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CONSULTANTS		M/s. ENGINEERS-INDIA RESEARCH LAB	
COMPANY		M/s. VRIKSHAM HOMES LLP, CHENNAI	
PROJECT		PROPOSED CONSTRUCTION OF RESIDENTIAL BUILDING (G+05) AT NO 1, NOWROJI RD(EAST-WEST), CHETPET, CHEENAI-600031.	
TITLE		GEOTECHNICAL INVESTIGATION REPORT	
0	04-09-2023	REC/ M/s. VRIKSHAM HOMES LLP /103/2023-24	
REV.	DATE	REPORT NUMBER	PREP. BY

For ENGINEERS- INDIA RESEARCH LAB

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CHAPTER-1

INTRODUCTION

1.0 Preamble

M/S.Vrilksham Homes Llp, Chennai Proposed to Construct a **Residential Building (G+05) At No 1, Now Roji Rd (East-West), Chetpet, Chennai-6000 31.**

For the purpose of designing the foundations, the responsibility of carrying out suitable soil investigations was entrusted to **M/s. Engineers-India Research Lab, 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 Three 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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CHAPTER-2

INVESTIGATION METHODOLOGY & TEST RESULTS

2.0 Field Testing:

2.1 Preamble:

Three 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.

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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 2.3.

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 2.3.

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 2.3.

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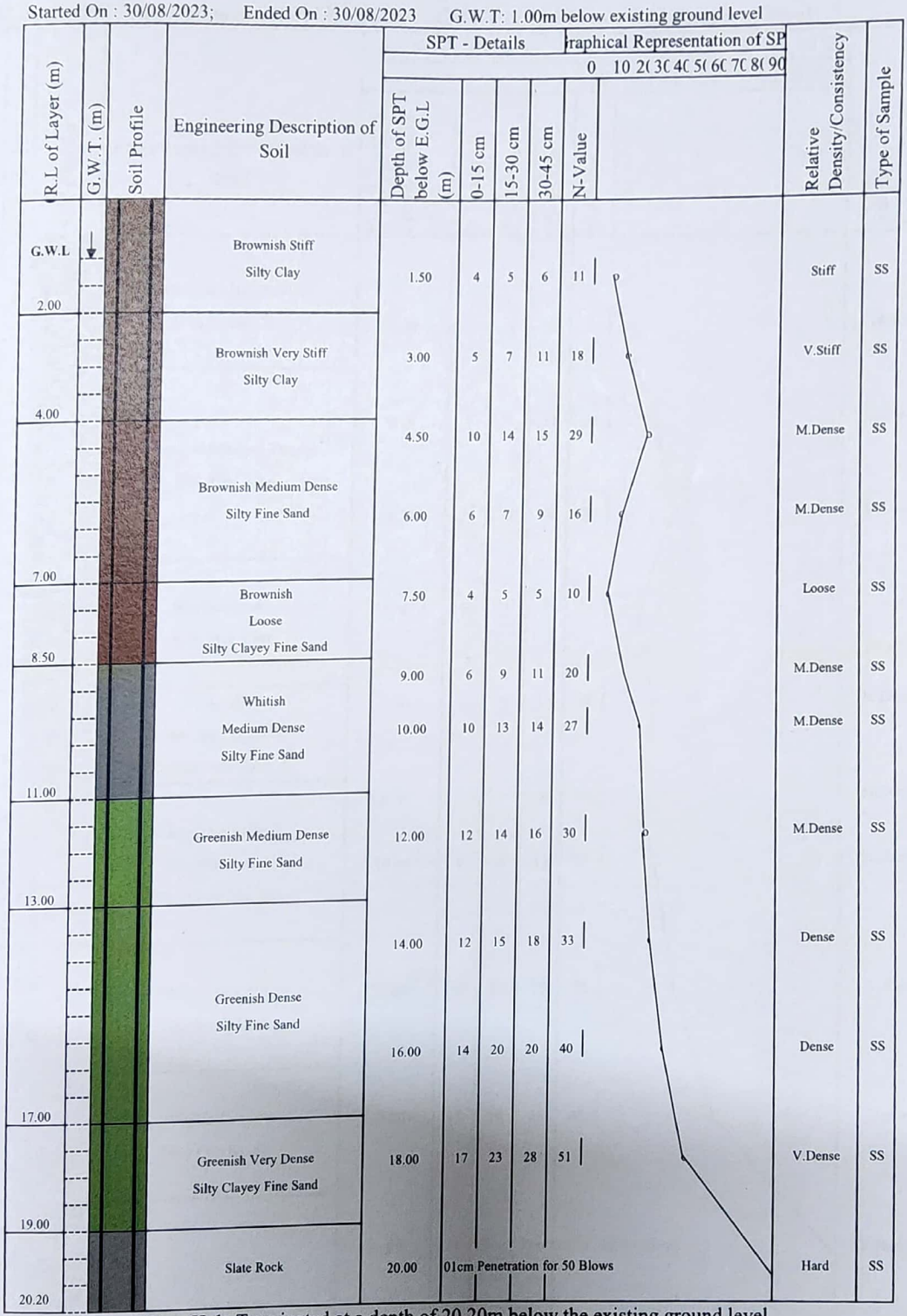
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Project : Proposed Construction of Residential Building (G+05) At No 1, Now Roji Rd (East-West), Chetpet, Chennai-600031.

