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| **CLIENT** | **MP DEVELOPERS, CHENNAI** |
| **PROJECT** | **PROPOSED CONSTRUCTION OF RESIDENTIAL BUILDING (STILT+03) 'MP PETALS' AT S.NO: 509/1C1G1, PATTA NO: 15707 AS PER PATTA S.NO: 509/1C1G1C & 509/1C1G1A OF KUNDRATHUR 'B' VILLAGE, KUNDRATHUR TALUK, KANCHEEPURAM DISTRICT, KUNDRATHUR MUNICIPALITY LIMIT** |
| **TITLE** | **GEOTECHNICAL INVESTIGATION REPORT** |

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| **REV.** | **DATE** | **REPORT NUMBER** | **PREP. BY** |

# DISCLAIMER

We've been asked to look into the ground and identify and quantify everything that mother nature has put there and 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

**MP Developers, Chennai** proposed to construct a **Residential Building (Stilt+03) 'MP Petals' at S.No. 509/1C1G1, Patta No: 15707 as per patta S.No: 509/1C1G1C & 509/1C1G1A of Kundrathur 'B' Village, Kundrathur Taluk, Kancheepuram District, Kundrathur Municipality Limit.**

For the purpose of designing the foundations, the responsibility of carrying out suitable soil investigations was entrusted to **M/s. Geo Mines ENGINEERS, 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 12.00m 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:

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 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 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.

### 2.4.2 Ground Water

For conducting suitable chemical tests, the ground water samples were 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 Figs. 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.

