GEOTECHNICAL REPORT

PROPOSED MANDOLI SUBSTATION PROJECT NEAR MANDOLI JAIL AT VILLAGE MANDOLI, NEW DELHI

SUBMITTED TO:

M/S. BSES YAMUNA POWER LIMITED

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

Project No. 19094 Dated. June, 2019 Revision-0

RAO ENGINEERING ENTERPRISES

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June 20th, 2019 Project No. 19094

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 Mandoli Substation Project Near Mandoli Jail at Village Mandoli, 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

Rao Engineering Enterprises New Delhi

(G.R.RAO)

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ILLUSTRATIONS

1.0 INTRODUCTION

1.1 Project Description

This soil investigation work, whose results are being presented herewith, has been carried out for Proposed Mandoli Substation Project Near Mandoli Jail at Village Mandoli, 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.

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.

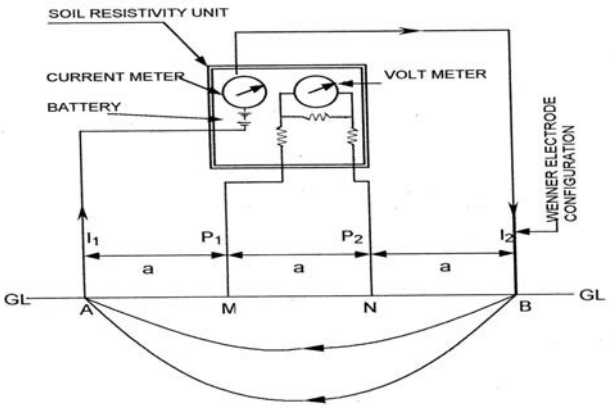
Measurements are made by causing a current, 'I', to pass through the earth and distribute within a relatively large hemispherical earth mass. The portion of the current that flows along the surface produces a voltage drop, 'V'. The resistance 'R', ratio of voltage drop 'V' to current 'I' is directly measured by Digital Earth Resistance Tester. The resistivity is determined from the following equation:

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

where:

ρ = 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 silty sand with brick bats was encountered to about 2.0 m depth below EGL. Below fill material, clayey silt was encountered to about 5.0 m depth and underlain by fine sand to about 8.0-9.0 m below EGL. Further, sandy silt was met to the final explored depth of 10.45 m below EGL.

The field SPT N-values generally range from 18 to 26 to about 2.0 m depth. Below this the field SPT N value range from 9 to 16 to about 5.0 m depth and range from 11 to 19 to about 9.0 m depth below EGL. Further SPT N-values range from 23 to 28 to the final explored depth of 10.45 m.

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 5.8-6.0 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 Electrical Resistivity Test Result

One (1) electrical resistivity test was conducted at the project site as per IS: 3043-1987. The test was conducted using the Wenner's configuration. The apparent resistivity value obtained has been analyzed to generate the polar curve. The polar curve is used to compute the mean resistivity.

Mean resistivity value at the electrical resistivity test (ERT) location is summarized in the table below:

Test Designation	Mean Resistivity, ohm-m	Corrosion potential*	Presentation of Results
ERT-1	7.9	Severely Corrosive	Sheet No. 7 & 8

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

The above value 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.

5.2 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. 9 & 10

5.3 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	30 T/m^2	35 T/m^2		
PLT-1	1.1	2.2	3.3	4.6	7.4	9.0	3.70	0.96

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).

5.4 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	30 T/m^2	35 T/m^2
PLT-1	44.0	88.0	132.0	184.0	296.0	360.0

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

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

5.5 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.
- 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 are of the opinion that open foundation is feasible foundation scheme to support the structural load.

As discussed in Section 4.1, fill is encountered at the site to about 2.0 m depth below EGL. Our recommended values of net allowable bearing pressures at minimum 2.5 m depth (at least 0.5 m into the natural strata) for open foundation are presented in Section 7.0.

Interconnecting beams should be provided either at plinth level or at foundation level in order to restrict differential settlements and to provide rigidity to the structure during earthquakes.

6.3 Allowable Bearing Pressure

Following criterion have been considered for evaluating the bearing capacity values:

(a) Settlement criteria

(b) Shear failure criterion

Shear failure condition as per I.S. 6403 has been considered for allowable bearing pressure computation. Allowable settlement value of 40 mm & 50 mm has been considered for deducing shear strength value.

6.4 Sample Calculations (Open Foundation)

Type of foundation	Open foundation
Depth of foundation	2.5 m below EGL*
Width of foundation	3.0 m

*Atleast 0.5 m into the natural soil strata.

I. SETTLEMENT CRITERIA (AS PER IS - 8009, PART-1, 1976, FIG.9, PAGE-17)

Weighted Average minimum Corrected 'N' value	11
Settlement undergone by footing per unit pressure	29.8 mm
Total Settlement undergone by footing (considering water table Correction factor taken as 0.6 for Worst condition)	47.7 mm
Allowable bearing pressure Corresponding to 50 mm allowable Settlement.	10.0 T/m²

III. SHEAR FAILURE CRITERION

The bearing capacity equation used is as follows:

$$q_{net\ safe} = \frac{1}{F}\left[cN_c\zeta_c\, d_c + q(N_q-1)\,\zeta_q d_q + 0.5\, B\,\gamma\, N_\gamma \zeta_\gamma\, d_\gamma\, R_w\right]$$

Where:

$q_{net\ safe}$ = safe net bearing capacity of soil based on the shear failure criterion.
q = overburden pressure
R_w = water table correction factor
F = Factor of safety, taken as equal to 2.5 in accordance with IS: 1904-1986.

$\zeta_c, \zeta_q, \zeta_\gamma$ = Shape factors. For Strip footings, $\zeta_c = \zeta_q = \zeta_\gamma = 1$
For Square footing, $\zeta_c = 1.3$, $\zeta_q = 1.2$, $\zeta_\gamma = 0.6$

d_c, d_q, d_γ = Depth factors

For $\phi \leq 10$, $d_c = 1 + 0.2 \tan (45 + \phi / 2)\ D / B$, $d_q = d_\gamma = 1$

For $\phi > 10$, $d_q = d_\gamma = 1 + 0.1 \tan (45 + \phi / 2)\ D / B$

Cohesion, c = 5.0 T/m²
Angle of shearing resistance, ϕ = 5 degrees
Bearing Capacity factors:

General Shear Failure :	N_c =	6.49	N_q =	1.57	N_γ =	0.45
Local Shear Failure :	N_c' =	5.99	N_q' =	1.35	N_γ' =	0.27

Density at Foundation Level, γ = 1.70 gms/cc
Net Safe Bearing Capacity , $q_{net\ safe}$ = 15.2 T/m²
(considering average of local & general shear criteria)

6.5 Definition of Gross and Net Bearing Pressure

For the purposes of this report, the net allowable bearing pressure should be calculated as the difference between total load on the foundation and the weight of the soil overlying the foundation divided by the effective area of the foundation. The gross bearing pressure is the total pressure at the foundation level including overburden pressure and surcharge load.