Location: BH-01

Started On : 30/08/2023; Ended On : 30/08/2023 G.W.T: 1.00m below existing ground level



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

Fig. 2.1 Soil Profile at BH-01 Location

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Project : Proposed Construction of

Location: BH-02

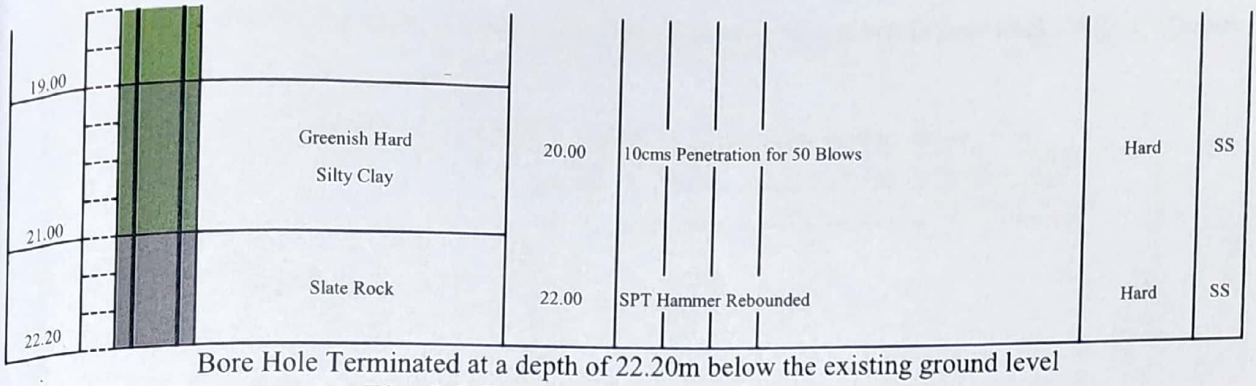
Started On : 31/08/2023; Ended On : 31/08/2023 G.W.T: 1.00m below existing ground level

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 0 10 20 30 40 50 60 70 80 90	Relative Density/Consistency	Type of Sample
G.W.L			Brownish Medium Stiff Silty Sandy Clay	1.50	2	2	3	5		M.Stiff	SS
2.00											
			Brownish Medium Dense Silty Fine Sand	3.00	7	9	11	20		M.Dense	SS
				4.50	10	13	14	27		M.Dense	SS
5.00											
			Blackish Loose Silty Fine Sand	6.00	6	7	7	14		Loose	SS
7.00											
			Blackish Medium Dense Silty Fine Sand	7.50	7	9	12	21		M.Dense	SS
8.50											
			Whitish to Greenish Medium Dense Silty Clayey Fine Sand	9.00	5	7	9	16		M.Dense	SS
				10.00	8	10	12	22		M.Dense	SS
11.00											
			Whitish Very Stiff Silty Sandy Clay	12.00	10	13	17	30		V.Stiff	SS
13.00											
			Whitish Dense Silty Fine Sand	14.00	15	20	26	46		Dense	SS
15.00											
			Greenish Very Dense Silty Fine Sand	16.00 -	24	15cms Penetration for 50 Blows				V.Dense	SS
				18.00	07cms Penetration for 50 Blows					V.Dense	SS

