# GEOTECHNICAL REPORT

## PROPOSED PANDAV NAGAR SUBSTATION PROJECT AT PANDAV NAGAR, NEW DELHI

## SUBMITTED TO:

**M/S. BSES YAMUNA POWER LIMITED**

Shakti Kiran Building, 3rd Floor, A-Block, Karkardooma, New Delhi

Project No. 19091 | Dated. June, 2019 | Revision-0


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June 19th, 2019 Project No. 19091

**M/s. BSES Yamuna Power Limited**
Shakti Kiran Building, 3rd Floor,
A-Block, Karkardooma,
New Delhi

**Sub: Final Report on Soil Investigation Work for Proposed Pandav Nagar Substation Project at Pandav Nagar, New Delhi**

We have carried out the soil investigation work for the proposed project. 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 ENGINEERING ENTERPRISES


(G.R.RAO)

## TABLE OF CONTENTS



## 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 Pandav Nagar Substation Project at Pandav Nagar, New Delhi.

M/s. Rao Engineering Enterprises has been retained by M/s. BSES Yamuna 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 three (3) boreholes to 10.0 m depth or refusal whichever is encountered earlier, observing ground water table levels, conducting required field and laboratory tests and their analysis.
3. conducting one (1) electrical resistivity test (ERT's) to provide data for the grounding systems;
4. conducting one (1) plate load test at specified location and depth to assess the load-settlement behavior of soils under loading;
5. Preparation and submission of technical report in triplicate.

Electrical Resistivity test (ERT) was not performed at the site due to non-availability of space and also filled up material was encountered at site to about 2.0 m depth below EGL.

## 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 (soil) 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's 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.

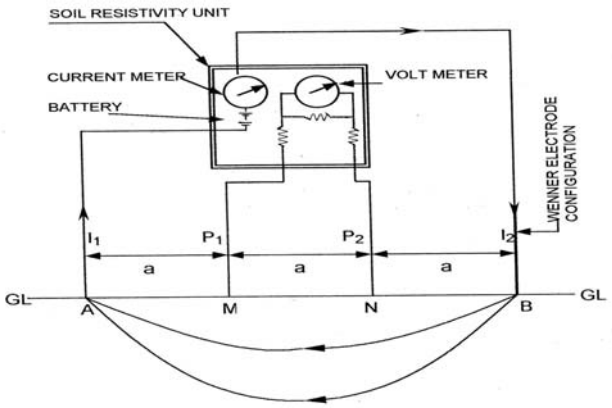
Measurements are made by causing a current, 'I', to pass through the earth and distribute within a relatively large hemispherical earth mass. The portion of the current that flows along the surface produces a voltage drop, 'V'. The resistance 'R', ratio of voltage drop 'V' to current 'I' is directly 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. The schematic arrangement of electrodes is shown below:




NOTE: $I_1$ AND $I_2$ ARE CURRENT ELECTRODES

$P_1$ AND $P_2$ ARE POTENTIAL ELECTRODES

## 3.0 LABORATORY TESTS

Laboratory tests have been conducted on various selected soil and 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 |
| Unconfined Compression Test | | IS : 2720 (Part-10)-1991, RA-2010 |
| Unconsolidated Undrained Triaxial Shear Test | | IS : 2720 (Part-11)-1993, RA-2007 |
| Consolidated Drained Direct Shear Test | | IS : 2720 (Part-13)-1986, RA-2010 |
| 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 |
| 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 |

## 4.0 GENERAL SITE CONDITIONS

### 4.1 Site Stratigraphy

A heterogenous fill of sandy silt with brick bats and polyethene was encountered to about 2.0 m depth below EGL. Below fill material, clayey silt / sandy silt was encountered to about 9.5 m depth and underlain by fine sand to the final explored depth of 10.45 m.

The field SPT N-values generally range from 10 to 14 to about 2.0 m depth. Below this the field SPT N value range from 10 to 15 to about 5.0 m depth below EGL. Further SPT N-values range from 4 to 8 to about 9.5 m depth and range from 20 to 23 to the final explored depth of 10.45 m. The Soil is soft to firm in condition in between 5.0 and 9.5 m depth.

All test results are presented on the individual soil profiles on Sheet No. 1 to 3. A summary of the borehole profiles is illustrated on Sheet No. 4. Plots of field and corrected SPT values versus depth are presented on Sheet No. 5 & 6, respectively.

### 4.2 Groundwater

Based on our measurements in the completed boreholes, groundwater was met at 8.2~8.4 m depth below EGL during the period of our field investigations (June, 2019). Fluctuations may occur in the measured ground levels due to seasonal variations in rainfall, surface evaporation rates.

## 5.0 FIELD TEST RESULTS

### 5.1 Plate Load Test Details

One (1) plate load test was conducted on a 30 cm x 30 cm size square plate. The test details are as follows:

| Test Designation | Test Depth, m | Presentations of Test Results |
|---|---|---|
| PLT-1 | 2.5 | Sheet No. 7 & 8 |

### 5.2 Test Results

The following table summarizes the measured settlements of the plate under various loading intensities, as well as the interpreted ultimate bearing capacity (shear criterion) and modulus of subgrade reaction (k):

| Test No. | Measured Settlement (mm) under Applied Bearing Pressure of | | | | | | Ultimate Bearing Capacity, $Kg/cm^2$ | Computed modulus of Subgrade Reaction (k) for 75 cm size plate, $kg/cm^3$ |
|---|---|---|---|---|---|---|---|---|
| | 5 $T/m^2$ | 10 $T/m^2$ | 15 $T/m^2$ | 20 $T/m^2$ | 25 $T/m^2$ | 30 $T/m^2$ | | |
| PLT-1 | 0.8 | 1.6 | 2.0 | 2.7 | 3.4 | 4.2 | 3.30 | 1.22 |

Necessary corrections for curvature, plate bending, plate size and saturation have been applied to the "k-values" as per IS Code: 9214-1979 (RA-2007).

5.3 Interpretation of Plate Load Tests Results

The settlement for 3 m size foundations has been[1] extrapolated using the following equation applicable for soil encountered at the site;

$$\frac{S_f}{S_p} = \frac{B_f}{B_p}$$

where:

$S_f$ = settlement of foundation in mm.
$S_p$ = settlement of test plate in mm
$B_f$ = width of the foundation in m
$B_p$ = width of the plate in m

A multiplying factor of 2.0 has been applied to account for saturation. A multiplying factor of 2.0 has been applied to account for local variations in strata conditions. The following table summarizes the interpreted settlements for large-size foundations bearing at the test level:

| Test No. | Estimated Settlement for 3 m size foundations under applied bearing pressure of (mm) | | | | | |
|---|---|---|---|---|---|---|
| | 5 T/m$^2$ | 10 T/m$^2$ | 15 T/m$^2$ | 20 T/m$^2$ | 25 T/m$^2$ | 30 T/m$^2$ |
| PLT-1 | 32.0 | 64.0 | 80.0 | 108.0 | 136.0 | 168.0 |

The final values of safe bearing capacity for foundation design should be selected in conjunction with borehole and other field data.

