# GEOTECHNICAL REPORT

## PROPOSED 66 KV GRID SUBSTATION PROJECT AT BAKKARWALA, NEW DELHI

## SUBMITTED TO:

## M/S. BSES RAJDHANI POWER LIMITED

1st Floor, C-Block, BSES Bhawan, Nehru Place, Delhi – 110 019

Project No. 22115 Dated. October, 2022 Revision-0


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October 13th, 2022 Project No. 22115

**M/s. BSES Rajdhani Power Limited**
1st Floor, C-Block, BSES Bhawan,
Nehru Place, Delhi – 110 019

**Sub: Final Report on Soil Investigation work for Proposed 66 KV Grid Substation Project at Bakkarwala, New Delhi**

We have carried out the soil investigation work accordance with your Work Order No. SER/DSC/23567661 dated September 1st, 2022. We thank you for your business and hope that you are satisfied with our services rendered.

This Final Report presents our findings based on the soil investigation conducted by us at the project site. This report presents the field and laboratory test data along with our engineering recommendations, which shall help you in deciding the optimum foundation arrangement for use on site.

We have prepared this report based on our findings on site as well as our experience gained in our previous projects completed over the past 15 years. We appreciate the opportunity to perform this investigation for you and have pleasure in submitting this report. Please contact us when we can be of further service to you.

Yours faithfully,
RAO GEOTECHNICAL CONSULTANTS LLP

(G.R.RAO)

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## ILLUSTRATIONS



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# 1.0 INTRODUCTION

## 1.1 Project Description

This soil investigation work, whose results are being presented herewith, has been carried out for Proposed 66 KV Grid Substation Project at Bakkarwala, New Delhi.

M/s. Rao Geotechnical Consultants LLP has been retained by M/s. BSES Rajdhani Power Limited for carrying out the Geotechnical Investigation at the project site.

## 1.2 Aim of Soil Investigation

Soil investigation has been conducted at the site in order to evaluate the parameters required for design of foundations. These parameters are:

a) Type of foundation on which the proposed super structure will be supported.

b) Depth of foundation, and

c) Allowable bearing pressure at the founding level.

To evaluate these parameters, following engineering properties of the Sub-Soil have been studied:

Sub-soil penetration resistance characteristics which have been determined insitu. Properties like particle size distribution, atterberg's limits, bulk density, moisture content, and shear strength parameters; which have been determined in the laboratory by conducting testing of both disturbed as well as undisturbed samples.

## 1.3 Scope of Work

The stipulated scope of work comprised of the following:

1. Mobilization of equipment and personnel to the site and back.
2. Sinking six (6) boreholes to specified depth or refusal (N>100) whichever encountered earlier), observing ground water table levels, conducting required field and laboratory tests and their analysis.
3. Conducting six (6) electrical resistivity test (ERT's) to provide data for the grounding systems;
4. Preparation and submission of technical report in triplicate.

# 2.0 FIELD INVESTIGATIONS

## 2.1 Soil Borings

The boreholes were progressed using mechanized shell and auger drilling rig to the specified depth. The diameter of the borehole was 150 mm. Where caving of the borehole occurred, casing was used to keep the borehole stable. The work was in general accordance with IS: 1892-1979.

Standard Penetration Tests (SPT) were conducted in the boreholes at 1.5 m depth interval up to 15 m depth. The tests were conducted by connecting a split spoon sampler to 'A' rods and driving it by 45 cm using a 63.5 kg hammer falling freely from a height of 75 cm. The tests were conducted in accordance with IS: 2131-1981.

The number of blows for each 15 cm of penetration of the split spoon sampler was recorded. The blows required to penetrate the initial 15 cm of the split spoon for seating the sampler is ignored due to the possible presence of loose materials or cuttings from the drilling operation. The cumulative number of blows required to penetrate the balance 30 cm of the 45 cm sampling interval is termed the SPT value or the 'N' value.

Where the split spoon sampler did not penetrate the initial 15 cm seating in a total of 100 blows, it is indicated "Ref" for an indicated amount of penetration. The 'N' values are presented on the soil profile for each borehole.

Disturbed samples were collected from the split spoon after conducting SPT. The samples were preserved in transparent polythene bags. Undisturbed soil samples were collected by attaching 75 mm diameter thin walled 'Shelby' tubes and driving the sampler by light-hammering using a 63.5 kg hammer in accordance with IS: 2132-1986. The tubes were sealed with wax at both ends. All samples were transported to our laboratory for further examination and testing.

## 2.2 Groundwater

Groundwater level was measured in the boreholes after drilling and sampling was completed. The measured water levels are recorded on the individual soil profiles.

## 2.3 Electrical Resistivity Tests

Electrical resistivity of the substratum at the site was determined at specified locations. The electrical resistivity test is used for shallow subsurface exploration by means of electrical measures made at the ground surface. Resistivity measurements are made by driving four electrodes about 10 to 15 cm in to the ground at pre-selected electrode spacing. We used the Wenner electrode configuration for this study.

The four electrodes were spaced at equal distance along a line. The test procedure is in accordance with IS: 3043:1987 RA 2006. Measurements are made by causing a current, 'I', to pass through the earth and distribute within a relatively large hemispherical earth mass. The portion of the current that flows along the surface produces a voltage drop, 'V'. The resistance 'R', ratio of voltage drop 'V' to current 'I' is directly measured by Digital Earth Resistance Tester. The resistivity is determined from the following equation:

$$\rho = 2 \pi a R$$

where:

$\rho$ = apparent resistivity, ohm-m
a = spacing between the electrodes, meter
R = resistance, ohms

Results are presented as semi-logarithmic plot of apparent resistivity versus electrode spacing, as well as in the form of polar curves, as specified by IS: 3043:1987 RA 2006.

## 3.0 LABORATORY TESTS

Laboratory tests have been conducted on various selected soil & groundwater samples in the laboratory:

| Laboratory Test | | IS Code Referred |
|---|---|---|
| Bulk Density | | By calculations |
| Natural Moisture Content | | IS : 2720 (Part-2)-1973, RA-2010 |
| Specific Gravity | | IS : 2720 (Part-3)-1980, RA-2007 |
| Grain Size Analysis | | IS : 2720 (Part-4)-1985, RA-2010 |
| Liquid Limit and Plastic Limit | | IS : 2720 (Part-5)-1985, RA-2010 |
| Consolidated Drained Direct Shear Test | | IS : 2720 (Part-13)-1986, RA-2010 |
| Unconsolidated Undrained Triaxial Shear Test | | IS : 2720 (Part-11)-1993, RA-2007 |
| Chemical Analysis of soil | pH value | IS : 2720 (Part 26)-1987, RA-2007 |
| | sulphates | IS : 2720 (Part-27)-1977, RA-2010 |
| | chlorides | IS : 3025 (Part-32)-1988, RA-2009 |
| Chemical Analysis of water | pH value | IS : 3025 (Part-11)-1983, RA-2006 |
| | sulphates | IS : 3025 (Part-24)-1986, RA-2009 |
| | chlorides | IS : 3025 (Part-32)-1988, RA-2009 |

## 4.0 GENERAL SITE CONDITIONS

### 4.1 Site Stratigraphy

The surficial soils at the site consist of sandy silt / clayey silt to about 6.0-10.5 m depth below EGL. However at BH-2, 4 & 6 locations, a heterogenous fill of organic materials with sand & brick bats was met at the site to about 3.0 m depth below EGL. Below fill, silty sand / fine sand was to about 9-13.5 m depth and underlain by sandy silt to the final explored depth of 15.45 m below EGL.

The field SPT N-values range from 2 to 9 to about 6 m depth, indicating very loose to loose strata and range from 10 to 27 to about 12 m depth below EGL, indicating medium dense strata. Further, SPT N-values range from 15 to 35 to the final explored depth of 15.45 m depth below EGL.

All test results are presented on the individual soil profiles on Sheet No. 2 to 13. A summary of the borehole profiles is illustrated on Sheet No. 14 & 15. Plots of field and corrected SPT values versus depth are presented on Sheet No. 16 to 19.

### 4.2 Groundwater

Based on our measurements in the completed boreholes, groundwater was met at 0.5~1.0 m depth below EGL during the period of our field investigations (September-October, 2022).

Fluctuations may occur in the measured ground levels due to seasonal variations in rainfall, surface evaporation rates.

## 5.0 FIELD TEST RESULTS

### 5.1 Electrical Resistivity Test Result

Six (6) electrical resistivity tests were conducted at the project site as per IS: 3043-1987. The tests were conducted using the Wenner configuration. The apparent resistivity values obtained have been analyzed to generate the polar curve. The polar curve is used to compute the mean resistivity.

Mean resistivity values at the electrical resistivity tests (ERT) location are summarized in the table below:

| Test Designation | Mean Resistivity, ohm-m | Corrosion potential* | Presentation of Results |
|---|---|---|---|
| ERT-1 | 8.3 | Severely Corrosive | Sheet No. 20 |
| ERT-2 | 14.9 | | Sheet No. 21 |
| ERT-3 | 11.9 | | Sheet No. 22 |
| ERT-4 | 11.2 | | Sheet No. 23 |
| ERT-5 | 10.1 | | Sheet No. 24 |
| ERT-6 | 9.1 | | Sheet No. 25 |

* As per Clause 8.6.1 of Amendment No. 2 to IS: 3043-1987, dated January 2010.

The above values may be used for design of the electrical grounding system. The data may also be used to assess the corrosion potential for buried utility lines as per the guideline given in IS 3043-1987.

## 6.0 FOUNDATION ANALYSIS

### 6.1 General

For designing the foundation system, the following parameters are required:

a) Suitable type of foundation on which the proposed super-structure can be supported.

b) Depth of these foundations, and

c) Allowable bearing pressure at the founding level corresponding to various footing sizes.

A suitable foundation for any structure should have an adequate factor of safety against exceeding the bearing capacity of the supporting soils. Also the vertical movements due to compression of the soils should be within tolerable limits for the structure. We consider that foundation designed in accordance with the recommendations given herein will satisfy these criteria.

### 6.2 Foundation Type and Depth

Type of foundation to be adopted for a particular structure depends upon the loading intensity at the foundation level and the configuration of loading points.

As discussed in Section 4.1, very loose to loose stratum was encountered at the site to about 6.0 m depth below EGL. **Open / raft foundations bearing on the very loose to loose strata is not recommended.**

In view of the above, care must be taken during foundation planning and construction to ensure that the foundation performance on site is as per design. We suggest the RCC bored cast-in-situ piles may be used to support the structural loads.

This may help to transfer the superstructure loads to deeper and more competent strata. Recommendations are given herein for 300 mm, 400 mm & 500 mm diameter piles. (Refer to Section 7.0 for the suggested safe pile capacities)

6.3 Method of Analysis (Bored Cast-in-situ Pile Foundations)

Bored cast-in-situ RCC piles are a suitable foundation system to support the structural loads. The ultimate pile compressive capacity has been computed using the following equation as given in IS 2911: Part-1, Section 2 (2010).

$$Q_{ult} = \left[\sum_{i=1}^{n} f_s A_s L_i\right] + q_u A_p$$

$$= \left[\sum_{i=1}^{n} (\alpha c_i + p_i k \tan \delta_i) A_s L_i\right] + \left[c_p N_c + q_p N_q + \tfrac{1}{2}\gamma D N_\gamma\right] A_p$$

where:

| | | |
|---|---|---|
| *Qult* | = | *ultimate pile capacity* |
| $f_s$ | = | *unit skin friction* |
| $\alpha$ | = | *adhesion factor* |
| $c_i$ | = | *cohesion intercept in ith layer* |
| $p_i$ | = | *overburden pressure at centre of ith layer* |
| $k$ | = | *coefficient of lateral earth pressure* |
| $\delta_i$ | = | *angle of friction between soil and pile (taken as equal to φi) for the ith layer* |
| $A_s$ | = | *surface area of pile per m length* |
| $L_i$ | = | *length of pile section in ith layer* |
| $c_p$ | = | *cohesion intercept in bearing strata* |
| $q_u$ | = | *unit end bearing* |
| $q_p$ | = | *effective overburden pressure at pile toe* |
| $N_c$, $N_q$, $N_\gamma$ | = | *bearing capacity factors, which are a function of φ in the bearing strata* |
| $A_p$ | = | *pile cross sectional area* |

The overburden pressure is considered to become constant below a depth of 15 pile diameters.

The lateral load carrying capacity of bored piles has been computed based on IS: 2911 (Part-I / Sec-2), 2010. The pile head is assumed to be fixed. The lateral load carrying capacity of pile has been computed for a permissible horizontal deflection of 5 mm using the following equation for fixed head pile:

$$Q = \frac{12\ y\,E\,I}{(L_1 + L_f)^3}$$

where:

*Q* = *lateral load*
*E* = *the Young's modulus of pile material*
*I* = *moment of inertia of pile cross section.*
$L_f$ = *depth of fixity*
$L_1$ = *length of pile section below cut-off-level that may not contribute significantly to lateral resistance (in loose/weak soils)*
*y* = *horizontal deflection*

## 7.0 RECOMMENDATIONS

Pile capacity analysis for RCC bored cast-in-situ piles for the proposed structure has been done considering the following boundary conditions:

- Pile cut-off-level : 1.0 m below EGL
- Groundwater Level : 0.0 m or ground level for worst condition
- Overburden Pressure : Assumed to become constant below 15 times pile diameters
- Pile Head : Fixed Head Condition (for lateral capacity analysis)

The following table presents our recommended safe pile capacities for 300 mm, 400 mm & 500 mm diameter bored piles at the sites of the proposed structure:

| Pile Diameter, mm | Pile Length below COL, m | Recommended Pile Capacities, MT | | |
|---|---|---|---|---|
| | | Compression | Pullout | Lateral* |
| 300 | 9.0 | 8 | 5 | 0.6 |
| | 11.0 | 9 | 6 | |
| | 13.0 | 10 | 7 | |
| 400 | 11.0 | 15 | 10 | 0.9 |
| | 13.0 | 17 | 11 | |
| | 15.0 | 19 | 13 | |
| 500 | 13.0 | 27 | 16 | 1.3 |
| | 15.0 | 30 | 19 | |
| | 17.0 | 33 | 22 | |

* Grade of concrete M=30.

The following points are highlighted with reference to the above-recommended capacities:

1. The above values are based on IS: 2911(Part-1 Section 2) -2010 and include safety factor of 2.5 for compressive loads, and a safety factor of 3.0 for uplift loads.

2. Safe pile capacities for piles of intermediate lengths may be interpolated linearly between the values given above.

3. It should be ensured that the bottom of the pile bore is cleaned properly before casting the pile. This is important because the soil particles tend to settle down at the bottom of the pile bore, which may cause reduction in pile capacities.

4. The capacities given above may be taken as a guideline for initial design. Final pile capacities should be confirmed by conducting initial pile load tests as per IS: 2911-Part-IV. Also, routine load tests should be conducted on sufficient working piles to ensure that the piles are safe for the design loads.

5. Low strain pile integrity tests (PIT) should be done on all working piles as a quality check.

6. Since borehole depths were insufficient, the soil characteristics below the maximum explored depth have been assumed. The recommended pile capacities may therefore be considered as preliminary, to be used only for the purpose of initial planning only. The actual capacities may change depending upon the strata encountered.

7. A detailed geotechnical investigation should be carried out with sufficient boreholes to at least 25 m depth at each structure location to assess the final pile capacities for design.

## 8.0 CHEMICAL ATTACK

Results of chemical test on selected soil samples are presented on Sheet No. 47. The results indicate that the soils contain 0.09-0.13 percent sulphates and 0.01-0.05 percent chlorides. The pH value of soil is 7.1-7.6. The groundwater contains 308-392 mg/litre of sulphate and 78-210 mg/litre of chloride content. The pH value of groundwater is to about 6.9-7.7.

IS: 456-2000 recommends that precautions should be taken against chemical degradation of concrete if

- sulphates content of the soils exceeds 0.2 percent, or
- groundwater contains more than 300 mg /litre of sulphates ($SO_3$).

Comparing the test results with these specified limits, the sulphate content of the soil is less than the specified limit. Groundwater was met at 0.5~1.0 m at the site during our field investigation and is likely to influence foundation concrete. Therefore, strata at the site may be treated in **Class-2** category as described on IS: 456-2000.

In our opinion, the soils at site are not aggressive to foundation concrete. We recommend the following as a good practice to limit the potential for chemical attack:

(1) Concrete for pile caps should contain minimum cement content of 330 kg/m$^3$ of cement. Piles should contain at least 400 kg/m$^3$ of cement.

(2) Water cement ratio in foundation concrete should generally not exceed 0.50.

(3) A clear concrete cover over the reinforcement steel of at least 50 mm should be provided for all foundations.

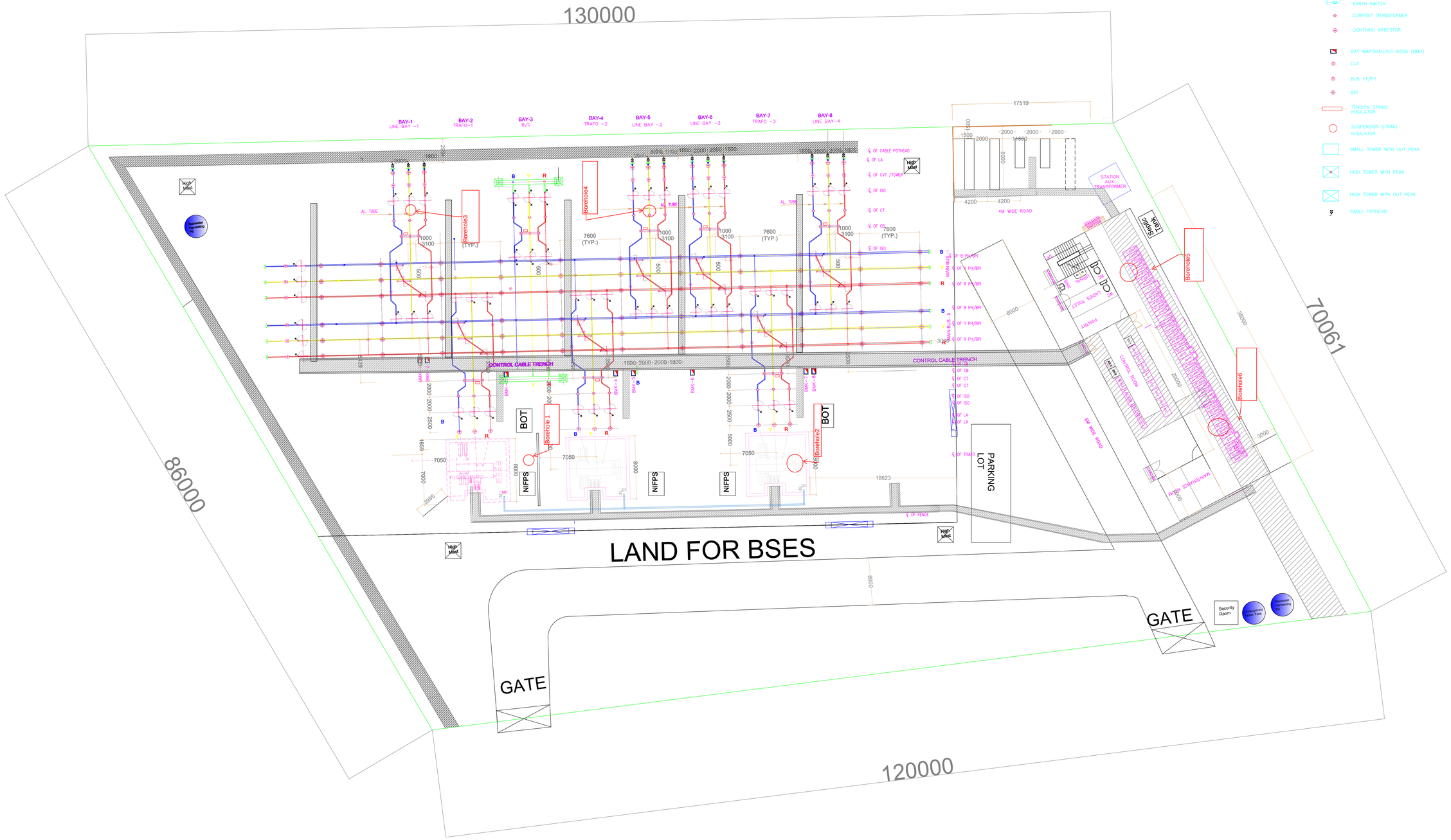
(4) Foundation concrete should be densified adequately using a vibrator so as to form a dense impervious mass.

## 9.0 VARIABILITY IN SUBSURFACE CONDITIONS

Subsurface conditions encountered during construction may vary somewhat from the conditions encountered during the site investigation. In case significant variations are encountered during construction, we request to be notified so that our engineers may review the recommendations in this report in light of these variations.

ANNEXURE - L

# THE LAYOUT IS TENTATIVE AND FOR TENDER PURPOSE ONLY




LEGEND:-

- R-PH AL PIPE BUSBAR
- Y-PH AL PIPE BUSBAR
- B-PH AL PIPE BUSBAR
- END CAP PIPE BUSBAR
- 66KV CIRCUIT BREAKER
- 66KV ISOLATOR WITHOUT EARTH SWITCH
- 66KV ISOLATOR WITH ONE EARTH SWITCH
- 66KV ISOLATOR WITH TWO EARTH SWITCH
- CURRENT TRANSFORMER
- LIGHTNING ARRESTOR
- BAY MARSHALLING KIOSK (BMK)
- CVT
- BUS VT/PT
- BPI
- TENSION STRING INSULATOR
- SUSPENSION STRING INSULATOR
- SMALL TOWER WITH OUT PEAK
- HIGH TOWER WITH PEAK
- HIGH TOWER WITH OUT PEAK
- CABLE POTHEAD

## Borehole Log (BH-1)

Location : Bakkarwala, New Delhi

Ground Water Level : 1 m

Termination Depth : 15.45 m

Drilling : Shell & Auger

Start Date : 05-Oct-22

Finish Date : 05-Oct-22

| Scale | Depth, m | Sample Designation | Groundwater depth, m | SPT Field Value, N | SPT Corrected Value, N" | Symbol | SOIL DESCRIPTION | Depth of Strata, (m) | Standard Penetration Test Results | Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Liquid (%) | Plastic (%) | Plasticity Index (%) | Specific Gravity | Density: Bulk Density (gm/cm$^3$) | Density: Dry Density (gm/cm$^3$) | Moisture Content (%) | Shear Tests: Cohesion Intercept, 'c' (kg/cm$^2$) | Shear Tests: Angle of Internal Friction, 'Φ' (degrees) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.5 | DS1 | | | | | | | | | | | | | | | | | | | | |
| | | | 1.0 | | | | | | | | | | | | | | | | | | | |
| | 1.5 | SPT1 | | 2 | 3 | | | | | 0 | 43 | 54 | 3 | | | | | | | | | |
| | 2.0 | DS2 | | | | | | | | | | | | | | | | | | | | |
| | 3.0 | SPT2 | | 7 | 10 | | Sandy silt, non- plasticity (ML) | | | | | | | | | | | | | | | |
| | 4.5 | SPT3 | | 11 | 14 | | | | | | | | | 21.6 | N.P. | | | | | | | |
| | 5.3 | UDS1 | | | | | | 6.0 | | | | | | | | | 2.62 | 1.68 | 1.52 | 10.4 | 0.0 | 27.0 |
| | 6.0 | SPT4 | | 13 | 15 | | | | | 1 | 36 | 57 | 6 | | | | | | | | | |
| | 7.5 | SPT5 | | 18 | 18 | | Light brown sandy silt with low plasticity (ML-CL) | | | | | | | | | | | | | | | |
| | 8.3 | UDS2 | | | | | | | | | | | | | | | | 1.73 | 1.55 | 11.8 | | |
| | 9.0 | SPT6 | | 47 | 34 | | | | | | | | | 23.4 | 18.6 | 4.8 | | | | | | |
| | | | | | | | | 10.5 | | | | | | | | | | | | | | |

Standard Penetration Test Results: Field Value, N; Corrected Value, N"; 0 20 40 60 80 100

## Borehole Log (BH-1)

Location : Bakkarwala, New Delhi

Ground Water Level : 1 m

Termination Depth : 15.45 m

Drilling : Shell & Auger

Start Date : 05-Oct-22

Finish Date : 05-Oct-22

| Scale | Depth, m | Sample Designation | Groundwater depth, m | SPT: Field Value, N | SPT: Corrected Value, N" | Symbol | SOIL DESCRIPTION | Depth of Strata, (m) | Standard Penetration Test Results | Grain Size Analysis: Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Atterberg Limits: Liquid (%) | Plastic (%) | Plasticity Index (%) | Specific Gravity | Density: Bulk Density (gm/cm$^3$) | Density: Dry Density (gm/cm$^3$) | Moisture Content (%) | Shear Tests: Cohesion Intercept, 'c' (kg/cm$^2$) | Shear Tests: Angle of Internal Friction, 'Φ' (degrees) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10.5 | SPT7 | | 45 | 32 | | Light brown silty sand (SM) | | | 4 | 57 | 37 | 2 | | | | | | | | | |
| | 11.3 | UDS3 | | | | | | | | | | | | | | | 2.70 | 1.88 | 1.63 | 15.6 | 0.0 | 30.0 |
| | 12.0 | SPT8 | | 20 | 18 | | | 13.5 | | | | | | | | | | | | | | |
| | 13.5 | SPT9 | | 25 | 20 | | Light brown sandy silt with low plasticity (ML-CL) | | | | | | | 22.6 | 18.1 | 4.5 | | | | | | |
| | 14.3 | UDS4 | | | | | | 15.0 | | | | | | | | | 2.67 | 1.92 | 1.65 | 16.2 | | |
| | 15.0 | SPT10 | | 41 | 27 | | Clayey silt with medium plasticity (CL) | 15.5 | | 4 | 34 | 51 | 11 | | | | | | | | | |