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

Fig. 2.2 Soil Profile at BH-02 Location

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Location: BH-03

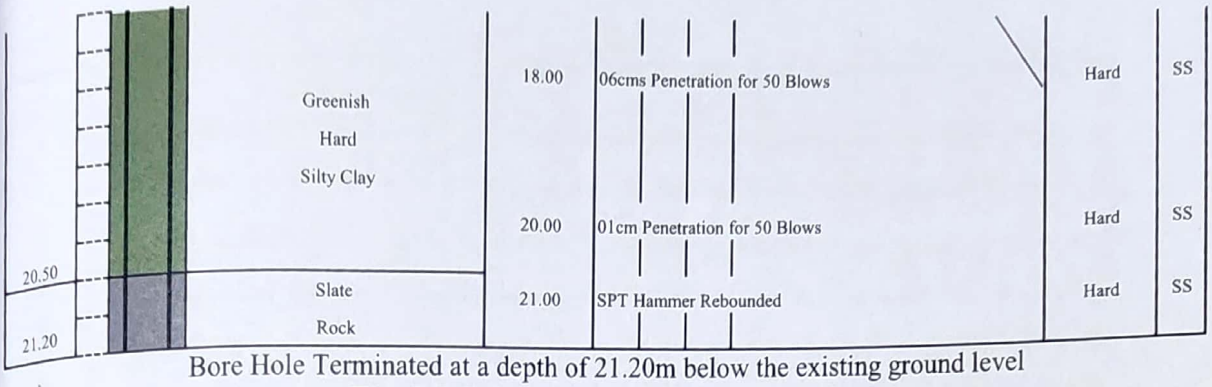
Started On : 01/09/2023; Ended On : 01/09/2023 G.W.T: 1.00m below existing ground level

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 0 10 20 30 40 50 60 70 80 90	Relative Density/Consistency	Type of Sample
G.W.L			Brownish Loose Silty Clayey Fine Sand	1.50	4	5	5	10		Loose	SS
2.00											
				3.00	5	7	9	16		M.Dense	SS
				4.50	7	9	15	24		M.Dense	SS
			Brownish Medium Dense Silty Fine Sand	6.00	9	11	11	22		M.Dense	SS
				7.50	10	13	14	27		M.Dense	SS
8.50											
				9.00	4	5	5	10		Loose	SS
			Greenish Loose Silty Clayey Fine Sand	10.00	5	7	7	14		Loose	SS
11.00											
			Greenish Medium Dense Silty Clayey Fine Sand	12.00	12	14	16	30		M.Dense	SS
13.00											
			Greenish Dense Silty Clayey Fine Sand	14.00	15	24	23	47		Dense	SS
15.00											
			Greenish Very Dense Silty Clayey Fine Sand	16.00	19	27	30	57		V.Dense	SS
17.00											

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Bore Hole Terminated at a depth of 21.20m below the existing ground level