The following equations may be used –

$$q_{net} = [(P_s + W_f + W_s) / A_f] - S_v$$
$$q_{gross} = q_{net} + S_v = (P_s + W_f + W_s) / A_f$$

where:

q_{net} = net allowable bearing pressure
q_{gross} = gross bearing pressure
P_s = superimposed static load on foundation
W_f = weight of foundation
W_s = weight of soil overlying foundation
A_f = effective area of foundation
S_v = overburden pressure at foundation level prior to excavation for foundation.

It may please be noted that safe bearing pressures recommended in this report refer to *"**net values**"*. Where filling is done, it should be treated as a surcharge over the foundation.

7.0 RECOMMENDATIONS

The following table presents our recommended values of net allowable bearing pressures for open foundations bearing at 2.5-3.0 m depth below EGL:

Foundation Depth below EGL, m	Recommended Net Allowable Bearing Pressure, T/m²	
	Total Settlement = 40 mm	Total Settlement = 50 mm
2.5	8.0	10.0
3.0	9.6	12.0

The above values include a safety factor of 2.5. The appropriate value of net bearing pressure may be selected as per the permissible settlement criterion.

Net bearing pressure for foundations at intermediate depths may be interpolated linearly between the values given above. Fill placed above EGL should be treated as surcharge load. Foundation should be seated 0.5 m into natural soil.

In order to restrict the influence of adjacent footings on each other, the lateral edge-to-edge spacing between the foundations should at least be equal to “0.8B” where” B” is the width of the larger footing.

8.0 CHEMICAL ATTACK

Results of chemical test on selected soil samples are presented on Sheet No. 14. The results indicate that the soils contain 0.11-0.16 percent sulphates and 0.13-0.15 percent chlorides and groundwater contain 256-302 percent sulphates and 108-135 percent chlorides. The pH value of soil is 7.2-7.5 and groundwater is 7.2-7.3.

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 5.8~6.0 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 open foundations concrete should be at least 281 kg/m^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 Mandoli Substation Project Near Mandoli Jail at Village Mandoli, New Delhi	Water Table, m :	5.9	Project No.	19094
		Termination Depth, m :	10.45		
Date of Start:	14-Jun-19	Date of Completion:	14-Jun-19		

Depth, m		Sample No.	Field SPT 'N' Value	Symbol	SOIL DESCRIPTION	Depth of Strata, (m)	Grain Size Analysis				Atterberg Limits			Specific Gravity	Density and Moisture			Shear Tests		
From	To						Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Liquid (%)	Plastic (%)	Plasticity Index (%)		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 bats															
1.50	1.95	SPT-1	26			2.00														
2.25	2.55	UDS-1			Light grey clayey silt of medium plasticity (CI)		0	4	75	21				2.70	1.75	1.56	12.3	UUT	0.58	5
3.00	3.45	SPT-2	15																	
4.50	4.95	SPT-3	9			5.00					41.2	23.1	18.1							
5.25	5.55	UDS-2			Light grey fine sand (SP-SM)		0	92	8	0				2.61	1.79	1.58	13.2	DST	0.00	28
6.00	6.45	SPT-4	11																	
7.50	7.95	SPT-5	17			8.00	0	93	7	0										
8.25	8.55	UDS-3			Light brown sandy silt of low plasticity (CL)						32.5	21.4	11.1		1.95	1.65	18.1	UUT	0.80	5
9.00	9.45	SPT-6	24				5	14	71	10				2.68						
10.00	10.45	SPT-7	27			10.45					30.6	21.7	8.9							

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

SOIL PROFILE: BH-2

Project:	Proposed Mandoli Substation Project Near Mandoli Jail at Village Mandoli, New Delhi			Water Table, m :	6.0	Project No.	19094
Date of Start:	15-Jun-19	Date of Completion:	15-Jun-19	Termination Depth, m :	10.45		

Depth, m		Sample No.	Field SPT 'N' Value	Symbol	SOIL DESCRIPTION	Depth of Strata, (m)	Grain Size Analysis				Atterberg Limits			Specific Gravity	Density and Moisture			Shear Tests		
From	To						Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Liquid (%)	Plastic (%)	Plasticity Index (%)		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 bats															
1.50	1.95	SPT-1	20			2.00														
2.25	2.55	UDS-1			Light grey clayey silt of medium plasticity (CI)						41.2	22.8	18.4		1.77	1.56	13.5	UUT	0.60	8
3.00	3.45	SPT-2	15				0	5	74	21				2.69						
4.50	4.95	SPT-3	11			5.00					40.1	22.5	17.6							
5.25	5.55	UDS-2			Light grey fine sand (SP-SM)		0	90	10	0				2.61	1.85	1.62	14.1			
6.00	6.45	SPT-4	14																	
7.50	7.95	SPT-5	18																	
8.25	8.55	UDS-3				9.00	0	92	8	0					1.95	1.66	17.5	DST	0.00	30
9.00	9.45	SPT-6	23		Light brown sandy silt of low plasticity (CL)		4	10	74	12				2.67						
10.00	10.45	SPT-7	26			10.45					33.1	21.2	11.9							

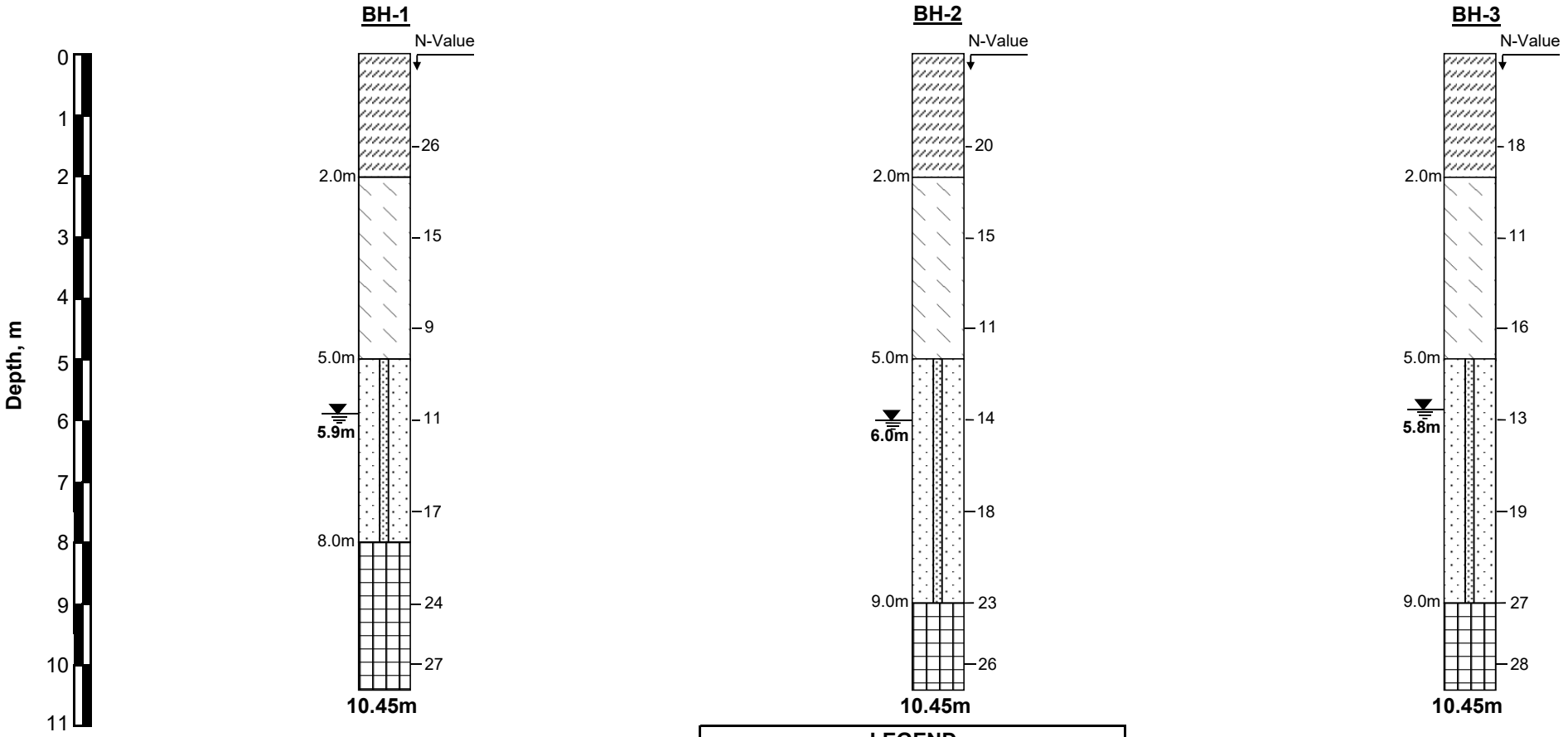
UUT : Unconsolidated Undrained Triaxial Shear Test DST: Drained Direct Shear Test, UCS : Unconfined Compressive Strength Remoulded Sample +