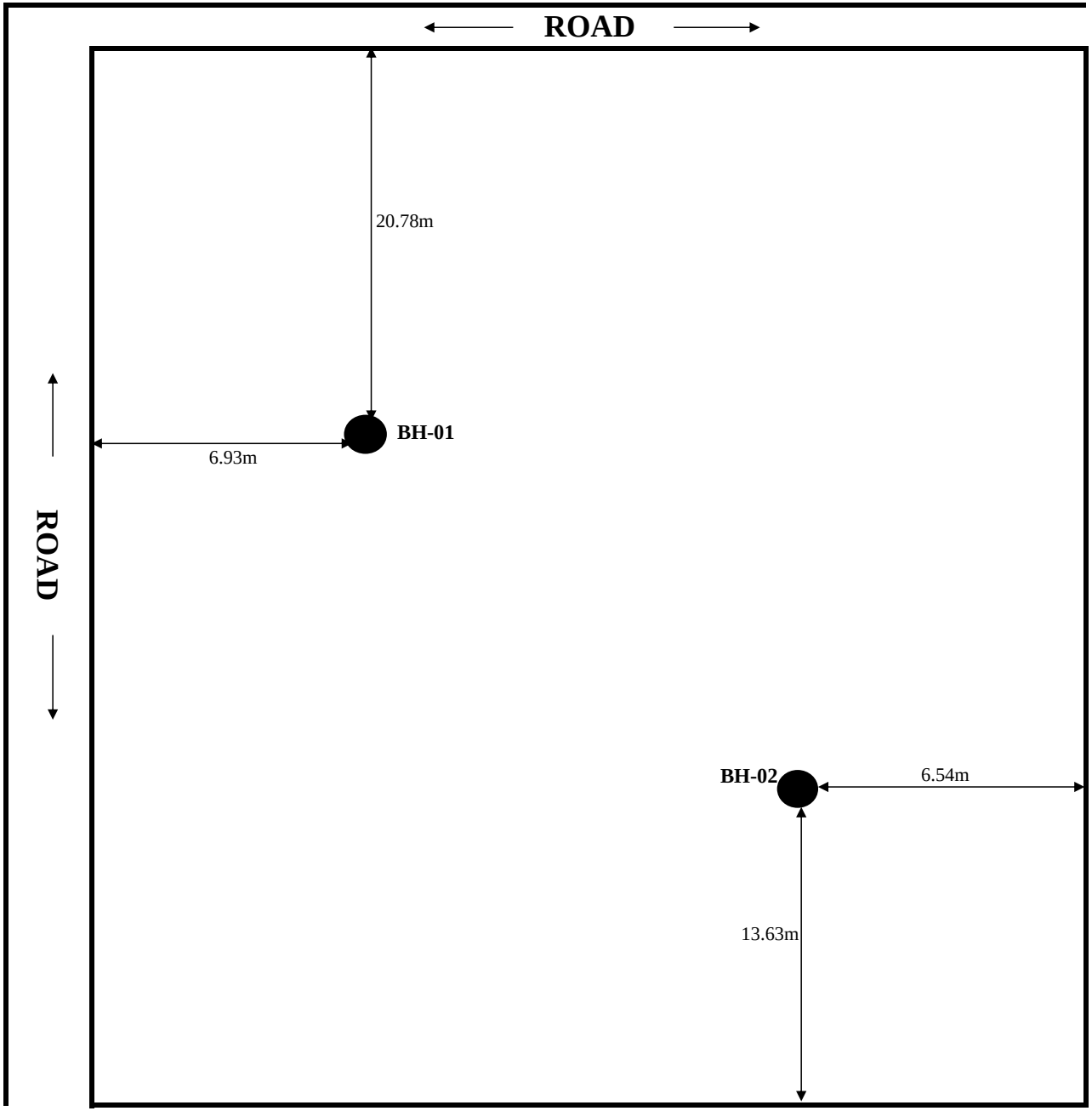



**Fig. 2.0: Site Plan Representing the locations of Field Investigation Points**

Project : Proposed Construction of Residential Building (Stilt+03) 'MP Petals' at S.No: 509/1C1G1, Patta No: 15707 as per patta S.No: 509/1C1G1C & 509/1C1G1A of Kundrathur 'B' Village, Kundrathur Taluk, Kancheepuram District, Kundrathur Municipality Limit

Location: BH-01

Started On : 16/06/2024; Ended On : 16/06/2024 G.W.T: 2.00m 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 | hical Representation o: 0 1 2 3 4 5 6 7 8 9 10 | Relative Density/Consistency | Type of Sample |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Brownish Medium Stiff | | | | | | | M.Stiff | DS |
| 1.00 | | | Silty Clay | | | | | | | | |
| | | | | 1.50 | 6 | 9 | 14 | 23 | o | V.Stiff | SS |
| G.W.T | ↓ | | Brownish Very Stiff | | | | | | | | |
| | | | Silty Sandy Clay | 2.50 | 10 | 12 | 13 | 25 | o | V.Stiff | SS |
| 3.00 | | | | | | | | | | | |
| | | | Blackish Stiff | 3.50 | 5 | 6 | 6 | 12 | | Stiff | SS |
| 4.00 | | | Silty Sandy Clay | | | | | | | | |
| | | | | 4.50 | 5 | 5 | 5 | 10 | | Stiff | SS |
| | | | Blackish Stiff | 6.00 | 4 | 5 | 6 | 11 | | Stiff | SS |
| | | | Silty Clay | | | | | | | | |
| | | | | 7.50 | 4 | 4 | 5 | 9 | | Stiff | SS |
| 8.00 | | | | | | | | | | | |
| | | | | 9.00 | 7 | 9 | 13 | 22 | | M.Dense | SS |
| | | | Greyish to Greenish Medium Dense | | | | | | | | |
| | | | Silty Clayey Fine Sand | 10.00 | 9 | 12 | 17 | 29 | | M.Dense | SS |
| 11.00 | | | | | | | | | | | |
| | | | Weathered Rock | 12.00 | SPT Hammer Rebounded | | | | | V.Dense | SS |
| 12.20 | | | | | | | | | | | |

Bore Hole Terminated at a depth of 12.20m below the existing groun

**Fig. 2.1 Soil Profile at BH-01 Location**

Project : Proposed Construction of Residential Building (Stilt+03) at S.No: 509/1C1G1, Patta No: 15707 as per patta S.No: 509/1C1G1C & 509/1C1G1A of Kundrathur 'B' Village, Kundrathur Taluk, Kancheepuram District, Kundrathur Municipality Limit