Fig. 2.3 Soil Profile at BH-03 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 2.00	11	SS	Silty Clay	31	1.7	62	21	41	0.76	9	Stiff	0	0	0	0	19	81	CH
2.00 to 4.00	18	SS	Silty Clay	28	1.8	66	24	42	0.90	-	V.Stiff	0	0	0	0	21	79	CI
4.00 to 7.00	22	SS	Silty Fine Sand	-	1.7	-	-	-	-	-	M.Dense	0	0	0	76	24	0	SM
7.00 to 8.50	10	SS	Silty Clayey Fine Sand	-	1.5	-	-	-	-	-	Loose	0	0	0	78	10	12	SM
8.50 to 11.00	23	SS	Silty Fine Sand	-	1.7	-	-	-	-	-	M.Dense	0	0	0	77	23	0	SM
11.00 to 13.00	30	SS	Silty Fine Sand	-	1.8	-	-	-	-	-	M.Dense	0	0.	0	80	20	0	SM
13.00 to 17.00	36	SS	Silty Fine Sand	-	1.9	-	-	-	-	-	Dense	0	0	0	82	18	0	SM
17.00 to 19.00	51	SS	Silty Clayey Fine Sand	-	2.0	-	-	-	-	-	V.Dense	0	0	0	70	12	18	SM
19.00 to 20.20	>100	SS	Slate Rock	14	2.0	38	29	9	2.67	-	Hard	0	0	0	0	25	75	CL

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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 2.00	5	SS	Silty Sandy Clay	45	1.5	77	24	53	0.60	4	M.Stiff	0	0	0	8	13	79	CH
2.00 to 5.00	23	SS	Silty Fine Sand	-	1.7	-	-	-	-	-	M.Dense	0	0	0	78	22	0	SM
5.00 to 7.00	14	SS	Silty Fine Sand	-	1.5	-	-	-	-	-	Loose	0	0	0	73	27	0	SM
7.00 to 8.50	21	SS	Silty Fine Sand	-	1.7	-	-	-	-	-	M.Dense	0	0	0	77	23	0	SM
8.50 to 11.00	19	SS	Silty Clayey Fine Sand	-	1.6	-	-	-	-	-	M.Dense	0	0	0	78	11	11	SM
11.00 to 13.00	30	SS	Silty Sandy Clay	20	1.9	44	33	11	2.18	-	V.Stiff	0	0	0	12	15	73	CI
13.00 to 15.00	46	SS	Silty Fine Sand	-	1.9	-	-	-	-	-	Dense	0	0	0	83	17	0	SM
15.00 to 19.00	>100	SS	Silty Fine Sand	-	2.0	-	-	-	-	-	V.Dense	0	0	0	89	11	0	SM
19.00 to 21.00	>100	SS	Silty Clay	15	2.0	40	30	10	2.50	-	Hard	0	0	0	0	24	76	CI
21.00 to 22.20	>100	SS	Slate Rock	13	2.0	35	25	10	2.20	-	Hard	0	0	0	0	25	75	CI

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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	10	SS	Silty Clayey Fine Sand	-	1.5	-	-	-	-	-	Loose	0	0	0	79	10	11	SM
2.00 to 8.50	22	SS	Silty Fine Sand	-	1.7	-	-	-	-	-	M.Dense	0	0	0	77	23	0	SM
8.50 to 11.00	12	SS	Silty Clayey Fine Sand	-	1.5	-	-	-	-	-	Loose	0	0	0	78	10	12	SM
11.00 to 13.00	30	SS	Silty Clayey Fine Sand	-	1.8	-	-	-	-	-	M.Dense	0	0	0	76	12	12	SM
13.00 to 15.00	47	SS	Silty Clayey Fine Sand	-	1.9	-	-	-	-	-	Dense	0	0	0	72	13	15	SM
15.00 to 17.00	57	SS	Silty Clayey Fine Sand	-	2.0	-	-	-	-	-	V.Dense	0	0	0	69	14	17	SM
17.00 to 20.50	>100	SS	Silty Clay	16	2.0	42	29	13	2.00	-	Hard	0	0	0	0	25	75	CI
20.50 to 21.20	>100	SS	Slate Rock	14	2.0	39	28	11	2.27	-	Hard	0	0	0	0	26	74	CL

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

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	2.00m
SPT of the layer	18
Consistency	Very Stiff
Un-drained Cohesion, Cu	120.00kPa

* **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	22
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.60^0

