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CHAPTER-1

INTRODUCTION

1.0 Preamble

Mr. Goutham Chand, Chennai proposed to construct a **Commercial Building (Stilt+05)** at **Old No-60, New No-74, Cathedral Road, Mylapore, Chennai-600086. Comprised in R.S. No-1206/10, Block No-25 of Mylapore Village, Mylapore Taluk, Chennai District, Greater Chennai Corporation, Division-118, Zone-1X.**

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 One Standard Soil investigation bore hole of 150mm diameter up to a 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)

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 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 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 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 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 locations, 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.

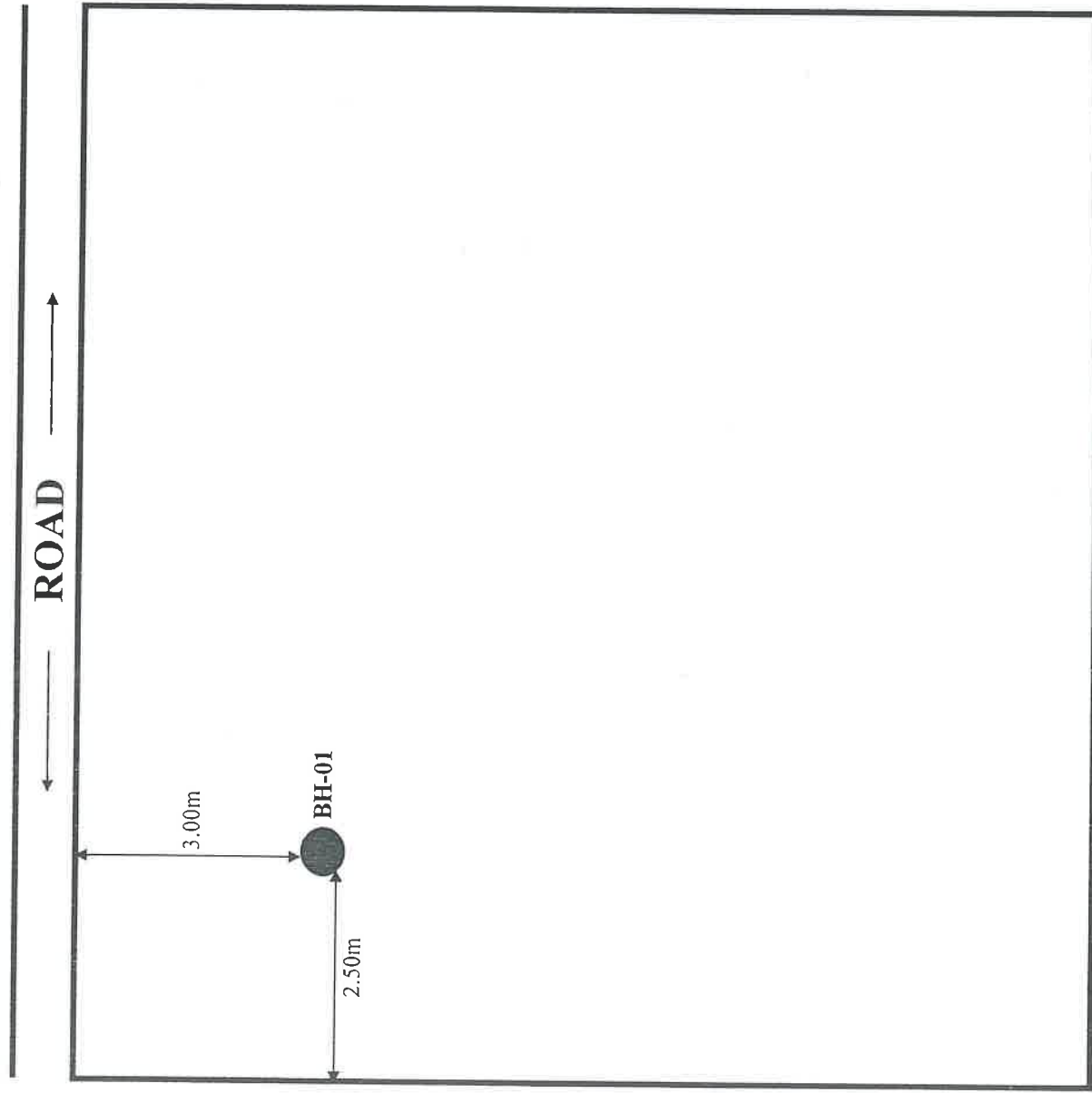


Fig. 2.0: Site Plan Representing the location of Field Investigation Point

Location: BH-01

Started On : 24/03/2019: Ended On : 24/03/2019 G.W.T: 4.50m below existing ground level