5.4 Limitations of Plate Load Tests

The analysis presented in this report is governed by the inherent limitations of plate load test. They are:

- The analysis is applicable only for uniform isotropic formations. Stratified deposits are not modeled effectively by the test.
- The test stresses the soils only to a depth of "2 $B_p$" below test level ($B_p$= plate width). Large size foundations will stress the deeper soils also. However, the behavior of the deeper soils cannot be evaluated by the test.

[1] Narayan V. Nayak "***Foundation Design Manual"***, Page no. 101, Sec-2.7.2.1

- The load test results do not take in to account the saturation / ground water table effect as ground water table is below the influence depth.

- The settlement measured during the test is primarily immediate settlement. Consolidation or long term settlement cannot be assessed by the test.

- The similitude law used for extrapolation of the test data may, at best, be treated as an approximation. Therefore, the final values of soil bearing capacity for foundation design should be selected after review of borehole data also.

## 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.

Reviewing the stratigraphy of the site on the basis of boreholes data, SPT values & laboratory test results, we found that fill is encountered at the site to about 2.0 m depth and cohesive soil is encountered in between 5.0 and 9.5 m depth, soft to firm in condition.

RCC bored cast pile foundations is suitable to support the structural load. Recommendations are presented herein for 300 mm & 400 mm diameter RCC bored cast-in-situ piles.

### 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* |
| *α* | = | *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 : 1.0~1.5 m below EGL for without basement area
- Groundwater table : Considered at 5 m depth for Worst Case

- 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, and 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 | 13 | 9 | 2.8 |
| | 10.0 | 17 | 10 | |
| | 11.0 | 18 | 11 | |
| 400 | 9.0 | 18 | 13 | 3.8 |
| | 10.0 | 25 | 14 | |
| | 11.0 | 27 | 16 | |
| 500 | 9.0 | 23 | 17 | 4.7 |
| | 10.0 | 36 | 19 | |
| | 11.0 | 39 | 21 | |

* 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. Stratum below the maximum explored depth at the structure location is assumed similar as above stratum due to insufficient data.

7. A detailed geotechnical investigation should be carried out with sufficient boreholes to at least 15 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. 12. The results indicate that the soils contain 0.11-0.16 percent sulphates and 0.10-0.14 percent chlorides and groundwater contain 289-340 percent sulphates and 144-179 percent chlorides. The pH value of soil is 7.3-7.5 and groundwater is 7.4-7.6.

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 8.2-8.4 m encountered at the site during our field investigation and is not likely to influence foundation concrete. Therefore, strata at the site may be treated in **Class-1** 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) The cement content in pile cap concrete should be at least 281 kg/$m^3$ and concrete of pile is 400 kg/$cm^3$.

(2) Water cement ratio in foundation concrete should generally not exceed 0.55.

(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.

# SOIL PROFILE: BH-1

| Project: | Proposed Pandav Nagar Substation Project at Pandav Nagar, New Delhi | | | Water Table, m : | 8.3 | Project No. | 19091 |
|---|---|---|---|---|---|---|---|
| Date of Start: | 12-Jun-19 | Date of Completion: | 12-Jun-19 | Termination Depth, m : | 10.45 | | |

| Depth, m | | | | | | | Grain Size Analysis | | | | Atterberg Limits | | | | Density and Moisture | | | Shear Tests | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From | To | Sample No. | Field SPT 'N' Value | Symbol | SOIL DESCRIPTION | Depth of Strata, (m) | Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Liquid (%) | Plastic (%) | Plasticity Index (%) | Specific Gravity | Bulk Density (gms/cm$^3$) | Dry Density (gms/cm$^3$) | Moisture Content (%) | Type of Test | Cohesion Intercept, 'c' (kg/cm$^2$) | Angle of Internal Friction, f (degrees) |
| 0.50 | 1.00 | DS-1 | | | Fill: Sandy silt with brick bat & Polyethene | | | | | | | | | | | | | | | |
| 1.50 | 1.95 | SPT-1 | 13 | | | 2.00 | | | | | | | | | | | | | | |
| 2.25 | 2.55 | UDS-1 | | | Light grey clayey silt of medium plasticity (CI) | | 0 | 5 | 74 | 21 | | | | 2.71 | 1.75 | 1.52 | 15.2 | UUT | 0.55 | 9 |
| 3.00 | 3.45 | SPT-2 | 12 | | | | | | | | 41.6 | 23.1 | 18.5 | | | | | | | |
| 4.50 | 4.95 | SPT-3 | 14 | | | | | | | | | | | | | | | | | |
| 5.25 | 5.55 | UDS-2 | | | | | | | | | | | | | 1.83 | 1.54 | 18.6 | | | |
| 6.00 | 6.45 | SPT-4 | 10 | | | | 0 | 3 | 75 | 22 | | | | 2.69 | | | | | | |
| 7.50 | 7.95 | SPT-5 | 5 | | | | | | | | 42.4 | 23.4 | 19.0 | | | | | | | |
| 8.25 | 8.55 | UDS-3 | | | | | | | | | | | | | 1.88 | 1.55 | 21.2 | UUT | 0.45 | 4 |
| 9.00 | 9.45 | SPT-6 | 7 | | | 9.50 | 0 | 6 | 74 | 20 | | | | | | | | | | |
| 10.00 | 10.45 | SPT-7 | 22 | | Light grey fine sand (SP-SM) | 10.45 | 0 | 92 | 8 | 0 | | | | 2.62 | | | | | | |

UUT : Unconsolidated Undrained Triaxial Shear Test DST: Drained Direct Shear Test, UCS : Unconfined Compressive Strength Remoulded Sample +