Location: BH-02

Started On : 16/06/2024; Ended On : 17/06/2024 G.W.T: 2.00m 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 | hical Representation o 0 1 2 3 4 5 6 7 8 9 10 | Relative Density/Consistency | Type of Sample |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Brownish Very Stiff Silty Clay | 1.50 | 7 | 8 | 8 | 16 | | V.Stiff | SS |
| **2.00** | ↓ | | | | | | | | | | |
| | | | Brownish Very Stiff Silty Sandy Clay | 2.50 | 8 | 10 | 11 | 21 | | V.Stiff | SS |
| 3.00 | | | | | | | | | | | |
| | | | Brownish Stiff Silty Sandy Clay | 3.50 | 4 | 5 | 6 | 11 | | Stiff | SS |
| 4.00 | | | | | | | | | | | |
| | | | Blackish Stiff Silty Clay | 4.50 | 4 | 6 | 6 | 12 | | Stiff | SS |
| | | | | 6.00 | 4 | 4 | 5 | 9 | | Stiff | SS |
| 6.50 | | | | | | | | | | | |
| | | | Blackish Medium Stiff Silty Clay | 7.50 | 4 | 4 | 4 | 8 | | M.Stiff | SS |
| 8.00 | | | | | | | | | | | |
| | | | Greyish to Greenish Medium Dense Silty Clayey Fine Sand | 9.00 | 9 | 9 | 10 | 19 | | M.Dense | SS |
| | | | | 10.00 | 7 | 10 | 13 | 23 | | M.Dense | SS |
| 10.50 | | | | | | | | | | | |
| | | | Weathered Rock | 12.00 | SPT Hammer Rebounded | | | | | V.Dense | SS |
| 12.20 | | | | | | | | | | | |

Bore Hole Terminated at a depth of 12.20m below the existing groun

**Fig. 2.2 Soil Profile at BH-02 Location**

## Table 2.1: Laboratory Test Results on the Soil Samples 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 1.00 | - | DS | Silty Clay | 33 | 1.51 | 56 | 24 | 32 | 0.72 | 13 | M.Stiff | 0 | 0 | 0 | 0 | 17 | 83 | CH |
| 1.00 to 3.00 | 24 | SS | Silty Sandy Clay | 23 | 1.81 | 47 | 25 | 22 | 1.09 | - | V.Stiff | 0 | 0 | 0 | 13 | 11 | 76 | CI |
| 3.00 to 4.00 | 12 | SS | Silty Sandy Clay | 29 | 1.59 | 50 | 25 | 25 | 0.84 | - | Stiff | 0 | 0 | 0 | 11 | 10 | 79 | CI |
| 4.00 to 8.00 | 10 | SS | Silty Clay | 31 | 1.56 | 53 | 25 | 28 | 0.79 | - | Stiff | 0 | 0 | 0 | 0 | 20 | 80 | CH |
| 8.00 to 11.00 | 25 | SS | Silty Clayey Fine Sand | - | 1.68 | - | - | - | - | - | M.Dense | 0 | 0 | 0 | 73 | 12 | 15 | SM |
| 11.00 to 12.20 | >100 | SS | Weathered Rock | - | 1.93 | - | - | - | - | - | V.Dense | 54 | 4 | 15 | 21 | 6 | 0 | SDR |

## Table 2.2: Laboratory Test Results on the Soil Samples 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 | 16 | SS | Silty Clay | 28 | 1.73 | 49 | 29 | 20 | 1.05 | 11 | V.Stiff | 0 | 0 | 0 | 0 | 21 | 79 | CI |
| 2.00 to 3.00 | 21 | SS | Silty Sandy Clay | 24 | 1.78 | 45 | 28 | 17 | 1.24 | - | V.Stiff | 0 | 0 | 0 | 12 | 9 | 79 | CI |
| 3.00 to 4.00 | 11 | SS | Silty Sandy Clay | 30 | 1.61 | 51 | 25 | 26 | 0.81 | - | Stiff | 0 | 0 | 0 | 10 | 7 | 83 | CH |
| 4.00 to 6.50 | 10 | SS | Silty Clay | 31 | 1.60 | 53 | 24 | 29 | 0.76 | - | Stiff | 0 | 0 | 0 | 0 | 19 | 81 | CH |
| 6.50 to 8.00 | 8 | SS | Silty Clay | 33 | 1.58 | 57 | 23 | 34 | 0.71 | - | M.Stiff | 0 | 0 | 0 | 0 | 17 | 83 | CH |
| 8.00 to 10.50 | 21 | SS | Silty Clayey Fine Sand | - | 1.63 | - | - | - | - | - | M.Dense | 0 | 0 | 0 | 77 | 9 | 14 | SM |
| 10.50 to 12.20 | >100 | SS | Weathered Rock | - | 1.92 | - | - | - | - | - | V.Dense | 55 | 11 | 9 | 21 | 4 | 0 | SDR |

**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 | 6.88 | 313.82 | 177.49 |
| BH-02 | 3.00 | 6.89 | 309.89 | 172.55 |