Standard Penetration Test Results: Field Value, N; Corrected Value, N"; 0 20 40 60 80 100

## Borehole Log (BH-2)

Location : Bakkarwala, New Delhi

Ground Water Level : 1 m

Termination Depth : 15.45 m

Drilling : Shell & Auger

Start Date : 04-Oct-22

Finish Date : 04-Oct-22

| Scale | Depth, m | Sample Designation | Groundwater depth, m | SPT Field Value, N | SPT Corrected Value, N" | Symbol | SOIL DESCRIPTION | Depth of Strata, (m) | Standard Penetration Test Results | Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Atterberg Limits Liquid (%) | Plastic (%) | Plasticity Index (%) | Specific Gravity | Density Bulk Density (gm/cm$^3$) | Density Dry Density (gm/cm$^3$) | Moisture Content (%) | Shear Tests Cohesion Intercept, 'c' (kg/cm$^2$) | Shear Tests Angle of Internal Friction, 'Φ' (degrees) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.5 | DS1 | 1.0 | | | | Fill - soil with organic material & brick bats | | | | | | | | | | | | | | | |
| | 1.5 | SPT1 | | 5 | 8 | | | 3.0 | | | | | | | | | | | | | | |
| | 2.0 | DS2 | | | | | | | | | | | | | | | | | | | | |
| | 3.0 | SPT2 | | 12 | 16 | | Light brown sandy silt with low plasticity (ML-CL) | | | 2 | 39 | 54 | 5 | | | | | | | | | |
| | 4.5 | SPT3 | | 16 | 18 | | | 6.0 | | | | | | 23.4 | 18.3 | 5.1 | | | | | | |
| | 5.3 | UDS1 | | | | | | | | | | | | | | | 2.65 | 1.70 | 1.52 | 11.8 | 0.0 | 28.0 |
| | 6.0 | SPT4 | | 12 | 14 | | Fine sand (SP-SM) | 7.5 | | 0 | 89 | 8 | 3 | | | | | | | | | |
| | 7.5 | SPT5 | | 22 | 20 | | Clayey silt with medium plasticity (CL) | | | 3 | 36 | 49 | 12 | | | | | | | | | |
| | 8.3 | UDS2 | | | | | | | | | | | | | | | 2.64 | 1.75 | 1.55 | 12.8 | 0.8 | 6.9 |
| | 9.0 | SPT6 | | 37 | 29 | | | 10.5 | | | | | | 32.8 | 23.4 | 9.4 | | | | | | |

Standard Penetration Test Results: Field Value, N; Corrected Value, N"; 0 20 40 60 80 100

## Borehole Log (BH-2)

Location : Bakkarwala, New Delhi

Ground Water Level : 1 m

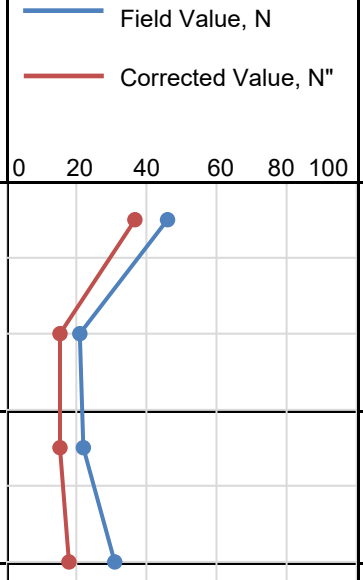
Termination Depth : 15.45 m

Drilling : Shell & Auger

Start Date : 04-Oct-22

Finish Date : 04-Oct-22

| Scale | Depth, m | Sample Designation | Groundwater depth, m | SPT: Field Value, N | SPT: Corrected Value, N" | Symbol | SOIL DESCRIPTION | Depth of Strata, (m) | Standard Penetration Test Results | Grain Size Analysis: Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Atterberg Limits: Liquid (%) | Plastic (%) | Plasticity Index (%) | Specific Gravity | Density: Bulk Density (gm/cm$^3$) | Density: Dry Density (gm/cm$^3$) | Moisture Content (%) | Shear Tests: Cohesion Intercept, 'c' (kg/cm$^2$) | Shear Tests: Angle of Internal Friction, 'Φ' (degrees) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10.5 | SPT7 | | 46 | 37 | | Fine sand (SP-SM) | | | 3 | 84 | 10 | 3 | | | | | | | | | |
| | 11.0 | DS3 | | | | | | | | | | | | | | | | | | | | |
| | 12.0 | SPT8 | | 21 | 15 | | | **13.5** | | | | | | | | | | | | | | |
| | 13.5 | SPT9 | | 22 | 15 | | Sandy silt, non- plasticity (ML) | | | 2 | 47 | 49 | 2 | | | | | | | | | |
| | 14.3 | UDS3 | | | | | | | | | | | | | | | 2.67 | 1.82 | 1.58 | 15.1 | 0.0 | 31.0 |
| | 15.0 | SPT10 | | 31 | 18 | | | **15.5** | | | | | | 21.7 | N.P. | | | | | | | |



## Borehole Log (BH-3)

Location : Bakkarwala, New Delhi

Ground Water Level : 1 m

Termination Depth : 15.45 m

Drilling : Shell & Auger

Start Date : 29-Sep-22

Finish Date : 29-Sep-22

| Scale | Depth, m | Sample Designation | Groundwater depth, m | SPT Field Value, N | SPT Corrected Value, N" | Symbol | SOIL DESCRIPTION | Depth of Strata, (m) | Standard Penetration Test Results | Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Liquid (%) | Plastic (%) | Plasticity Index (%) | Specific Gravity | Bulk Density (gm/cm$^3$) | Dry Density (gm/cm$^3$) | Moisture Content (%) | Cohesion Intercept, 'c' (kg/cm$^2$) | Angle of Internal Friction, 'Φ' (degrees) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.5 | DS1 | 1.0 | | | | Sandy silt, non- plasticity (ML) | 4.5 | Field Value, N; Corrected Value, N" (0 20 40 60 80 100) | | | | | | | | | | | | | |
| | 1.5 | SPT1 | | 2 | 3 | | | | | 0 | 43 | 52 | 5 | | | | | | | | | |
| | 2.0 | DS2 | | | | | | | | | | | | | | | | | | | | |
| | 3.0 | SPT2 | | 6 | 8 | | | | | | | | | 22.1 | N.P. | | | | | | | |
| | 4.5 | SPT3 | | 8 | 10 | | Clayey silt with medium plasticity (CL) | 6.0 | | 0 | 32 | 57 | 11 | | | | 2.64 | 1.70 | 1.53 | 10.9 | 0.5 | - |
| | 5.3 | UDS1 | | | | | | | | | | | | | | | | | | | | |
| | 6.0 | SPT4 | | 14 | 16 | | Fine sand (SP-SM) | 7.5 | | 1 | 88 | 9 | 2 | | | | | | | | | |
| | 7.5 | SPT5 | | 16 | 17 | | Light brown silty sand (SM) | 9.0 | | 1 | 56 | 41 | 2 | | | | 2.67 | 1.77 | 1.57 | 12.7 | 0.0 | 29.0 |
| | 8.3 | UDS2 | | | | | | | | | | | | | | | | | | | | |
| | 9.0 | SPT6 | | 13 | 15 | | Clayey silt with medium plasticity (CL) | 10.5 | | | | | | 31.9 | 20.8 | 11.1 | | | | | | |

## Borehole Log (BH-3)

Location : Bakkarwala, New Delhi

Ground Water Level : 1 m

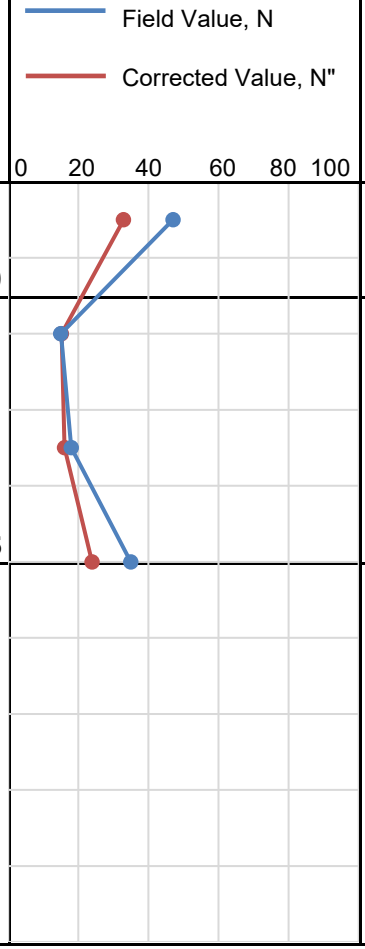
Termination Depth : 15.45 m

Drilling : Shell & Auger

Start Date : 29-Sep-22

Finish Date : 29-Sep-22

| Scale | Depth, m | Sample Designation | Groundwater depth, m | SPT: Field Value, N | SPT: Corrected Value, N" | Symbol | SOIL DESCRIPTION | Depth of Strata, (m) | Standard Penetration Test Results | Grain Size Analysis: Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Atterberg Limits: Liquid (%) | Plastic (%) | Plasticity Index (%) | Specific Gravity | Density: Bulk Density (gm/cm$^3$) | Density: Dry Density (gm/cm$^3$) | Moisture Content (%) | Shear Tests: Cohesion Intercept, 'c' (kg/cm$^2$) | Shear Tests: Angle of Internal Friction, 'Φ' (degrees) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10.5 | SPT7 | | 47 | 33 | | Fine sand (SP-SM) | | | 4 | 91 | 4 | 1 | | | | | | | | | |
| | 11.0 | DS3 | | | | | | 12.0 | | | | | | | | | | | | | | |
| | 12.0 | SPT8 | | 15 | 15 | | Clayey silt with medium plasticity (CL) | | | 3 | 35 | 50 | 12 | | | | | | | | | |
| | 13.5 | SPT9 | | 18 | 16 | | | | | | | | | | | | | | | | | |
| | 14.3 | UDS3 | | | | | | | | | | | | | | | 2.66 | 1.84 | 1.61 | 14.2 | 0.9 | 7.4 |
| | 15.0 | SPT10 | | 35 | 24 | | | 15.5 | | | | | | 32.6 | 21.0 | 11.6 | | | | | | |



## Borehole Log (BH-4)

Location : Bakkarwala, New Delhi

Ground Water Level : 1 m

Termination Depth : 15.45 m

Drilling : Shell & Auger

Start Date : 30-Sep-22

Finish Date : 30-Sep-22

| Scale | Depth, m | Sample Designation | Groundwater depth, m | SPT Field Value, N | SPT Corrected Value, N" | Symbol | SOIL DESCRIPTION | Depth of Strata, (m) | Standard Penetration Test Results | Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Liquid (%) | Plastic (%) | Plasticity Index (%) | Specific Gravity | Density: Bulk Density (gm/cm$^3$) | Density: Dry Density (gm/cm$^3$) | Moisture Content (%) | Shear Tests: Cohesion Intercept, 'c' (kg/cm$^2$) | Shear Tests: Angle of Internal Friction, 'Φ' (degrees) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.5 | DS1 | 1.0 | | | | Fill - soil with organic material & brick bats | | | | | | | | | | | | | | | |
| | 1.5 | SPT1 | | 2 | 3 | | | | | | | | | | | | | | | | | |
| | 2.0 | DS2 | | | | | | 3.0 | | | | | | | | | | | | | | |
| | 3.0 | SPT2 | | 5 | 7 | | Clayey silt with medium plasticity (CL) | | | 2 | 37 | 51 | 10 | | | | | | | | | |
| | 4.5 | SPT3 | | 7 | 9 | | | | | | | | | 31.7 | 22.1 | 9.6 | | | | | | |
| | 5.0 | DS3 | | | | | | | | | | | | | | | 2.64 | | | | | |
| | 6.0 | SPT4 | | 17 | 18 | | | | | | | | | | | | | | | | | |
| | 7.5 | SPT5 | | 18 | 18 | | | | | | | | | | | | | | | | | |
| | 8.3 | UDS1 | | | | | | | | | | | | | | | 2.65 | 1.80 | 1.58 | 14.2 | 0.7 | 6.1 |
| | 9.0 | SPT6 | | 19 | 18 | | | | | | | | | 32.1 | 23.0 | 9.1 | | | | | | |
| | | | | | | | | 10.5 | | | | | | | | | | | | | | |

Standard Penetration Test Results: Field Value, N; Corrected Value, N"; 0 20 40 60 80 100

## Borehole Log (BH-4)

Location : Bakkarwala, New Delhi

Ground Water Level : 1 m

Termination Depth : 15.45 m

Drilling : Shell & Auger

Start Date : 30-Sep-22

Finish Date : 30-Sep-22

| Scale | Depth, m | Sample Designation | Groundwater depth, m | SPT: Field Value, N | SPT: Corrected Value, N" | Symbol | SOIL DESCRIPTION | Depth of Strata, (m) | Standard Penetration Test Results | Grain Size Analysis: Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Atterberg Limits: Liquid (%) | Plastic (%) | Plasticity Index (%) | Specific Gravity | Density: Bulk Density (gm/cm$^3$) | Density: Dry Density (gm/cm$^3$) | Moisture Content (%) | Shear Tests: Cohesion Intercept, 'c' (kg/cm$^2$) | Shear Tests: Angle of Internal Friction, 'Φ' (degrees) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10.5 | SPT7 | | 37 | 27 | | Fine sand (SP-SM) | | | 3 | 90 | 5 | 2 | | | | | | | | | |
| | 11.0 | DS4 | | | | | | | | | | | | | | | | | | | | |
| | 12.0 | SPT8 | | 16 | 16 | | | 13.5 | | | | | | | | | | | | | | |
| | 13.5 | SPT9 | | 19 | 17 | | Sandy silt, non- plasticity (ML) | | | | | | | 21.1 | N.P. | | 2.66 | 1.84 | 1.59 | 15.7 | 0.0 | 30.0 |
| | 14.3 | UDS2 | | | | | | 15.0 | | | | | | | | | | | | | | |
| | 15.0 | SPT10 | | 33 | 23 | | Clayey silt with medium plasticity (CL) | 15.5 | | 3 | 34 | 51 | 12 | | | | | | | | | |

Standard Penetration Test Results: Field Value, N; Corrected Value, N"; 0 20 40 60 80 100

## Borehole Log (BH-5)

Location : Bakkarwala, New Delhi

Ground Water Level : 0.5 m

Termination Depth : 15.45 m

Drilling : Shell & Auger

Start Date : 01-Oct-22

Finish Date : 01-Oct-22

| Scale | Depth, m | Sample Designation | Groundwater depth, m | SPT: Field Value, N | SPT: Corrected Value, N" | Symbol | SOIL DESCRIPTION | Depth of Strata, (m) | Standard Penetration Test Results | Grain Size Analysis: Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Atterberg Limits: Liquid (%) | Plastic (%) | Plasticity Index (%) | Specific Gravity | Density: Bulk Density (gm/cm$^3$) | Density: Dry Density (gm/cm$^3$) | Moisture Content (%) | Shear Tests: Cohesion Intercept, 'c' (kg/cm$^2$) | Shear Tests: Angle of Internal Friction, 'Φ' (degrees) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.5 | DS1 | **0.5** | | | | Sandy silt, non- plasticity (ML) | | | | | | | | | | | | | | | |
| | 1.5 | SPT1 | | 4 | 6 | | | **3.0** | | | | | | 20.9 | N.P. | | | | | | | |
| | 2.0 | DS2 | | | | | | | | | | | | | | | | | | | | |
| | 3.0 | SPT2 | | 9 | 12 | | Clayey silt with medium plasticity (CL) | | | 1 | 33 | 54 | 12 | | | | | | | | | |
| | 4.5 | SPT3 | | 12 | 15 | | | | | | | | | 31.7 | 22.3 | 9.4 | | | | | | |
| | 5.3 | UDS1 | | | | | | **6.0** | | | | | | | | | 2.64 | 1.72 | 1.53 | 12.1 | 0.6 | 7.2 |
| | 6.0 | SPT4 | | 20 | 19 | | Fine sand (SP-SM) | | | 2 | 92 | 4 | 2 | | | | | | | | | |
| | 7.5 | SPT5 | | 19 | 18 | | | **7.5** | | | | | | | | | | | | | | |
| | 8.3 | UDS2 | | | | | Light brown silty sand (SM) | | | 2 | 52 | 44 | 2 | | | | 2.67 | 1.81 | 1.58 | 14.6 | 0.0 | 29.0 |
| | 9.0 | SPT6 | | 18 | 18 | | | **10.5** | | | | | | | | | | | | | | |

Standard Penetration Test Results: Field Value, N; Corrected Value, N"; 0 20 40 60 80 100

## Borehole Log (BH-5)

Location : Bakkarwala, New Delhi

Ground Water Level : 0.5 m

Termination Depth : 15.45 m

Drilling : Shell & Auger

Start Date : 01-Oct-22

Finish Date : 01-Oct-22

| Scale | Depth, m | Sample Designation | Groundwater depth, m | SPT: Field Value, N | SPT: Corrected Value, N" | Symbol | SOIL DESCRIPTION | Depth of Strata, (m) | Standard Penetration Test Results | Grain Size Analysis: Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Atterberg Limits: Liquid (%) | Plastic (%) | Plasticity Index (%) | Specific Gravity | Density: Bulk Density (gm/cm$^3$) | Density: Dry Density (gm/cm$^3$) | Moisture Content (%) | Shear Tests: Cohesion Intercept, 'c' (kg/cm$^2$) | Shear Tests: Angle of Internal Friction, 'Φ' (degrees) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10.5 | SPT7 | | 27 | 29 | | Fine sand (SP-SM) | | | 2 | 89 | 6 | 3 | | | | | | | | | |
| | 11.0 | DS3 | | | | | | 12.0 | | | | | | | | | | | | | | |
| | 12.0 | SPT8 | | 18 | 17 | | Sandy silt, non- plasticity (ML) | | | 1 | 48 | 49 | 2 | | | | | | | | | |
| | 13.5 | SPT9 | | 20 | 17 | | | | | | | | | 22.8 | N.P. | | | | | | | |
| | 14.3 | UDS3 | | | | | | 15.0 | | | | | | | | | 2.67 | 1.84 | 1.60 | 14.9 | | |
| | 15.0 | SPT10 | | 34 | 23 | | Clayey silt with medium plasticity (CL) | 15.5 | | 3 | 35 | 50 | 12 | | | | | | | | | |

## Borehole Log (BH-6)

Location : Bakkarwala, New Delhi

Ground Water Level : 1 m

Termination Depth : 15.45 m

Drilling : Shell & Auger

Start Date : 03-Oct-22

Finish Date : 03-Oct-22

| Scale | Depth, m | Sample Designation | Groundwater depth, m | SPT Field Value, N | SPT Corrected Value, N" | Symbol | SOIL DESCRIPTION | Depth of Strata, (m) | Standard Penetration Test Results | Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Liquid (%) | Plastic (%) | Plasticity Index (%) | Specific Gravity | Bulk Density (gm/cm$^3$) | Dry Density (gm/cm$^3$) | Moisture Content (%) | Cohesion Intercept, 'c' (kg/cm$^2$) | Angle of Internal Friction, 'Φ' (degrees) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.5 | DS1 | 1.0 | | | | Fill - soil with organic material & brick bats | 3.0 | Field Value, N; Corrected Value, N"; 0 20 40 60 80 100 | | | | | | | | | | | | | |
| | 1.5 | SPT1 | | 2 | 3 | | | | | | | | | | | | | | | | | |
| | 2.0 | DS2 | | | | | | | | | | | | | | | | | | | | |
| | 3.0 | SPT2 | | 6 | 8 | | Clayey silt with medium plasticity (CL) | 4.5 | | 0 | 34 | 54 | 12 | | | | | | | | | |
| | 4.5 | SPT3 | | 8 | 10 | | Light brown sandy silt with low plasticity (ML-CL) | 6.0 | | | | | | 22.2 | 17.9 | 4.3 | 2.64 | 1.75 | 1.55 | 12.7 | | |
| | 5.3 | UDS1 | | | | | | | | | | | | | | | | | | | | |
| | 6.0 | SPT4 | | 10 | 12 | | Light brown silty sand (SM) | 9.0 | | 0 | 57 | 41 | 2 | | | | | | | | | |
| | 7.5 | SPT5 | | 22 | 20 | | | | | | | | | | | | | | | | | |
| | 8.3 | UDS2 | | | | | | | | | | | | | | | 2.67 | 1.80 | 1.58 | 14.2 | 0.0 | 29.0 |
| | 9.0 | SPT6 | | 22 | 20 | | Clayey silt with medium plasticity (CL) | | | 2 | 36 | 52 | 10 | | | | | | | | | |