SOIL PROFILE: BH-3

Project:	Proposed Mandoli Substation Project Near Mandoli Jail at Village Mandoli, New Delhi	Water Table, m :	5.8	Project No.	19094
		Termination Depth, m :	10.45		
Date of Start:	16-Jun-19	Date of Completion:	16-Jun-19		

Depth, m		Sample No.	Field SPT 'N' Value	Symbol	SOIL DESCRIPTION	Depth of Strata, (m)	Grain Size Analysis				Atterberg Limits			Specific Gravity	Density and Moisture			Shear Tests		
From	To						Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Liquid (%)	Plastic (%)	Plasticity Index (%)		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 bats															
1.50	1.95	SPT-1	18			2.00														
2.25	2.55	UDS-1			Light grey clayey silt of medium plasticity (CI)		0	4	74	22				2.69	1.77	1.55	14.1	UUT	0.50	8
3.00	3.45	SPT-2	11																	
4.50	4.95	SPT-3	16			5.00					41.5	23.2	18.3							
5.25	5.55	UDS-2			Light grey fine sand (SP-SM)		0	91	9	0				2.63	1.87	1.63	14.5	DST	0.00	29
6.00	6.45	SPT-4	13																	
7.50	7.95	SPT-5	19																	
8.25	8.55	UDS-3				9.00	0	90	10	0					1.96	1.66	17.8			
9.00	9.45	SPT-6	27		Light brown sandy silt of low plasticity (CL)						31.6	22.2	9.4	2.61						
10.00	10.45	SPT-7	28			10.45	4	14	71	11										

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



LEGEND	
SYMBOL	DESCRIPTION
	Filled up
	Sandy silt (ML-CL)
	Silty sand (SM)
	Clayey silt (CI)
	Water Table

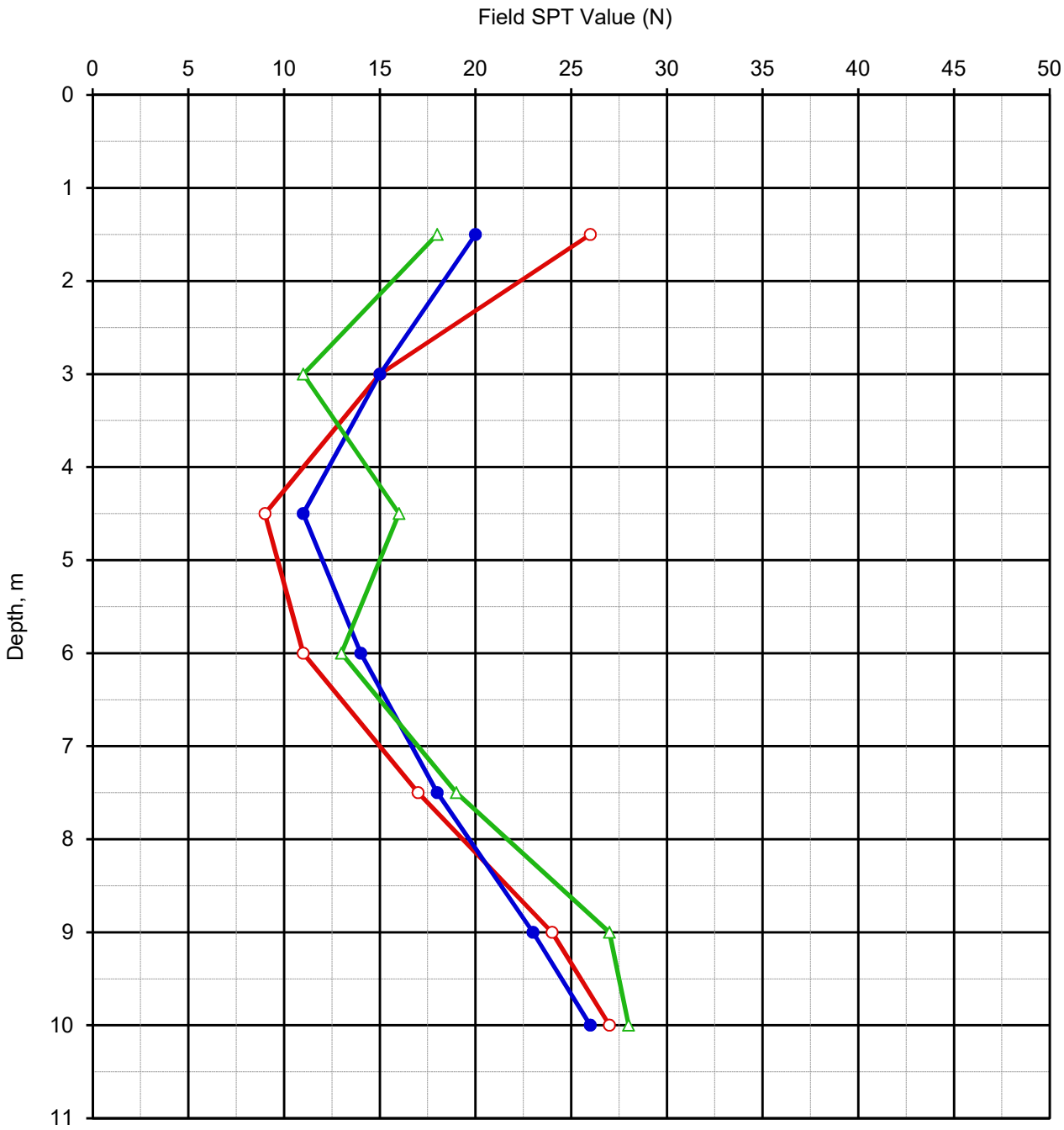
Summary of Borehole Profiles

Proposed Mandoli Substation Project Near Mandoli Jail at Village Mandoli, New Delhi