# SOIL PROFILE: BH-2

| Project: | Proposed Pandav Nagar Substation Project at Pandav Nagar, New Delhi | Water Table, m : | 8.2 | Project No. | 19091 |
|---|---|---|---|---|---|
| | | Termination Depth, m : | 10.45 | | |
| Date of Start: | 12-Jun-19 | Date of Completion: | 12-Jun-19 | | |

| Depth, m | | | | | | | Grain Size Analysis | | | | Atterberg Limits | | | | Density and Moisture | | | Shear Tests | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From | To | Sample No. | Field SPT 'N' Value | Symbol | SOIL DESCRIPTION | Depth of Strata, (m) | Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Liquid (%) | Plastic (%) | Plasticity Index (%) | Specific Gravity | Bulk Density (gms/cm$^3$) | Dry Density (gms/cm$^3$) | Moisture Content (%) | Type of Test | Cohesion Intercept, 'c' (kg/cm$^2$) | Angle of Internal Friction, f (degrees) |
| 0.50 | 1.00 | DS-1 | | | Fill: Sandy silt with brick bat & Polyethene | | | | | | | | | | | | | | | |
| 1.50 | 1.95 | SPT-1 | 14 | | | 2.00 | | | | | | | | | | | | | | |
| 2.25 | 2.55 | UDS-1 | | | Light grey clayey silt of medium plasticity (CI) | | 0 | 21 | 65 | 14 | | | | 2.68 | 1.75 | 1.54 | 13.5 | UUT | 0.60 | 8 |
| 3.00 | 3.45 | SPT-2 | 10 | | | 4.50 | | | | | 33.1 | 22.2 | 10.9 | | | | | | | |
| 4.50 | 4.95 | SPT-3 | 14 | | Light grey clayey silt of medium plasticity (CI) | | 0 | 3 | 76 | 21 | | | | | | | | | | |
| 5.25 | 5.55 | UDS-2 | | | | | | | | | 43.2 | 23.2 | 20.0 | 2.71 | 1.78 | 1.52 | 17.4 | UCS | 0.76 | - |
| 6.00 | 6.45 | SPT-4 | 8 | | | | | | | | | | | | | | | | | |
| 7.50 | 7.95 | SPT-5 | 4 | | | | | | | | | | | | | | | | | |
| 8.25 | 8.55 | UDS-3 | | | | | 0 | 4 | 77 | 19 | | | | 2.70 | 1.86 | 1.54 | 20.8 | UUT | 0.55 | 4 |
| 9.00 | 9.45 | SPT-6 | 7 | | | 9.50 | | | | | 40.8 | 22.9 | 17.9 | | | | | | | |
| 10.00 | 10.45 | SPT-7 | 20 | | Light grey fine sand (SP-SM) | 10.45 | 0 | 93 | 7 | 0 | | | | 2.60 | | | | | | |

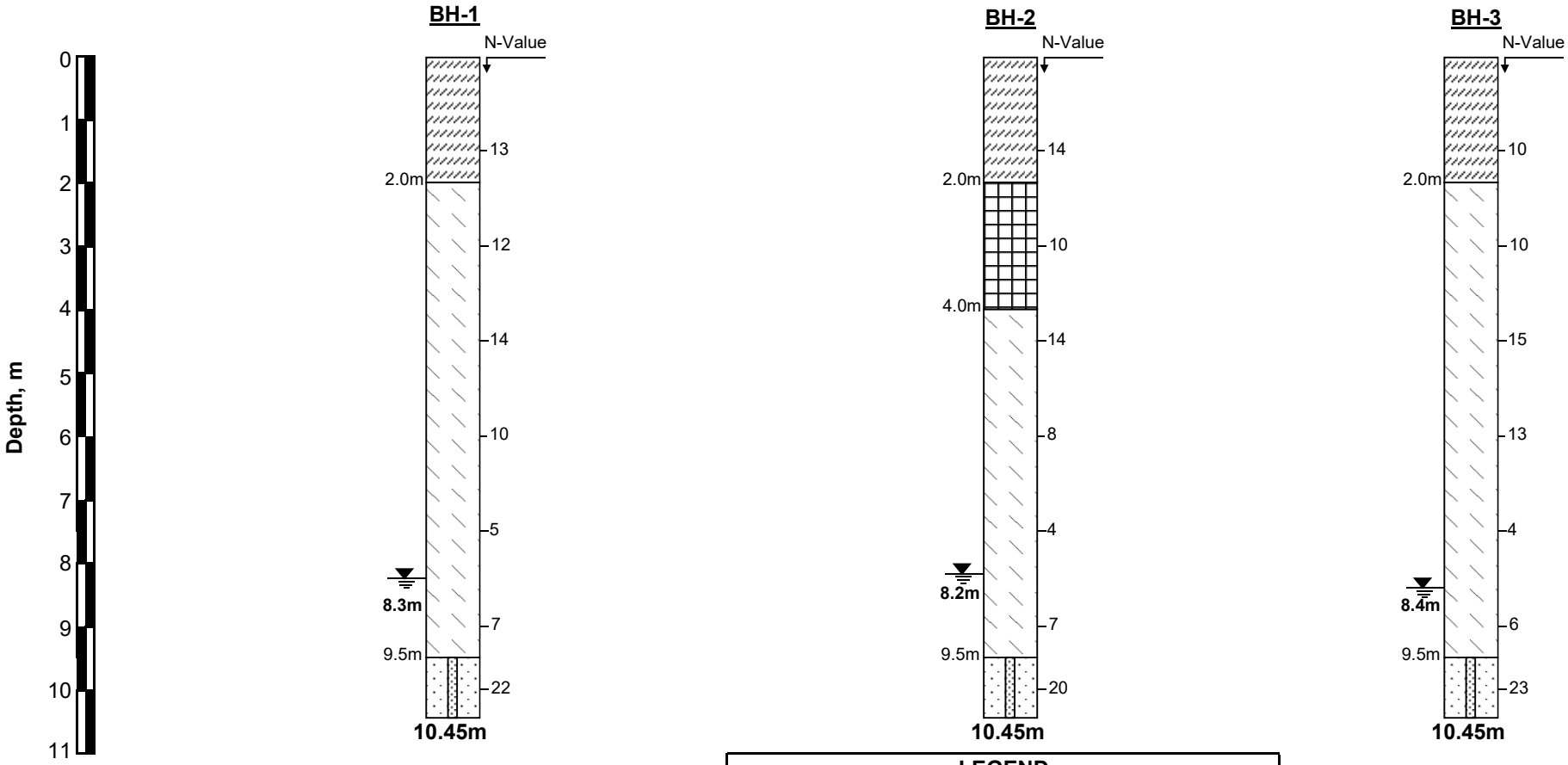
UUT : Unconsolidated Undrained Triaxial Shear Test  DST: Drained Direct Shear Test,  UCS : Unconfined Compressive Strength  Remoulded Sample +