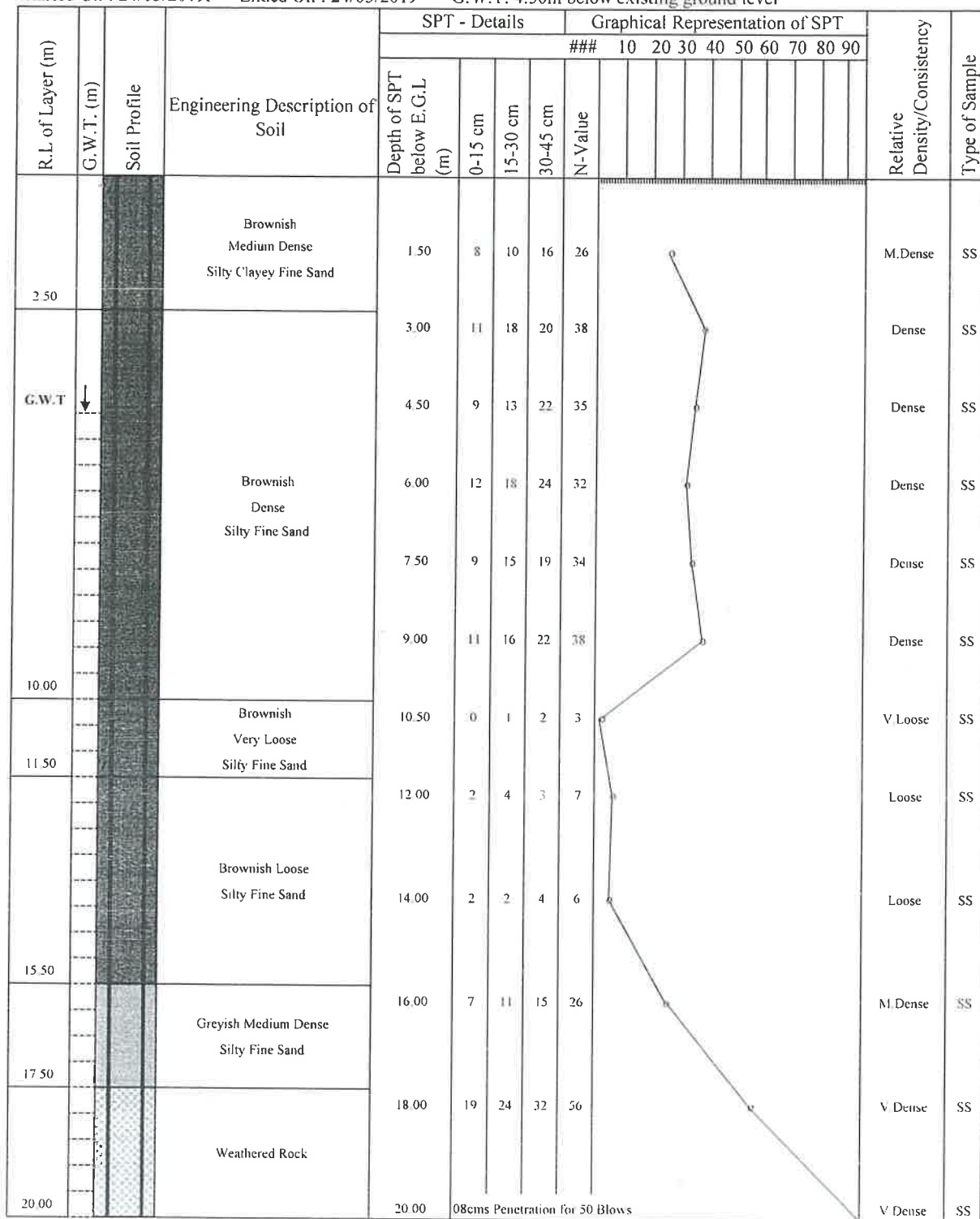


Fig. 2.1 Soil Profile at BH-01 Location

Table 2.1: Laboratory Test Result on the Soil Sample Collected from BH-01

Depth of Sample below E.G.L. (m)	SPT of Sample	Type of Sample	Engineering Description of Soil	NMC(%)	Natural Density (g/cc)	Clay					Relative Density/ Consistency	Sieve Analysis						IS-Classification
						LL (%)	PL (%)	PI	I _c	FS		Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	
0.00 to 2.50	26	SS	Silty Clayey Fine Sand	-	1.8	-	-	-	-	-	M.Dense	0	0	0	78	9	13	SM
2.50 to 10.00	35	SS	Silty Fine Sand	-	1.9	-	-	-	-	-	Dense	0	0	0	82	18	0	SM
10.00 to 11.50	3	SS	Silty Fine Sand	-	1.3	-	-	-	-	-	V.Loose	0	0	0	67	33	0	SM
11.50 to 15.50	6	SS	Silty Fine Sand	-	1.5	-	-	-	-	-	Loose	0	0	0	70	30	0	SM
15.50 to 17.50	26	SS	Silty Fine Sand	-	1.8	-	-	-	-	-	M.Dense	0	0	0	80	20	0	SM
17.50 to 20.00	56	SS	Weathered Rock	-	2.0	-	-	-	-	-	V.Dense	42	12	16	25	5	0	SDR

Table 2.2: Chemical Analysis Result conducted on Water Sample collected from BH-01				
Location	Depth of Sample below E.G.L. (m)	pH	Chlorides (ppm)	Sulphates (ppm)
BH-01	4.50	7.66	313.04	352.17

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 2.50m depth)**

Type of Strata	Silty Clayey Fine Sand
Colour	Brownish
Thickness of Layer	2.50m
SPT of the layer	26
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	34.80°
- * **Layer-2 (from 2.50m to 10.00m depth)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	7.50m
SPT of the layer	35
Relative Density	Dense
Angle of Shearing Resistance, ϕ	37.375°
- * **Layer-3 (from 10.00m to 11.50m depth)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	1.50m
