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CLIENT	**Er. DEVA CONSTRUCTIONS AND CONTRACTORS PRIVATE LIMITED, CHENNAI**
PROJECT	**PROPOSED CONSTRUCTION OF RESIDENTIAL BUILDING (STILT+05) AT S.NOS. 1323/1 PART 1302/1A PART 2B PART AND 1323/1A1PART, BLOCK NOS. 47, 48, 49, 25th STREET, KORATTUR, CHENNAI**
TITLE	**GEOTECHNICAL INVESTIGATION REPORT**

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Director

GEOMINES ENGINEERS PVT. LTD. GMEPL Chennai

REV.	DATE	REPORT NUMBER	PREP. BY
0	06-02-2024	GMEPL/Er. DEVA CONSTRUCTIONS AND CONTRACTORS PRIVATE LIMITED/521/2023-24	

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.

GEOMINES ENGINEERS (P) LTD. GMEPL Chennai

CONTENTS

CHAPTER-1

INTRODUCTION

1.0 Preamble

Er. Deva Constructions and Contractors Private Limited, Chennai proposed to construct a **Residential Building (Stilt+05) at Survey Nos. 1323/1 part 1302/1A part 2B part and 1323/1A1part, Block Nos. 47, 48, 49, 25th Street, Korattur, Chennai.** For the purpose of designing the foundations, the responsibility of carrying out suitable soil investigations 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 One Standard Soil investigation bore hole of 150mm diameter up to depth of 23.00m below existing ground level as directed by the engineer-in-charge.
- Conducting Standard Penetration Test (SPT) at regular depth intervals.
- Collection of Split Spoon Samples or Disturbed Soil Samples
- Collection of water samples from each bore hole.
- Conducting relevant laboratory test results.

1.2 Structure of the Report

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

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CHAPTER-2

INVESTIGATION METHODOLOGY & TEST RESULTS

2.0 Field Testing:

2.1 Preamble:

One standard soil investigation borehole was 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 was 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 borehole.

2.5 Summary of Field Work

The location of the borehole is shown in site plan given in Fig. 2.0. The soil profile obtained at each location is shown in Fig. 2.1.

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. This result is presented in Table 2.1.

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 location, such tests were conducted and the test results are presented in Table 2.1.

2.6.3 Chemical Analysis Tests:

2.6.3.1 Water Sample:

On representative water sample, chemical analysis tests were conducted to estimate pH, Chlorides and Sulphates. These results are presented in Table-2.2.