# SOIL PROFILE: BH-3

| Project: | Proposed Pandav Nagar Substation Project at Pandav Nagar, New Delhi | | | Water Table, m : | 8.3 | Project No. | 19091 |
|---|---|---|---|---|---|---|---|
| Date of Start: | 12-Jun-19 | Date of Completion: | 12-Jun-19 | Termination Depth, m : | 10.45 | | |

| Depth, m | | | | | | | Grain Size Analysis | | | | Atterberg Limits | | | | Density and Moisture | | | Shear Tests | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From | To | Sample No. | Field SPT 'N' Value | Symbol | SOIL DESCRIPTION | Depth of Strata, (m) | Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Liquid (%) | Plastic (%) | Plasticity Index (%) | Specific Gravity | Bulk Density (gms/cm$^3$) | Dry Density (gms/cm$^3$) | Moisture Content (%) | Type of Test | Cohesion Intercept, 'c' (kg/cm$^2$) | Angle of Internal Friction, f (degrees) |
| 0.50 | 1.00 | DS-1 | | | Fill: Sandy silt with brick bat & Polyethene | | | | | | | | | | | | | | | |
| 1.50 | 1.95 | SPT-1 | 10 | | | 2.00 | | | | | | | | | | | | | | |
| 2.25 | 2.55 | UDS-1 | | | Light grey clayey silt of medium plasticity (Cl) | | 0 | 3 | 78 | 19 | | | | | 1.74 | 1.53 | 13.9 | UUT | 0.55 | 7 |
| 3.00 | 3.45 | SPT-2 | 10 | | | | | | | | 39.6 | 23.1 | 16.5 | 2.71 | | | | | | |
| 4.50 | 4.95 | SPT-3 | 15 | | | | | | | | | | | | | | | | | |
| 5.25 | 5.55 | UDS-2 | | | | | 0 | 4 | 74 | 22 | | | | | 1.84 | 1.58 | 16.7 | | | |
| 6.00 | 6.45 | SPT-4 | 13 | | | | | | | | | | | | | | | | | |
| 7.50 | 7.95 | SPT-5 | 4 | | | | | | | | 42.3 | 22.9 | 19.4 | 2.70 | | | | | | |
| 8.25 | 8.55 | UDS-3 | | | | | | | | | | | | | 1.90 | 1.57 | 21.2 | UUT | 0.60 | 4 |
| 9.00 | 9.45 | SPT-6 | 6 | | | 9.50 | 0 | 3 | 77 | 20 | | | | | | | | | | |
| 10.00 | 10.45 | SPT-7 | 23 | | Light grey fine sand (SP-SM) | 10.45 | 0 | 90 | 10 | 0 | | | | | | | | | | |

UUT : Unconsolidated Undrained Triaxial Shear Test DST: Drained Direct Shear Test, UCS : Unconfined Compressive Strength Remoulded Sample +




| LEGEND | |
|---|---|
| SYMBOL | DESCRIPTION |
| | Fill |
| | Sandy silt (CL) |
| | Clayey silt (CI) |
| | Fine sand (SP-SM) |
| | Water Table |

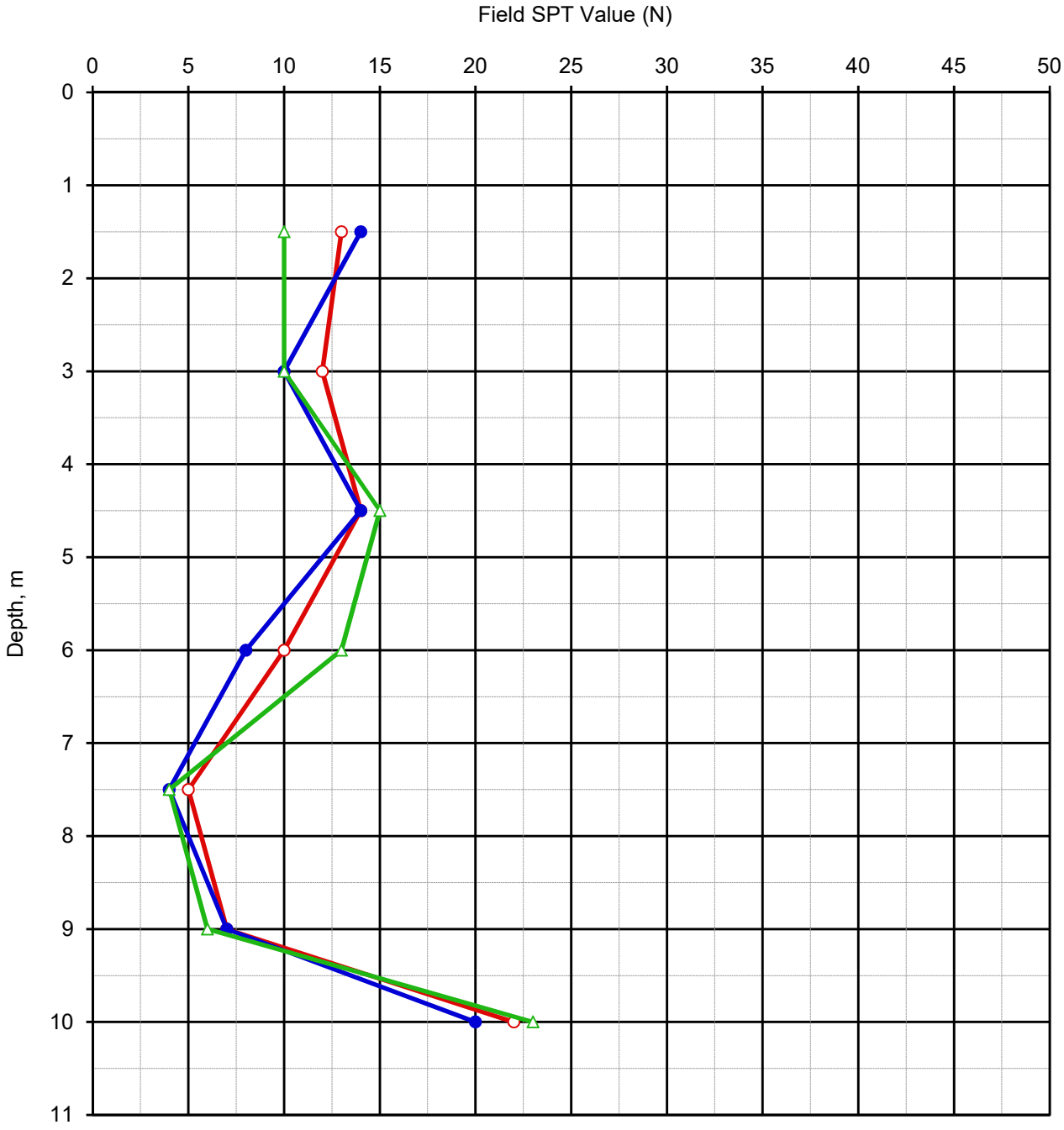
**Summary of Borehole Profiles**

**Proposed Pandav Nagar Substation Project at Pandav Nagar, New Delhi**

## Standard Penetration Test

IS : 2131-1981, RA-2007

| Borehole Details | |
|---|---|
| Symbol | Borehole Number |
| | BH-1 |
| | BH-2 |
| | BH-3 |