SPT of the layer	03
Relative Density	Very Loose
Angle of Shearing Resistance, ϕ	28.60°

* Layer-4 (from 11.50m to 15.50m depth)	
Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	4.00m
SPT of the layer	06
Relative Density	Loose
Angle of Shearing Resistance, ϕ	29.20 ⁰
* Layer-5 (from 15.50m to 17.50m depth)	
Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	2.00m
SPT of the layer	26
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	34.80 ⁰
* Layer-6 (from 17.50m to 20.00m depth)	
Type of Strata	Weathered Rock
Colour	-
Thickness of Layer	2.50m
SPT of the layer	>100
Relative Density	Very Dense
Angle of Shearing Resistance, ϕ	42.50 ⁰

Ground Water

Ground water table was not encountered at the depth of 4.50m below the existing ground level during the fourth week of March 2019.

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 along the depth of borehole.

Considering BH-01 as design borehole, the coarse-grained strata encountered at shallow depths hold good to act as bearing strata from shear strength characteristics and deformation considerations only for nominal column loads in the range of 700kN to 800kN respectively.

If coarse-grained 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 foundation and effective surcharge over the bearing strata.

Care shall also be taken in designing the open foundation system (if recommended) so that the dispersed open foundation stresses on the underlying relatively weak soil layer encountered at 10.00m depths from existing ground level (SPT @ 10.50m is 03, Ref. BH-01) are within its safe bearing capacity limits.