Standard Penetration Test

IS : 2131-1981, RA-2007

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



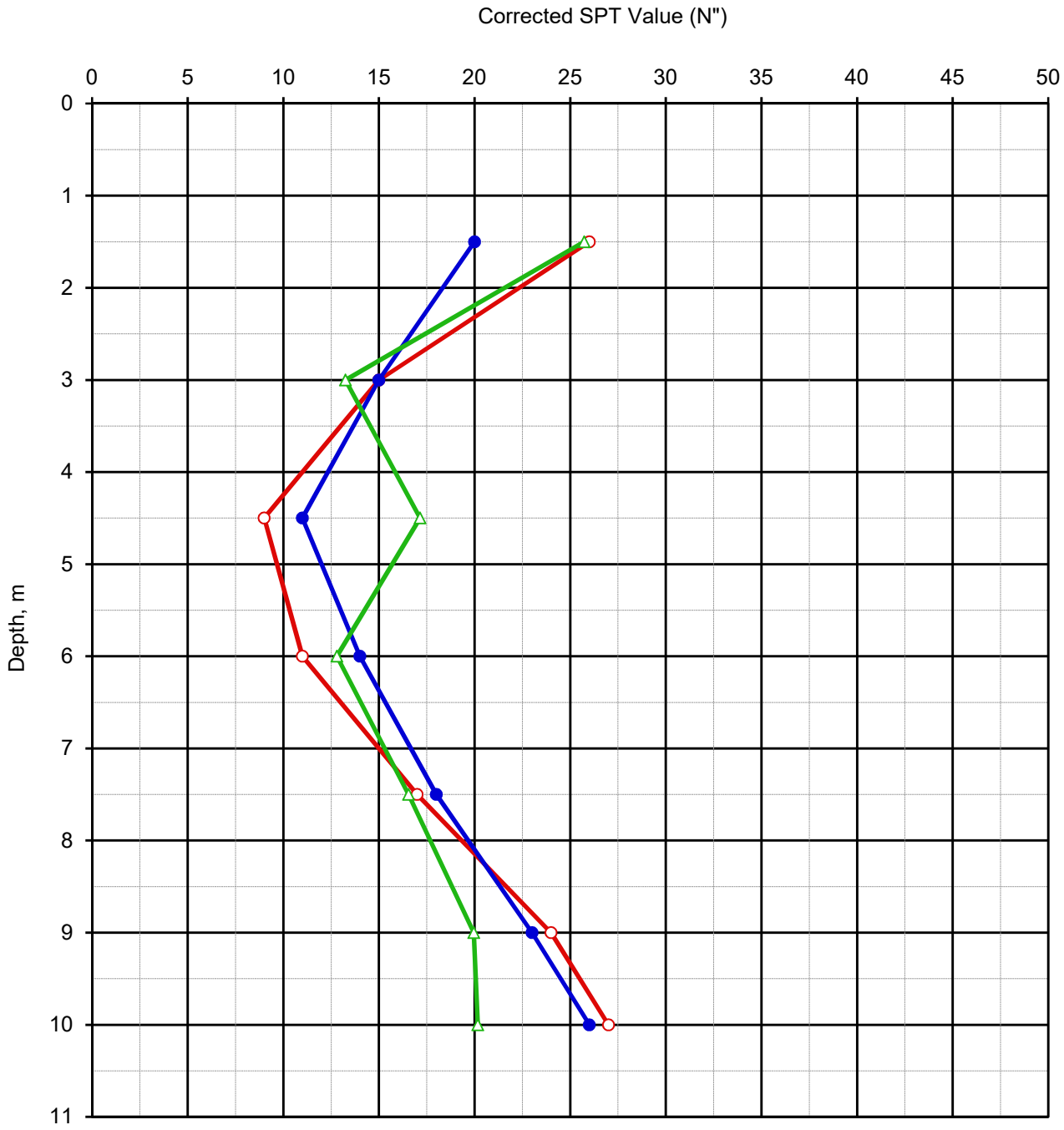
Field SPT Values vs. Depth

Proposed Mandoli Substation Project Near Mandoli Jail at Village Mandoli, New Delhi