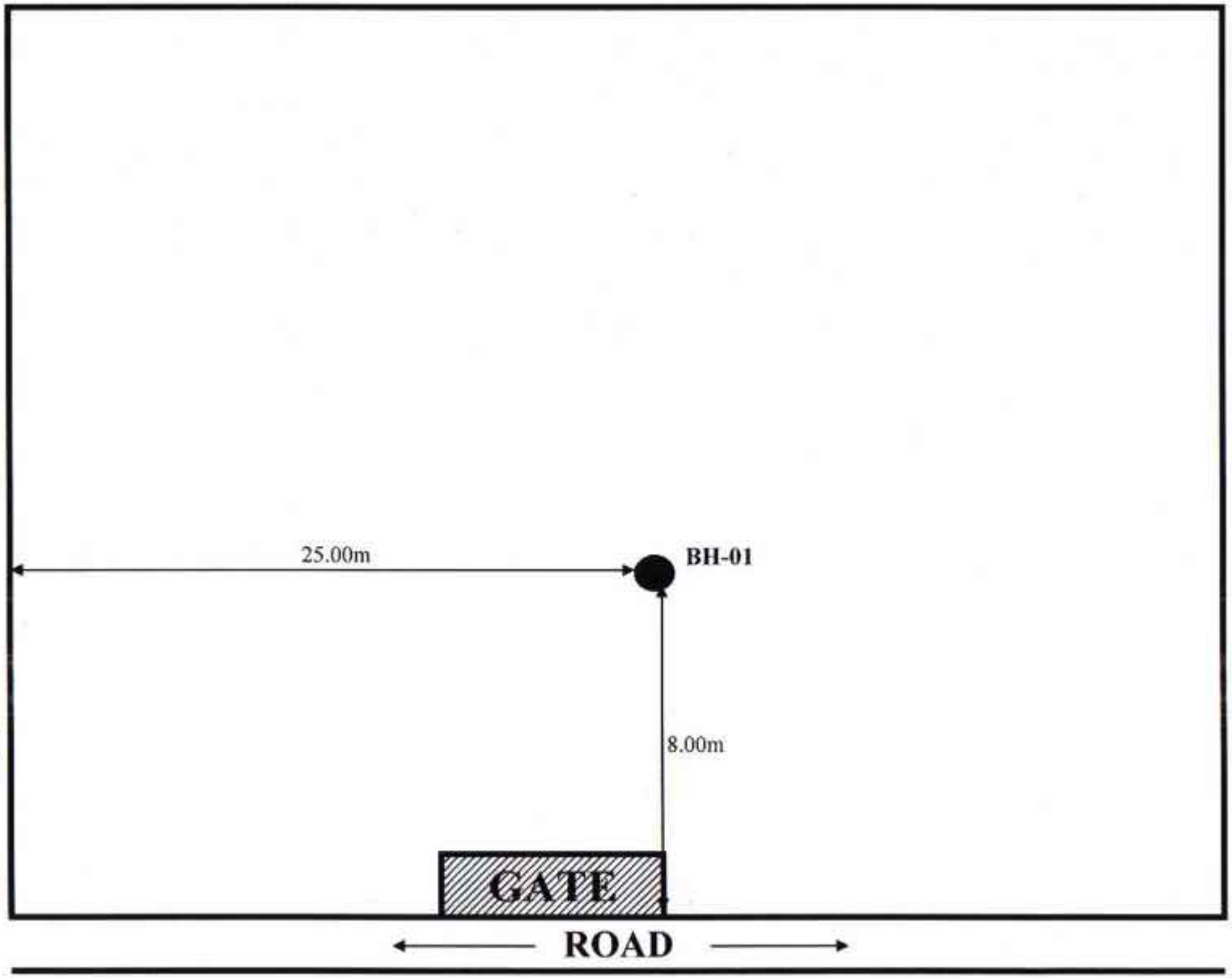
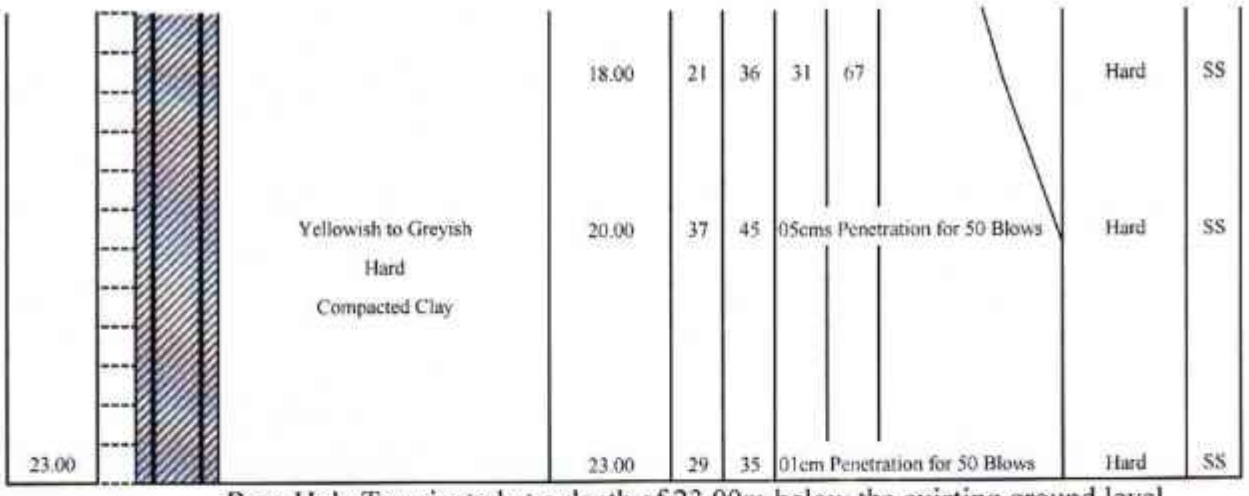


Fig. 2.0: Site Plan Representing the location of Field Investigation Point



Bore Hole Terminated at a depth of 23.00m below the existing ground level

Fig. 2.1 Soil Profile at BH-01 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 3.00	10	SS	Silty Clay	29	1.7	53	24	29	0.83	9	Stiff	0	0	0	0	21	79	CH
3.00 to 4.00	8	SS	Silty Clay	33	1.6	56	25	31	0.74	-	M.Stiff	0	0	0	0	18	82	CH
4.00 to 5.00	5	SS	Silty Clay	37	1.5	60	21	39	0.59	-	M.Stiff	0	0	0	0	17	83	CH
5.00 to 7.00	13	SS	Silty Fine Sand	-	1.5	-	-	-	-	-	Loose	0	0	0	77	23	0	SM
7.00 to 11.00	11	SS	Silty Clay	31	1.7	55	27	28	0.86	-	Stiff	0	0	0	0	20	80	CH
11.00 to 13.00	5	SS	Silty Clay	36	1.5	58	22	36	0.61	-	M.Stiff	0	0	0	0	16	84	CH
13.00 to 17.00	37	SS	Silty Clay	19	2.0	43	28	15	1.60	-	Hard	0	0	0	0	23	77	CI
17.00 to 23.00	83	SS	Compacted Clay	15	2.0	34	27	7	2.71	-	Hard	0	0	0	0	25	75	CL