Further, the refusal strata encountered in the form of Weathered Rock below 17.50m depths from existing ground level can also be considered as god end bearing strata to transfer the column loads.

Considering the above, suitable foundation systems are presented below.

4.2 Foundation System

4.2.1 Open Foundation System (Refer BH-01)

*Considering the shear strength characteristics of coarse-grained soil strata encountered at shallow depths and presence of underlying relatively weak soil layer encountered @ 10.00m depths from existing ground level, open foundation system of **Isolated Column Footing** type located at a design depth of 2.20m below present existing ground level (EGL) 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)	Observed Thickness of Fill at Site (m)	Depth of Isolated Column Footing below Natural Ground Level (m)	Safe Bearing Capacity (t/m ²)	Elastic Settlements (mm)
Isolated Column Footing	2.20	0.00	2.20	20	40

The computations for above are annexed to this report.

Notes

Safe Bearing Capacity of open foundation is restricted considering the presence of underlying relatively weak soil layer encountered at a depth of 10.00m below existing ground level i.e. 7.80m distant apart from the bottom level of footing.

4.2.2 Deep Foundation System-18.00m long Bored Cast-in-Situ Friction cum End Bearing Piles

In case, the impending foundation stresses are more than the safe bearing capacity of open foundation system as presented in Clause 4.2.1, Chapter-IV, deep foundation system consisting of 18.00m 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 18.00m 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 (t)	Safe Pull Out Capacity (t)
1	Bored Cast-in-Situ	18.00	400	80	57
2			450	90	65
3			500	100	72
4			550	110	79

The computations of safe load carrying capacity for 400mm diameter and 18.00m long bored cast-in-situ Friction cum End Bearing pile are annexed to this report.

CHAPTER-5

CONCLUSIONS & RECOMMENDATIONS

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

Open Foundation System

2. Safe bearing capacity of open foundation system is computed considering any rise in the ground water table up to or above the level of footing.
3. Safe Bearing Capacity of open foundation is restricted considering the presence of underlying relatively weak soil layer encountered at a depth of 10.00m below existing ground level i.e. 7.80m distant apart from the bottom level of footing.
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.

Open Foundation Depths

5. Depth of open excavations below present existing ground level shall be 2.20m.
6. Observed Thickness of Filled up soil @ Site is 0.00m.
7. Depth of Isolated Column Footing below natural ground level will be 2.20m.
8. *Care shall be taken so that the ultimate bearing strata are none other than recommended Medium Dense Silty Clayey Fine Sand type. The same shall be verified by our Geotechnical Engineer during open foundation excavations process is under progress. (IMPORTANT)*

Restrictions considering the presence of underlying relatively weak soil layer @ 10.00m depths from existing ground level

9. Least dimension of footing shall be in no case more than 3.00m.

OR

Clear distance between the two adjacent footings shall be in no case less than 1.00m.

Usages on Excavated Earth

10. **Excavated coarse-grained soil encountered at shallow depths can be used for back filling purposes.**

Other Recommendations

11. It is recommended to connect the grade beams for the entire structure to act as a single unit against any differential settlements in between the individual footings.
12. Special provisions to contain any lateral soil collapse from the walls of excavated open foundation pits are recommended. (IMPORTANT)

Deep Foundation System

13. Deep foundation system presented in Clause 4.2.2, Chapter-IV can be adopted for foundation design purposes.
14. Suitable pile load tests (as per I.S: 2911, part-IV) shall be performed to confirm the presented safe load carrying capacities (**provisional**).
15. **Care shall be taken so that the ultimate bearing strata are none other than “Weathered Rock” strata.**
16. Piles shall be grouped according to the column design load requirements.
17. Safe load carrying capacities of piles shall be limited to their structural capacities.