Standard Penetration Test

IS : 2131-1981, RA-2007

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



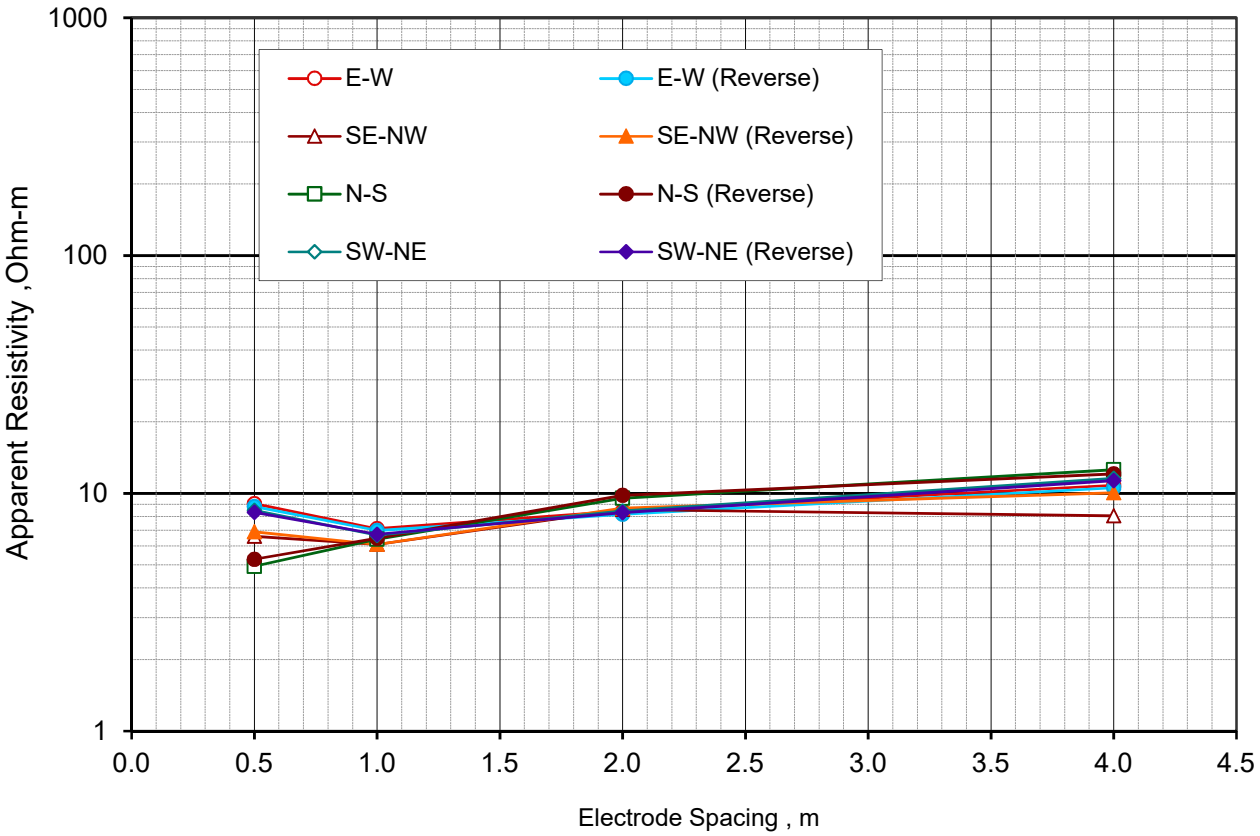
Corrected SPT Values vs. Depth

Proposed Mandoli Substation Project Near Mandoli Jail at Village Mandoli, New Delhi

Electrical Resistivity Test No.: ERT-1

IS: 3043-1987, RA-2006

Test Details
Test Designation : ERT-1



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	9.0	8.8	6.6	6.9	4.9	5.3	8.5	8.3
1.0	7.1	7.0	6.1	6.1	6.4	6.5	6.7	6.7
2.0	8.4	8.2	8.5	8.7	9.6	9.8	8.4	8.3
4.0	10.8	10.6	8.0	10.1	12.6	12.1	11.6	11.3
6.0	Space not Available							
8.0								
Mean Resistivity	8.8	8.6	7.3	7.9	8.4	8.4	8.8	8.7

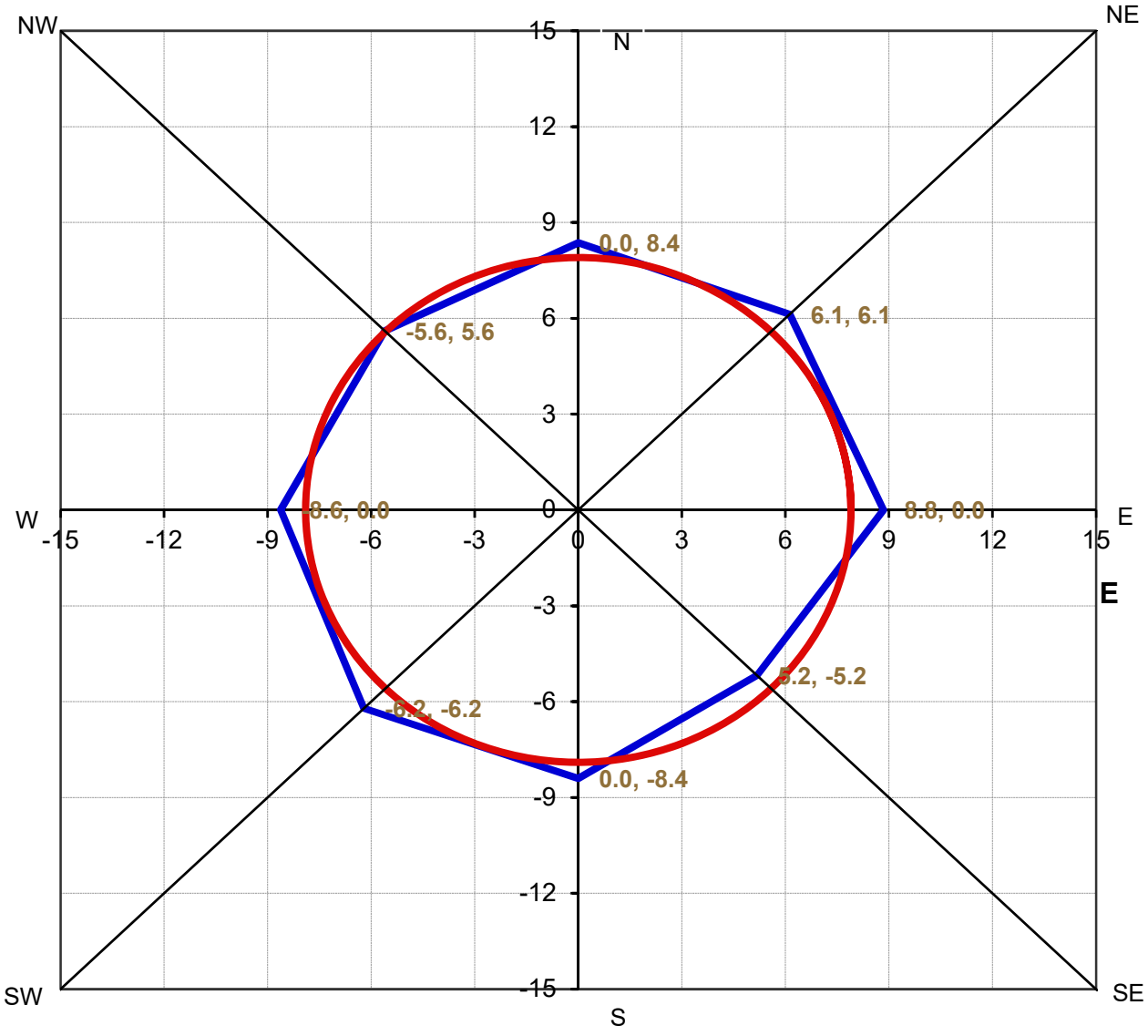
Mean Resistivity Value, ohm-m : 7.9 ohm-m

Apparent Resistivity Values (ERT-1)

