**	**3267.8**	**kN**
	Safe Load Carrying Capacity (Qsafe =Qu/2.50)	**1307.1**	**kN**
	However, limit Q_{safe} to the structural capacity of pile:	**1200.0**	**kN**

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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 $f_{ck} =$ 40 N/mm^2

Diameter of Pile $D =$ 50 cm

Modulas of Elasticity of Concrete (E) $5000 \sqrt{f_{ck}} = 5000 \times \sqrt{40}$ N/mm^2
[As per IS 456 :2000 pg. no : 16]

$=$ 316227.77 Kg/cm^2

Moment of Inertia of Pile (I) $\frac{\pi \times D^4}{64} = \frac{3.14 \times 50^4}{64}$ cm^4

$=$ 306640.6 cm^4

K_2 (constant) $=$ 48.800 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]

$=$ 211.13 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

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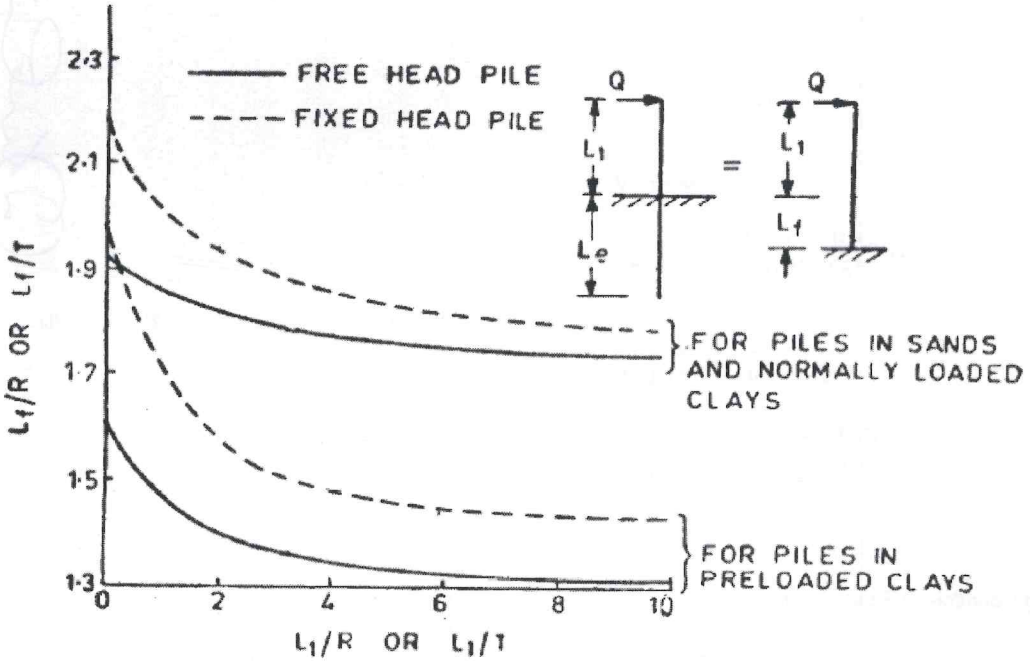


FIG. 2 DETERMINATION OF DEPTH FIXITY

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 = 464.49 cm [As per IS : 2911 (Part 1 / Sec 1) -
= 4.64 m appendix-B, Cl.5.5.2]

Embedded Length

Le > 4 x R [As per IS : 2911 (Part 1 / Sec 1) -
> 8.4 m appendix-B, Cl.5.5.2]

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Calculation of Lateral capacity of pile

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

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

Where ,

Y = Lateral deflection of pile = 10 mm (As per IS2911, part1 / sec.1)

Modulas of Elasticity of Concrete (E) = 316227.77 Kg/cm2

Moment of Inertia of Pile (I) = 306640.6 cm4

L1 + Lf = 0 + 557.39
= 464.5 cm
= 4.64 m

Safe Lateral Load Carrying Capacity

$$Q = \frac{12 \times 316227.77 \times 306640.6 \times 0.10}{464.5 \times 464.5 \times 4.64 \times 2.5}$$

= 4.6 MT

= 46 kN

S.No	Diameter of Pile (mm)	Depth of Fixity of Pile below Ground Level (m)	Safe Lateral Load Carrying Capacity (MT)
1	500	4.64	4.60
2	550	5.11	5.10
3	600	5.57	5.60
4	650	6.04	6.00

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