## Borehole Log (BH-6)

Location : Bakkarwala, New Delhi

Ground Water Level : 1 m

Termination Depth : 15.45 m

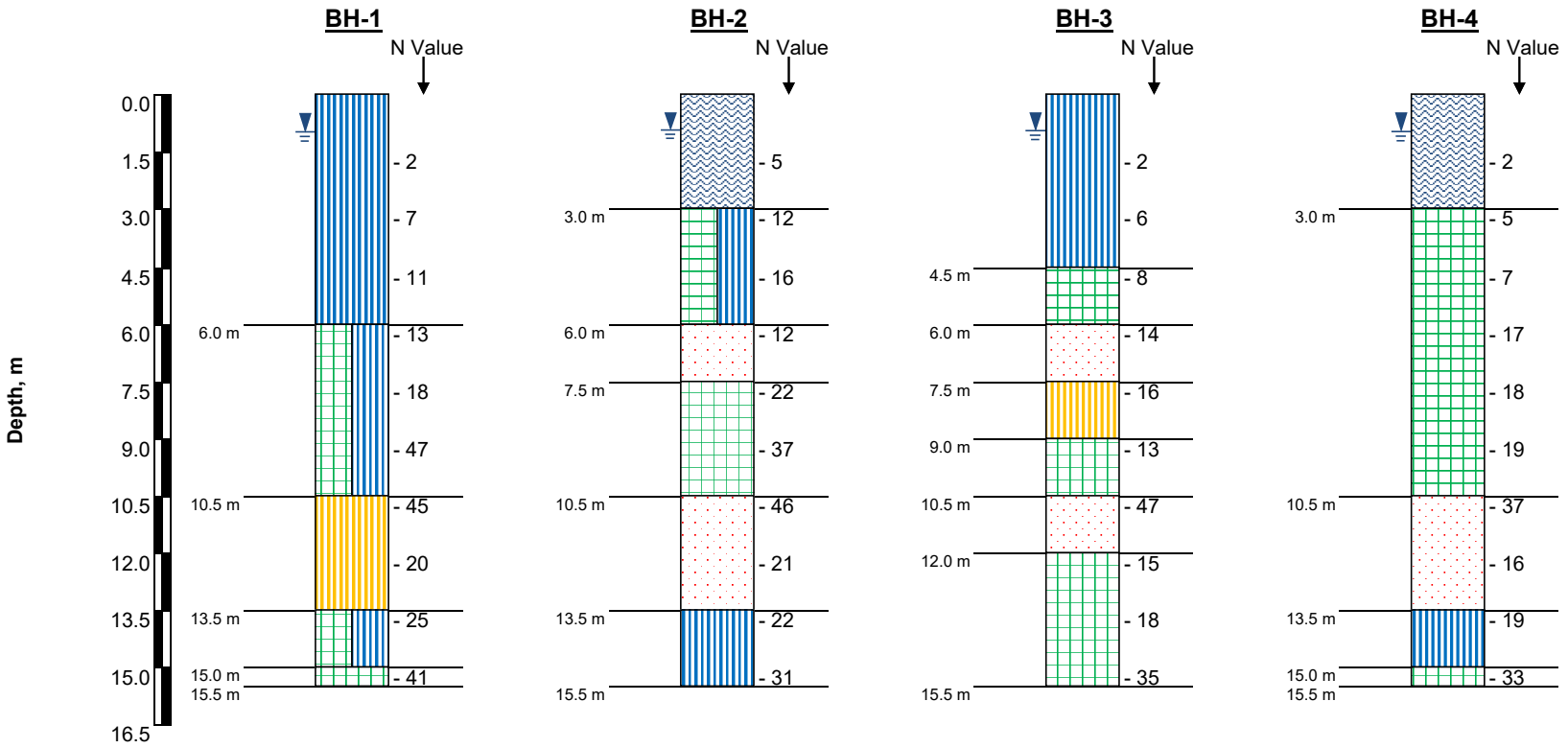
Drilling : Shell & Auger

Start Date : 03-Oct-22

Finish Date : 03-Oct-22

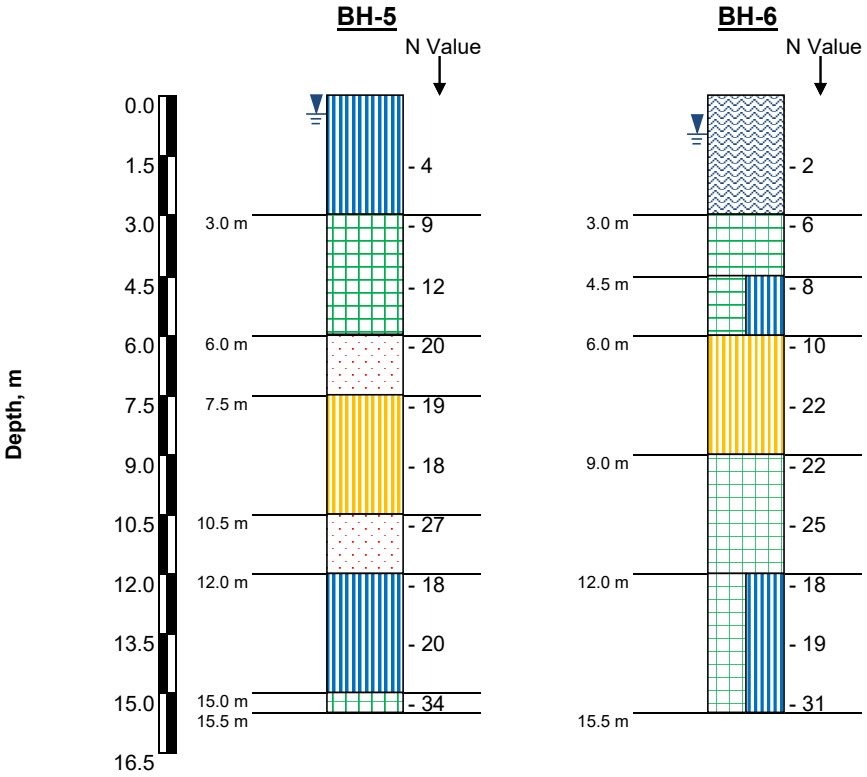
| Scale | Depth, m | Sample Designation | Groundwater depth, m | SPT: Field Value, N | SPT: Corrected Value, N" | Symbol | SOIL DESCRIPTION | Depth of Strata, (m) | Standard Penetration Test Results | Grain Size Analysis: Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Atterberg Limits: Liquid (%) | Plastic (%) | Plasticity Index (%) | Specific Gravity | Density: Bulk Density (gm/cm$^3$) | Density: Dry Density (gm/cm$^3$) | Moisture Content (%) | Shear Tests: Cohesion Intercept, 'c' (kg/cm$^2$) | Shear Tests: Angle of Internal Friction, 'Φ' (degrees) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10.5 | SPT7 | | 25 | 21 | | Clayey silt with medium plasticity (CL) | | | | | | | 32.2 | 22.9 | 9.3 | | | | | | |
| | 11.3 | UDS3 | | | | | | 12.0 | | | | | | | | | | 1.83 | 1.59 | 14.8 | 0.7 | - |
| | 12.0 | SPT8 | | 18 | 17 | | Light brown sandy silt with low plasticity (ML-CL) | | | 1 | 44 | 48 | 7 | | | | | | | | | |
| | 13.5 | SPT9 | | 19 | 17 | | | | | | | | | | | | | | | | | |
| | 14.3 | UDS4 | | | | | | | | | | | | | | | 2.65 | 1.87 | 1.62 | 15.6 | 0.0 | 31.0 |
| | 15.0 | SPT10 | | 31 | 21 | | | 15.5 | | | | | | 22.8 | 18.0 | 4.8 | | | | | | |

Standard Penetration Test Results: Field Value, N; Corrected Value, N"; 0 20 40 60 80 100



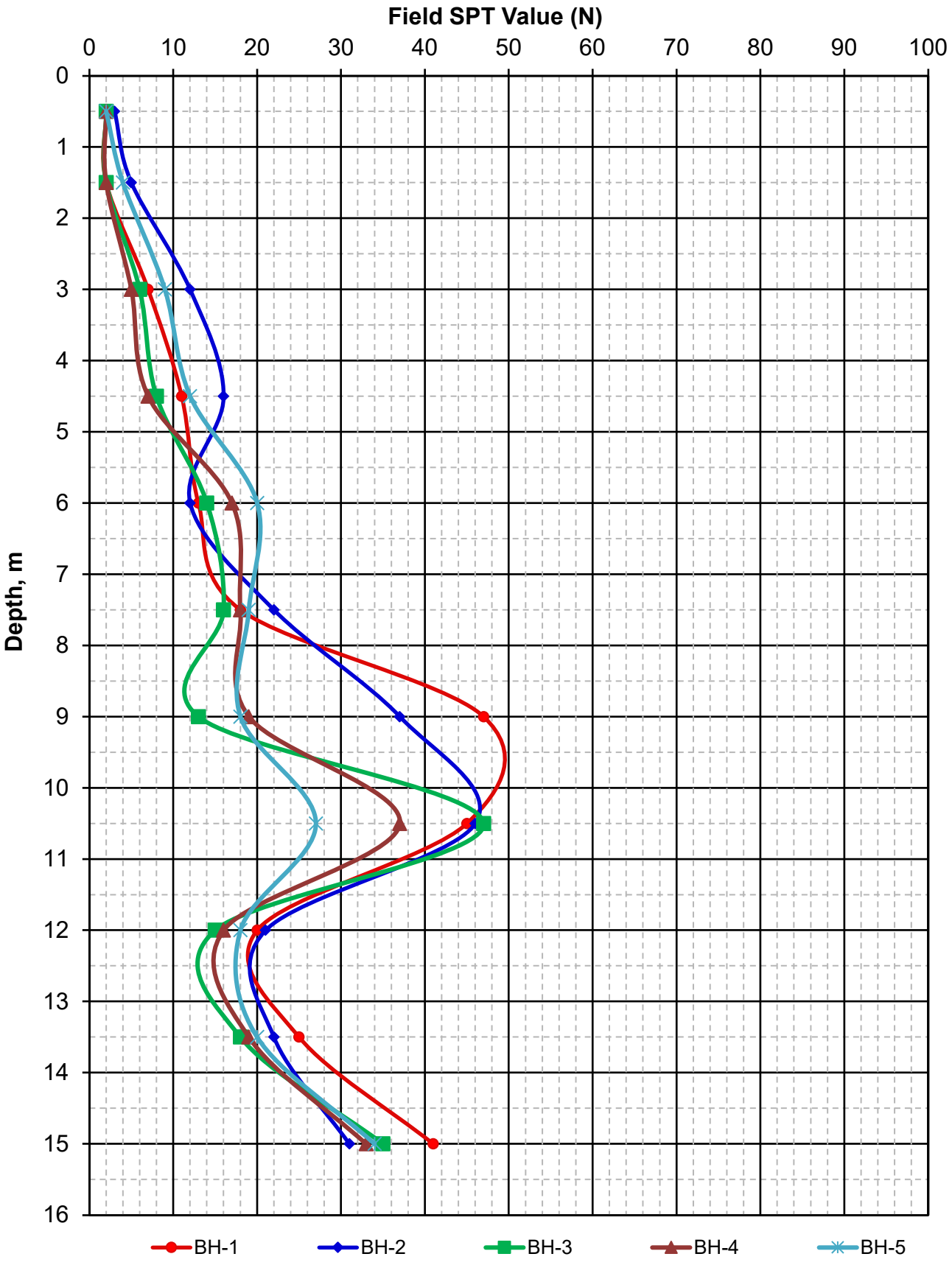

| LEGEND | |
|---|---|
| SYMBOL | DESCRIPTION |
| | GW level |
| | Fill |
| | Fine sand (SP-SM) |
| | Sandy silt (ML-CL) |
| | Clayey silt (CL) |
| | Silty sand (SM) |
| | Sandy silt (ML) |

## Cross Section of Boreholes

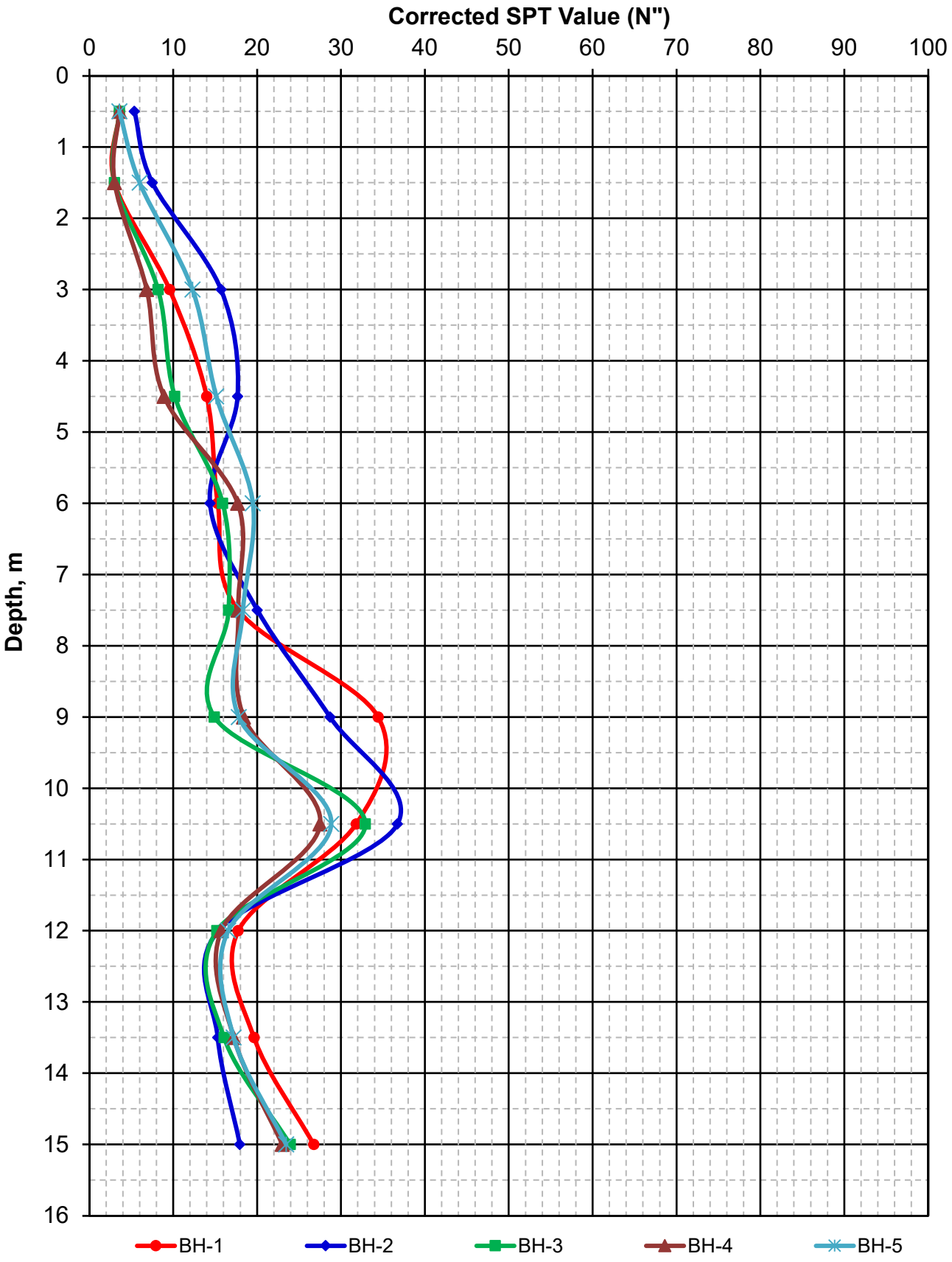



| LEGEND | |
|---|---|
| SYMBOL | DESCRIPTION |
| | GW level |
| | Fill |
| | Fine sand (SP-SM) |
| | Sandy silt (ML-CL) |
| | Clayey silt (CL) |
| | Silty sand (SM) |
| | Sandy silt (ML) |

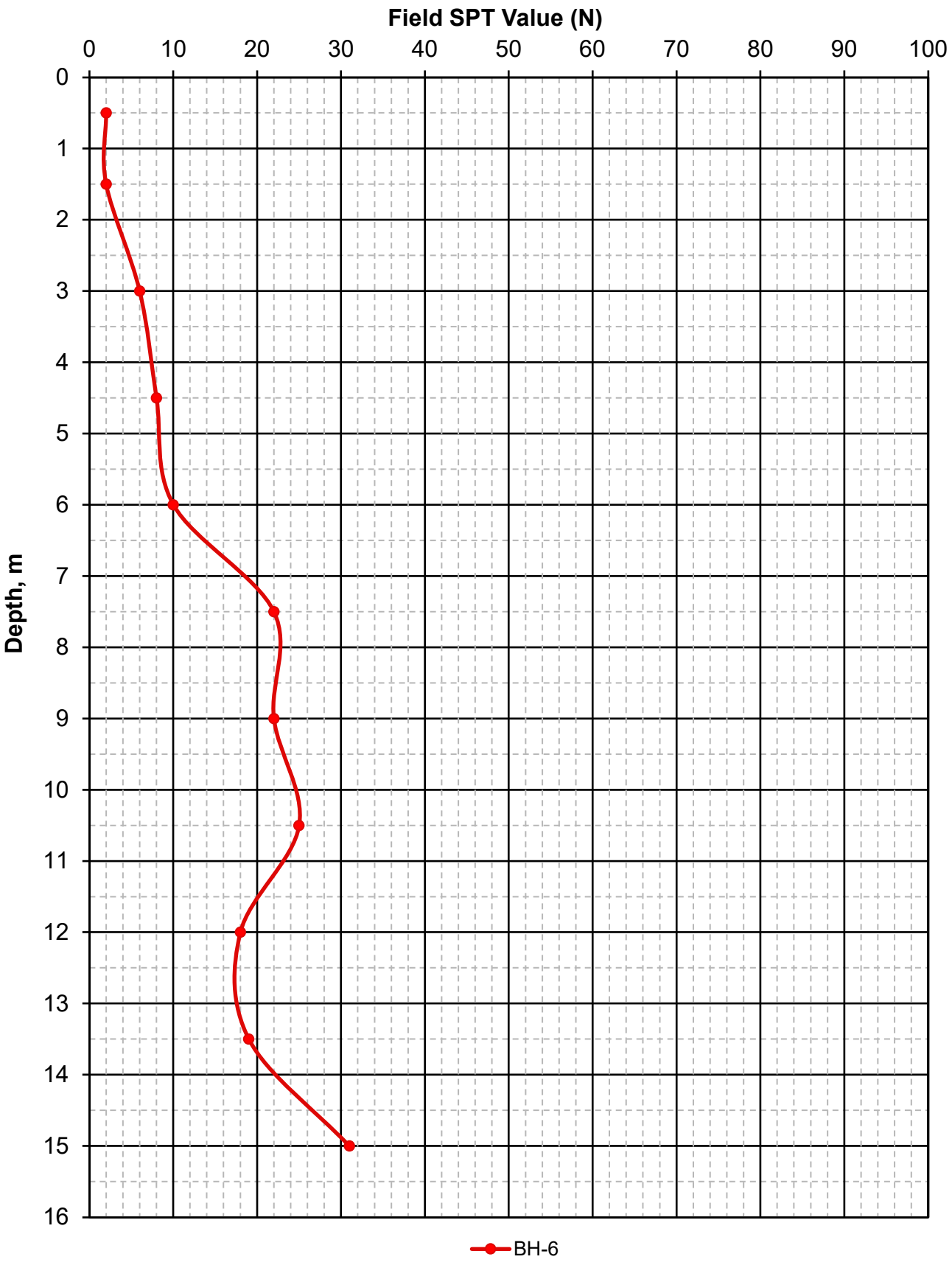
## Cross Section of Boreholes



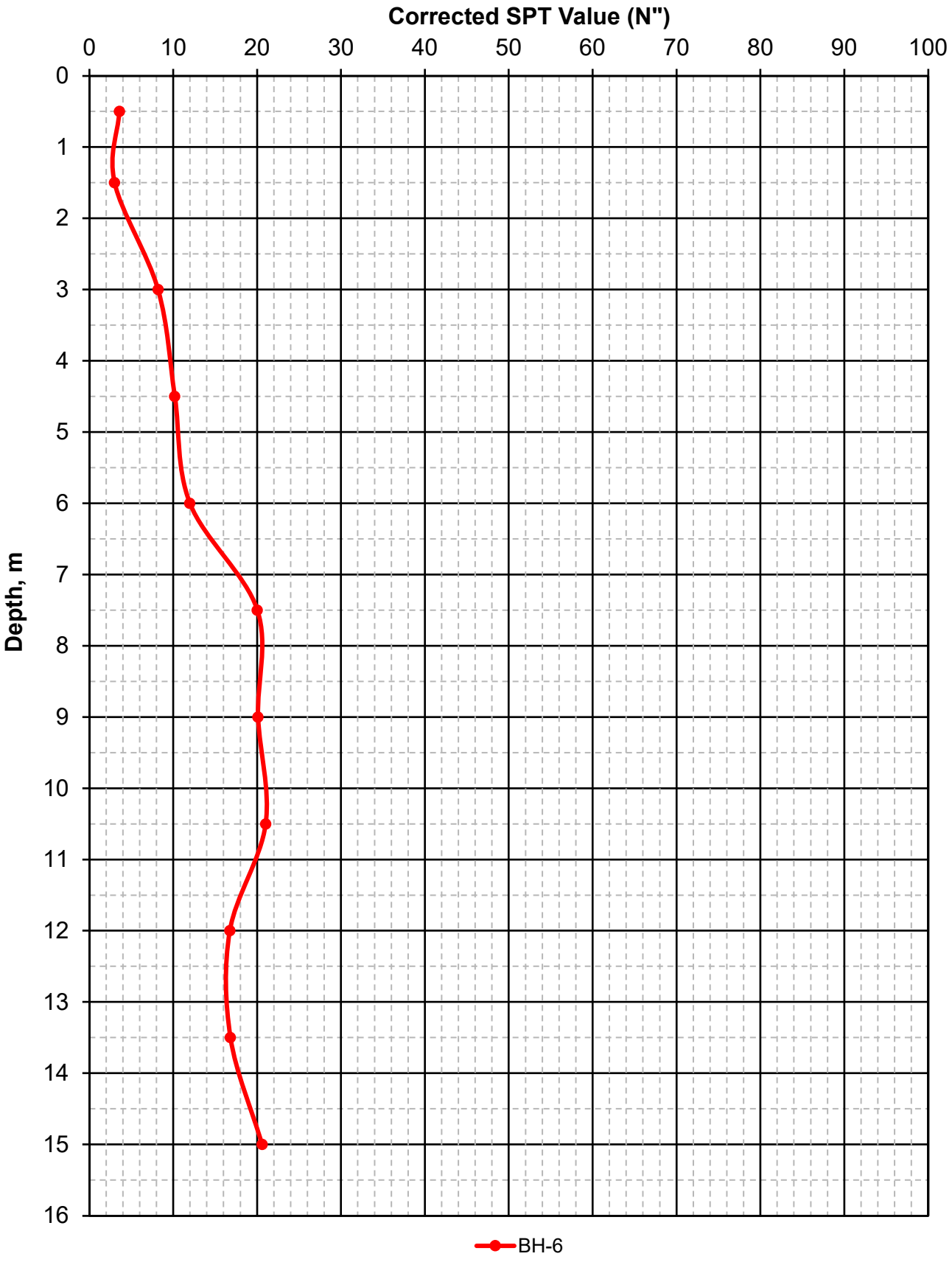

Plot of Field SPT-N value v/s depth




Plot of Corrected SPT-N" value v/s depth




Plot of Field SPT-N value v/s depth




Plot of Corrected SPT-N" value v/s depth

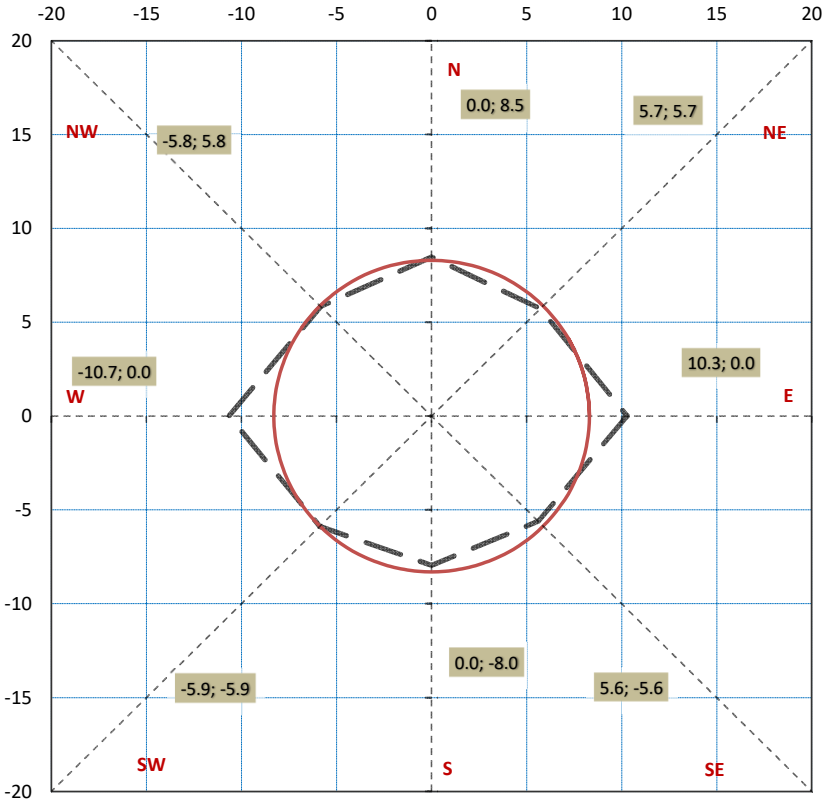
# ELECTRICAL RESISTIVITY TEST RESULTS

IS: 3043-1987, RA-2006

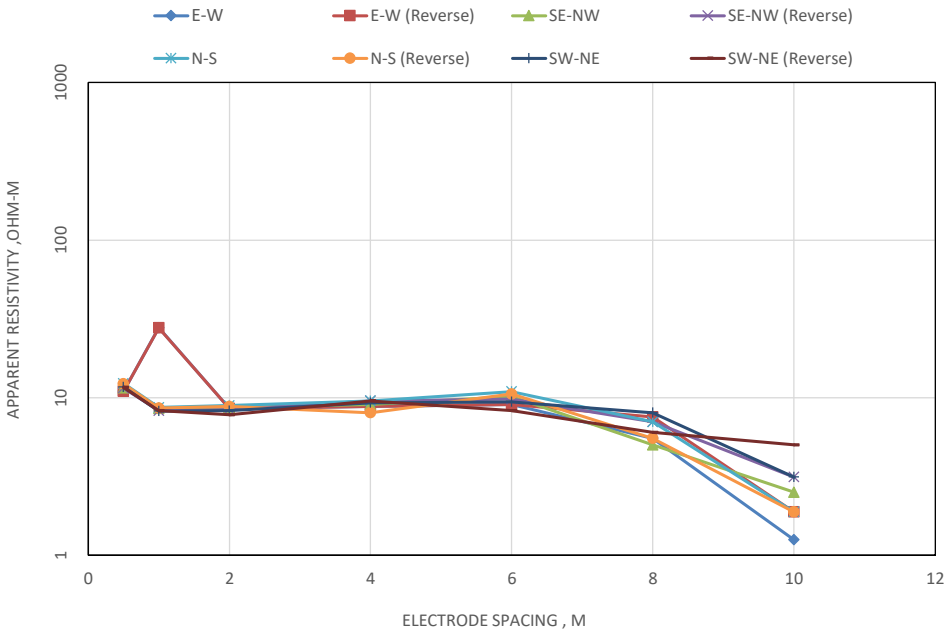
| Test Details |
|---|
| Test Designation : ERT 01 |

| Electrode Spacing, m | Apparent Resistivity, Ohm-m | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | E-W | E-W (Reverse) | SE-NW | SE-NW (Reverse) | N-S | N-S (Reverse) | SW-NE | SW-NE (Reverse) |
| 0.5 | 11.0 | 11.0 | 11.6 | 11.5 | 12.3 | 12.3 | 11.7 | 11.6 |
| 1.0 | 27.8 | 27.8 | 8.5 | 8.3 | 8.7 | 8.6 | 8.2 | 8.3 |
| 2.0 | 8.5 | 8.5 | 8.7 | 8.4 | 8.9 | 8.8 | 8.3 | 7.8 |
| 4.0 | 8.8 | 8.8 | 9.0 | 9.6 | 9.6 | 8.0 | 9.3 | 9.6 |
| 6.0 | 9.0 | 9.0 | 10.2 | 9.8 | 10.9 | 10.6 | 9.4 | 8.3 |
| 8.0 | 5.5 | 7.5 | 5.0 | 7.0 | 7.0 | 5.5 | 8.0 | 6.0 |
| 10.0 | 1.3 | 1.9 | 2.5 | 3.1 | 1.9 | 1.9 | 3.1 | 5.0 |
| Mean Resistivity | 10.3 | 10.7 | 7.9 | 8.3 | 8.5 | 8.0 | 8.3 | 8.1 |