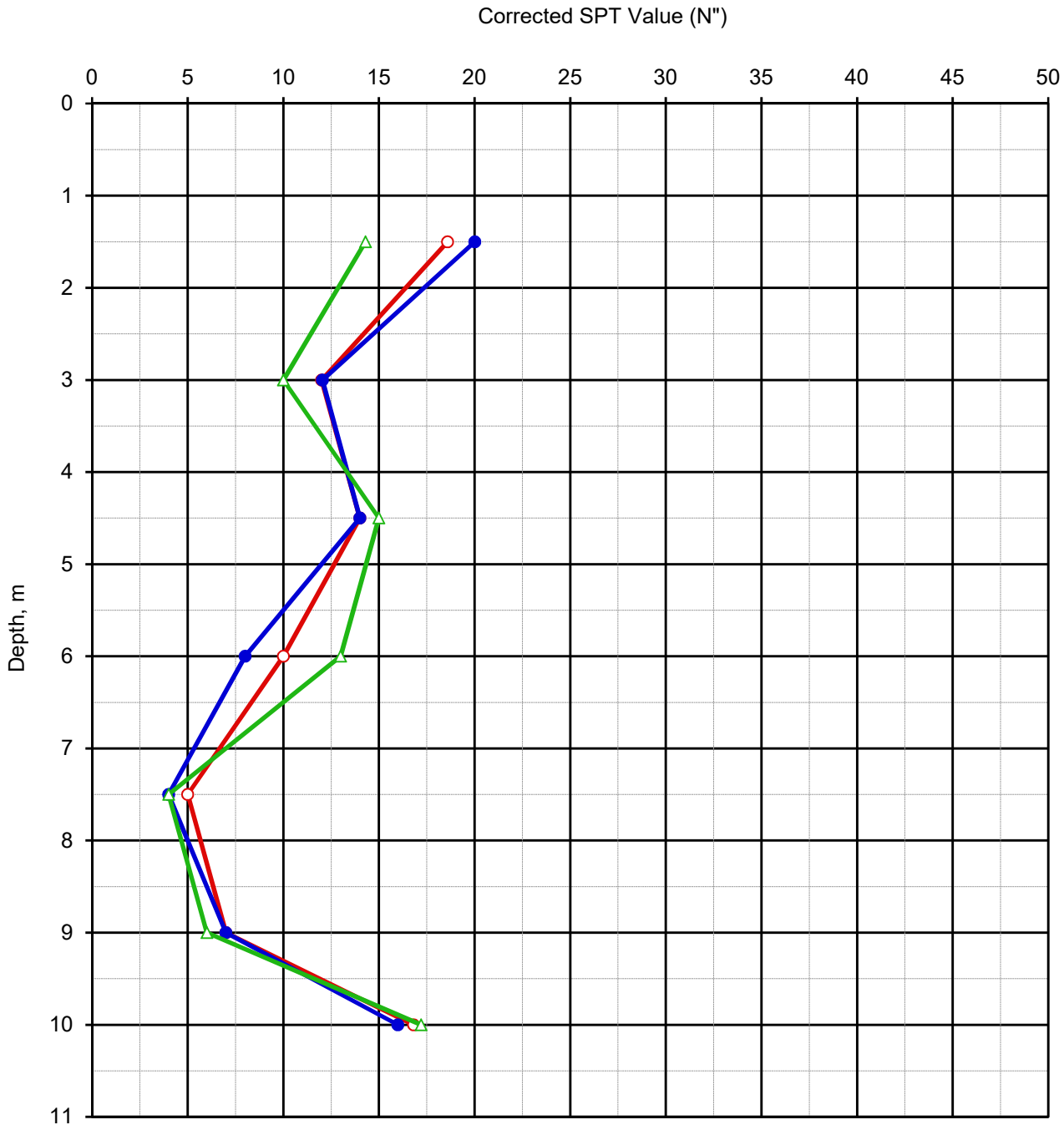

**Field SPT Values vs. Depth**

**Proposed Pandav Nagar Substation Project at Pandav Nagar, New Delhi**

## Standard Penetration Test

IS : 2131-1981, RA-2007

| Borehole Details | |
|---|---|
| Symbol | Borehole Number |
| | BH-1 |
| | BH-2 |
| | BH-3 |