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

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

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SPT of the layer	10
Relative Density	Loose
Angle of Shearing Resistance, ϕ	30.00⁰
* **Layer-5 (from 8.50m to 11.00m depth)**	
Type of Strata	Silty Fine Sand
Colour	Whitish
Thickness of Layer	2.50m
SPT of the layer	23
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.90⁰
* **Layer-6 (from 11.00m to 13.00m depth)**	
Type of Strata	Silty Fine Sand
Colour	Greenish
Thickness of Layer	2.00m
SPT of the layer	30
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	36.00⁰
* **Layer-7 (from 13.00m to 17.00m depth)**	
Type of Strata	Silty Fine Sand
Colour	Greenish
Thickness of Layer	4.00m
SPT of the layer	36
Relative Density	Dense
Angle of Shearing Resistance, ϕ	37.65⁰
* **Layer-8 (from 17.00m to 19.00m depth)**	
Type of Strata	Silty Clayey Fine Sand
Colour	Greenish
Thickness of Layer	2.00m
SPT of the layer	51
Relative Density	Very Dense
Angle of Shearing Resistance, ϕ	41.15⁰
* **Layer-9 (from 19.00m to 20.20m depth)**	
Type of Strata	Slate Rock
Colour	-
Thickness of Layer	1.20m
SPT of the layer	>100
Consistency	Hard
Un-drained Cohesion, Cu	666.66kPa

Ground Water

Ground water table was encountered at a depth of 0.00m below the existing ground level during the last 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 Sandy Clay
Colour	Brownish
Thickness of Layer	2.00m

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SPT of the layer	05
Consistency	Medium Stiff
Un-drained Cohesion, Cu	33.33kPa
* **Layer-2 (from 2.00m to 5.00m depth)**	
Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	3.00m
SPT of the layer	23
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.90^0
* **Layer-3 (from 5.00m to 7.00m depth)**	
Type of Strata	Silty Fine Sand
Colour	Blackish
Thickness of Layer	2.00m
SPT of the layer	14
Relative Density	Loose
Angle of Shearing Resistance, ϕ	31.20^0
* **Layer-4 (from 7.00m to 8.50m depth)**	
Type of Strata	Silty Fine Sand
Colour	Blackish
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 8.50m to 11.00m depth)**	
Type of Strata	Silty Clayey Fine Sand
Colour	Whitish to Greenish
Thickness of Layer	2.50m
SPT of the layer	19
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	32.70^0
* **Layer-6 (from 11.00m to 13.00m depth)**	
Type of Strata	Silty Sandy Clay
Colour	Whitish
Thickness of Layer	2.00m
SPT of the layer	30
Consistency	Very Stiff
Un-drained Cohesion, Cu	200.00kPa
* **Layer-7 (from 13.00m to 15.00m depth)**	
Type of Strata	Silty Fine Sand
Colour	Whitish
Thickness of Layer	2.00m
SPT of the layer	46
Relative Density	Dense
Angle of Shearing Resistance, ϕ	40.10^0
* **Layer-8 (from 15.00m to 19.00m depth)**	
Type of Strata	Silty Fine Sand
Colour	Greenish
Thickness of Layer	4.00m
SPT of the layer	>100

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Relative Density	Very Dense
Angle of Shearing Resistance, ϕ	42.50^0
* **Layer-9 (from 19.00m to 21.00m depth)**	
Type of Strata	Silty Clay
Colour	Greenish
Thickness of Layer	2.00m
SPT of the layer	>100
Consistency	Hard
Un-drained Cohesion, Cu	666.66kPa
* **Layer-10 (from 21.00m to 22.20m depth)**	
Type of Strata	Slate Rock
Colour	-
Thickness of Layer	1.20m
SPT of the layer	>100
Consistency	Hard
Un-drained Cohesion, Cu	666.66kPa

Ground Water

Ground water table was encountered at a depth of 0.00m below the existing ground level during the last 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 Clayey Fine Sand
Colour	Brownish
Thickness of Layer	2.00m
SPT of the layer	10
Relative Density	Loose
Angle of Shearing Resistance, ϕ	30.00^0
* **Layer-2 (from 2.00m to 8.50m depth)**	
Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	6.50m
SPT of the layer	22
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.60^0
* **Layer-3 (from 8.50m to 11.00m depth)**	
Type of Strata	Silty Clayey Fine Sand
Colour	Greenish
Thickness of Layer	2.50m
SPT of the layer	12
Relative Density	Loose
Angle of Shearing Resistance, ϕ	30.60^0
* **Layer-4 (from 11.00m to 13.00m depth)**	
Type of Strata	Silty Clayey Fine Sand
Colour	Greenish
Thickness of Layer	2.00m
SPT of the layer	30