## POLAR RESISTIVITY CURVE




**MEAN RESISTIVITY VALUE = 8.3 ohm-m**




**Total Area of Polygon : 215**

**Radius of Equivalent Circle = Mean Resistivity : 8.3 ohm-m**

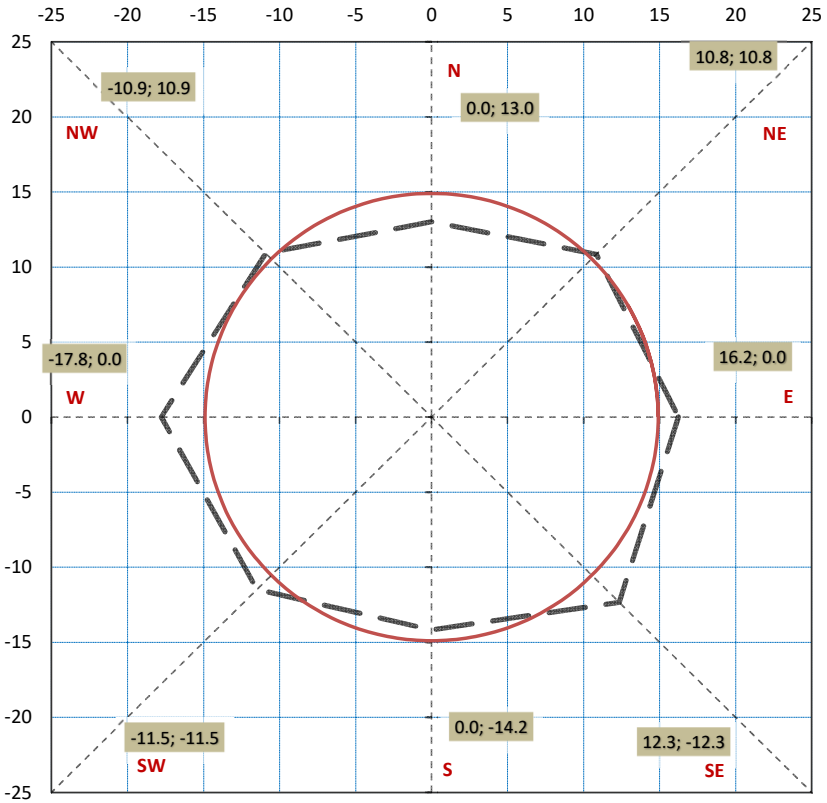
# ELECTRICAL RESISTIVITY TEST RESULTS

IS: 3043-1987, RA-2006

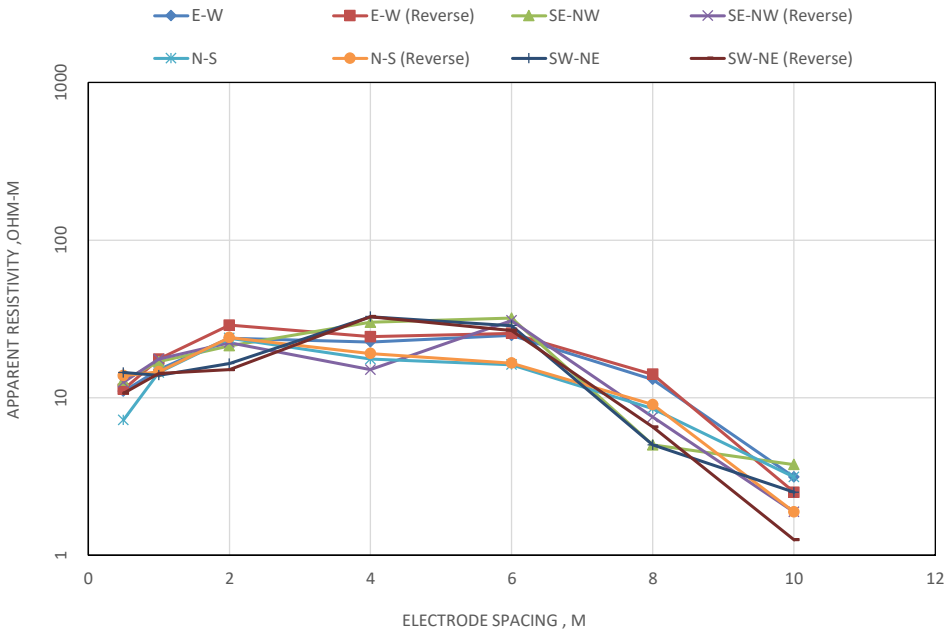
| Test Details |
|---|
| Test Designation : ERT 02 |

| Electrode Spacing, m | Apparent Resistivity, Ohm-m | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | E-W | E-W (Reverse) | SE-NW | SE-NW (Reverse) | N-S | N-S (Reverse) | SW-NE | SW-NE (Reverse) |
| 0.5 | 11.0 | 11.3 | 12.9 | 12.6 | 7.2 | 13.8 | 14.5 | 10.7 |
| 1.0 | 15.1 | 17.6 | 17.0 | 17.6 | 14.5 | 14.6 | 13.9 | 14.3 |
| 2.0 | 23.9 | 28.9 | 21.4 | 22.4 | 23.9 | 24.1 | 16.5 | 15.1 |
| 4.0 | 22.6 | 24.4 | 30.2 | 15.1 | 17.6 | 19.1 | 32.7 | 32.7 |
| 6.0 | 24.9 | 25.6 | 32.0 | 30.9 | 16.2 | 16.6 | 28.7 | 26.8 |
| 8.0 | 13.1 | 14.1 | 5.0 | 7.5 | 8.5 | 9.0 | 5.0 | 6.5 |
| 10.0 | 3.1 | 2.5 | 3.8 | 1.9 | 3.1 | 1.9 | 2.5 | 1.3 |
| Mean Resistivity | 16.2 | 17.8 | 17.5 | 15.4 | 13.0 | 14.2 | 16.2 | 15.3 |

## POLAR RESISTIVITY CURVE




**MEAN RESISTIVITY VALUE = 14.9 ohm-m**




**Total Area of Polygon : 697**

**Radius of Equivalent Circle = Mean Resistivity : 14.9 ohm-m**

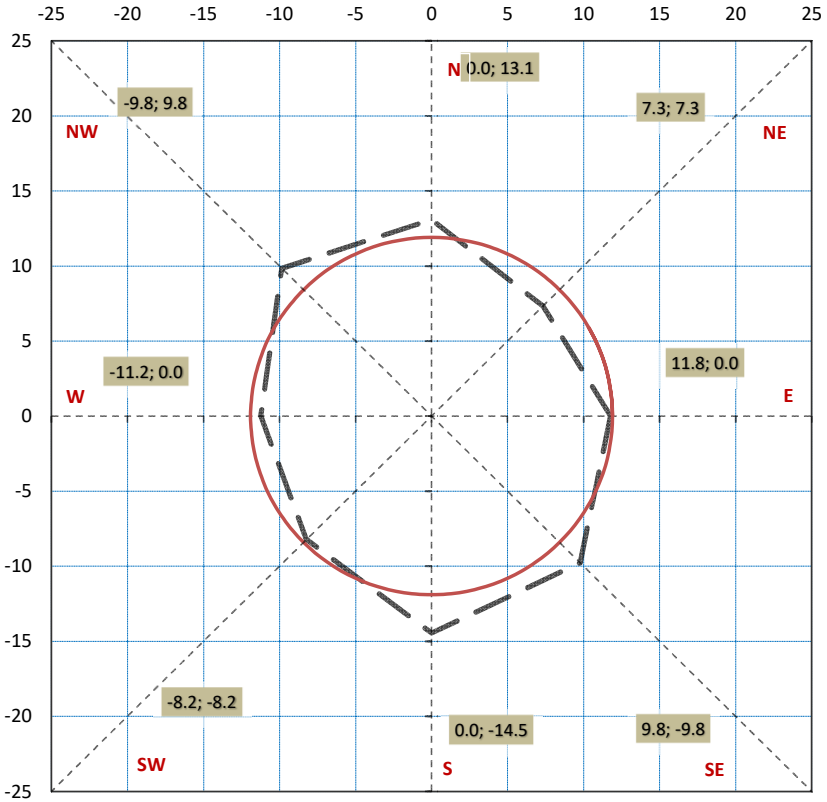
# ELECTRICAL RESISTIVITY TEST RESULTS

IS: 3043-1987, RA-2006

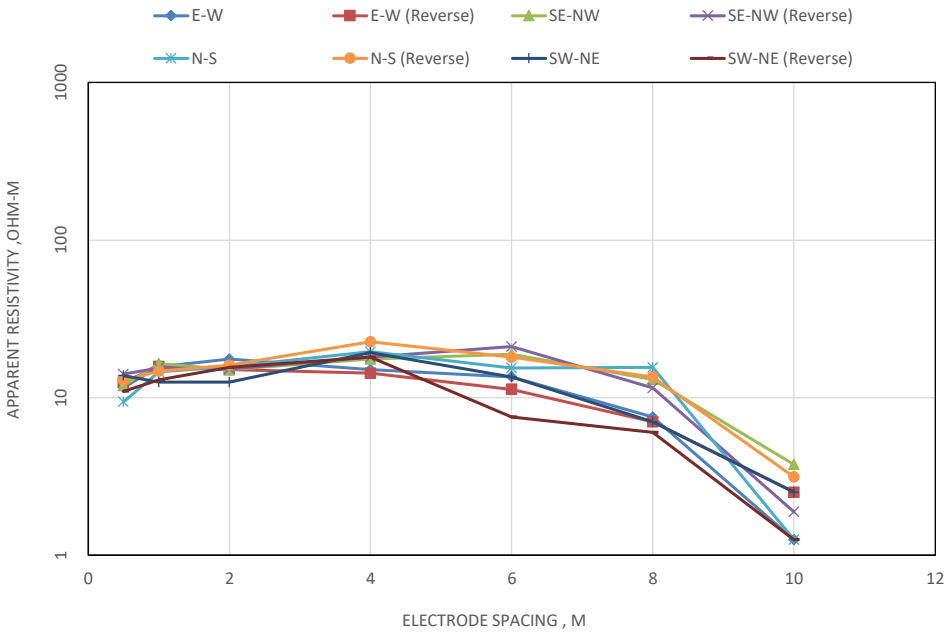
| Test Details |
|---|
| Test Designation : ERT 03 |

| Electrode Spacing, m | Apparent Resistivity, Ohm-m | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | E-W | E-W (Reverse) | SE-NW | SE-NW (Reverse) | N-S | N-S (Reverse) | SW-NE | SW-NE (Reverse) |
| 0.5 | 11.6 | 12.6 | 11.9 | 14.1 | 9.4 | 12.9 | 13.8 | 11.0 |
| 1.0 | 15.7 | 15.8 | 16.5 | 15.5 | 14.6 | 14.8 | 12.6 | 13.0 |
| 2.0 | 17.6 | 15.1 | 15.1 | 15.2 | 15.7 | 16.1 | 12.6 | 15.6 |
| 4.0 | 15.1 | 14.3 | 17.6 | 18.1 | 19.6 | 22.6 | 19.4 | 18.1 |
| 6.0 | 13.6 | 11.3 | 18.8 | 21.1 | 15.5 | 18.1 | 13.6 | 7.5 |
| 8.0 | 7.5 | 7.0 | 13.1 | 11.6 | 15.6 | 13.6 | 7.0 | 6.0 |
| 10.0 | 1.3 | 2.5 | 3.8 | 1.9 | 1.3 | 3.1 | 2.5 | 1.3 |
| Mean Resistivity | 11.8 | 11.2 | 13.8 | 13.9 | 13.1 | 14.5 | 11.6 | 10.4 |

## POLAR RESISTIVITY CURVE




**MEAN RESISTIVITY VALUE = 11.9 ohm-m**




**Total Area of Polygon : 444**

**Radius of Equivalent Circle = Mean Resistivity : 11.9 ohm-m**

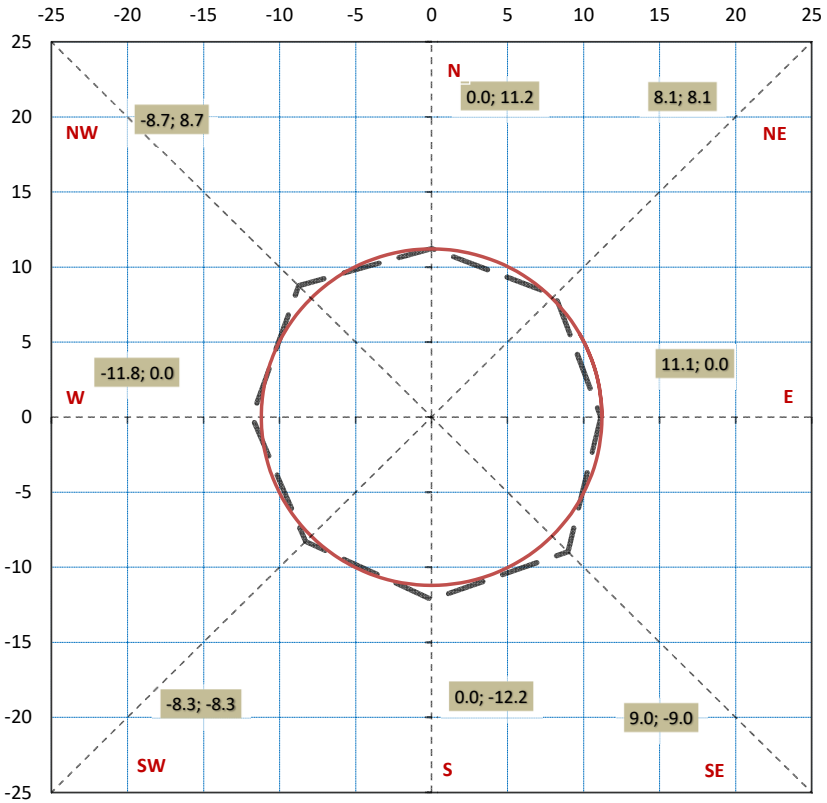
# ELECTRICAL RESISTIVITY TEST RESULTS

IS: 3043-1987, RA-2006

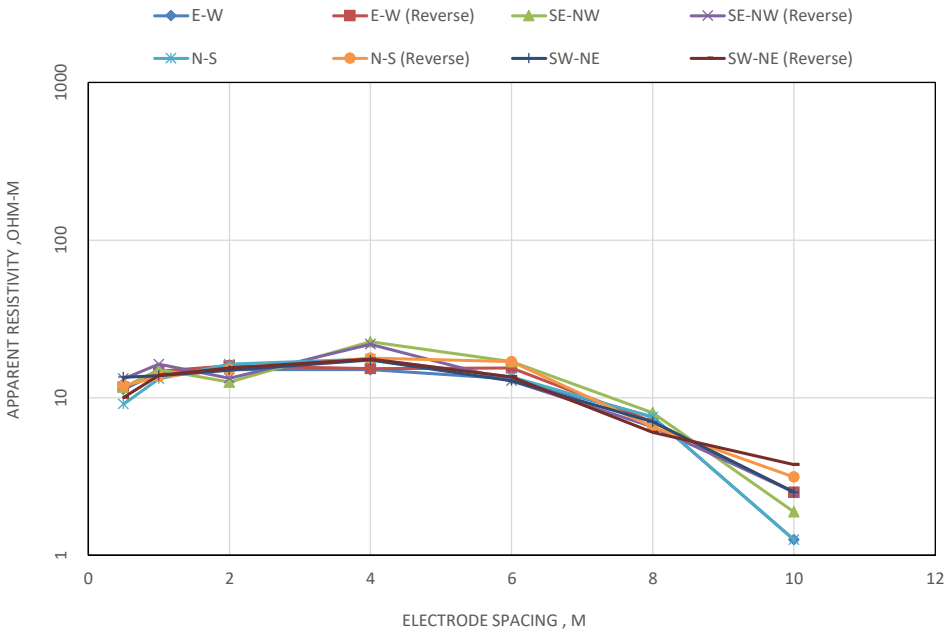
| Test Details |
|---|
| Test Designation : ERT 04 |

| Electrode Spacing, m | Apparent Resistivity, Ohm-m | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | E-W | E-W (Reverse) | SE-NW | SE-NW (Reverse) | N-S | N-S (Reverse) | SW-NE | SW-NE (Reverse) |
| 0.5 | 11.3 | 11.6 | 11.6 | 13.2 | 9.1 | 11.9 | 13.5 | 10.1 |
| 1.0 | 14.5 | 14.8 | 15.1 | 16.3 | 13.2 | 13.6 | 13.8 | 13.9 |
| 2.0 | 15.1 | 16.0 | 12.6 | 13.3 | 16.3 | 15.1 | 15.0 | 15.5 |
| 4.0 | 15.1 | 15.3 | 22.6 | 21.9 | 17.6 | 17.8 | 17.3 | 17.6 |
| 6.0 | 13.2 | 15.5 | 17.0 | 12.8 | 13.6 | 17.0 | 12.8 | 13.6 |
| 8.0 | 7.5 | 7.0 | 8.0 | 6.5 | 7.5 | 6.5 | 7.0 | 6.0 |
| 10.0 | 1.3 | 2.5 | 1.9 | 2.5 | 1.3 | 3.1 | 2.5 | 3.8 |
| Mean Resistivity | 11.1 | 11.8 | 12.7 | 12.4 | 11.2 | 12.2 | 11.7 | 11.5 |

## POLAR RESISTIVITY CURVE




**MEAN RESISTIVITY VALUE = 11.2 ohm-m**




**Total Area of Polygon : 395**

**Radius of Equivalent Circle = Mean Resistivity : 11.2 ohm-m**

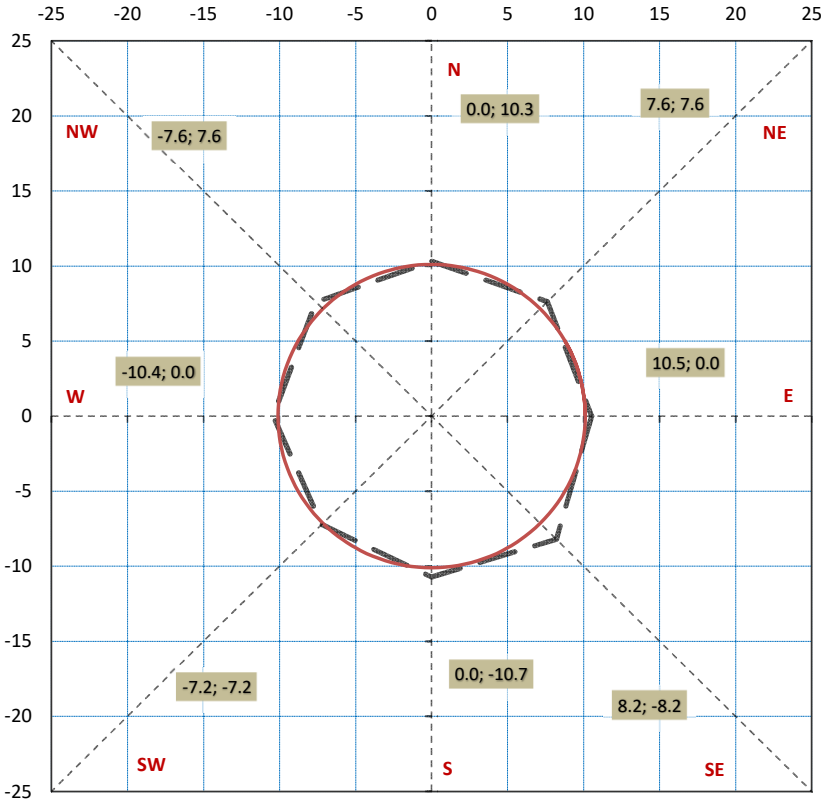
# ELECTRICAL RESISTIVITY TEST RESULTS

IS: 3043-1987, RA-2006

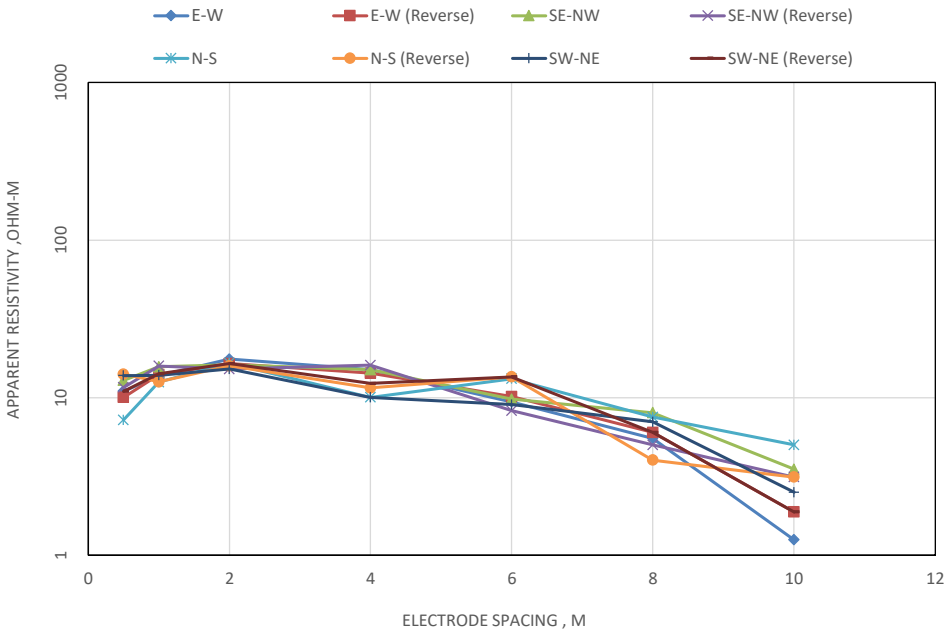
| Test Details |
|---|
| Test Designation : ERT 05 |

| Electrode Spacing, m | Apparent Resistivity, Ohm-m | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | E-W | E-W (Reverse) | SE-NW | SE-NW (Reverse) | N-S | N-S (Reverse) | SW-NE | SW-NE (Reverse) |
| 0.5 | 11.0 | 10.1 | 12.9 | 11.6 | 7.2 | 14.1 | 13.8 | 11.0 |
| 1.0 | 13.8 | 14.0 | 15.7 | 15.9 | 12.6 | 12.6 | 13.9 | 14.2 |
| 2.0 | 17.6 | 16.5 | 16.2 | 15.2 | 16.6 | 16.0 | 15.2 | 16.5 |
| 4.0 | 15.1 | 14.3 | 15.1 | 16.1 | 10.1 | 11.6 | 10.1 | 12.3 |
| 6.0 | 9.4 | 10.2 | 9.8 | 8.3 | 13.2 | 13.6 | 9.0 | 13.6 |
| 8.0 | 5.5 | 6.0 | 8.0 | 5.0 | 7.5 | 4.0 | 7.0 | 6.0 |
| 10.0 | 1.3 | 1.9 | 3.5 | 3.1 | 5.0 | 3.1 | 2.5 | 1.9 |
| Mean Resistivity | 10.5 | 10.4 | 11.6 | 10.8 | 10.3 | 10.7 | 10.2 | 10.8 |