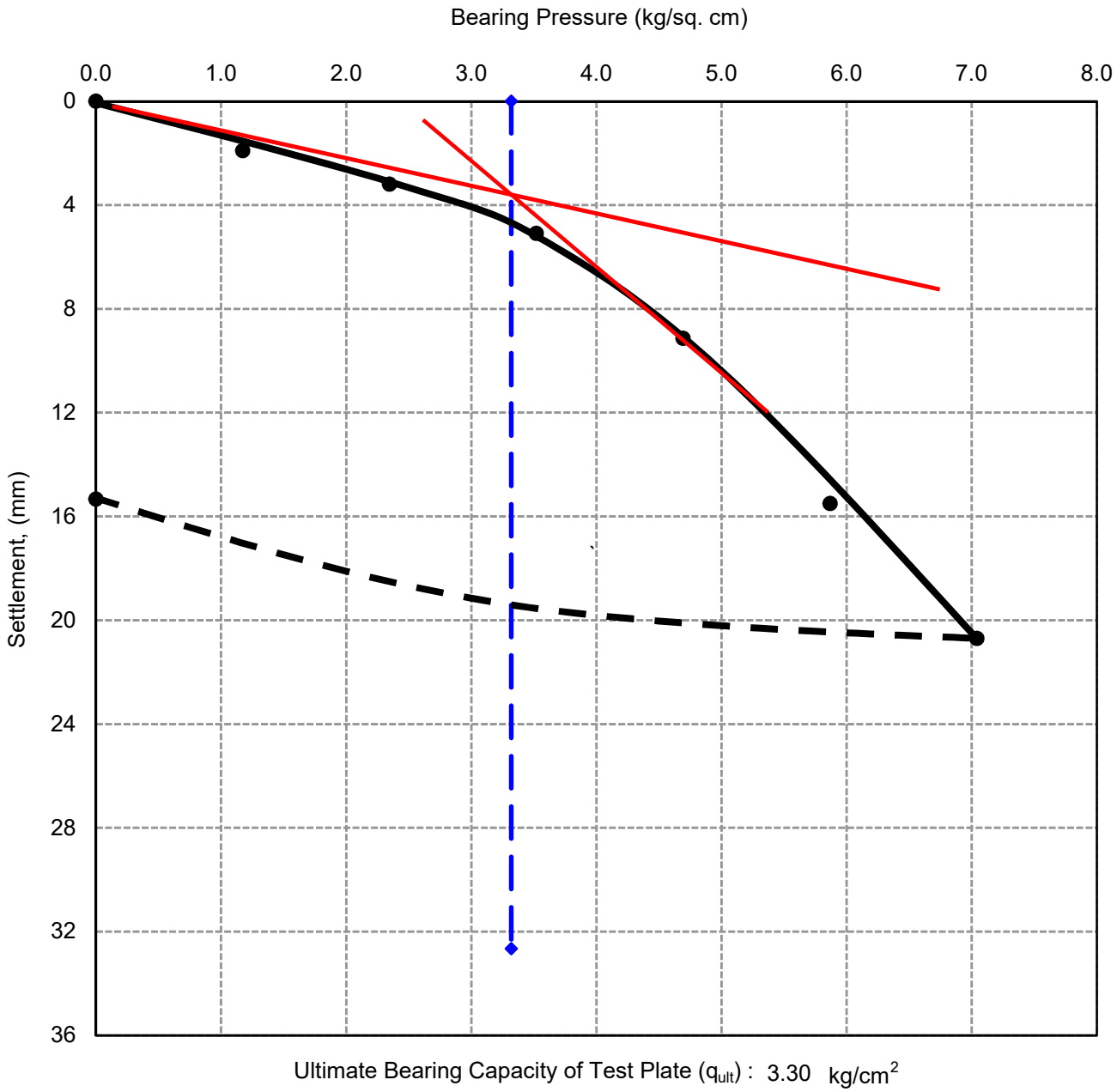

**Corrected SPT Values vs. Depth**

**Proposed Pandav Nagar Substation Project at Pandav Nagar, New Delhi**

## Plate Load Test No.: PLT-1

IS: 1888-1982, RA-2007

| Test Details |
|---|
| Size of Plate : 30cm x 30cm |
| Test Depth : 2.5 m |



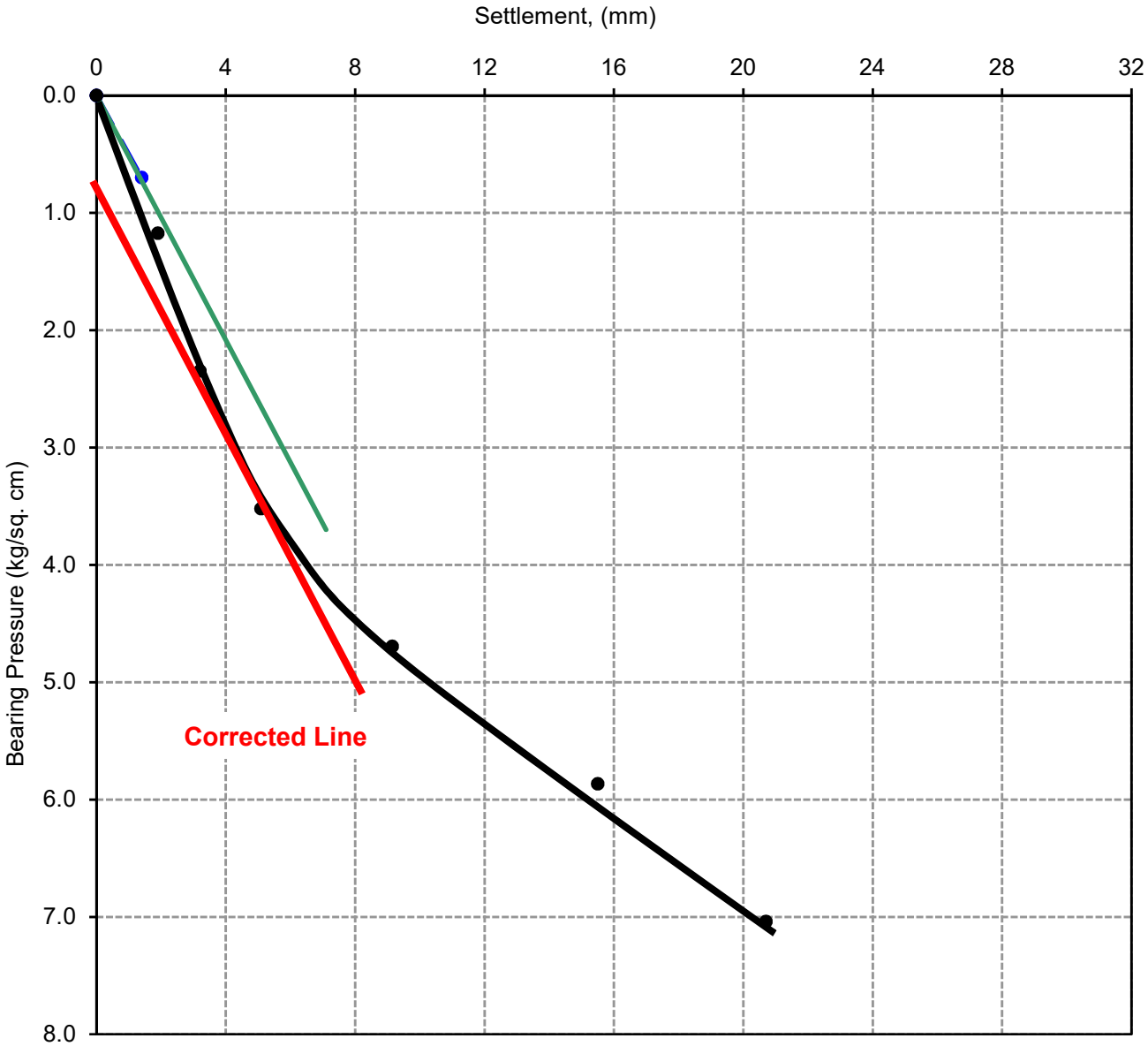

**Bearing Pressure vs. Settlement (PLT-1)**

**Proposed Pandav Nagar Substation Project at Pandav Nagar, New Delhi**

## Plate Load Test No.: PLT-1

IS: 1888-1982, RA-2007

| Test Details |
|---|
| Size of Plate : 30cm x 30cm |
| Test Depth : 2.5 m |




Calculation for Modulus of Subgrade Reaction (k):