Electrical Resistivity Test No.: ERT-1

IS: 3043-1987, RA-2006

Test Details
Test Designation : ERT-1



Total Area of Polygon : 198

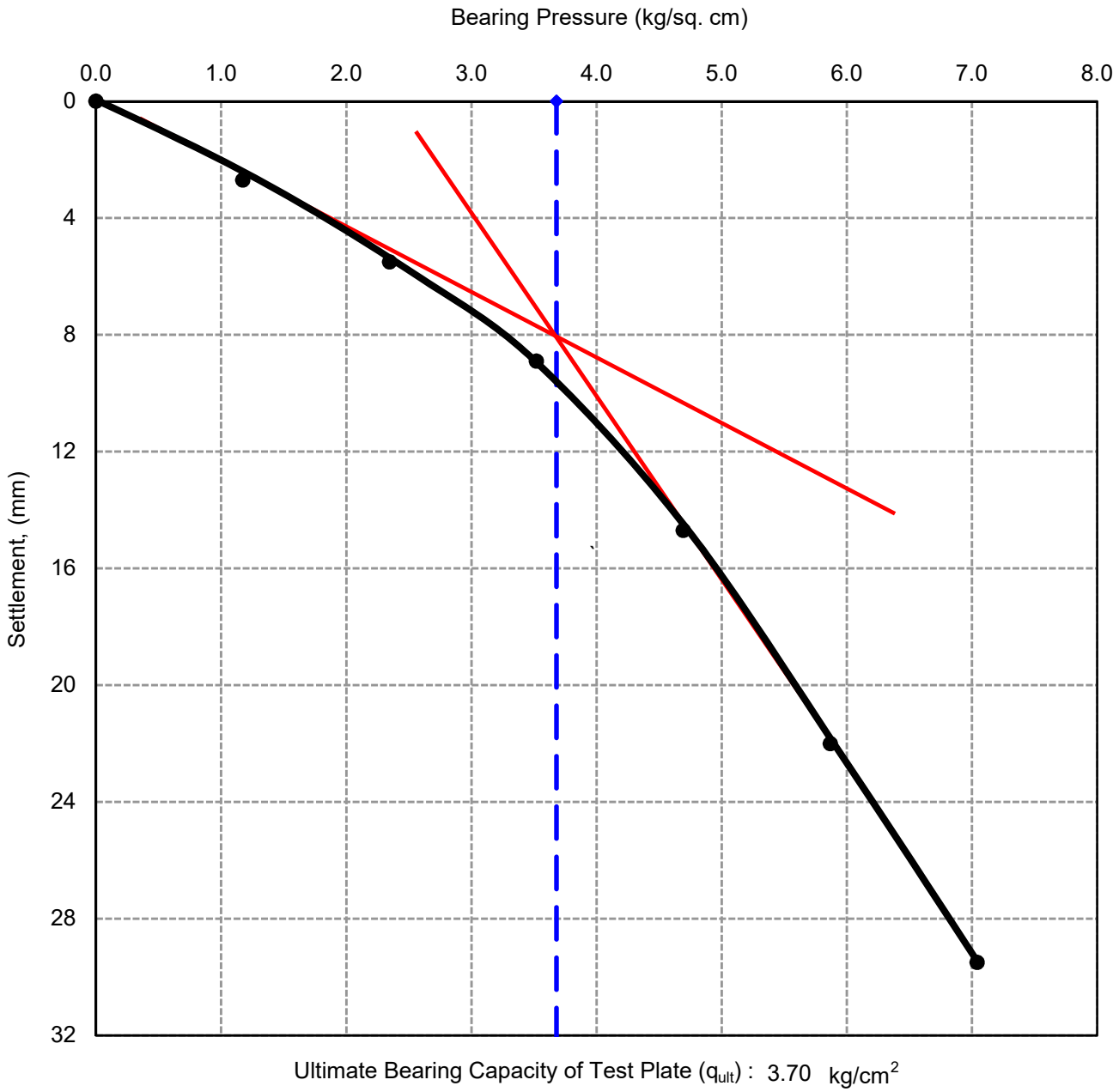
Radius of Equivalent Circle=Mean Resistivity : 7.9 ohm-m

Polar Resistivity Curves (ERT-1)

Plate Load Test No.: PLT-1

IS: 1888-1982, RA-2007

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



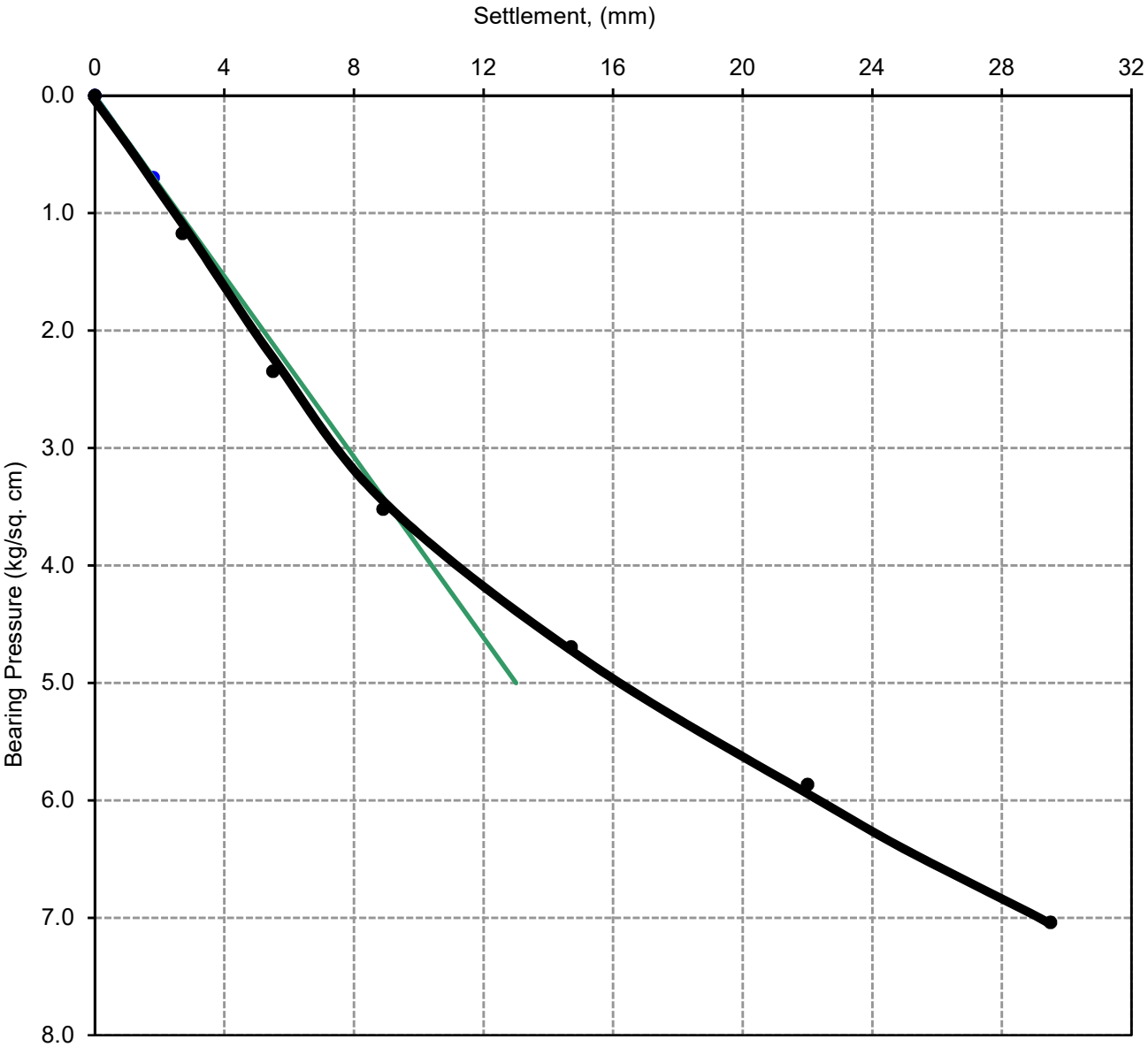
Bearing Pressure vs. Settlement (PLT-1)

Proposed Mandoli Substation Project Near Mandoli Jail at Village Mandoli, 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 : 3.89 kg/cm^3