## POLAR RESISTIVITY CURVE




**MEAN RESISTIVITY VALUE = 10.1 ohm-m**




**Total Area of Polygon : 322**

**Radius of Equivalent Circle = Mean Resistivity : 10.1 ohm-m**

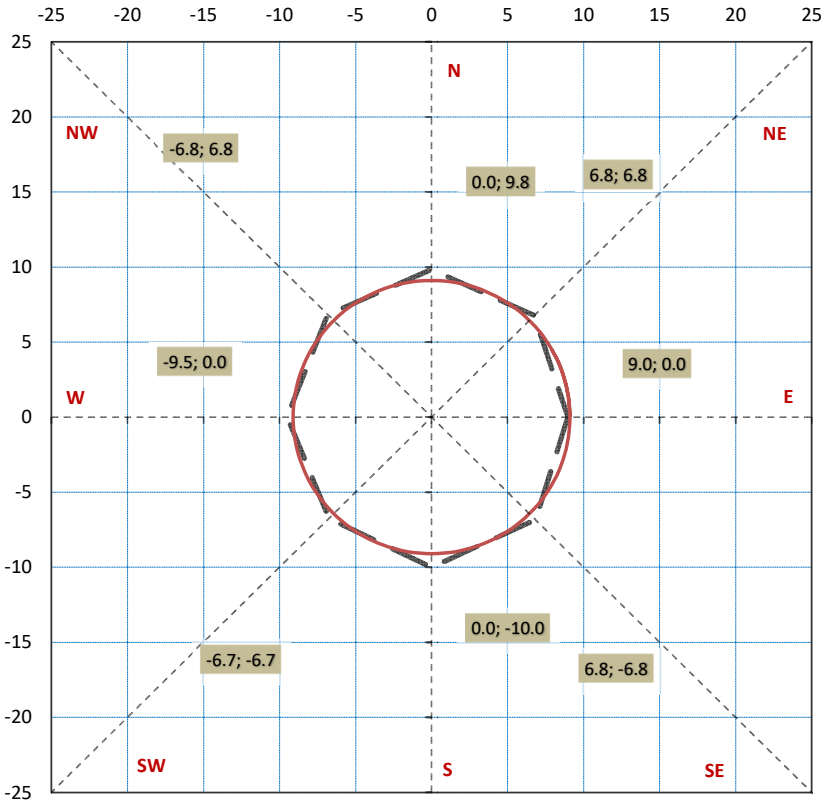
# ELECTRICAL RESISTIVITY TEST RESULTS

IS: 3043-1987, RA-2006

| Test Details |
|---|
| Test Designation : ERT 06 |

| Electrode Spacing, m | Apparent Resistivity, Ohm-m | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | E-W | E-W (Reverse) | SE-NW | SE-NW (Reverse) | N-S | N-S (Reverse) | SW-NE | SW-NE (Reverse) |
| 0.5 | 10.1 | 9.4 | 10.4 | 11.0 | 9.1 | 9.1 | 12.3 | 11.0 |
| 1.0 | 13.1 | 12.7 | 15.7 | 15.8 | 16.3 | 16.1 | 14.6 | 14.5 |
| 2.0 | 11.3 | 11.6 | 11.4 | 10.3 | 10.3 | 10.1 | 10.7 | 11.2 |
| 4.0 | 15.1 | 16.1 | 12.6 | 13.1 | 10.8 | 11.8 | 10.1 | 13.6 |
| 6.0 | 7.9 | 9.8 | 9.4 | 8.3 | 11.7 | 13.6 | 8.3 | 9.8 |
| 8.0 | 4.0 | 5.0 | 7.0 | 6.0 | 8.0 | 5.5 | 6.5 | 5.0 |
| 10.0 | 1.3 | 1.9 | 1.3 | 3.1 | 2.5 | 3.8 | 4.4 | 1.9 |
| Mean Resistivity | 9.0 | 9.5 | 9.7 | 9.7 | 9.8 | 10.0 | 9.5 | 9.6 |

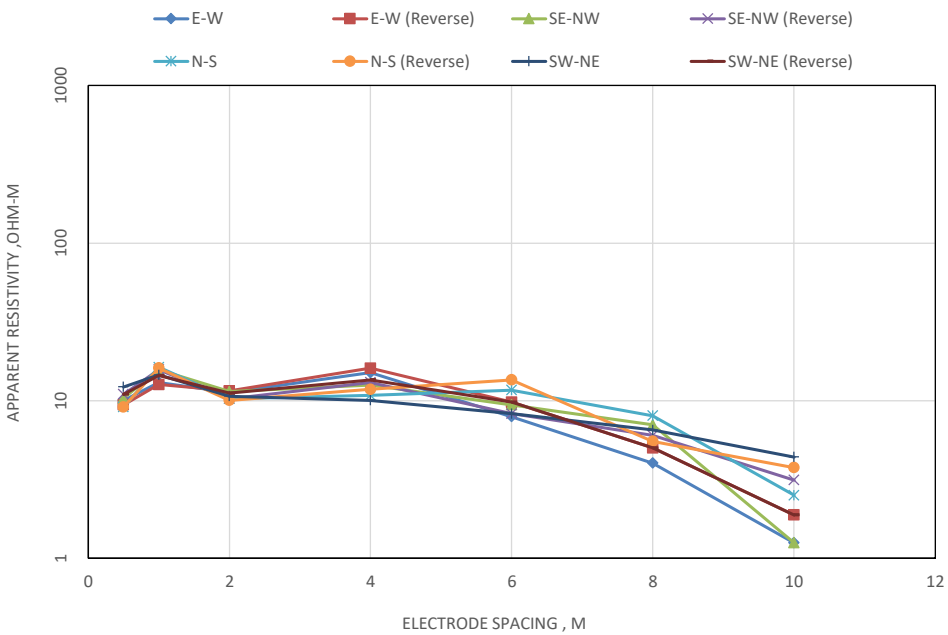
## POLAR RESISTIVITY CURVE

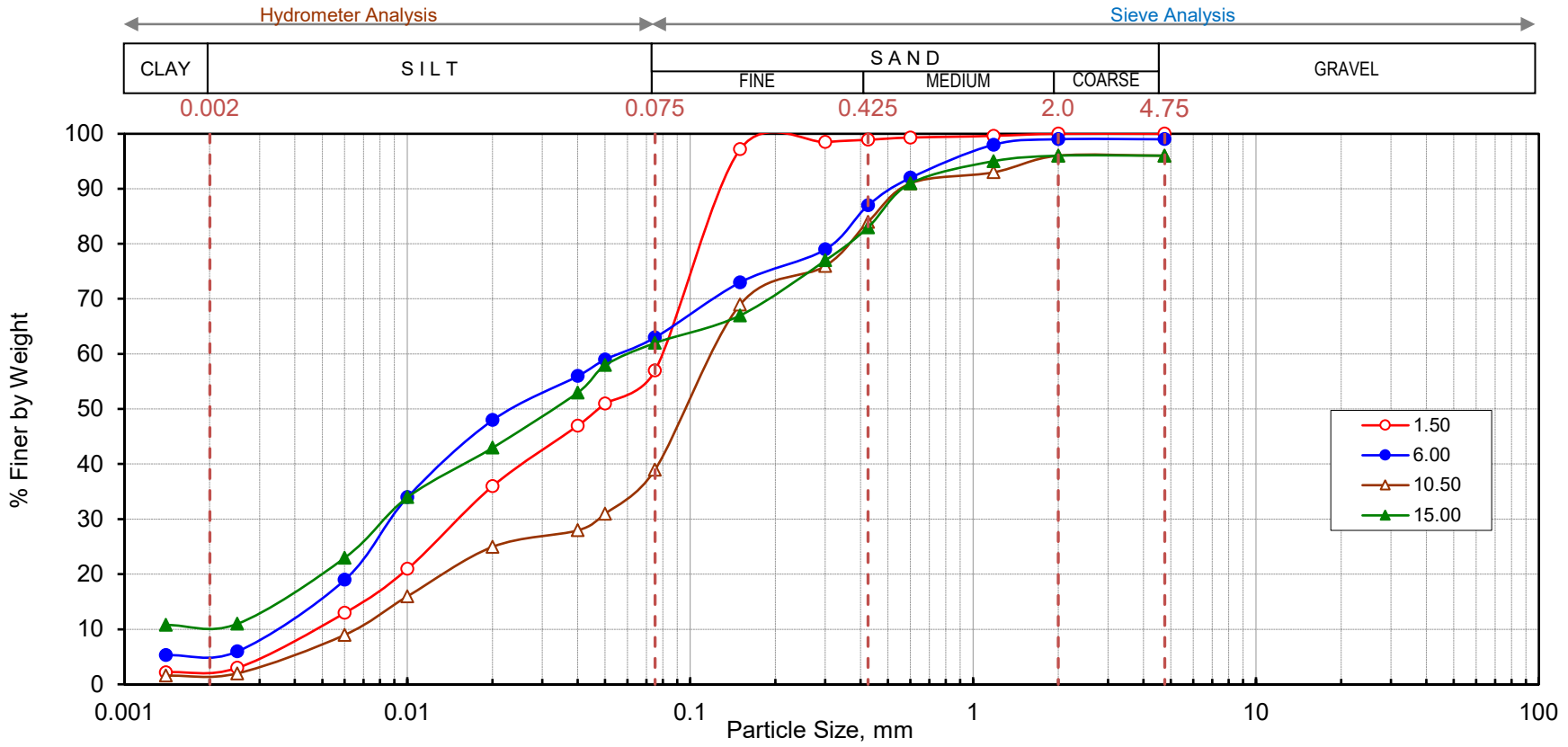



**Total Area of Polygon :** 260

**Radius of Equivalent Circle = Mean Resistivity :** 9.1 ohm-m

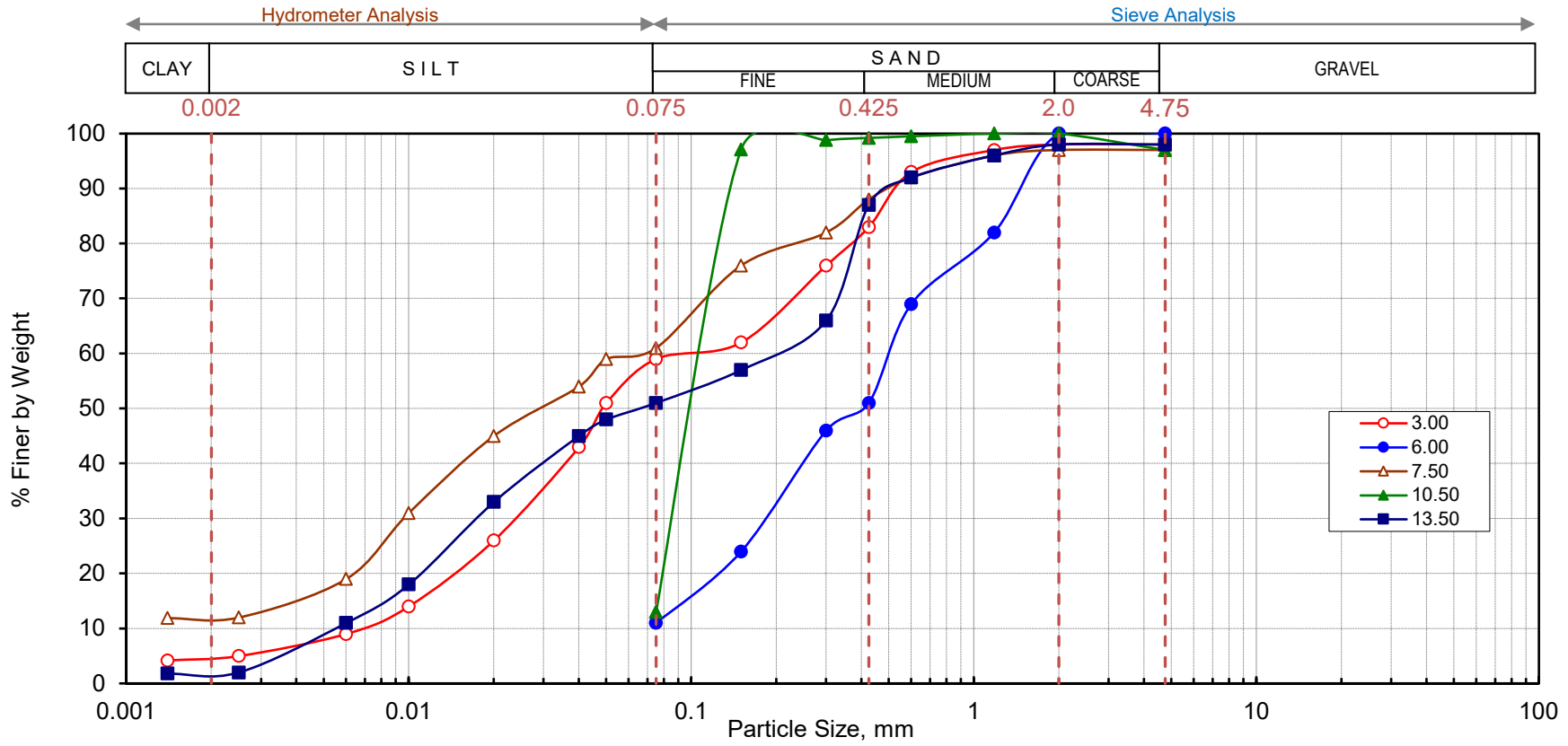
**MEAN RESISTIVITY VALUE = 9.1 ohm-m**





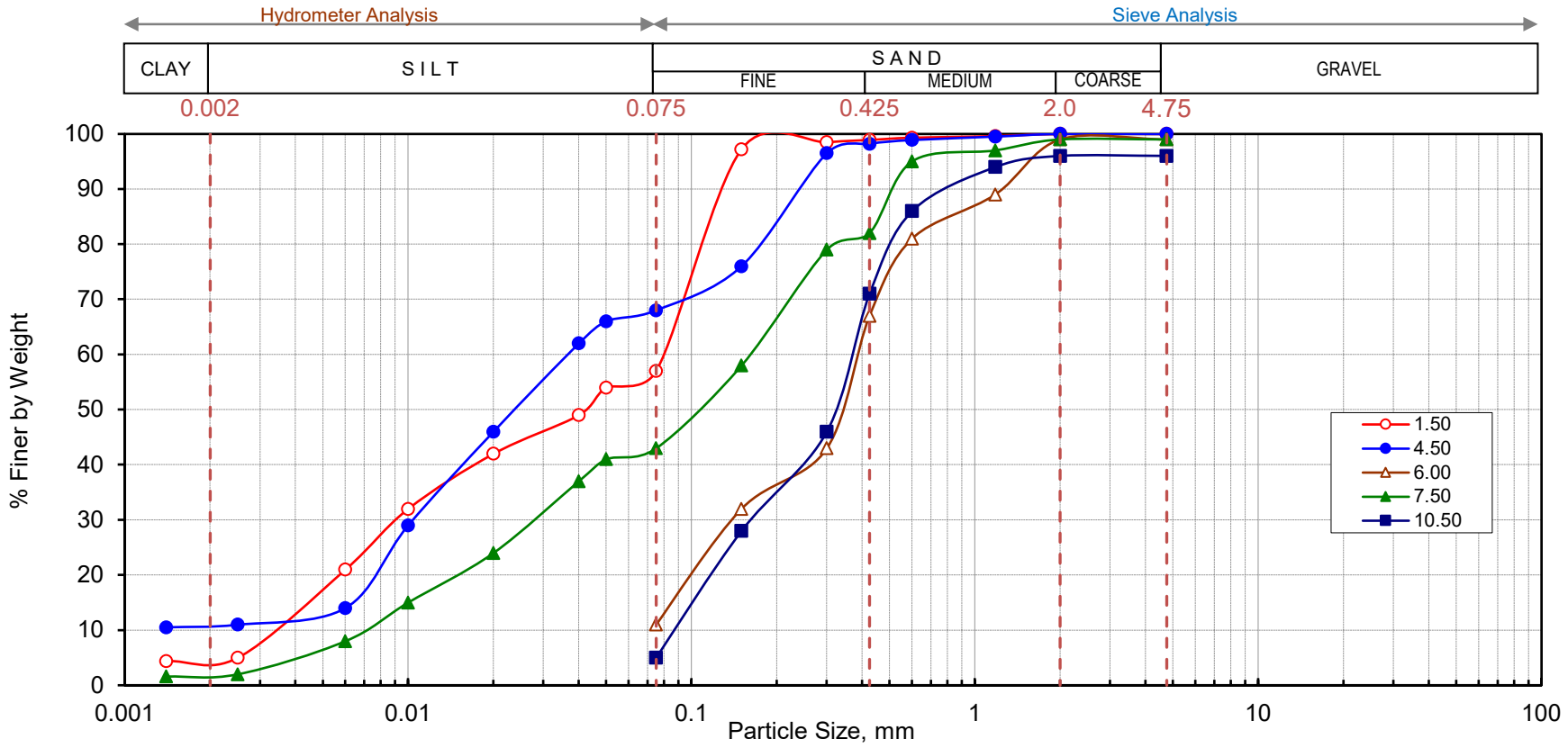

| Sample Details | | | | Test Results | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | Borehole Number | Sample Depth, m | Sample Description | Gravel % | Sand % | Silt % | Clay % | | $D_{60}$ | $D_{30}$ | $D_{10}$ | $C_u$ | $C_c$ |
| Bakkarwala | BH-1 | 1.50 | Sandy silt (ML) | 0 | 43 | 54 | 3 | | 0.081 | 0.016 | 0.005 | 16.3 | 0.64 |
| | BH-1 | 6.00 | Clayey silt (ML-CL) | 1 | 36 | 57 | 6 | | 0.056 | 0.009 | 0.004 | 15.7 | 0.40 |
| | BH-1 | 10.50 | Silty sand (SM) | 4 | 57 | 37 | 2 | | 0.128 | 0.047 | 0.007 | 19.4 | 2.60 |
| | BH-1 | 15.00 | Clayey silt (CL) | 4 | 34 | 51 | 11 | | 0.063 | 0.009 | | | |
| | | | | | | | | | | | | | |

## Grain Size Distribution



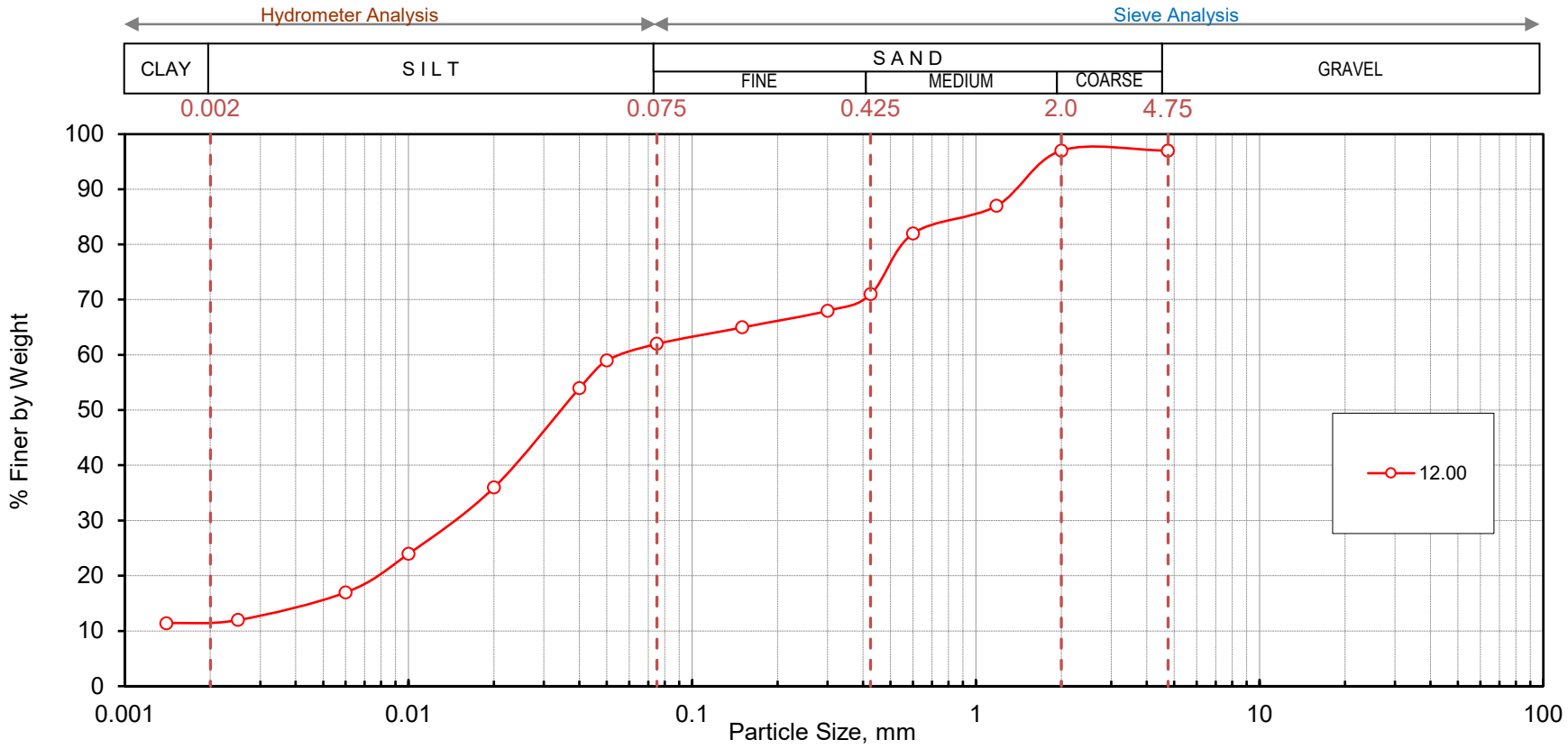

| Sample Details | | | | Test Results | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | Borehole Number | Sample Depth, m | Sample Description | Gravel % | Sand % | Silt % | Clay % | | $D_{60}$ | $D_{30}$ | $D_{10}$ | $C_u$ | $C_c$ |
| Bakkarwala | BH-2 | 3.00 | Clayey silt (CL-ML) | 2 | 39 | 54 | 5 | | 0.100 | 0.025 | 0.007 | 14.7 | 0.90 |
| | BH-2 | 6.00 | Fine sand (SP-SM) | 0 | 89 | 11 | 0 | | 0.513 | 0.191 | | | |
| | BH-2 | 7.50 | Clayey silt (CL) | 3 | 36 | 49 | 12 | | 0.063 | 0.010 | | | |
| | BH-2 | 10.50 | Fine sand (SP-SM) | 3 | 84 | 13 | 0 | | 0.117 | 0.090 | | | |
| | BH-2 | 13.50 | Sandy silt (ML) | 2 | 47 | 49 | 2 | | 0.200 | 0.018 | 0.006 | 35.6 | 0.29 |

## Grain Size Distribution



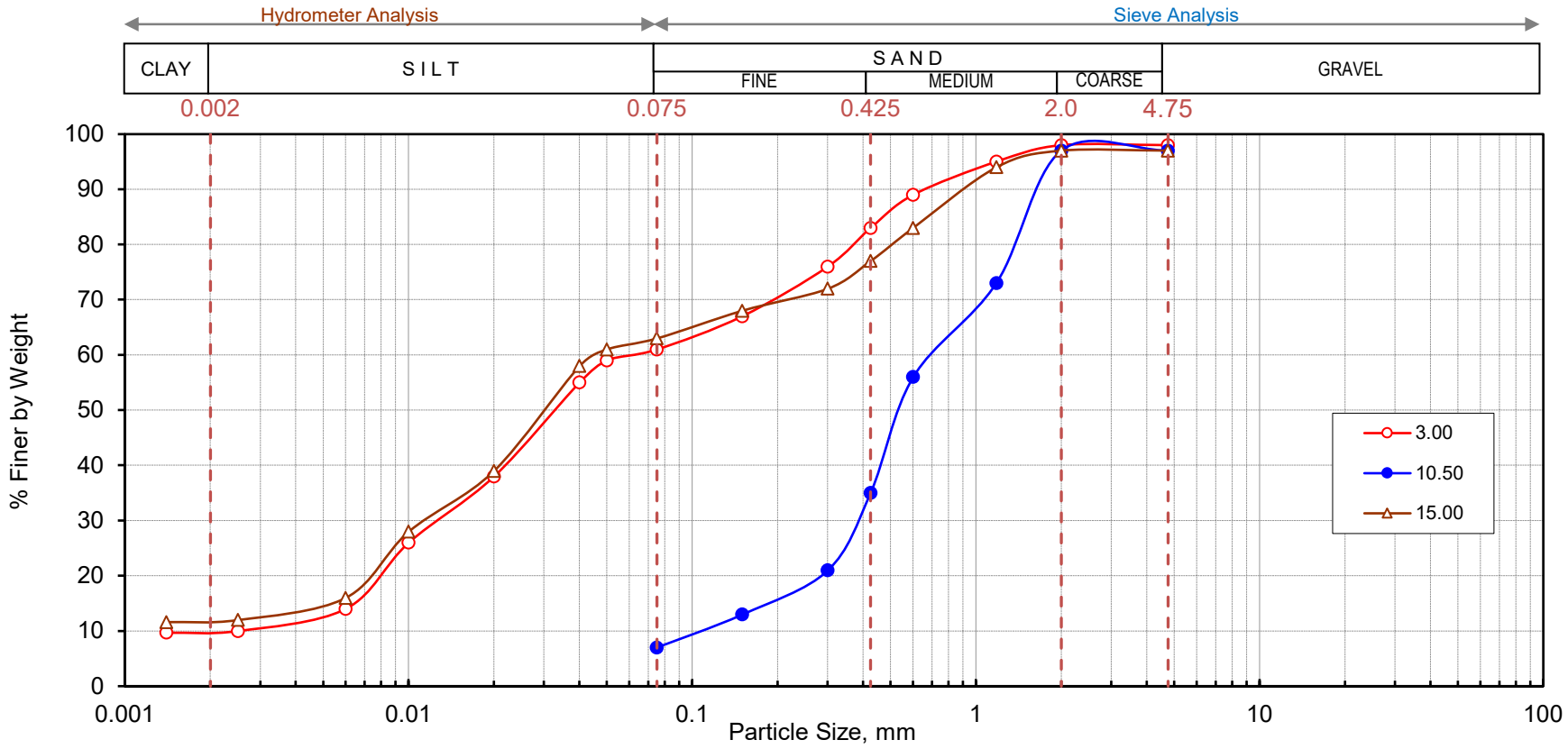

| Sample Details | | | | Test Results | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | Borehole Number | Sample Depth, m | Sample Description | Gravel % | Sand % | Silt % | Clay % | | $D_{60}$ | $D_{30}$ | $D_{10}$ | $C_u$ | $C_c$ |
| Bakkarwala | BH-3 | 1.50 | Sandy silt (ML) | 0 | 43 | 52 | 5 | | 0.081 | 0.009 | 0.004 | 22.4 | 0.30 |
| | BH-3 | 4.50 | Clayey silt (CL) | 0 | 32 | 57 | 11 | | 0.038 | 0.011 | | | |
| | BH-3 | 6.00 | Fine sand (SP-SM) | 1 | 88 | 11 | 0 | | 0.389 | 0.143 | | | |
| | BH-3 | 7.50 | Silty sand (SM) | 1 | 56 | 41 | 2 | | 0.164 | 0.029 | 0.007 | 23.0 | 0.73 |
| | BH-3 | 10.50 | Fine sand (SP-SM) | 4 | 91 | 5 | 0 | | 0.370 | 0.167 | 0.091 | 4.1 | 0.82 |