i) Applying curvature correction, $K_u$ : 5.00 kg/cm$^3$

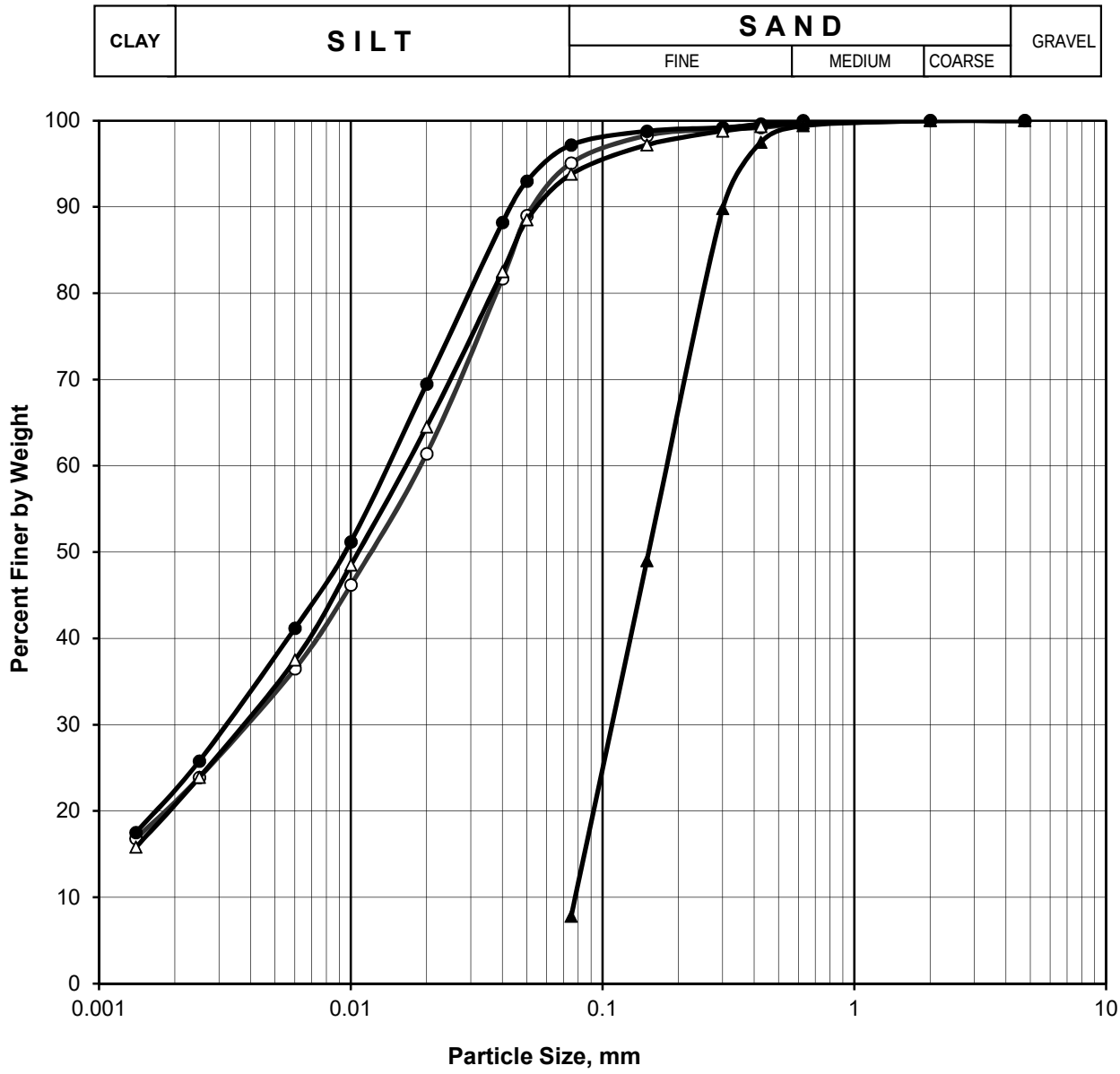
ii) Correction for bending of plate, $K_b$ : 4.46 kg/cm$^3$

iii) Correction for Saturation, $K_s$ : 2.23 kg/cm$^3$

iv) Correction for size of plate, $K_d$ : 1.22 kg/cm$^3$

**Determination of Modulus of Subgrade Reaction (PLT-1)**

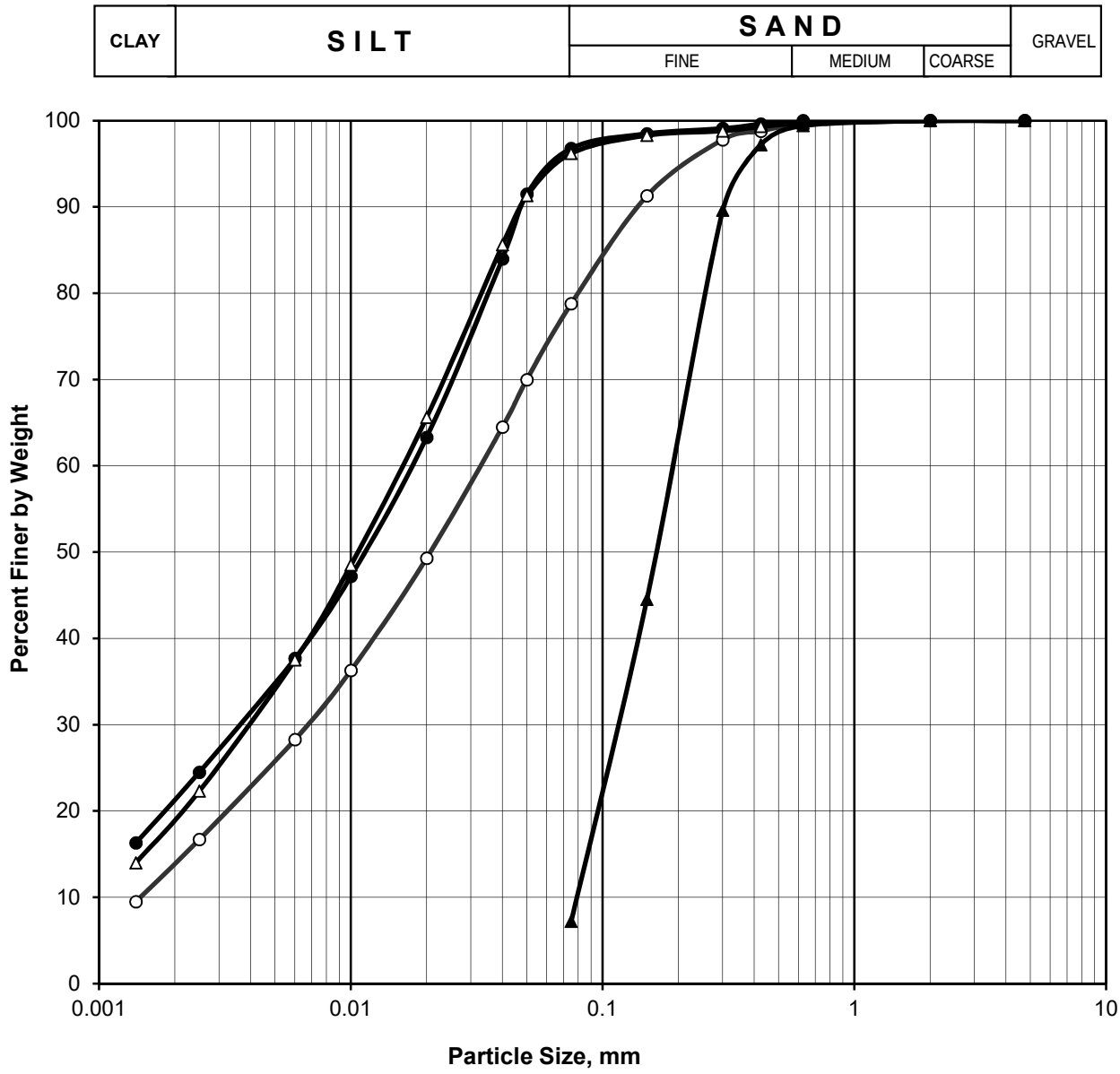
**Proposed Pandav Nagar Substation Project at Pandav Nagar, New Delhi**




| SYMBOL | BH | DEPTH (m) | DESCRIPTION | GRAVEL % | SAND % | SILT % | CLAY % |
|---|---|---|---|---|---|---|---|
| ○ | 1 | 2.25 | Clayey silt **(CI)** | 0 | 5 | 74 | 21 |
| ● | 1 | 6.00 | Clayey silt **(CI)** | 0 | 3 | 75 | 22 |
| △ | 1 | 9.00 | Clayey silt **(CI)** | 0 | 6 | 74 | 20 |
| ▲ | 1 | 10.00 | Fine sand **(SP-SM)** | 0 | 92 | 8 | 0 |