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Table 2.2: Chemical Analysis Results conducted on Water Sample collected from BH-01				
Location	**Depth of Sample below E.G.L. (m)**	**pH**	**Chlorides (ppm)**	**Sulphates (ppm)**
BH-01	3.00	6.81	299.18	134.39

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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 3.00m depth)**

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	3.00m
SPT of the layer	10
Consistency	Stiff
Un-drained Cohesion, Cu	66.66kPa

* **Layer-2 (from 3.00m to 4.00m depth)**

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	1.00m
SPT of the layer	08
Consistency	Medium Stiff
Un-drained Cohesion, Cu	53.33kPa

* **Layer-3 (from 4.00m to 5.00m depth)**

Type of Strata	Silty Clay
Colour	Blackish
Thickness of Layer	1.00m
SPT of the layer	05
Consistency	Medium Stiff
Un-drained Cohesion, Cu	33.33kPa

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* **Layer-4 (from 5.00m to 7.00m depth)**	
Type of Strata	Silty Fine Sand
Colour	Blackish
Thickness of Layer	2.00m
SPT of the layer	13
Relative Density	Loose
Angle of Shearing Resistance, ϕ	30.90^0
* **Layer-5 (from 7.00m to 11.00m depth)**	
Type of Strata	Silty Clay
Colour	Blackish
Thickness of Layer	4.00m
SPT of the layer	11
Consistency	Stiff
Un-drained Cohesion, Cu	73.33kPa
* **Layer-6 (from 11.00m to 13.00m depth)**	
Type of Strata	Silty Clay
Colour	Blackish
Thickness of Layer	2.00m
SPT of the layer	05
Consistency	Medium Stiff
Un-drained Cohesion, Cu	33.33kPa
* **Layer-7 (from 13.00m to 17.00m depth)**	
Type of Strata	Silty Clay
Colour	Yellowish to Greyish
Thickness of Layer	4.00m
SPT of the layer	37
Consistency	Hard
Un-drained Cohesion, Cu	246.66kPa
* **Layer-8 (from 17.00m to 23.00m depth)**	
Type of Strata	Compacted Clay
Colour	Yellowish to Greyish
Thickness of Layer	6.00m
SPT of the layer	83
Consistency	Hard
Un-drained Cohesion, Cu	553.33kPa

Ground Water

Ground water table was encountered at a depth of 1.50m below the existing ground level during the first week of February 2024.

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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 uniformly stratified from type but possess varying shear strength characteristics along the depth of borehole.

It can further be envisaged that the sub-soil strata encountered at shallow depths are weak from both shear strength characteristics and deformation considerations and hence cannot be taken as bearing strata for proposed impending loads from structure.

However, the sub-soil strata encountered up to the depth of investigations can offer a good frictional resistance against suitably designed structural member or element if being cast or driven in such soils.

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 Piles

Considering the weak shear strength characteristics of sub-soil strata encountered at shallow depths, deep foundation system consisting of 20.00m long bored cast-in-situ Friction Piles can be adopted.

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

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

S. No	Type of Installation of Pile	Type of Pile Head Group	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	20.00	500	70	70
2				550	80	80
3				600	90	90
4				650	100	100

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

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CHAPTER-5

CONCLUSIONS & RECOMMENDATIONS

1. Deep Foundation system presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
2. Suitable pile load tests (as per I.S: 2911, part-IV) shall be performed to confirm the presented **theoretical** safe load carrying capacities and arrive at the **allowable** load carrying capacity of piles under considerations. (**Mandatory**).
3. Pile cap can be located over 0.30m thick well compacted ground replaced soil surface. Ground replacement can be carried out with CNS (cohesive non-swelling) soil.
4. Piles shall be grouped according to the column design load requirements.
5. Allowable load carrying capacities of piles shall be limited to their structural capacities.