# 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 1.00m depth)**

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

* **Layer-2 (from 1.00m to 3.00m depth)**

| | |
|---|---|
| Type of Strata | Silty Sandy Clay |
| Colour | Brownish |
| Thickness of Layer | 2.00m |
| SPT of the layer | 24 |
| Consistency | Very Stiff |
| Un-drained Cohesion, Cu | 160.00kPa |

* **Layer-3 (from 3.00m to 4.00m depth)**

| | |
|---|---|
| Type of Strata | Silty Sandy Clay |
| Colour | Blackish |
| Thickness of Layer | 1.00m |
| SPT of the layer | 12 |
| Consistency | Stiff |
| Un-drained Cohesion, Cu | 80.00kPa |

* **Layer-4 (from 4.00m to 8.00m depth)**

| | |
|---|---|
| Type of Strata | Silty Clay |
| Colour | Blackish |
| Thickness of Layer | 4.00m |
| SPT of the layer | 10 |
| Consistency | Stiff |
| Un-drained Cohesion, Cu | 66.66kPa |

* **Layer-5 (from 8.00m to 11.00m depth)**

| | |
|---|---|
| Type of Strata | Silty Clayey Fine Sand |
| Colour | Greyish to Greenish |
| Thickness of Layer | 3.00m |
| SPT of the layer | 25 |
| Relative Density | Medium Dense |
| Angle of Shearing Resistance, $\phi$ | $34.50^0$ |

* **Layer-6 (from 11.00m to 12.20m depth)**

| | |
|---|---|
| Type of Strata | Weathered Rock |
| Colour | - |
| Thickness of Layer | 1.20m |
| SPT of the layer | >100 |
| Relative Density | Very Dense |
| Angle of Shearing Resistance, $\phi$ | $42.50^0$ |

**Ground Water**

Ground water table was encountered at a depth of 2.00m below the existing ground level during the third week of June 2024.

### 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 Clay |
| Colour | Brownish |
| Thickness of Layer | 2.00m |
| SPT of the layer | 16 |
| Consistency | Very Stiff |
| Un-drained Cohesion, Cu | 106.66kPa |

* **Layer-2 (from 2.00m to 3.00m depth)**

| | |
|---|---|
| Type of Strata | Silty Sandy Clay |
| Colour | Brownish |
| Thickness of Layer | 1.00m |
| SPT of the layer | 21 |
| Consistency | Very Stiff |
| Un-drained Cohesion, Cu | 140.00kPa |

* **Layer-3 (from 3.00m to 4.00m depth)**

| | |
|---|---|
| Type of Strata | Silty Sandy Clay |
| Colour | Brownish |
| Thickness of Layer | 1.00m |
| SPT of the layer | 11 |
| Consistency | Stiff |
| Un-drained Cohesion, Cu | 73.33kPa |

* **Layer-4 (from 4.00m to 6.50m depth)**

| | |
|---|---|
| Type of Strata | Silty Clay |
| Colour | Blackish |
| Thickness of Layer | 2.50m |
| SPT of the layer | 10 |
| Consistency | Stiff |
| Un-drained Cohesion, Cu | 66.66kPa |

* **Layer-5 (from 6.50m to 8.00m depth)**

| | |
|---|---|
| Type of Strata | Silty Clay |
| Colour | Blackish |
| Thickness of Layer | 1.50m |
| SPT of the layer | 08 |
| Consistency | Medium Stiff |
| Un-drained Cohesion, Cu | 53.33kPa |

* **Layer-6 (from 8.00m to 10.50m depth)**

| | |
|---|---|
| Type of Strata | Silty Clayey Fine Sand |
| Colour | Greyish to Greenish |
| Thickness of Layer | 2.50m |
| SPT of the layer | 21 |
| Relative Density | Medium Dense |
| Angle of Shearing Resistance, $\phi$ | $33.30^0$ |

* **Layer-7 (from 10.50m to 12.20m depth)**

| | |
|---|---|
| Type of Strata | Weathered Rock |
| Colour | - |
| Thickness of Layer | 1.70m |
| SPT of the layer | >100 |
| Relative Density | Very Dense |
| Angle of Shearing Resistance, $\phi$ | $42.50^0$ |

**Ground Water**

Ground water table was encountered at a depth of 2.00m below the existing ground level during the third week of June 2024.

# 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, BH-02 being relatively weak from deformation considerations than that of other borehole location and hence shall be considered as design borehole to determine the bearing strata and its safe bearing capacity.