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Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	36.00^0
* **Layer-5 (from 13.00m to 15.00m depth)**	
Type of Strata	Silty Clayey Fine Sand
Colour	Greenish
Thickness of Layer	2.00m
SPT of the layer	47
Relative Density	Dense
Angle of Shearing Resistance, ϕ	40.325^0
* **Layer-6 (from 15.00m to 17.00m depth)**	
Type of Strata	Silty Clayey Fine Sand
Colour	Greenish
Thickness of Layer	2.00m
SPT of the layer	57
Relative Density	Very Dense
Angle of Shearing Resistance, ϕ	42.05^0
* **Layer-7 (from 17.00m to 20.50m depth)**	
Type of Strata	Silty Clay
Colour	Greenish
Thickness of Layer	3.50m
SPT of the layer	>100
Consistency	Hard
Un-drained Cohesion, Cu	666.66kPa
* **Layer-8 (from 20.50m to 21.20m depth)**	
Type of Strata	Slate Rock
Colour	-
Thickness of Layer	0.70m
SPT of the layer	>100
Consistency	Hard
Un-drained Cohesion, Cu	666.66kPa

Ground Water

Ground water table was encountered at a depth of 0.00m below the existing ground level during the first week of September 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 uniformly stratified from type but possess non-uniform shear strength characteristics, BH-01 being relatively weak from deformation considerations and hence shall be considered as design borehole to determine the bearing strata and its safe bearing capacity.

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

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

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

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

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underlying relatively weak soil layer encountered at 7.00m depths from present existing ground level (SPT @ 7.50m is 10, Ref. BH-01) are within their safe bearing capacity limits.

Further, the refusal soil (SPT>50) strata encountered below 19.00m 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.

4.2 Foundation System

4.2.1 Open Foundation System (BH-01)

Considering the uniformity in sub-soil stratifications at shallow depths, shear strength, presence of underlying relatively weak soil layer at 7.00m depths from existing ground level, highly plastic characteristics of fine-grained soil strata encountered at shallow depths, open foundation system of ***Isolated Column Footing*** *type located at a design depth of 1.70m below present existing ground level over 0.30m thick well compacted CNS (Cohesive Non-Swelling) soil can be adopted.*

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

Type of Open Foundation System	Total Depth of Excavations below existing ground level (m)	Backfill with well compacted CNS (m)	Depth of **Isolated Column Footing** below Existing Ground Level (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
Isolated Column Footing	**2.00**	**0.30**	**1.70**	**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 layer encountered at 7.00m depths from existing ground level i.e. 5.00m distant apart from the bottom level of footing.

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4.2.2 Deep Foundation System-20.00m Long Bored Cast-in-Situ Friction cum End Bearing Piles

In case, the safe bearing capacity of open foundation system presented above in Clause 4.2.1 is lower than the foundation stresses, deep foundation system consisting of 20.00m long bored cast-in-situ Friction cum End Bearing Piles can also be adopted.

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

For four different diameters, the safe load carrying capacities of 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	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	20.00	450	130	119
2				500	150	133
3				550	170	146
4				600	190	159

The computations of safe load carrying capacity for 450mm diameter and 20.00m long bored cast-in-situ Friction cum End Bearing Piles are annexed to this report.

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CHAPTER-5

CONCLUSIONS & RECOMMENDATIONS

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

Open Foundation System

2. The safe bearing capacity of open foundation system is computed considering rise in the ground water table up to or above the level of footing.
3. In case, ground water table is encountered within recommended depth of foundation system, provision shall be made to continuously bail the water out of the foundation pits to keep the surfaces of pit consolidated dry.
4. Safe Bearing Capacity of open foundation system is restricted considering the presence of underlying relatively weak soil strata encountered at 7.00m depths below existing ground level (SPT @ 7.50m is 10, Ref. BH-01) i.e. 5.00m distant apart from the bottom level of footing.