General

6. **CNS can be well graded and non-plastic earth like quarry dust or clean river sand or sand: gravels mix (1:2) or fly-ash that shall be well compacted at site to achieve more than 95% of laboratory maximum dry density at optimum moisture content.**
7. As the chlorides and sulphates present in the collected water sample are within the permissible limits, no special steel or cement is recommended to be used for **open** foundation construction purposes only (if adopted). **However, it is recommended to extract the water samples at different intervals up to higher depths from an open-well/dug-well and tested for the chemical parameters as per the required usage or purpose and also to understand the construction material to be used for deep foundation purposes.**

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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):	**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:	10	
Bulk Density of the strata,γ:	17	kN/m^3
Undrained Shear Strength,C_u:	66.67	kPa
R.L of top of Strata:	0.00	m
R.L of bottom of Strata:	-3.00	m
Average Thickness of Strata,l_c:	3.00	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}:	21.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	10.50	kN/m^2
Adhesion,α:	0.40	
Skin Resistance of the pile,q_s:	125.66	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:	8	
Bulk Density of the strata,γ:	16	kN/m^3
Undrained Shear Strength,C_u:	53.33	kPa
R.L of top of Strata:	-3.00	m
R.L of bottom of Strata:	-4.00	m
Average Thickness of Strata,l_c:	1.00	m
Effective overburden pressure over the top of strata,σ_{top}:	21.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	27.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	24.00	kN/m^2
Adhesion,α:	0.60	
Skin Resistance of the pile,q_s:	50.27	kN
(q_s:α*Cu*pi()*d*lc)		

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1.2.1.3 **Layer-III**

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:	-4.00	m
R.L of bottom of Strata:	-5.00	m
Average Thickness of Strata,l_c:	1.00	m
Effective overburden pressure over the top of strata,σ_{top}:	27.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	32.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	29.50	kN/m^2
Adhesion,α:	0.70	
Skin Resistance of the pile,q_s:	36.65	kN

(q_s:α*Cu*pi()*d*lc)

1.2.1.4 **Layer-IV**

Type of Strata:	Silty Fine Sand	
Average SPT of the strata,N:	13	
Bulk Density of the strata,γ:	15	kN/m^3
Angle of Shearing Resistance,ϕ:	30.9	Deg.
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}:	32.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	42.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	37.00	kN/m^2
Coeff. Of Earth Pressure, k:	1.00	
Skin Resistance of the pile,q_s:	69.57	kN

(q_s:σ*k*tanϕ*pi()*d*lc)

1.2.1.5 **Layer-V**

Type of Strata:	Silty Clay	
Average SPT of the strata,N:	11	
Bulk Density of the strata,γ:	17	kN/m^3
Undrained Shear Strength,C_u:	73.33	kPa
R.L of top of Strata:	-7.00	m
R.L of bottom of Strata:	-11.00	m
Average Thickness of Strata,l_c:	4.00	m
Effective overburden pressure over the top of strata,σ_{top}:	42.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	70.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	56.00	kN/m^2
Adhesion,α:	0.40	
Skin Resistance of the pile,q_s:	184.31	kN

(q_s:α*Cu*pi()*d*lc)

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1.2.1.6 **Layer-VI**

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:	-11.00	m
R.L of bottom of Strata:	-13.00	m
Average Thickness of Strata,l_c:	2.00	m
Effective overburden pressure over the top of strata,σ_{top}:	70.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	80.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	75.00	kN/m^2
Adhesion,α:	0.70	
Skin Resistance of the pile,q_s:	73.30	kN

(q_s:α*Cu*pi()*d*lc)

1.2.1.7 Layer-VII

Type of Strata:	Silty Clay	
Average SPT of the strata,N:	37	
Bulk Density of the strata,γ:	20	kN/m^3
Undrained Shear Strength,C_u:	246.67	kPa
R.L of top of Strata:	-13.00	m
R.L of bottom of Strata:	-17.00	m
Average Thickness of Strata,l_c:	4.00	m
Effective overburden pressure over the top of strata,σ_{top}:	80.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	120.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	100.00	kN/m^2
Adhesion,α:	0.40	
Skin Resistance of the pile,q_s:	619.94	kN

(q_s:α*Cu*pi()*d*lc)

1.2.1.8 Layer-VIII

Type of Strata:	Compacted Clay	
Average SPT of the strata,N:	60	
Bulk Density of the strata,γ:	20	kN/m^3
Undrained Shear Strength,C_u:	400.00	kPa
R.L of top of Strata:	-17.00	m
R.L of bottom of Strata:	-20.00	m
Average Thickness of Strata,l_c:	3.00	m
Effective overburden pressure over the top of strata,σ_{top}:	120.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	150.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	135.00	kN/m^2
Adhesion,α:	0.40	
Skin Resistance of the pile,q_s:	753.98	kN

(q_s:α*Cu*pi()*d*lc)