**Grain Size Analysis**

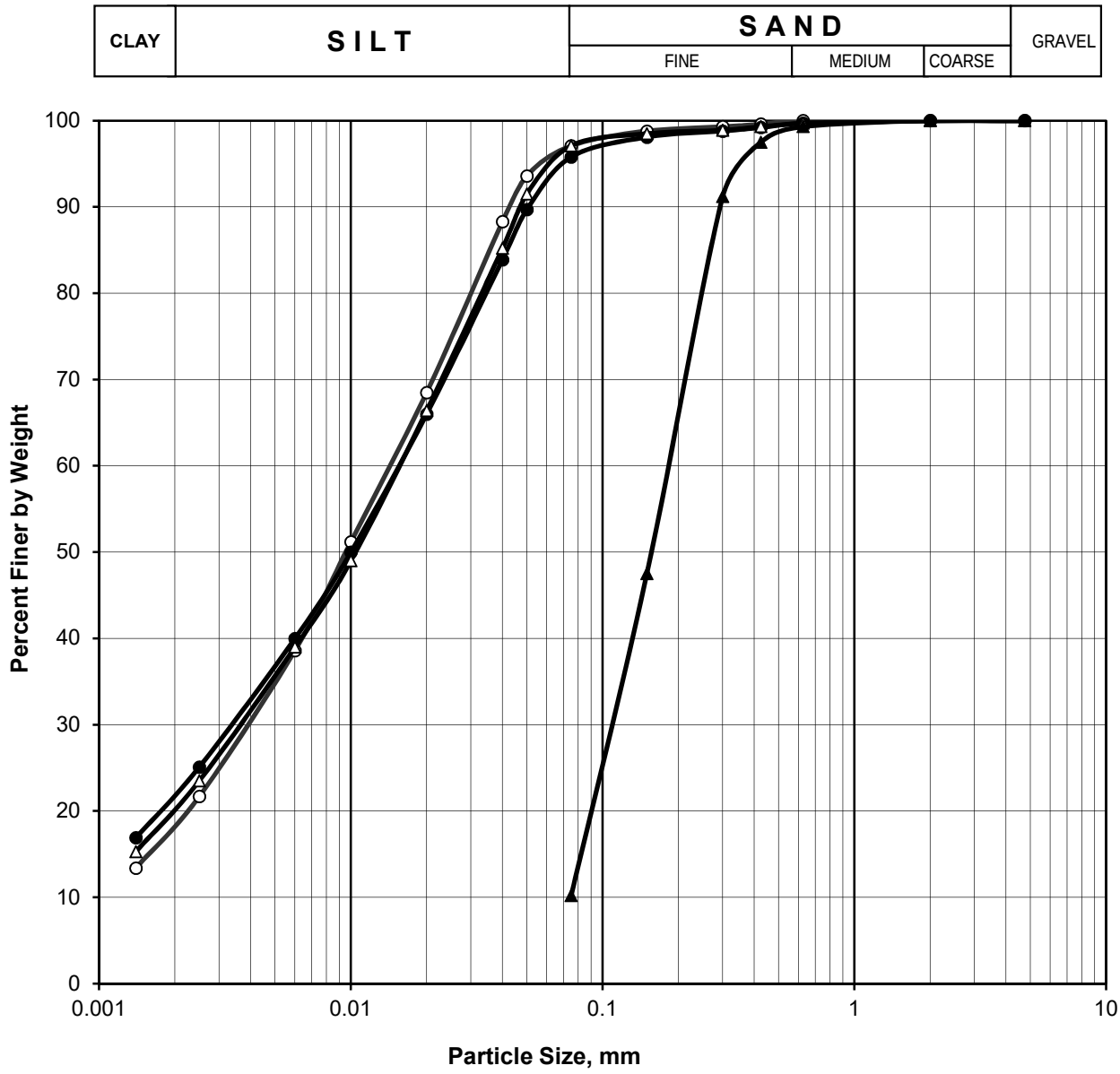
**Proposed Pandav Nagar Substation Project at Pandav Nagar, New Delhi**




| SYMBOL | BH | DEPTH (m) | DESCRIPTION | GRAVEL % | SAND % | SILT % | CLAY % |
|---|---|---|---|---|---|---|---|
| ○ | 2 | 2.25 | Sandy silt **(CL)** | 0 | 21 | 65 | 14 |
| ● | 2 | 4.50 | Clayey silt **(CI)** | 0 | 3 | 76 | 21 |
| △ | 2 | 8.25 | Clayey silt **(CI)** | 0 | 4 | 77 | 19 |
| ▲ | 2 | 10.00 | Fine sand **(SP-SM)** | 0 | 93 | 7 | 0 |

**Grain Size Analysis**

**Proposed Pandav Nagar Substation Project at Pandav Nagar, New Delhi**




| SYMBOL | BH | DEPTH (m) | DESCRIPTION | GRAVEL % | SAND % | SILT % | CLAY % |
|---|---|---|---|---|---|---|---|
| ○ | 3 | 2.25 | Clayey silt **(CI)** | 0 | 3 | 78 | 19 |
| ● | 3 | 5.25 | Clayey silt **(CI)** | 0 | 4 | 74 | 22 |
| △ | 3 | 9.00 | Clayey silt **(CI)** | 0 | 3 | 77 | 20 |
| ▲ | 3 | 10.00 | Fine sand **(SP-SM)** | 0 | 90 | 10 | 0 |

**Grain Size Analysis**

**Proposed Pandav Nagar Substation Project at Pandav Nagar, New Delhi**

# CHEMICAL TEST RESULTS

## SOIL-EXTRACT WATER:

| Borehole No. | Depth, m | Sulphate Content ($SO_3$), % | Chloride Content (CL), % | pH Value |
|---|---|---|---|---|
| 1 | 1.50 | 0.16 | 0.10 | 7.4 |
| 2 | 4.50 | 0.11 | 0.14 | 7.5 |
| 3 | 2.25 | 0.14 | 0.11 | 7.3 |

## GROUND WATER:

| Borehole No. | Depth, m | Sulphate Content ($SO_3$), mg/l | Chloride Content (CL), mg/l | pH Value |
|---|---|---|---|---|
| 1 | - | 340 | 167 | 7.5 |
| 2 | - | 302 | 179 | 7.4 |
| 3 | - | 289 | 144 | 7.6 |