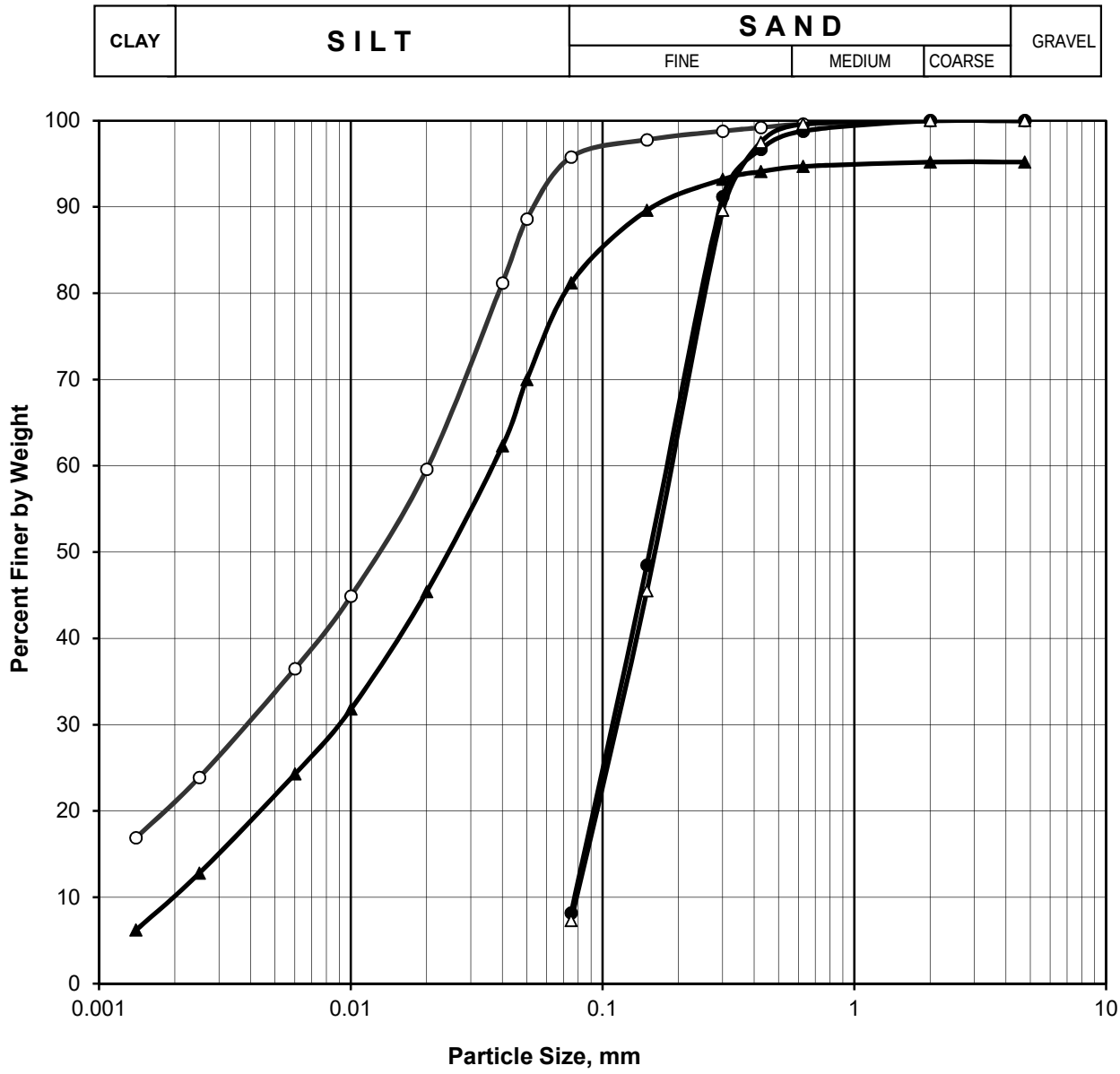
ii) Correction for bending of plate, K_b : 3.52 kg/cm^3

iii) Correction for Saturation, K_s : 1.76 kg/cm^3

iv) Correction for size of plate, K_d : 0.96 kg/cm^3

Determination of Modulus of Subgrade Reaction (PLT-1)

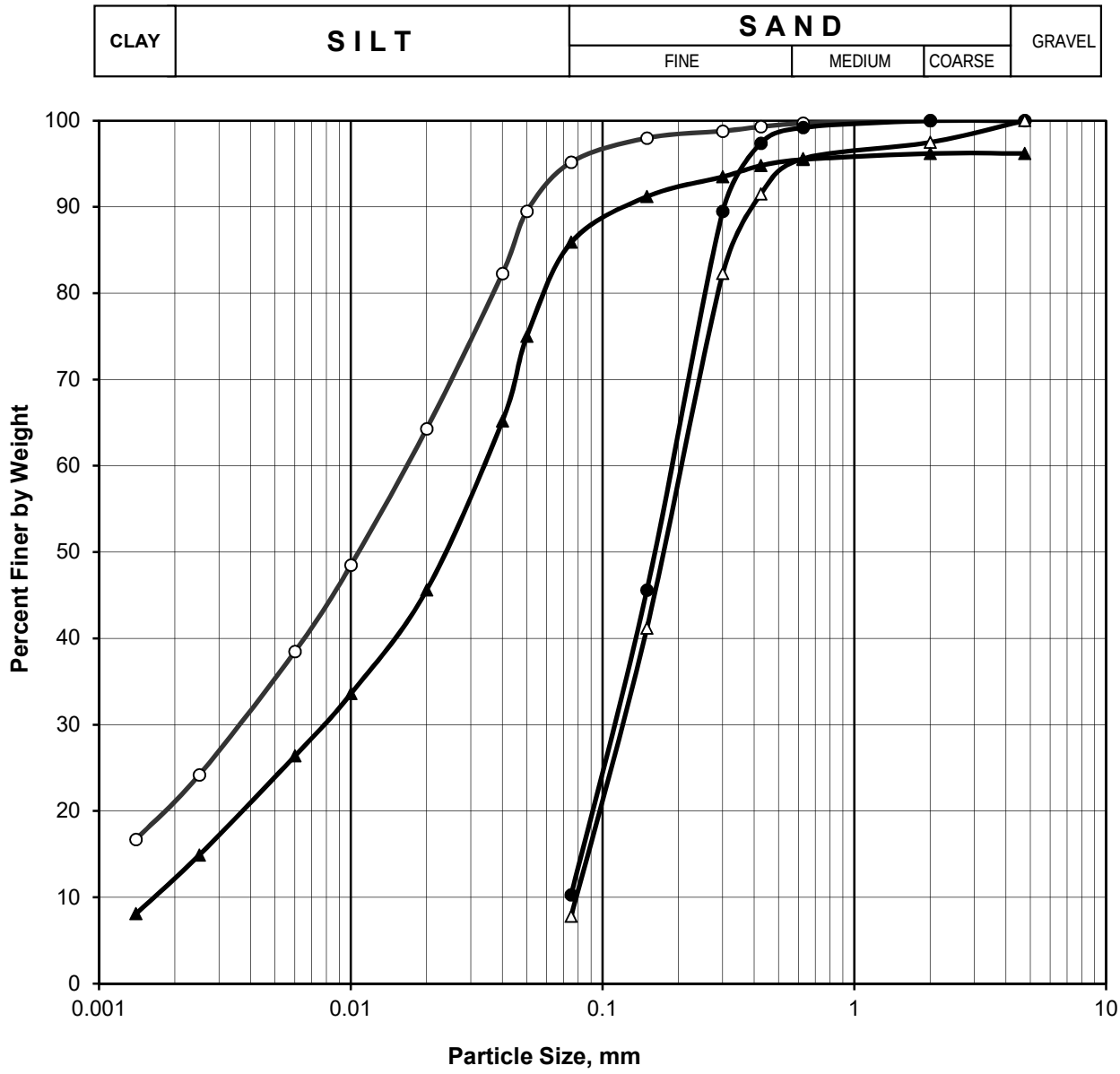
Proposed Mandoli Substation Project Near Mandoli Jail at Village Mandoli, New Delhi