General

18. As the chlorides and sulphates present in water sample are within the permissible limits, no special steel or cement is recommended to be used for foundation construction purposes. **However, it is recommended to test the water samples at deeper levels from a dug-well or an open well to establish the parameters as per the requirements of the proposed structure.**

For GEO MINES ENGINEERS (P) LTD.

K. Sujia
Director

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 Col. Footing
R.L of the top of Borehole (m):	0.00 m
Depth of Foundation below existing ground level (D_f):	2.20 m
Observed Thickness of fill at site:	0.00 m
Effective Depth of Foundation below natural ground level (D_f):	2.20 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 :	26
(considered based upon the density of the strata)	
Type of Shear Failure:	General
Angle of Shearing Resistance - Limited to a Maximum of:	34.80 Deg.

1.3 Design Parameters:

Bulk Density of Soil above the foundation depth (γ_{bulk})	17.00 kN/m ³
Effective Overburden pressure at foundation level (q)	15.40 kPa
Water Table Correction Factor (w')	0.50

Bearing Capacity Factors:

$$N_c = N/A$$

$$N_q = 32.70$$

$$N_\gamma = 47.00$$

Shape Factors:

$$S_c = N/A$$

$$S_q = 1.70$$

$$S_\gamma = 0.60$$

Depth Factors :

$$D_c = N/A$$

$$D_q = 1.00$$

$$D_f = 1.00$$

Inclination Factor:

$$I_c = N/A$$

$$I_q = 1.00$$

$$I_\gamma = 1.00$$

1.4 Ultimate Bearing Capacity (Q_u) :

$$Q_u = C_u * N_c * S_c * D_c * I_{c+q} * (N_q - 1) * S_q * D_q * I_q + 0.5 * B * \gamma * N_\gamma * S_\gamma * D_\gamma * I_\gamma * w'$$

$$Q_u = 973.54 \text{ kPa}$$

1.5 Safe Bearing Capacity (Q_{safe}) :

$$\text{Factor of Safety (F.S.)} : 2.50$$

$$Q_{safe} : 389.42 \text{ kPa}$$

$$\text{Recommended Safe Bearing Capacity: } 200.00 \text{ kPa}$$

Safe Bearing Capacity of open foundation is restricted considering the presence of underlying relatively weak soil layer encountered at a depth of 10.00m below existing ground level i.e. 7.80m 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 200kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 200kPa and average SPT of 26 considering extent of pressure bulb below bottom level of footing are computed to be in the order of 40mm which is within the permissible limits of 50mm for isolated column footing as per I.S:1904.

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):	400.0 mm
Assumed R.L of E.G.L:	0.000 m
Length of pile below E.G.L.(l) :	18.000 m
R.L. of Bot. of Pile	-18.00 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 Clayey Fine Sand

Average SPT of the strata,N:	26
Bulk Density of the strata, γ :	17 kN/m ³
Angle of Shearing Resistance, ϕ :	34.8 Deg.
R.L of top of Strata:	0.00 m
R.L of bottom of Strata:	-2.50 m
Average Thickness of Strata, I_c :	2.50 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} :	17.50 kN/m ²
Effective overburden pressure at the middle of the strata, σ_{middle} :	8.75 kN/m ²
Coeff. Of Earth Pressure, k:	1.50
Skin Resistance of the pile, q_s :	28.66 kN
$(q_s: \sigma * k * \tan \phi * \pi() * d * I_c)$	

1.2.1.2

Layer-II

Type of Strata: Silty Sand

Average SPT of the strata,N:	35
Bulk Density of the strata, γ :	19 kN/m ³
Angle of Shearing Resistance, ϕ :	37.375 Deg.
R.L of top of Strata:	-2.50 m
R.L of bottom of Strata:	-10.00 m
Average Thickness of Strata, I_c :	7.50 m
Effective overburden pressure over the top of strata, σ_{top} :	17.50 kN/m ²
Effective overburden pressure over the bottom of strata, σ_{bottom} :	85.00 kN/m ²
Effective overburden pressure at the middle of the strata, σ_{middle} :	51.25 kN/m ²
Coeff. Of Earth Pressure, k:	2.00
Skin Resistance of the pile, q_s :	737.93 kN
$(q_s: \sigma * k * \tan \phi * \pi() * d * I_c)$	