Considering BH-02 as design borehole, it can further be envisaged that the medium 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 **presumptive** column loads in the range of 600kN to 700kN respectively.

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

Care shall be taken in locating the foundation system on such type of medium plastic fine-grained soil 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 so that the dispersed foundation stresses on the underlying relatively weak soil strata encountered at 3.00m depths below existing ground level (SPT @ 3.50m is 11, Ref. BH-02) are within its safe bearing capacity limits.

Further, the refusal soil strata (SPT>60) encountered below a maximum depth of 11.00m from present existing ground level (Ref. BH-01) 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-02)

*Considering the medium plasticity of fine-grained soil strata encountered at shallow depths, their shear strength characteristics and presence of underlying relatively weak soil strata encountered at 3.00m below existing ground level, open foundation system of* ***Isolated Column Footing*** *located at a design depth of 2.00m below present existing ground level over 0.30m thick 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 Present Existing Ground Level (m) | Safe Bearing Capacity ($MT/m^2$) | Elastic Settlements (mm) |
|---|---|---|---|---|---|
| **Isolated Column Footing** | **2.30** | **0.30** | **2.00** | **14** | **42** |

The computations for above are annexed to this report.

**Notes**

Safe Bearing Capacity of open foundation system is restricted considering the presence of underlying relatively weak soil strata encountered at 3.00m depths

below existing ground level (SPT @ 3.50m is 11, Ref. BH-02) i.e. 1.00m distant apart from the bottom level of footing.

### 4.2.2 Deep Foundation System-12.00m Long Bored Cast-in-Situ Friction cum End Bearing Piles

In case, the safe bearing capacity of open foundation system presented above in Clause 4.2.1 is lower than the impending foundation stresses, deep foundation system consisting of 12.00m 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 12.00m 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 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 | 12.00 | 400 | 50 | 22 |
| 2 | | | | 450 | 60 | 25 |
| 3 | | | | 500 | 70 | 28 |
| 4 | | | | 550 | 80 | 32 |

The computations of safe load carrying capacity for 400mm diameter and 12.00m long bored cast-in-situ Friction cum End Bearing Piles are annexed to this report.

# CHAPTER5

# 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. 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 3.00m depths below existing ground level (SPT @ 3.50m is 11, Ref. BH-02) i.e. 1.00m distant apart from the bottom level of footing.

**Open Foundation Depths & Foundation Dimensional Restrictions**

5. Depth of open excavations below present existing ground level shall be 2.30m.
6. Recommended Thickness of CNS Back-Fill @ Site is 0.30m.
7. Depth of Isolated Column Footing below existing ground level will be 2.00m.
8. *Considering the impact of dispersed but overlapping open foundation stresses on the underlying relatively weak soil layer that is 1.00m distant apart from the bottom level of proposed isolated column footing for the presented safe bearing capacity of 14MT/sq.m., the least dimension of footing shall be in no case more than 2.50m.*

**Usage of Excavated Earth**

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

**IMPORTANT RECOMMENDATIONS**

11. Open foundation system presented above will be conducive only if proper drainage arrangements are made to channel the run-off into the drains and hence containing any water seepage into the ground. Also, there shall not be any underground plumbing line leakages which may lead to softening of high/medium plastic fine-grained soil recommended as bearing strata.

**DEEP FOUNDATION SYSTEM**

12. 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. (**Note**)
13. *Care shall be taken so that the ultimate end bearing soil strata are none other than recommended "Weathered Rock" type. The same shall be reaffirmed by our Geotechnical Engineer during foundation laying works are under progress.*
14. 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.
15. Piles shall be grouped according to the column design load requirements.
16. Allowable load carrying capacities of piles shall be limited to their structural capacities.

**General**

17. **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.**
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 **open** foundation construction purposes. **However, it is recommended to extract the water samples at different intervals up to deeper levels 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**. (IMPORTANT)

# DESIGN OF OPEN FOUNDATION SYSTEM (Ref. BH-02)

## 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 excavations below existing ground level ($D_f$): | 2.30 | m |
| Recommended Thickness of CNS Back-Fill below Footing: | 0.30 | m |
| Effective Depth of Foundation below existing ground level ($D_f$): | 2.00 | 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 Sandy Clay | |
| Design SPT-value of the Bearing Strata : (considered based upon the density of the strata) | 16 | |
| Type of Shear Failure: | General | |
| Undrained Cohesion, Cu: | 106.67 | kPa |