Ultimate Skin Resistance,q_s: 1913.68 kN

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1.2.2 Computation of End Bearing Resistance:

Ultimate End Bearing Resistance (Qp) Ngelcted for Friction Pile

1.3.0	**Ultimate Load Carrying Capacity ($Qu=Qs+Q_p$)**	**1913.7**	**kN**
	Safe Load Carrying Capacity (Qsafe =Qu/2.5)	**765.5**	**kN**
	However, limit Q_{safe} to the structural capacity of pile:	**700.0**	**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} = 30 N/mm^2

Diameter of Pile

D = 50 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)

$\frac{\pi \times D^4}{64}$ = $\frac{3.14 \times 50^4}{64}$ 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]

= 203.67 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

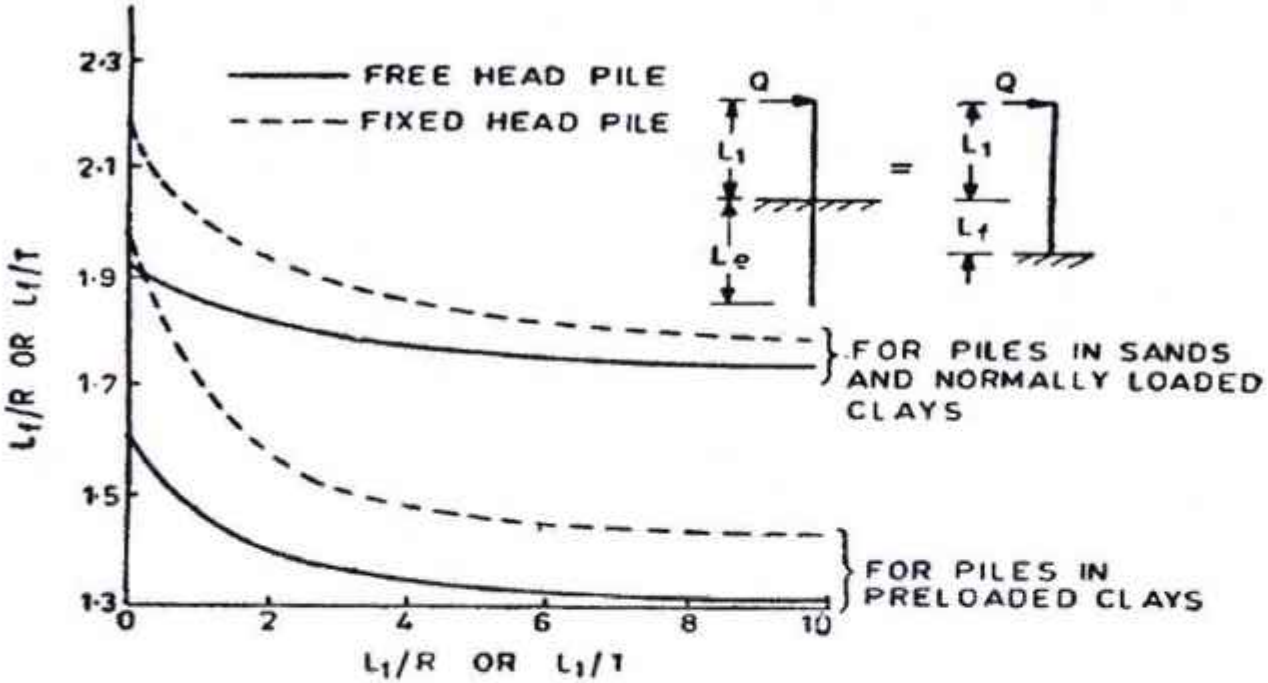

FIG. 2 DETERMINATION OF DEPTH FIXITY

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 = 448.08 cm [As per IS : 2911 (Part 1 / Sec 1) -
= 4.48 m appendix-B, Cl.5.5.2]

Embedded Length

Le > 4 x R [As per IS : 2911 (Part 1 / Sec 1) -
> 8.1 m appendix-B, Cl.5.5.2]

Calculation of Lateral capacity of pile

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

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

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) = 306640.6 cm4

L1 + Lf = 0 + 448.08
= 448.1 cm
= 4.48 m

Safe Lateral Load Carrying Capacity

$$Q = \frac{12 \times 273861.28 \times 306640.6 \times 0.05}{448.1 \times 448.1 \times 448.1 \times 2.5}$$

= 2.2 MT

= 22 kN

S.No	Diameter of Pile (mm)	Depth of Fixity of Pile below Ground Level (m)	Safe Lateral Load Carrying Capacity (MT)
1	500	4.48	2.20
2	550	4.93	2.50
3	600	5.38	2.70
4	650	5.83	2.90

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