## Grain Size Distribution



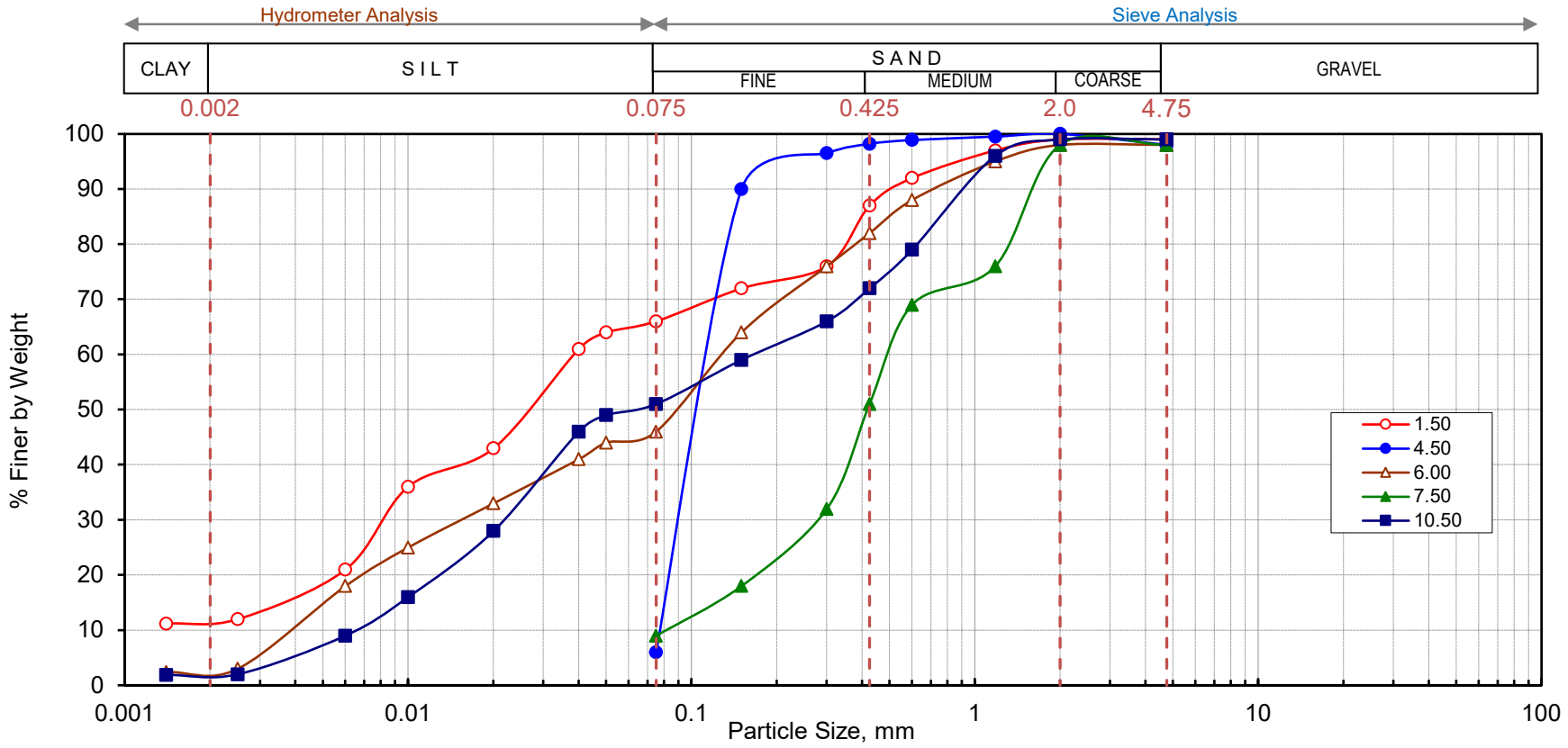

| Sample Details | | | | Test Results | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | Borehole Number | Sample Depth, m | Sample Description | Gravel % | Sand % | Silt % | Clay % | | $D_{60}$ | $D_{30}$ | $D_{10}$ | $C_u$ | $C_c$ |
| Bakkarwala | BH-3 | 12.00 | Clayey silt (CL) | 3 | 35 | 50 | 12 | | 0.058 | 0.015 | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

## Grain Size Distribution



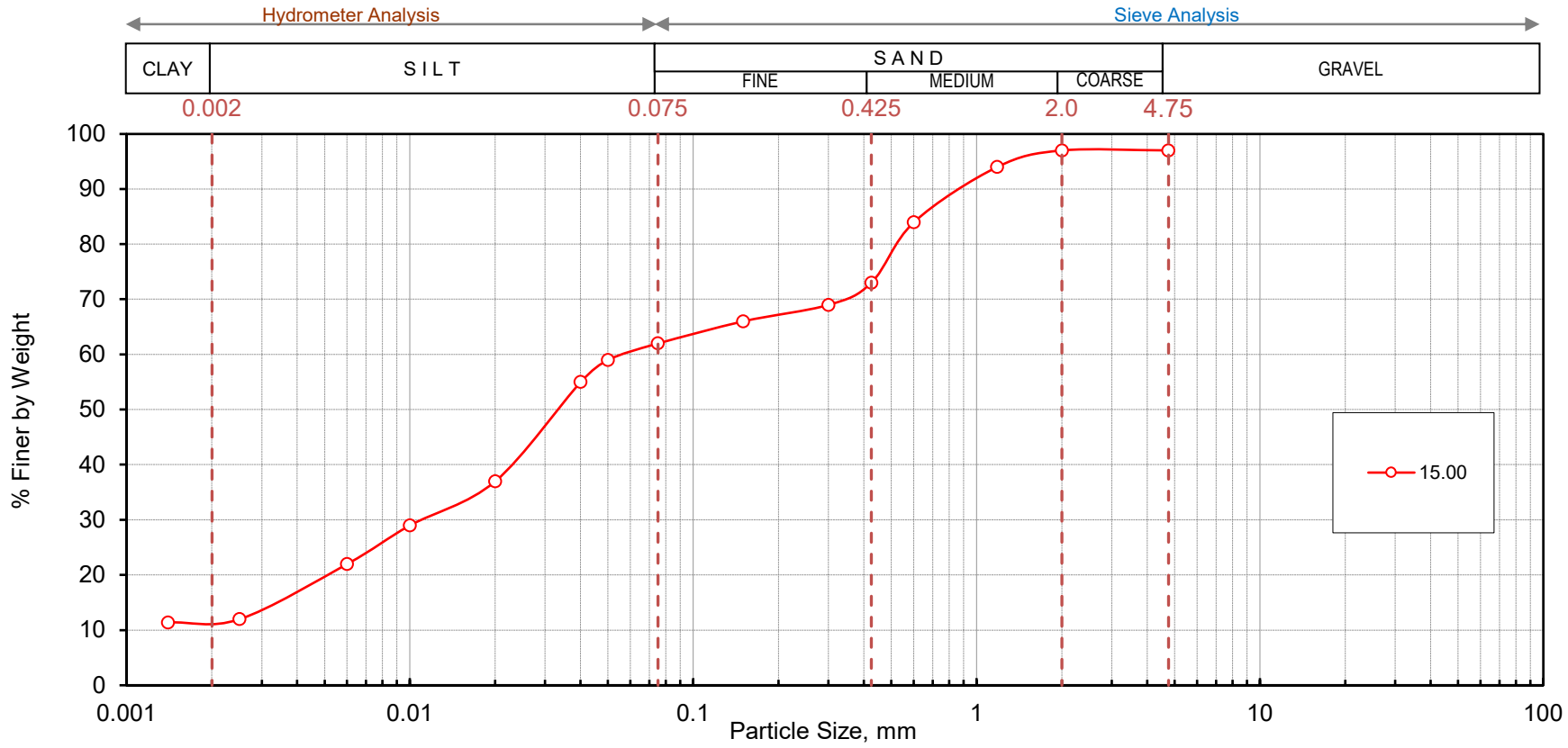

| Sample Details | | | | Test Results | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | Borehole Number | Sample Depth, m | Sample Description | Gravel % | Sand % | Silt % | Clay % | | $D_{60}$ | $D_{30}$ | $D_{10}$ | $C_u$ | $C_c$ |
| Bakkarwala | BH-4 | 3.00 | Clayey silt (CL) | 2 | 37 | 51 | 10 | | 0.063 | 0.013 | | | |
| | BH-4 | 10.50 | Fine sand (SP-SM) | 3 | 90 | 7 | 0 | | 0.736 | 0.380 | 0.113 | 6.6 | 1.75 |
| | BH-4 | 15.00 | Sandy silt (ML) | 3 | 34 | 51 | 12 | | 0.047 | 0.012 | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

## Grain Size Distribution



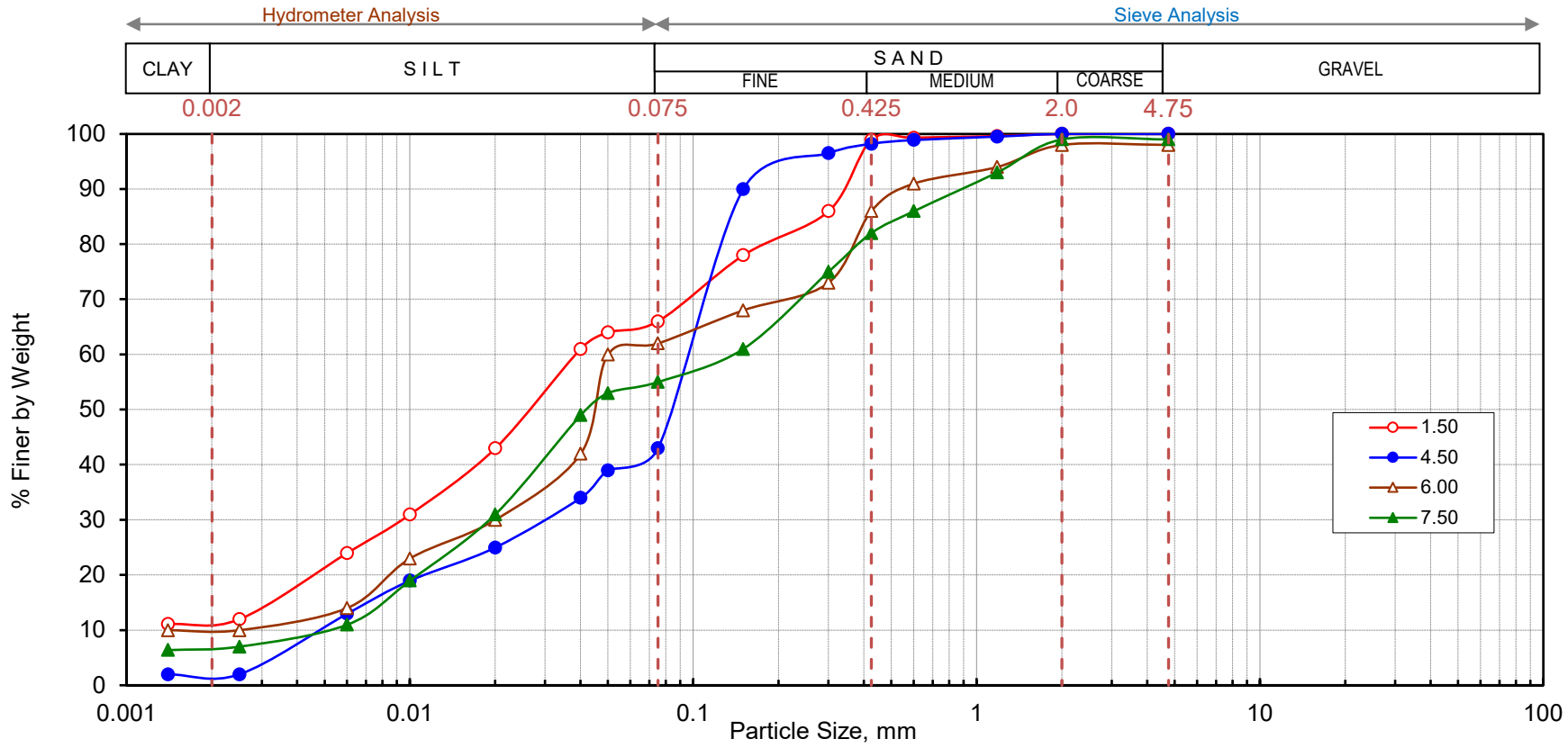

| Sample Details | | | | Test Results | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | Borehole Number | Sample Depth, m | Sample Description | Gravel % | Sand % | Silt % | Clay % | | $D_{60}$ | $D_{30}$ | $D_{10}$ | $C_u$ | $C_c$ |
| Bakkarwala | BH-4 | 1.50 | Clayey silt (CL) | 1 | 33 | 54 | 12 | | 0.039 | 0.008 | | | |
| | BH-4 | 4.50 | Fine sand (SP-SM) | 2 | 92 | 6 | 0 | | 0.123 | 0.096 | 0.079 | 1.6 | 0.96 |
| | BH-4 | 6.00 | Silty sand (SM) | 2 | 52 | 43 | 3 | | 0.133 | 0.016 | 0.004 | 32.3 | 0.48 |
| | BH-4 | 7.50 | Fine sand (SP-SM) | 2 | 89 | 9 | 0 | | 0.513 | 0.279 | 0.083 | 6.2 | 1.82 |
| | BH-4 | 10.50 | Sandy silt (ML) | 1 | 48 | 49 | 2 | | 0.171 | 0.022 | 0.007 | 26.1 | 0.44 |

## Grain Size Distribution



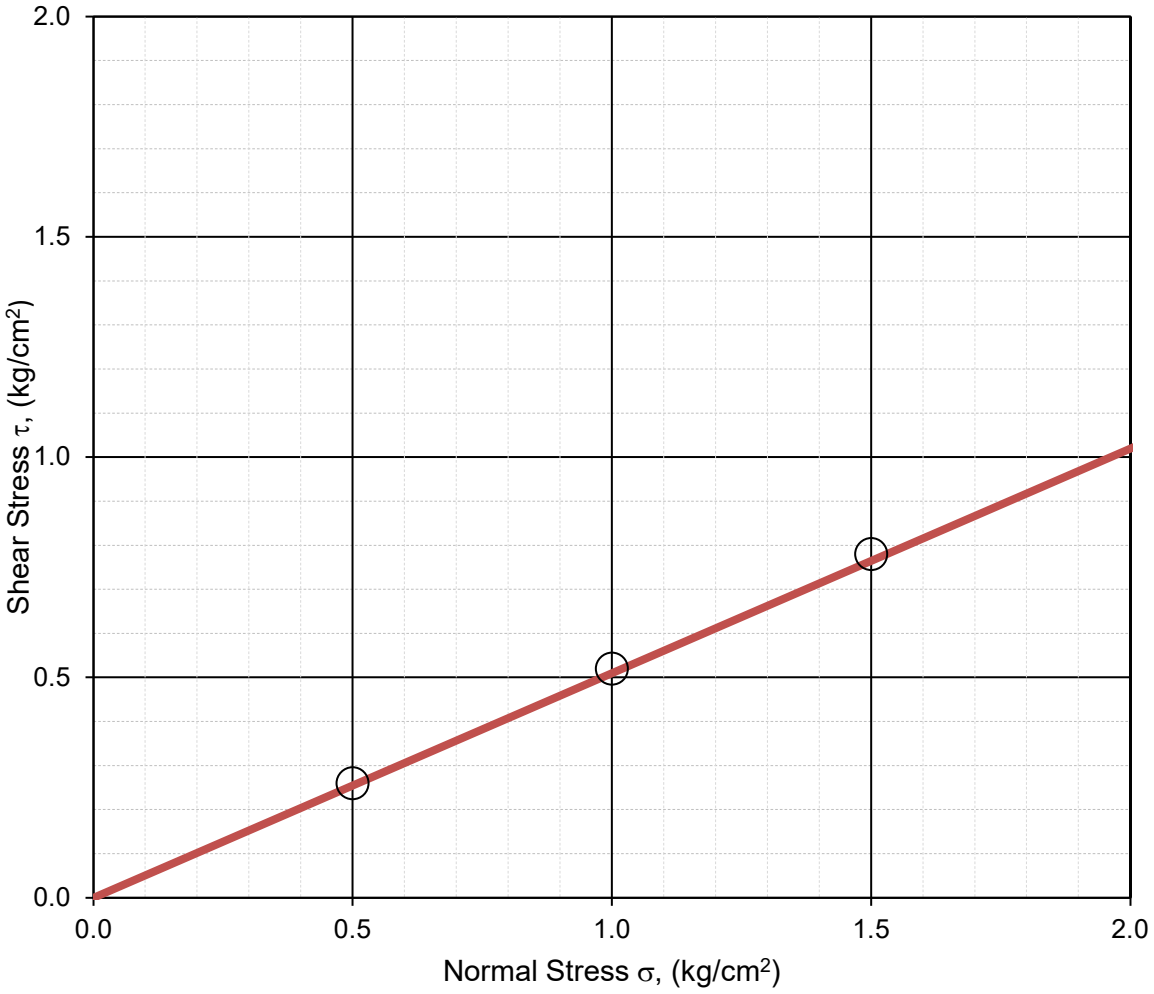

| Sample Details | | | | Test Results | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | Borehole Number | Sample Depth, m | Sample Description | Gravel % | Sand % | Silt % | Clay % | | $D_{60}$ | $D_{30}$ | $D_{10}$ | $C_u$ | $C_c$ |
| Bakkarwala | BH-5 | 15.00 | Clayey silt (CL) | 3 | 35 | 50 | 12 | | 0.058 | 0.011 | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

## Grain Size Distribution




| Sample Details | | | | Test Results | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | Borehole Number | Sample Depth, m | Sample Description | Gravel % | Sand % | Silt % | Clay % | | $D_{60}$ | $D_{30}$ | $D_{10}$ | $C_u$ | $C_c$ |
| Bakkarwala | BH-6 | 1.50 | Clayey silt (CL) | 0 | 34 | 54 | 12 | | 0.039 | 0.009 | | | |
| | BH-6 | 4.50 | Silty sand (SM) | 0 | 57 | 41 | 2 | | 0.102 | 0.031 | 0.005 | 20.2 | 1.88 |
| | BH-6 | 6.00 | Clayey silt (CL) | 2 | 36 | 52 | 10 | | 0.050 | 0.020 | | | |
| | BH-6 | 7.50 | Clayey silt (ML-CL) | 1 | 44 | 48 | 7 | | 0.138 | 0.019 | 0.005 | 26.8 | 0.52 |
| | | | | | | | | | | | | | |

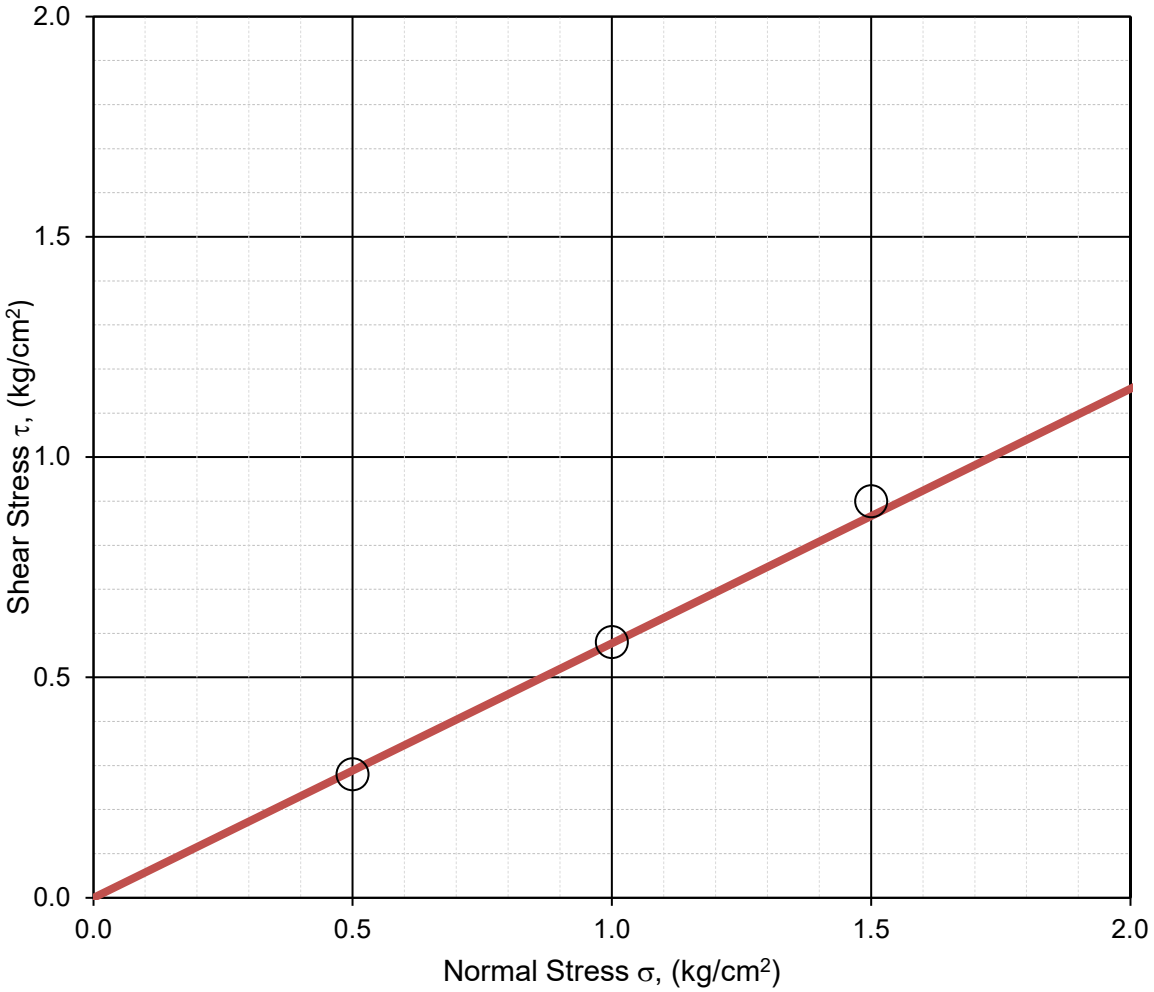
## Grain Size Distribution




| | | |
|---|---|---|
| Borehole No. | = | 1 |
| Sample Depth, m | = | 2.25 |
| Sample Description | = | Silty sand |

| | | |
|---|---|---|
| **Cohesion Intercept, c (kg/cm²)** | = | **0** |
| **Angle of Internal Friction, ø (degrees)** | = | **27** |