1.2.1.3

Layer-III

Type of Strata: Silty Sand

Average SPT of the strata, N : 3

Bulk Density of the strata, γ : 13 kN/m³

Angle of Shearing Resistance, ϕ : 28.6 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} : 85.00 kN/m²

Effective overburden pressure over the bottom of strata, σ_{bottom} : 89.50 kN/m²

Effective overburden pressure at the middle of the strata, σ_{middle} : 87.25 kN/m²

Coeff. Of Earth Pressure, k : 1.00

Skin Resistance of the pile, q_s : 89.67 kN

$$(q_s: \sigma * k * \tan \phi * \pi() * d * I_c)$$

1.2.1.4

Layer-IV

Type of Strata: Silty Sand

Average SPT of the strata, N : 6

Bulk Density of the strata, γ : 15 kN/m³

Angle of Shearing Resistance, ϕ : 29.2 Deg.

R.L of top of Strata: -11.50 m

R.L of bottom of Strata: -15.50 m

Average Thickness of Strata, I_c : 4.00 m

Effective overburden pressure over the top of strata, σ_{top} : 89.50 kN/m²

Effective overburden pressure over the bottom of strata, σ_{bottom} : 109.50 kN/m²

Effective overburden pressure at the middle of the strata, σ_{middle} : 99.50 kN/m²

Coeff. Of Earth Pressure, k : 1.00

Skin Resistance of the pile, q_s : 279.52 kN

$$(q_s: \sigma * k * \tan \phi * \pi() * d * I_c)$$

1.2.1.5

Layer-V

Type of Strata: Silty Sand

Average SPT of the strata, N : 26

Bulk Density of the strata, γ : 18 kN/m³

Angle of Shearing Resistance, ϕ : 34.8 Deg.

R.L of top of Strata: -15.50 m

R.L of bottom of Strata: -17.50 m

Average Thickness of Strata, I_c : 2.00 m

Effective overburden pressure over the top of strata, σ_{top} : 109.50 kN/m²

Effective overburden pressure over the bottom of strata, σ_{bottom} : 125.50 kN/m²

Effective overburden pressure at the middle of the strata, σ_{middle} : 117.50 kN/m²

Coeff. Of Earth Pressure, k : 1.50

Skin Resistance of the pile, q_s : 307.87 kN

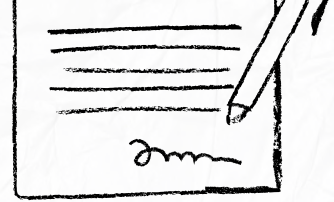
$$(q_s: \sigma * k * \tan \phi * \pi() * d * I_c)$$

Ultimate Skin Resistance, q_s : 1443.64 kN

1.2.2 Computation of End Bearing Resistance:

Type of Bearing Strata	Weathered Rock
Cross-Sectional Area of pile, A_p :	0.126 m ²
R.L of bottom of pile:	-18.00
Minimum SPT-value of the Bearing Strata	60
Angle of Shear Resistance, ϕ :	42.50 Deg.
Effective Overburden Pressure, q :	24.00 kPa
Bearing Capacity Factor(N_q)	220.00
Ultimate End Bearing Resistance (Q_p)	663.5 kN
$(Q_p = A_p * q * N_q)$	

1.3.0	Ultimate Load Carrying Capacity ($Q_u = Q_s + Q_p$)	2107.1 kN
	Safe Load Carrying Capacity ($Q_{safe} = Q_u / 2.50$)	842.9 kN
	However, limit Q_{safe} to the structural capacity of pile:	800.0 kN



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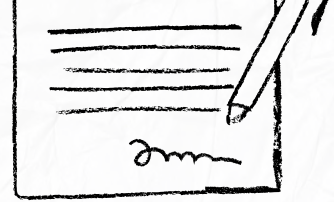
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