Open Foundation Depths

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

Usage of Excavated Earth

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

Deep Foundation System

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

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

General

17. **CNS can be well graded coarse-grained soil like quarry dust or clean river sand or sand: gravels mix (1:2) or fly-ash.**
18. As the chlorides and sulphates present in the collected water samples are within the permissible limits, no special steel or cement is recommended to be used for foundation construction purposes.

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

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1.1 Geometrical Data :

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

1.2 Soil Data :

Type of Bearing Strata :	Silty 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})	17.00	kN/m^3
Effective Overburden pressure at foundation level (q)	11.90	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = 5.14

N_q = N/A

N_γ = N/A

Shape Factors:

S_c = 1.00

S_q = N/A

S_γ = N/A

Depth Factors :

D_c = 1.00

D_q = N/A

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D_γ = N/A

Inclination Factor:

I_c = 1.00

I_q = N/A

N/A

1.4 Ultimate Bearing Capacity (Qu) :

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

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

Restricted considering the presence of underlying relatively weak soil layer encountered at 7.00m depths from existing ground level i.e. 5.00m distant apart from the bottom level of footing.

1.6 Settlements

Since, the bearing strata are stiff fine-grained type, the settlements under the allowable safe bearing pressure 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 as per I.S:1904.

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DESIGN OF PILE FOUNDATION (Ref. BH-01)

Refer, IS:2911(Part I/Sec 2)-1979, Reaffirmed 1997

1.0 Type of Installation of Pile **Bored Cast in Situ**

1.1 Geometrical Data

Assumed Diameter of pile(D):	**450.0**	mm
Assumed R.L of E.G.L:	0.000	m
Length of pile below E.G.L.(l) :	**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:	11	
Bulk Density of the strata,γ:	17	kN/m^3
Undrained Cohesion, Cu:	73.33	kPa
R.L of top of Strata:	0.00	m
R.L of bottom of Strata:	-2.00	m
Average Thickness of Strata,I_c:	2.00	m
Effective overburden pressure over the top of strata,σ_{top}:	0.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	14.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	7.00	kN/m^2
Adhesion Factor, α:	0.40	
Skin Resistance of the pile,q_s:	82.94	kN

(q_s:α*Cu*pi()*d*Ic)

1.2.1.2 **Layer-II**

Type of Strata:	Silty Clay	
Average SPT of the strata,N:	18	
Bulk Density of the strata,γ:	18	kN/m^3
Undrained Cohesion, Cu:	120.00	kPa
R.L of top of Strata:	-2.00	m
R.L of bottom of Strata:	-4.00	m
Average Thickness of Strata,I_c:	2.00	m
Effective overburden pressure over the top of strata,σ_{top}:	14.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	30.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	22.00	kN/m^2
Adhesion Factor, α:	0.40	
Skin Resistance of the pile,q_s:	135.72	kN

(q_s:α*Cu*pi()*d*Ic)

1.2.1.3 **Layer-III**

Type of Strata:	Silty Fine Sand	
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:	-4.00	m
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}:	30.00	kN/m^2

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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}:	40.50	kN/m^2
Coeff. Of Earth Pressure, k:	1.50	
Skin Resistance of the pile, q_s:	171.18	kN

(q_s:σ*k*tanϕ*pi()*d*Ic)

1.2.1.4 **Layer-IV**

Type of Strata:	Silty Clayey Fine Sand	
Average SPT of the strata,N:	10	
Bulk Density of the strata,γ:	15	kN/m^3
Angle of Shearing Resistance,ϕ:	30	Deg.
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}:	58.50	kN/m^2
Effective overburden pressure at the middle of the strata, σ_{middle}:	54.75	kN/m^2
Coeff. Of Earth Pressure, k:	1.00	
Skin Resistance of the pile, q_s:	67.03	kN

(q_s:σ*k*tanϕ*pi()*d*Ic)