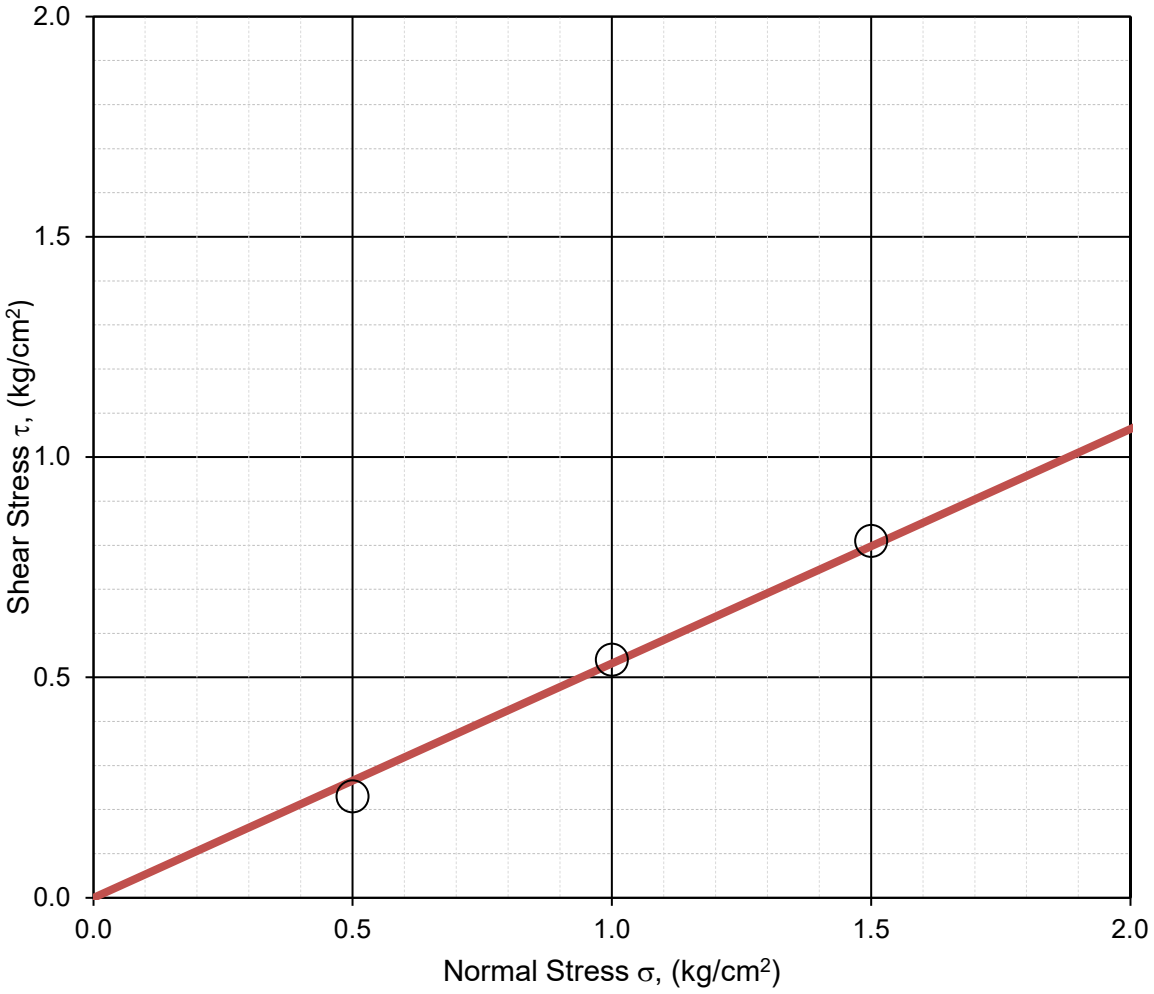
## Consolidated Drained Direct Shear Test




| | | |
|---|---|---|
| Borehole No. | = | 1 |
| Sample Depth, m | = | 11.25 |
| Sample Description | = | Silty sand |

| | | |
|---|---|---|
| **Cohesion Intercept, c (kg/cm²)** | = | **0** |
| **Angle of Internal Friction, ø (degrees)** | = | **30** |

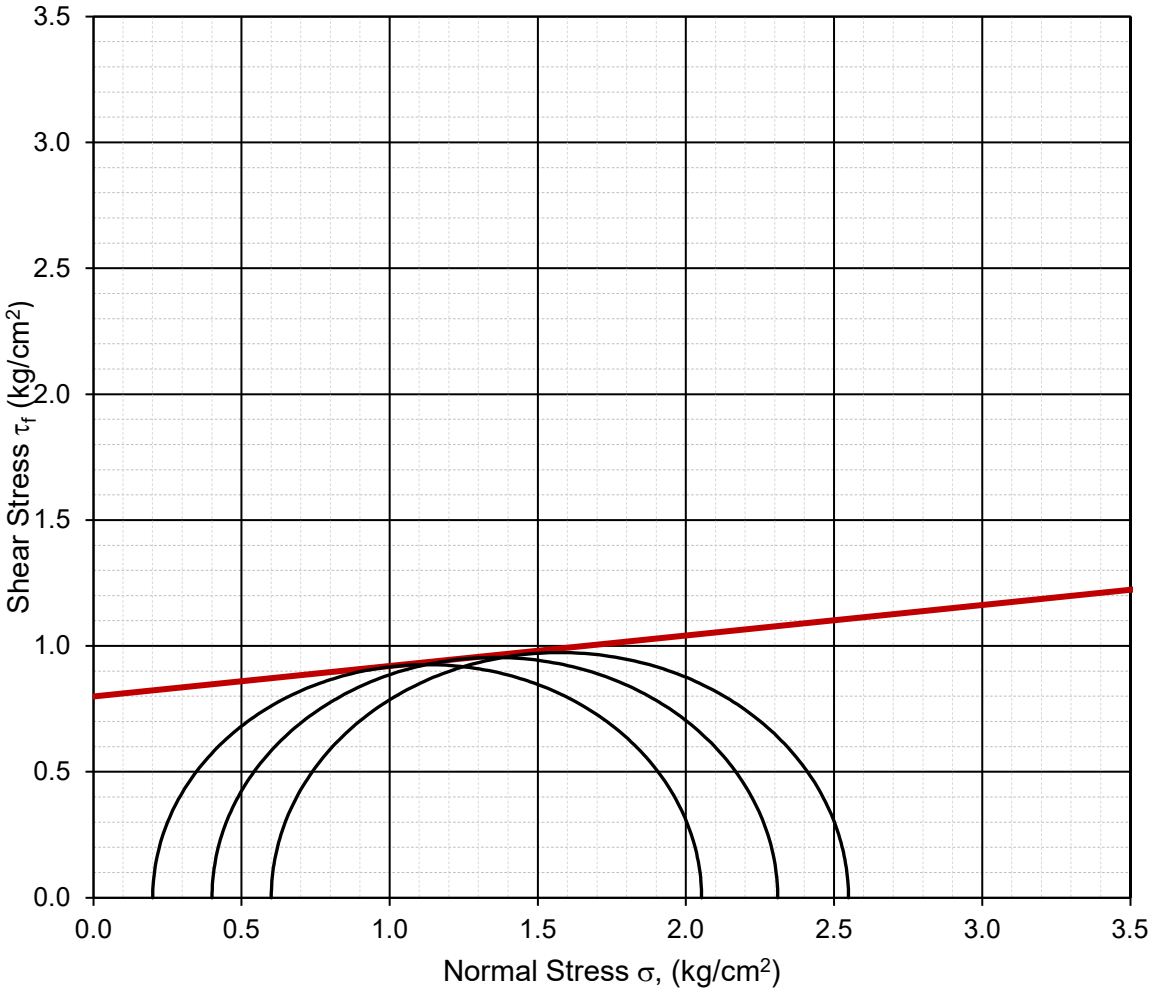
## Consolidated Drained Direct Shear Test




| | | |
|---|---|---|
| Borehole No. | = | 2 |
| Sample Depth, m | = | 5.25 |
| Sample Description | = | Silty sand |

| | | |
|---|---|---|
| **Cohesion Intercept, c (kg/cm²)** | = | **0** |
| **Angle of Internal Friction, ø (degrees)** | = | **28** |

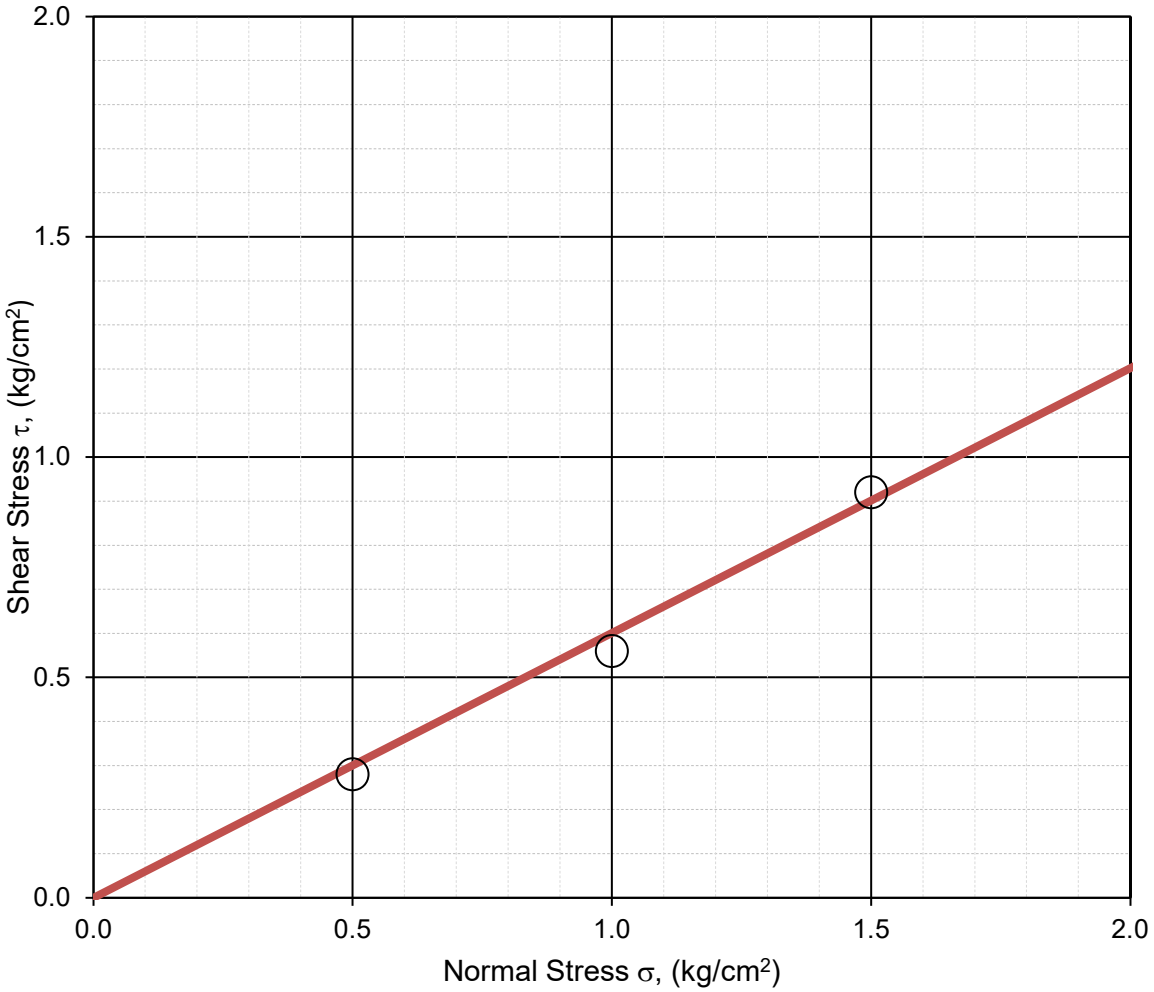
## Consolidated Drained Direct Shear Test




| | | |
|---|---|---|
| Borehole No. | = | 2 |
| Sample Depth, m | = | 8.25 |
| Sample Description | = | Sandy silt |

| | | |
|---|---|---|
| **Cohesion Intercept, c (kg/cm$^2$)** | = | **0.8** |
| **Angle of Internal Friction, ø (degrees)** | = | **6.9** |

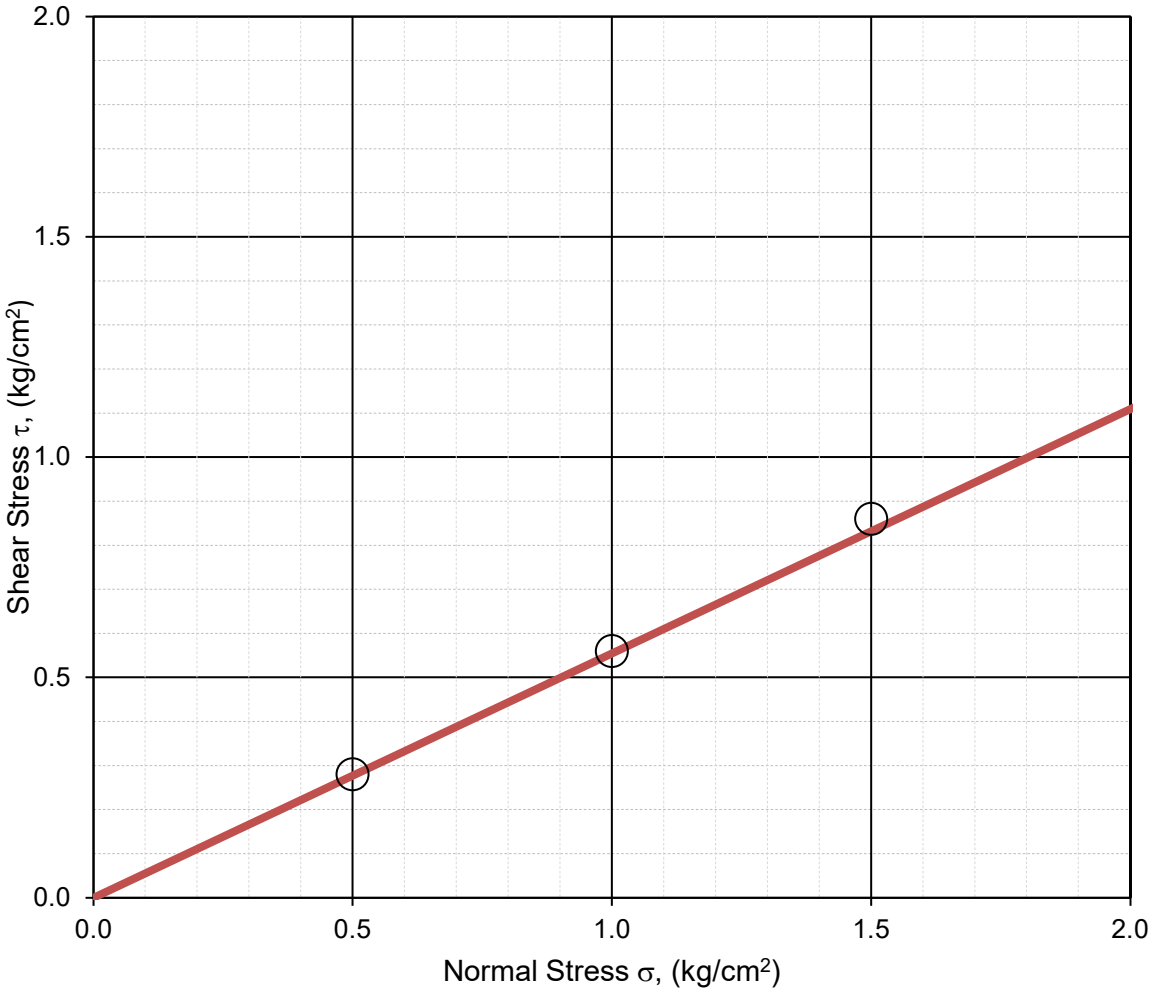
## Unconsolidation Undrained Triaxial Test




| | | |
|---|---|---|
| Borehole No. | = | 2 |
| Sample Depth, m | = | 14.25 |
| Sample Description | = | Silty sand |

| | | |
|---|---|---|
| **Cohesion Intercept, c (kg/cm²)** | = | **0** |
| **Angle of Internal Friction, ø (degrees)** | = | **31** |

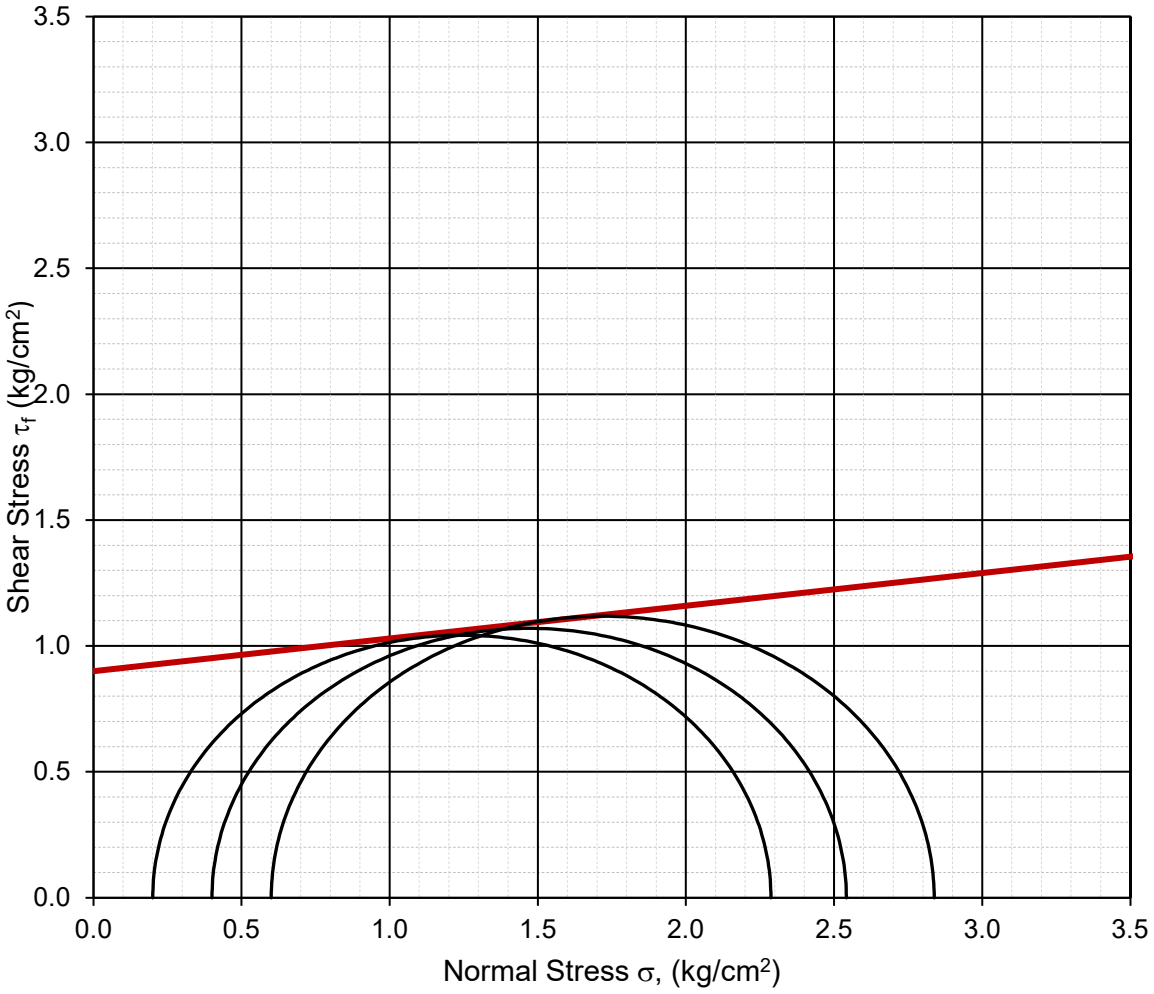
## Consolidated Drained Direct Shear Test




| | | |
|---|---|---|
| Borehole No. | = | 3 |
| Sample Depth, m | = | 8.25 |
| Sample Description | = | Silty sand |

| | | |
|---|---|---|
| **Cohesion Intercept, c (kg/cm$^2$)** | **=** | **0** |
| **Angle of Internal Friction, ø (degrees)** | **=** | **29** |

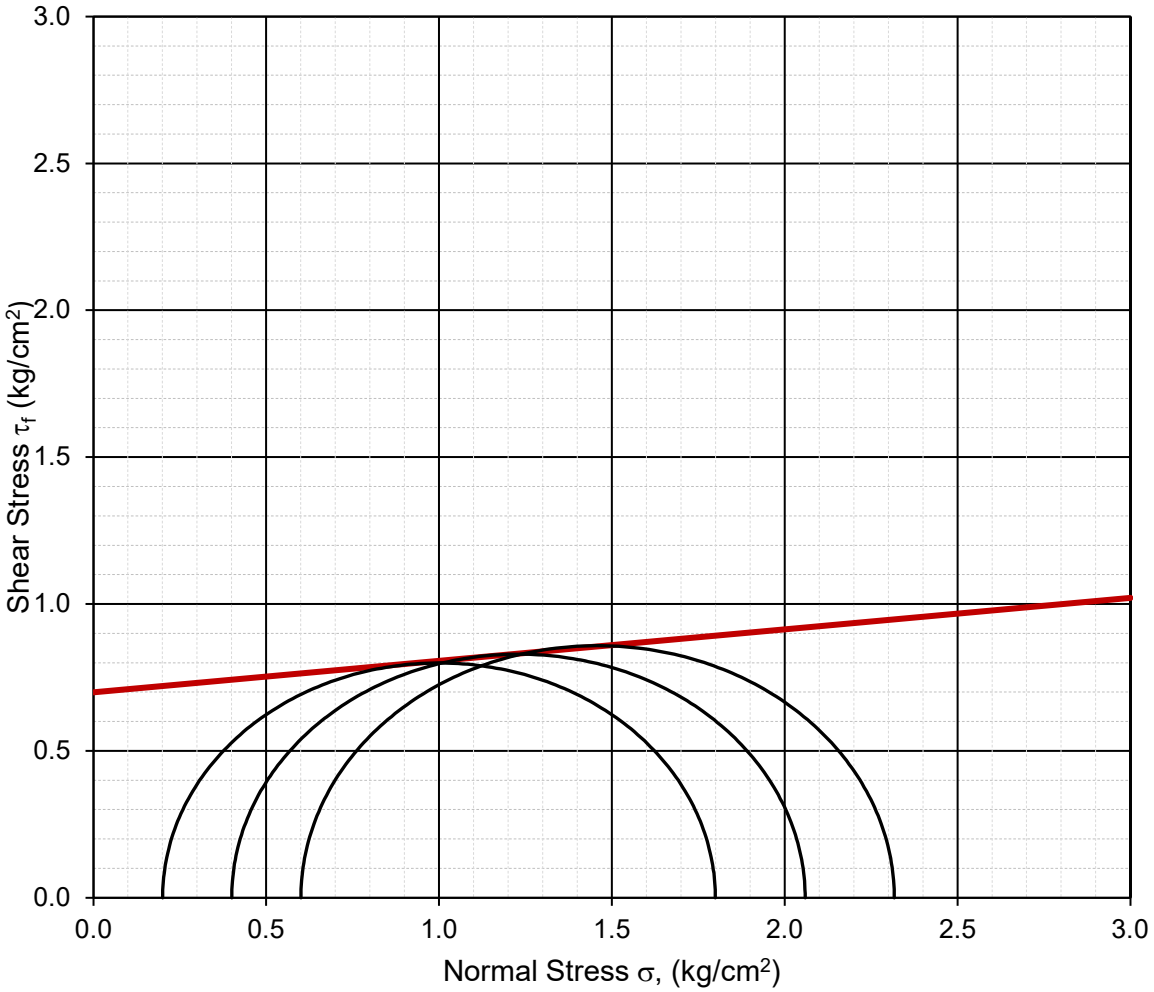
## Consolidated Drained Direct Shear Test




| | | |
|---|---|---|
| Borehole No. | = | 4 |
| Sample Depth, m | = | 8.25 |
| Sample Description | = | Clayey silt |

| | | |
|---|---|---|
| **Cohesion Intercept, c (kg/cm$^2$)** | = | **0.9** |
| **Angle of Internal Friction, ø (degrees)** | = | **7.4** |

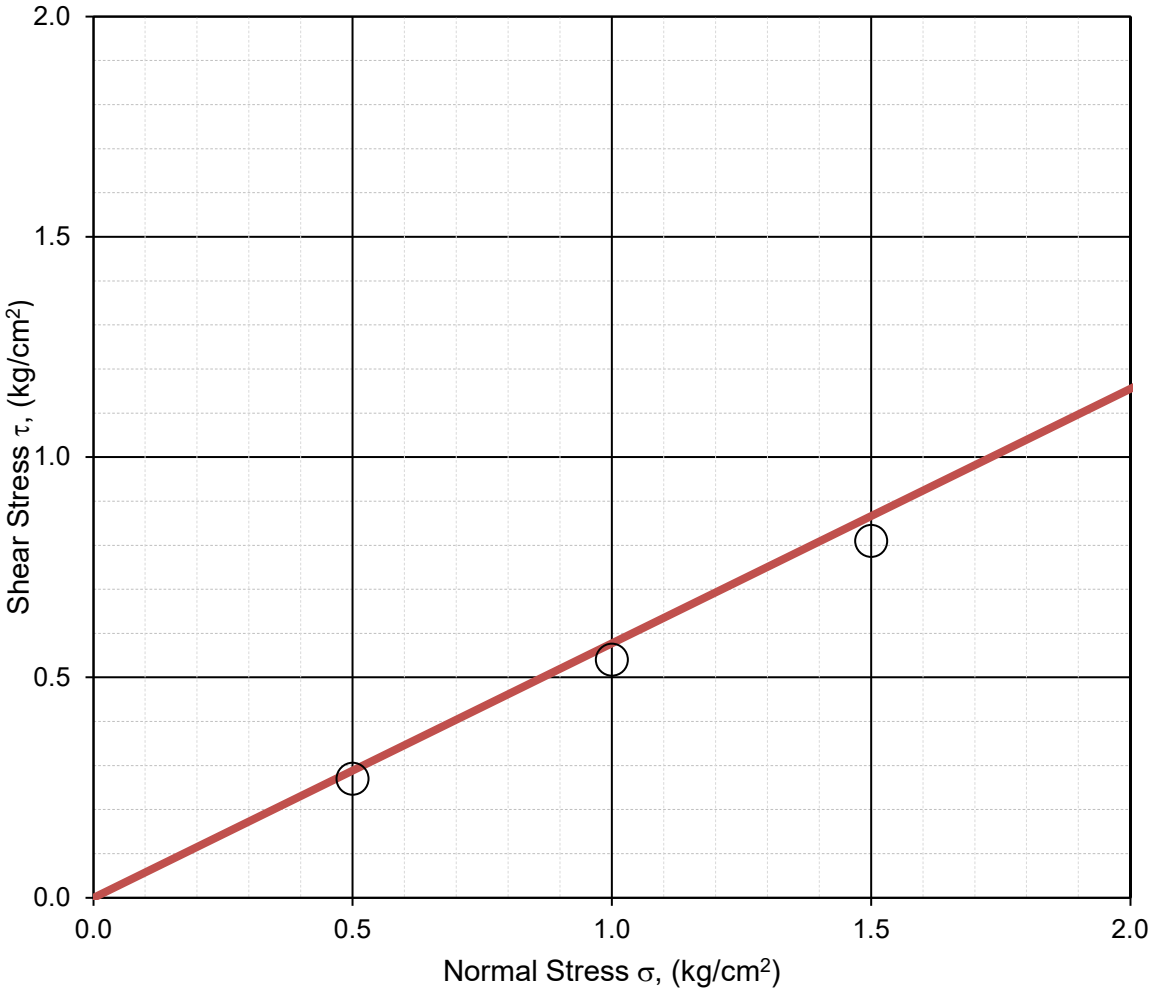
## Unconsolidation Undrained Triaxial Test




| | | |
|---|---|---|
| Borehole No. | = | 4 |
| Sample Depth, m | = | 8.25 |
| Sample Description | = | Clayey silt |

| | | |
|---|---|---|
| **Cohesion Intercept, c (kg/cm$^2$)** | = | **0.7** |
| **Angle of Internal Friction, ø (degrees)** | = | **6.1** |