### 1.3 Design Parameters:

| | | |
|---|---|---|
| Bulk Density of Soil above the foundation detph ($\gamma_{bulk}$) | 17.30 | $kN/m^3$ |
| Effective Overburden pressure at foundation level (q) | 14.60 | kPa |
| Water Table Correction Factor (w') | 0.50 | |

Bearing Capacity Factors:

$N_c$ = 5.14

$N_q$ = N/A

$N_\gamma$ = N/A

Shape Factors:

$S_c$ = 1.30

$S_q$ = N/A

$S_\gamma$ = N/A

Depth Factors :

$D_c$ = 1.00

$D_q$ = N/A

$D_\gamma$ = N/A

Inclination Factor:

$I_c$ = 1.00

$I_q$ = N/A

$I_\gamma$ = 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*γ*Nγ*Sγ*Dγ*Ig*w'

$Q_u$ = 712.75 kPa

### 1.5 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 285.10 kPa

Recommended Safe Bearing Capacity: 140.00 kPa

**Restricted considering the presence of underlying relatively weak soil layer encountered at 3.00m depths from existing ground level i.e. 1.00m distant apart from the bottom level of footing.**

### 1.6 Settlements

Since, the bearing strata are very stiff fine-grained type, the settlements under the allowable safe bearing pressure 140kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 140kPa and average SPT of 16 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.

# DESIGN OF PILE FOUNDATION (Ref.BH-02)

**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) : | **12.000** | m |
| R.L. of Bot. of Pile | -12.00 | 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: | 16 | |
| Bulk Density of the strata,$\gamma$: | 18 | $kN/m^3$ |
| Undrained Shear Strength,$C_u$: | 106.67 | 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,$\sigma_{top}$: | 0.00 | $kN/m^2$ |
| Effective overburden pressure over the bottom of strata,$\sigma_{bottom}$: | 16.00 | $kN/m^2$ |
| Effective overburden pressure at the middle of the strata,$\sigma_{middle}$: | 8.00 | $kN/m^2$ |
| Adhesion,$\alpha$: | 0.40 | |
| Skin Resistance of the pile,$q_s$: | 107.23 | kN |
| ($q_s$:$\alpha$*Cu*pi()*d*Ic) | | |

**1.2.1.2** **Layer-II**

| | | |
|---|---|---|
| Type of Strata: | Silty Sandy Clay | |
| Average SPT of the strata,N: | 21 | |
| Bulk Density of the strata,$\gamma$: | 19 | $kN/m^3$ |
| Undrained Shear Strength,$C_u$: | 140.00 | kPa |
| R.L of top of Strata: | -2.00 | m |
| R.L of bottom of Strata: | -3.00 | m |
| Average Thickness of Strata,$I_c$: | 1.00 | m |
| Effective overburden pressure over the top of strata,$\sigma_{top}$: | 16.00 | $kN/m^2$ |
| Effective overburden pressure over the bottom of strata,$\sigma_{bottom}$: | 25.00 | $kN/m^2$ |
| Effective overburden pressure at the middle of the strata,$\sigma_{middle}$: | 20.50 | $kN/m^2$ |
| Adhesion,$\alpha$: | 0.40 | |
| Skin Resistance of the pile,$q_s$: | 70.37 | kN |
| ($q_s$:$\alpha$*Cu*pi()*d*Ic) | | |

**1.2.1.3** **Layer-III**

| | |
|---|---|
| Type of Strata: | Silty Sandy Clay |

| | | |
|---|---|---|
| Average SPT of the strata,N: | 11 | |
| Bulk Density of the strata,$\gamma$: | 17 | $kN/m^3$ |
| Undrained Shear Strength,$C_u$: | 73.33 | kPa |
| R.L of top of Strata: | -3.00 | m |
| R.L of bottom of Strata: | -4.00 | m |
| Average Thickness of Strata,$I_c$: | 1.00 | m |
| Effective overburden pressure over the top of strata,$\sigma_{top}$: | 25.00 | $kN/m^2$ |
| Effective overburden pressure over the bottom of strata,$\sigma_{bottom}$: | 32.00 | $kN/m^2$ |
| Effective overburden pressure at the middle of the strata,$\sigma_{middle}$: | 28.50 | $kN/m^2$ |
| Adhesion,$\alpha$: | 0.40 | |
| Skin Resistance of the pile,$q_s$: | 36.86 | kN |
| ($q_s$:$\alpha$*Cu*pi()*d*Ic) | | |