1.2.1.5 **Layer-V**

Type of Strata:	Silty Fine Sand	
Average SPT of the strata,N:	23	
Bulk Density of the strata,γ:	17	kN/m^3
Angle of Shearing Resistance,ϕ:	33.9	Deg.
R.L of top of Strata:	-8.50	m
R.L of bottom of Strata:	-11.00	m
Average Thickness of Strata, I_c:	2.50	m
Effective overburden pressure over the top of strata, σ_{top}:	58.50	kN/m^2
Effective overburden pressure over the bottom of strata, σ_{bottom}:	76.00	kN/m^2
Effective overburden pressure at the middle of the strata, σ_{middle}:	67.25	kN/m^2
Coeff. Of Earth Pressure, k:	1.50	
Skin Resistance of the pile, q_s:	239.57	kN

(q_s:σ*k*tanϕ*pi()*d*Ic)

1.2.1.6 **Layer-VI**

Type of Strata:	Silty 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:	-11.00	m
R.L of bottom of Strata:	-13.00	m
Average Thickness of Strata, I_c:	2.00	m
Effective overburden pressure over the top of strata, σ_{top}:	76.00	kN/m^2
Effective overburden pressure over the bottom of strata, σ_{bottom}:	92.00	kN/m^2
Effective overburden pressure at the middle of the strata, σ_{middle}:	84.00	kN/m^2
Coeff. Of Earth Pressure, k:	1.50	
Skin Resistance of the pile, q_s:	258.84	kN

(q_s:σ*k*tanϕ*pi()*d*Ic)

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2.1.7 **Layer-VII**

Type of Strata:	Silty Fine Sand	
Average SPT of the strata,N:	36	
Bulk Density of the strata,γ:	19	kN/m^3
Angle of Shearing Resistance,ϕ:	37.65	Deg.
R.L of top of Strata:	-13.00	m
R.L of bottom of Strata:	-17.00	m
Average Thickness of Strata,I_c:	4.00	m
Effective overburden pressure over the top of strata,σ_{top}:	92.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	128.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	110.00	kN/m^2
Coeff. Of Earth Pressure, k:	2.00	
Skin Resistance of the pile,q_s:	959.79	kN

(q_s:σ*k*tanϕ*pi()*d*Ic)

2.1.8 **Layer-VIII**

Type of Strata:	Silty Clayey Fine Sand	
Average SPT of the strata,N:	51	
Bulk Density of the strata,γ:	20	kN/m^3
Angle of Shearing Resistance,ϕ:	41.15	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}:	128.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	148.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	138.00	kN/m^2
Coeff. Of Earth Pressure, k:	2.50	
Skin Resistance of the pile,q_s:	852.45	kN

(q_s:σ*k*tanϕ*pi()*d*Ic)

2.1.9 **Layer-IX**

Type of Strata:	Slate Rock	
Average SPT of the strata,N:	60	
Bulk Density of the strata,γ:	20	kN/m^3
Undrained Cohesion, Cu:	400.00	kPa
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}:	148.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	158.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	153.00	kN/m^2
Adhesion Factor, α:	0.40	
Skin Resistance of the pile,q_s:	226.19	kN

(q_s:α*Cu*pi()*d*Ic)

Ultimate Skin Resistance,q_s: 2993.72 kN

1.2.2 **Computation of End Bearing Resistance:**

Type of Bearing Strata	Slate Rock	
Cross-Sectional Area of pile,Ap:	0.159	m^2
R.L of bottom of pile:	-20.00	
Minimum SPT-value of the Bearing Strata	60	

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Un-drained Cohesion, Cu:	400.00	kPa
Bearing Capacity Factor(Nc)	9.00	
Ultimate End Bearing Resistance (Qp)	**572.6**	**kN**
(Qp=Ap*q*Nq)		

1.3.0

Ultimate Load Carrying Capacity ($Qu=Qs+Q_p$)	**3566.3**	**kN**
Safe Load Carrying Capacity (Qsafe =Qu/2.50)	**1426.5**	**kN**
However, limit Q_{safe} to the structural capacity of pile:	**1300.0**	**kN**

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