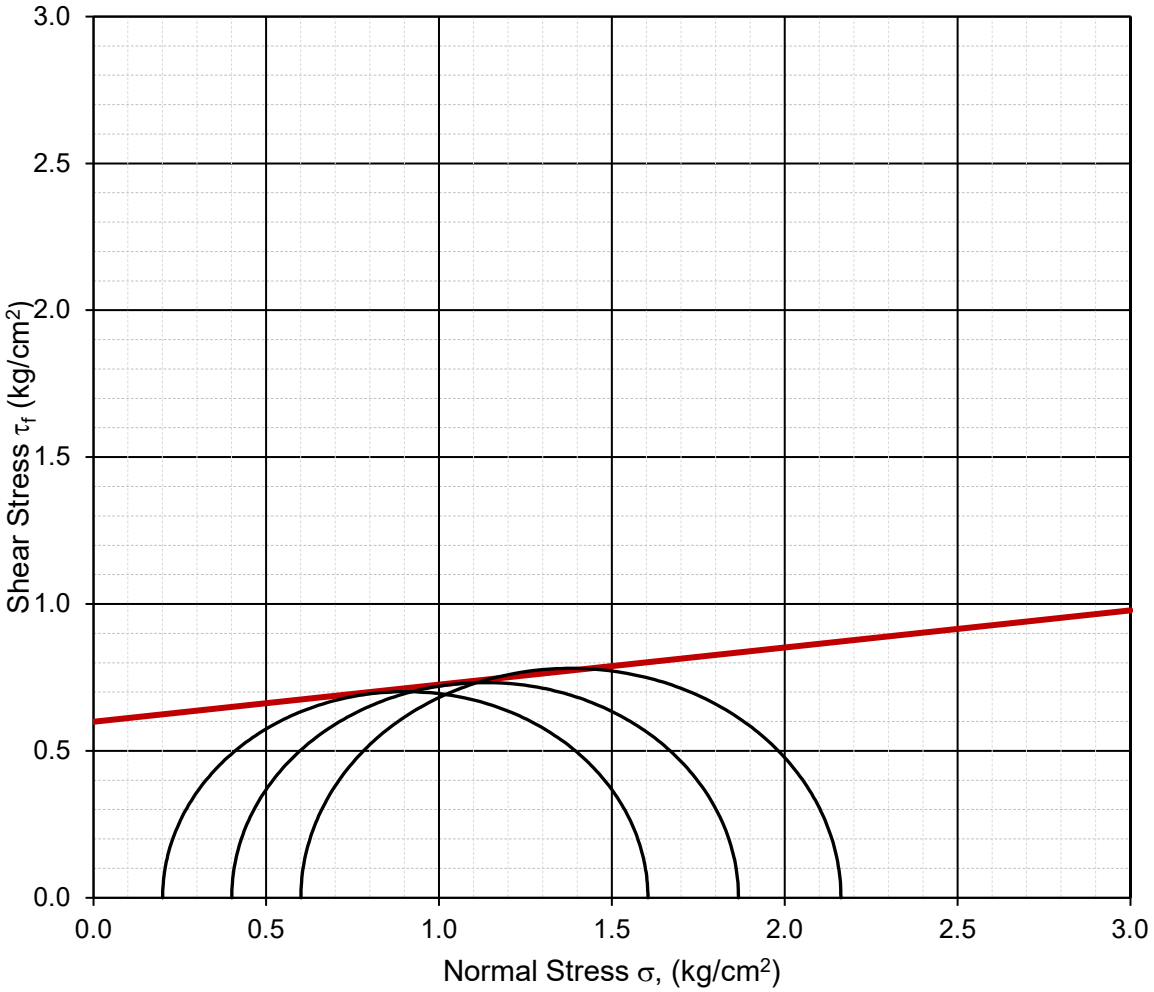
## Unconsolidation Undrained Triaxial Test




| | | |
|---|---|---|
| Borehole No. | = | 4 |
| Sample Depth, m | = | 14.25 |
| Sample Description | = | Silty sand |

| | | |
|---|---|---|
| **Cohesion Intercept, c (kg/cm²)** | = | **0** |
| **Angle of Internal Friction, ø (degrees)** | = | **30** |

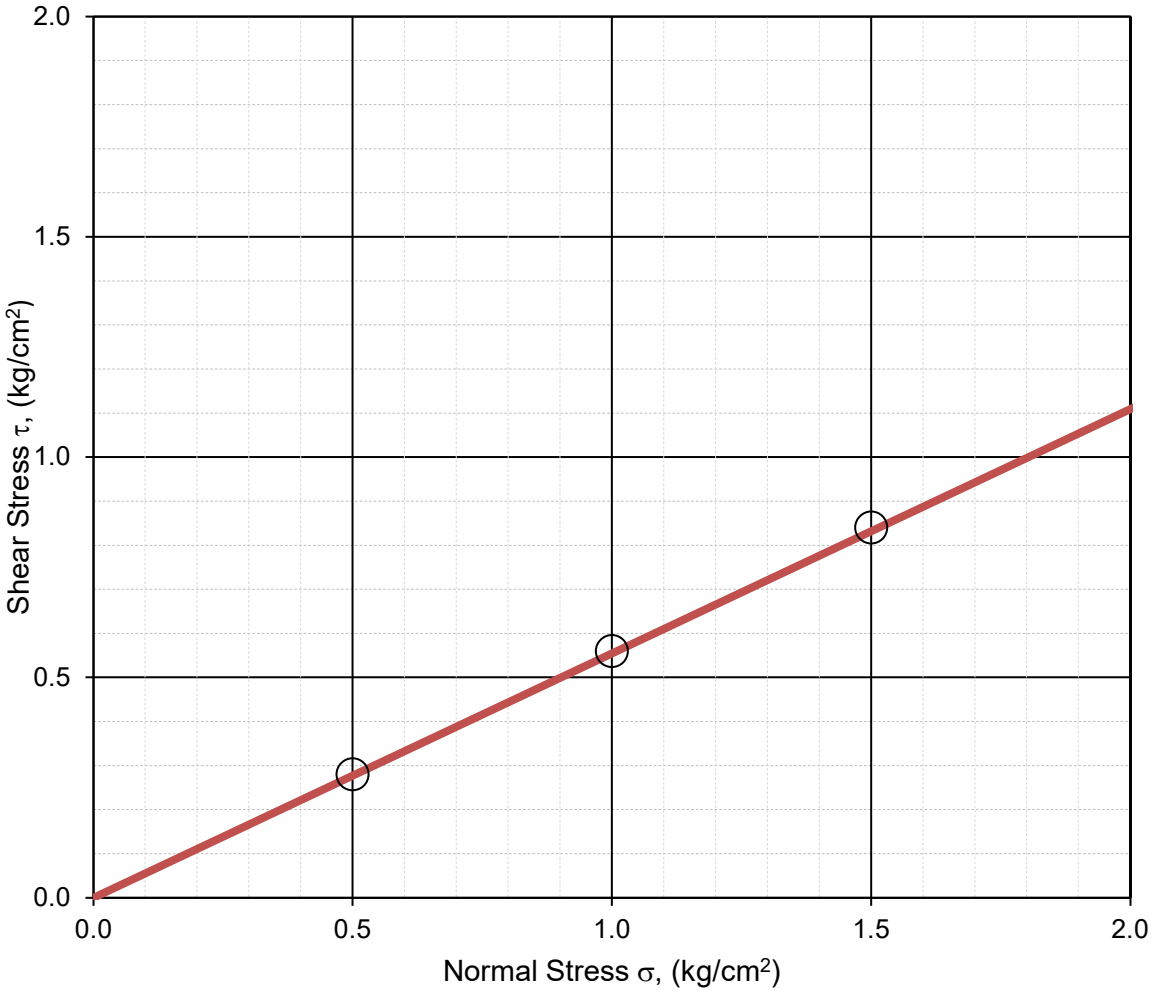
## Consolidated Drained Direct Shear Test




| | | |
|---|---|---|
| Borehole No. | = | 5 |
| Sample Depth, m | = | 5.25 |
| Sample Description | = | Clayey silt |

| | | |
|---|---|---|
| **Cohesion Intercept, c (kg/cm$^2$)** | **=** | **0.6** |
| **Angle of Internal Friction, ø (degrees)** | **=** | **7.2** |

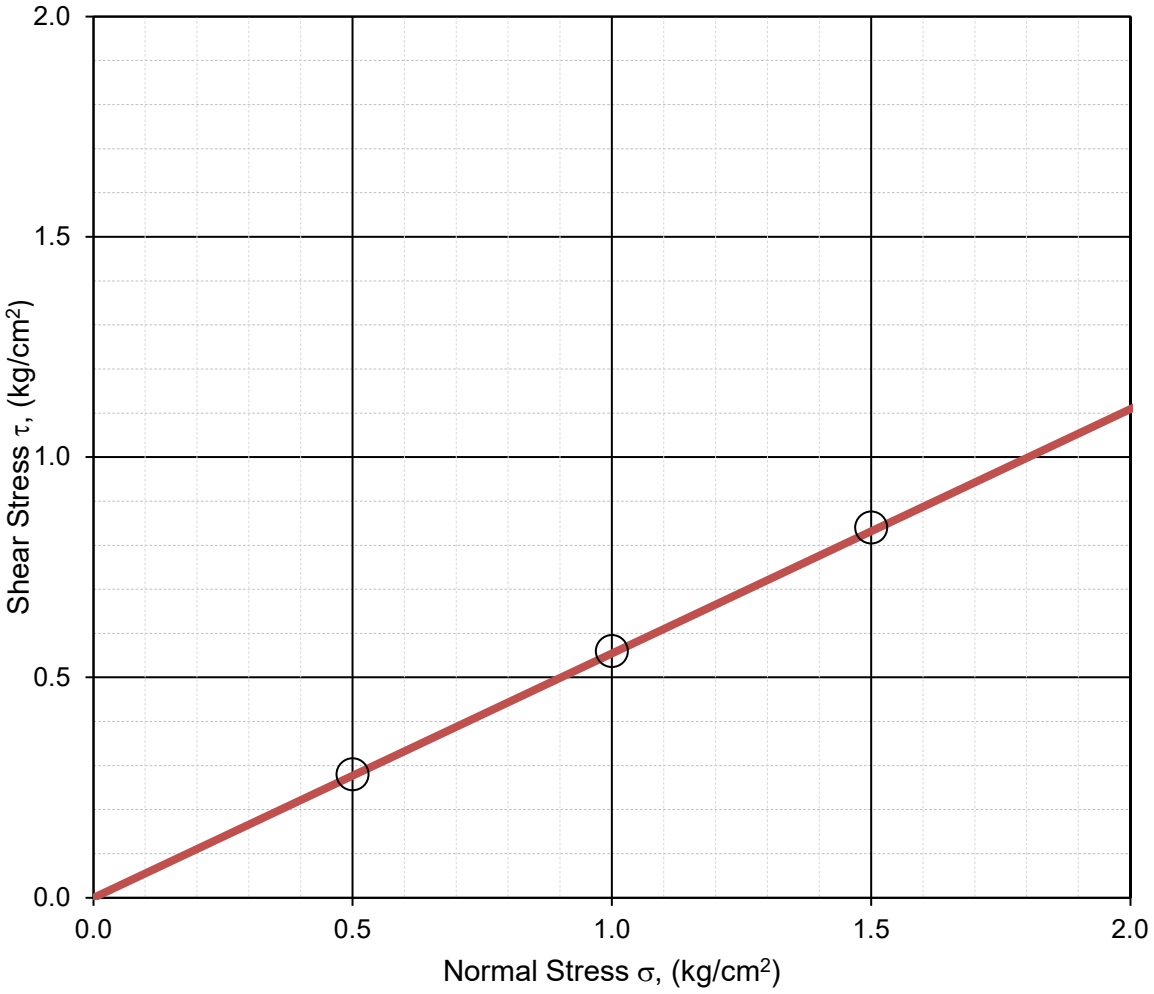
## Unconsolidation Undrained Triaxial Test




| | | |
|---|---|---|
| Borehole No. | = | 5 |
| Sample Depth, m | = | 8.25 |
| Sample Description | = | Silty sand |

| | | |
|---|---|---|
| **Cohesion Intercept, c (kg/cm²)** | **=** | **0** |
| **Angle of Internal Friction, ø (degrees)** | **=** | **29** |

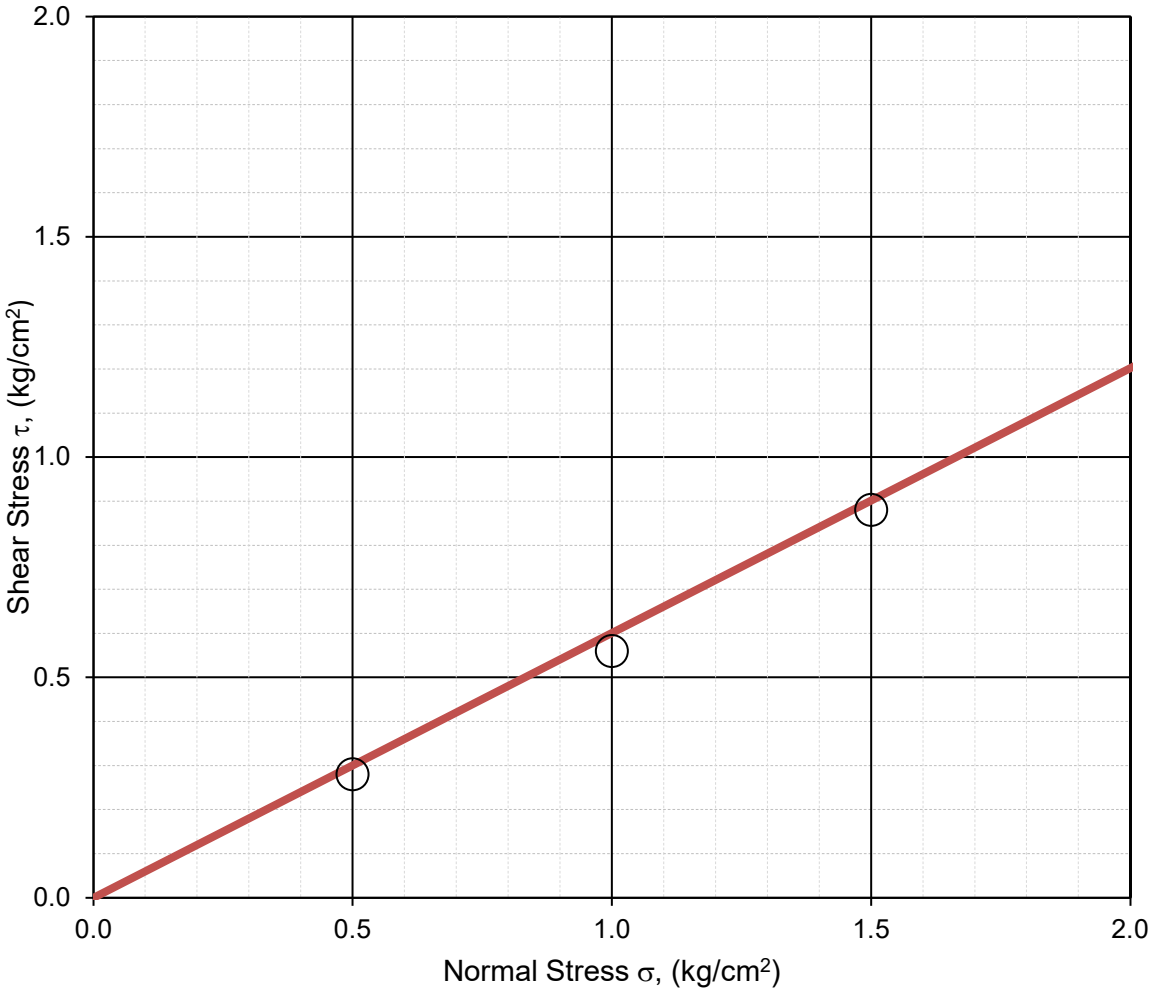
## Consolidated Drained Direct Shear Test




| | | |
|---|---|---|
| Borehole No. | = | 6 |
| Sample Depth, m | = | 8.25 |
| Sample Description | = | Silty sand |

| | | |
|---|---|---|
| **Cohesion Intercept, c (kg/cm$^2$)** | **=** | **0** |
| **Angle of Internal Friction, ø (degrees)** | **=** | **29** |

## Consolidated Drained Direct Shear Test




| | | |
|---|---|---|
| Borehole No. | = | 6 |
| Sample Depth, m | = | 14.25 |
| Sample Description | = | Sandy silt |

| | | |
|---|---|---|
| **Cohesion Intercept, c (kg/cm²)** | = | **0** |
| **Angle of Internal Friction, ø (degrees)** | = | **31** |

## Consolidated Drained Direct Shear Test

# CHEMICAL TEST RESULTS

## SOIL-EXTRACT WATER:

| Borehole No. | Depth, m | Sulphate Content ($SO_3$), % | Chloride Content (CL), % | pH Value |
|---|---|---|---|---|
| BH-1 | 0.50 | 0.09 | 0.01 | 7.3 |
| BH-2 | 4.50 | 0.11 | 0.03 | 7.6 |
| BH-3 | 2.00 | 0.12 | 0.05 | 7.4 |
| BH-4 | 5.25 | 0.11 | 0.02 | 7.4 |
| BH-5 | 0.50 | 0.13 | 0.03 | 7.5 |
| BH-6 | 4.50 | 0.11 | 0.04 | 7.1 |

## GROUNDWATER:

| Borehole No. | Depth, m | Sulphate Content ($SO_3$), mg/l | Chloride Content (CL), mg/l | pH Value |
|---|---|---|---|---|
| BH-1 | - | 392 | 132 | 7.0 |
| BH-2 | - | 348 | 140 | 6.9 |
| BH-3 | - | 308 | 145 | 7.2 |
| BH-4 | - | 311 | 210 | 7.8 |
| BH-5 | - | 318 | 78 | 7.0 |
| BH-6 | - | 358 | 149 | 7.7 |

# COMPUTATION OF SAFE PILE CAPACITIES

## Analysis based on IS 2911 (Part 1 / Section 2) : 2010

### A. SAFE AXIAL COMPRESSIVE PILE CAPACITY

$Q_{safe} = (1/FS)\{\Sigma_{1\ to\ n}[(\alpha c + p k \tan\delta) A_s L] + [(cN_c + pN_q + 0.5D\,\gamma' N_\gamma) A_p]\} - W$

### B. SAFE AXIAL PULL-OUT PILE CAPACITY

$Q_{safe} = (1/FS)\{\Sigma_{1\ to\ n}[(\alpha c + p k \tan\delta) A_s L]\} + W$

### C. LATERAL LOAD CARRYING CAPACITY

$H = yn * EI / (e+z_f)^3 \ \xi \ 10^3$

where :

| | | | | | |
|---|---|---|---|---|---|
| $Q_{safe}$ | = | safe axial pile capacity | FS | = | Factor of safety |
| $\alpha$ | = | adhesion factor (*function of* $C_u$) | p | = | Overburden pressure |
| $\delta$ | = | angle of wall friction between soil and pile | c | = | cohesion intercept |
| L | = | Pile segment length in selected layer | k | = | Coefficient of earth pressure |
| $\gamma'$ | = | effective density of soil | D | = | Pile diameter |
| $N_c, N_q, N_\gamma$ | = | Bearing capacity factors | $A_s$ | = | Pile surface area per m length |
| n | = | number of layers | $A_p$ | = | Pile end bearing area |
| y | = | Lateral deflection at pile top | e | = | Free-standing length of pile |
| H | = | Lateral load applied | $z_f$ | = | Depth of fixity |

## GENERALIZED DESIGN PROFILE

| Layer No. | Depth,m | | Soil Classification | c, kN/m$^2$ | $\delta(=\phi)$ degrees | $\gamma$, kN/m$^3$ | k | $\alpha$ | $N_c$ | $N_q$ | $N_\gamma$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | From | To | | | | | | | | | |
| 1 | 0.0 | 3.0 | Fill | 0 | 0 | 16.0 | 1.0 | | | | |
| 2 | 3.0 | 6.0 | Sandy silt | 40 | 5 | 16.5 | 1.0 | 1.00 | 9.0 | | 0.45 |
| 3 | 6.0 | 12.0 | Silty sand | 0 | 29 | 17.5 | 1.0 | | | 18.08 | 19.34 |
| 4 | 12.0 | 15.0 | Sandy silt | 0 | 30 | 18.5 | 1.0 | | | 20.95 | 22.40 |
| 5 | 15.0 | 20.0 | Sandy silt (assumed) | 0 | 30 | 19.0 | 1.0 | | | 20.95 | 22.40 |

Pile Cross section : Circle
Pile Diameter ,D : 300 mm
Pile cut-off Level (COL) : 1.0 m
Design Water Table Depth : 0.0 m
Factor of Safety : 2.5 for compression
3.0 for pull-out
Overburden Pressure to be considered below GL
Overburden pressure constant below 15 pile diameters, i.e. 4.5 m below 0.0 m
i.e. 4.5 m below 0.0 m

Grade of Concrete : M 30
Soil Classification: Cohesive
Normally Consolidated or Preconsolidated Clays? N
Design SPT N Value of Soft NC Clay 4
Saturation : Submerged
Pile Head : Fixed
Free Standing Length of Pile (e) : 0.0 m

Percentage of Ultimate Shaft Resistance to be used for Ultimate Pullout Capacity: 0.7

## COMPUTED SAFE PILE CAPACITIES

| Depth Below GL , m | Pile Length below COL, m | Unit Skin Friction | Skin Friction in Layer | Cumulative Skin Friction ① | Unit End Bearing | Total End Bearing ② | Weight of Pile ③ | Ultimate Compressive Capacity | Safe Compressive Capacity {(①+②)/SF} - ③ | | Ultimate Pullout Capacity | Safe Pullout Capacity ①x/SF + ③ | | Lateral Pile Capacity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $kN/m^2$ | kN | kN | $kN/m^2$ | kN | kN | kN | kN | **MT** | kN | kN | **MT** | **MT** |
| 10.0 | 9.0 | 15 | 49 | 177 | 523 | 37 | 9 | 214 | 77 | **8** | 133 | 50 | **5** | |
| 12.0 | 11.0 | 15 | 9 | 206 | 523 | 37 | 11 | 243 | 86 | **9** | 155 | 59 | **6** | |
| 14.0 | 13.0 | 16 | 21 | 237 | 610 | 43 | 13 | 280 | 99 | **10** | 178 | 68 | **7** | **0.6** |

Moment of Inertia, I : 3.976E-04 $m^4$

Modulus of Elasticity : 27386 MPa

Modulus of Subgrade Reaction, ηh : 0.2 $MN/m^3$

Stiffness Factor, T = 2.22 m

e/T = 0.0

zf/T = 2.19

Depth of Fixity, $z_f$ = 4.87 m

e + $z_f$ = 4.87 m

Permissible Lateral Pile Deflection, y = 5.0 mm

**Computed Lateral Capacity of Pile, H** = 6 **kN**

= **0.6** **Tonnes**