**1.2.1.4 Layer-IV**

| | | |
|---|---|---|
| Type of Strata: | Silty Clay | |
| Average SPT of the strata,N: | 10 | |
| Bulk Density of the strata,$\gamma$: | 17 | $kN/m^3$ |
| Undrained Shear Strength,$C_u$: | 66.67 | kPa |
| R.L of top of Strata: | -4.00 | m |
| R.L of bottom of Strata: | -6.50 | m |
| Average Thickness of Strata,$I_c$: | 2.50 | m |
| Effective overburden pressure over the top of strata,$\sigma_{top}$: | 32.00 | $kN/m^2$ |
| Effective overburden pressure over the bottom of strata,$\sigma_{bottom}$: | 49.50 | $kN/m^2$ |
| Effective overburden pressure at the middle of the strata,$\sigma_{middle}$: | 40.75 | $kN/m^2$ |
| Adhesion,$\alpha$: | 0.40 | |
| Skin Resistance of the pile,$q_s$: | 83.78 | kN |
| ($q_s$:$\alpha$*Cu*pi()*d*Ic) | | |

**1.2.1.5 Layer-V**

| | | |
|---|---|---|
| Type of Strata: | Silty Clay | |
| Average SPT of the strata,N: | 8 | |
| Bulk Density of the strata,$\gamma$: | 16 | $kN/m^3$ |
| Undrained Shear Strength,$C_u$: | 53.33 | kPa |
| R.L of top of Strata: | -6.50 | m |
| R.L of bottom of Strata: | -8.00 | m |
| Average Thickness of Strata,$I_c$: | 1.50 | m |
| Effective overburden pressure over the top of strata,$\sigma_{top}$: | 49.50 | $kN/m^2$ |
| Effective overburden pressure over the bottom of strata,$\sigma_{bottom}$: | 58.50 | $kN/m^2$ |
| Effective overburden pressure at the middle of the strata,$\sigma_{middle}$: | 54.00 | $kN/m^2$ |
| Adhesion,$\alpha$: | 0.60 | |
| Skin Resistance of the pile,$q_s$: | 60.32 | kN |
| ($q_s$:$\alpha$*Cu*pi()*d*Ic) | | |

**1.2.1.6 Layer-VI**

| | | |
|---|---|---|
| Type of Strata: | Silty Clayey Fine Sand | |
| Average SPT of the strata,N: | 21 | |
| Bulk Density of the strata,$\gamma$: | 17 | $kN/m^3$ |
| Angle of Shearing Resistance,$\phi$: | 33.30 | Deg. |
| R.L of top of Strata: | -8.00 | m |
| R.L of bottom of Strata: | -10.50 | m |
| Average Thickness of Strata,$I_c$: | 2.50 | m |
| Effective overburden pressure over the top of strata,$\sigma_{top}$: | 58.50 | $kN/m^2$ |
| Effective overburden pressure over the bottom of strata,$\sigma_{bottom}$: | 76.00 | $kN/m^2$ |
| Effective overburden pressure at the middle of the strata,$\sigma_{middle}$: | 67.25 | $kN/m^2$ |
| Coeff. Of Earth Pressure, k: | 1.50 | |
| Skin Resistance of the pile,$q_s$: | 208.17 | kN |
| ($q_s$:$\sigma$*k*tan$\phi$*pi()*d*Ic) | | |
| **Ultimate Skin Resistance,$q_s$:** | **566.73** | **kN** |

### 1.2.2 Computation of End Bearing Resistance:

| | | |
|---|---|---|
| Type of Bearing Strata | Weathered Rock | |
| Cross-Sectional Area of pile,Ap: | 0.126 | $m^2$ |
| R.L of bottom of pile: | -12.00 | |
| Minimum SPT-value of the Bearing Strata | 60 | |
| Angle of Shear Resistance, $\phi$: | 42.50 | Deg. |
| Effective Overburden Pressure, q: | 36.00 | kPa |
| Bearing Capacity Factor(Nq) | 220.00 | |

| | | |
|---|---|---|
| **1.3.0 Ultimate Load Carrying Capacity (Qu=Qs+$Q_p$)** | **1562.0** | **kN** |
| **Safe Load Carrying Capacity (Qsafe =Qu/2.5)** | **624.8** | **kN** |
| **However, limit $Q_{safe}$ to the structural capacity of pile:** | **500.0** | **kN** |



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