SYMBOL	BH	DEPTH (m)	DESCRIPTION	GRAVEL %	SAND %	SILT %	CLAY %
○	1	2.25	Clayey silt **(CI)**	0	4	75	21
●	1	5.25	Fine sand **(SP-SM)**	0	92	8	0
△	1	8.25	Fine sand **(SP-SM)**	0	93	7	0
▲	1	10.00	Sandy silt **(CL)**	5	14	71	10

Grain Size Analysis

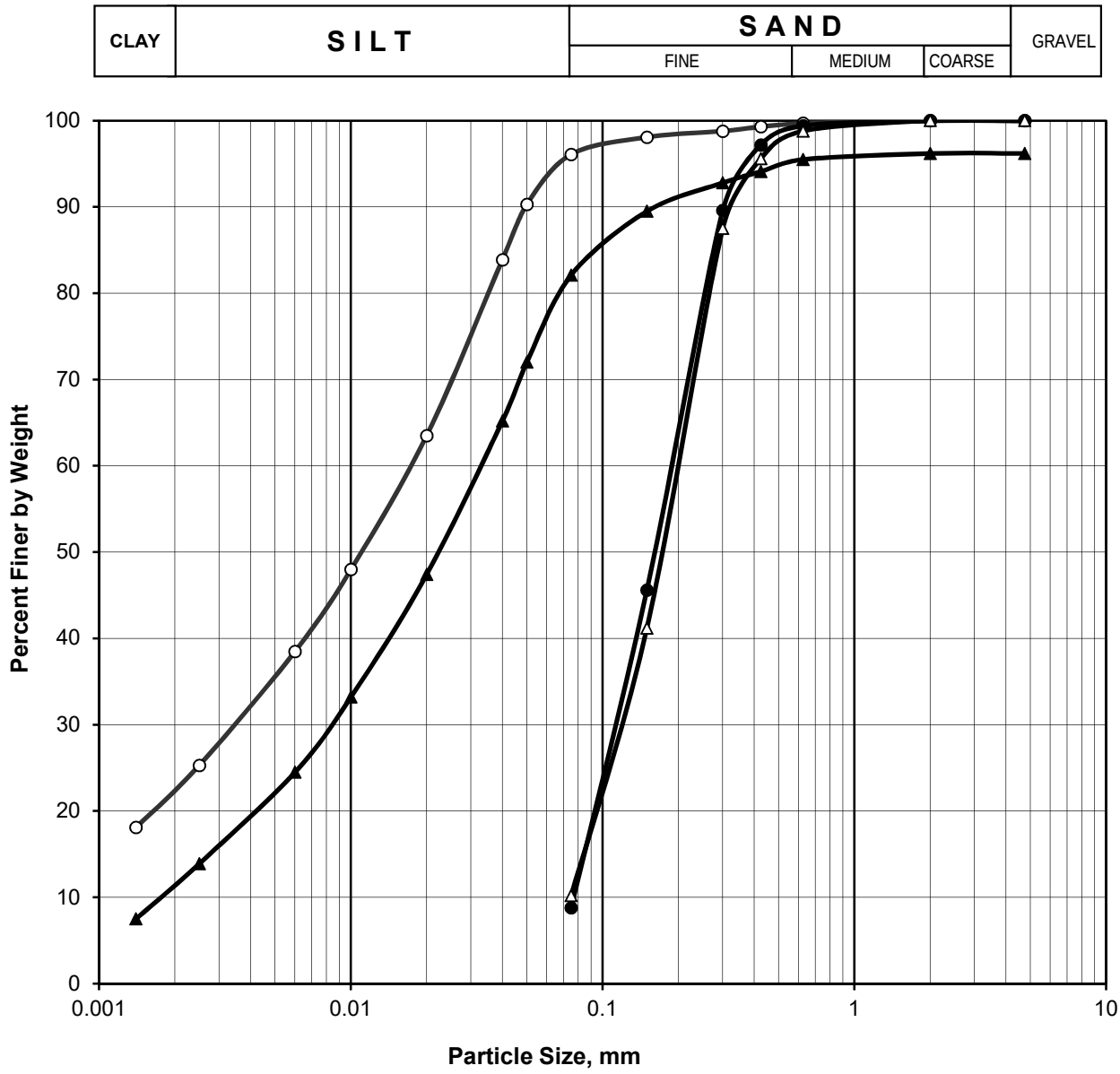
Proposed Mandoli Substation Project Near Mandoli Jail at Village Mandoli, New Delhi



SYMBOL	BH	DEPTH (m)	DESCRIPTION	GRAVEL %	SAND %	SILT %	CLAY %
○	2	3.00	Clayey silt **(CI)**	0	5	74	21
●	2	5.25	Fine sand **(SP-SM)**	0	90	10	0
△	2	8.25	Fine sand **(SP-SM)**	0	92	8	0
▲	2	9.00	Sandy silt **(CL)**	4	10	74	12

Grain Size Analysis

Proposed Mandoli Substation Project Near Mandoli Jail at Village Mandoli, New Delhi



SYMBOL	BH	DEPTH (m)	DESCRIPTION	GRAVEL %	SAND %	SILT %	CLAY %
○	1	2.25	Clayey silt **(CI)**	0	4	74	22
●	1	5.25	Fine sand **(SP-SM)**	0	91	9	0
△	1	8.25	Fine sand **(SP-SM)**	0	90	10	0
▲	1	10.00	Sandy silt **(CL)**	4	14	71	11

Grain Size Analysis

Proposed Mandoli Substation Project Near Mandoli Jail at Village Mandoli, New Delhi

CHEMICAL TEST RESULTS

SOIL-EXTRACT WATER:

Borehole No.	Depth, m	Sulphate Content (SO_3), %	Chloride Content (CL), %	pH Value
1	2.25	0.16	0.13	7.4
2	3.00	0.11	0.15	7.2
3	4.50	0.14	0.13	7.5

GROUND WATER:

Borehole No.	Depth, m	Sulphate Content (SO_3), mg/l	Chloride Content (CL), mg/l	pH Value
1	-	302	112	7.2
2	-	256	135	7.3
3	-	288	108	7.3