PROJECT: REPORT ON

Soil Investigation work for G.T Road Grid Substation in BSES Yamuna Power Limited

Prepared By:

MEGS GEO ENGINEERING SERVICE

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Prepared for:

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CONTENTS

1.0 Introduction

M/s. BSES Yamuna Power Limited is planning to setup a grid substation at G.T road, near Jhilmil, Shahdara, Delhi. For the purpose of the design, M/s MEGS Geo Engineering Service has been awarded the work of characterizing the deposits at site and accessing the nature of the formation for the project. A detailed geotechnical exploration at proposed location at G.T sub-station in Delhi was planned for comprehensive study and to confirm the subsoil conditions and to establish the various soil parameters and its behavior, to assess the general stability of site.

2.0 Purpose of Study

The overall purposes of this study are to evaluate the stratigraphy at the project site for site characterization and to develop geotechnical recommendations for foundation design and construction. To accomplish these purposes, the study was conducted as follows:

2.1. Drilling two (2) boreholes to specified depths through soil, in order to evaluate the stratigraphy at the site and to collect soil samples for laboratory testing.

2.2. conducting two Electrical resistivity tests (ERT) at the specified location;

2.3. Testing selected soil samples in the laboratory to determine pertinent index and engineering properties; and

2.4. Analyzing all field and laboratory data to develop geotechnical recommendations for foundations design and construction.

3.0 Laboratory Tests

A) On soil Samples

(a) Natural moisture content
(b) Dry density
(c) Particle size analysis
(d) Specific Gravity
(e) Atterberg Limits
(f) Direct shear test

B) Chemical Test on Water/Soil sample

(a) pH value
(b) Sulphate content
(c) Chloride content

4.0 Site Exploration:

4.1 The required equipment and team were mobilized to the site for carrying out the required field work. The locations for bore holes and depths adopted were given by the engineer-in-charge. All the boreholes and tests on samples collected were carried out in the presence of the representative of site-in-charge. Borehole location plan are enclosed.

4.2 All the boreholes of 150 mm diameter in soil strata were bored using shell and auger method. Casing was used as per requirement to retain the boreholes.

The details of the various bores/ tests conducted at site are given as below-

4.3 The standard penetration tests were conducted at 1.5 m intervals up to the depth of exploration.

For conducting SPT, IS Code: 2131-1981 was followed. After reaching the required depth of test, the bottom of the bore hole was cleaned properly and spoon is properly and centrally seated in position in the borehole. Standard split spoon sampler attached to lower end

of "A" drill rods was driven in the bore holes by means of standard hammer of 63.5 kg falling freely from a height of 75 cm. The sampler was driven 45 cm. and the number of blows required for each 15 cm. penetration were recorded. The number of blows for the first 15 cm. penetration was considered as seating drive. The number of blows for last 30 cm penetration was designated as SPT 'N' value. SPT soil samples obtained from standard split spoon sampler for all the above standard penetration tests were collected in polythene bags, sealed, labeled and sent to the laboratory for testing.

4.4 The undisturbed soil samples were collected in good quality thin walled seamless tubes, of. dia of 100 mm and length of 450 mm with area ratio less than 15%. The UDS tubes are gently pushed in soil using hydraulic push rig/gently hammering action. After retrieval of UDS tube from the borehole, ends of the tube with sample were sealed with freshly molten wax of minimum 20mm thick, properly labeled, marked an arrow showing upward direction and dispatched to laboratory for testing. At site sample tubes were covered with wet gunny bags.

4.5 On encountering the water table, its depth was recorded everyday in each borehole prior to resumption of day's work. The observation of depth of water table was continued for next seven days in the completed boreholes. When it was fully stabilized, the depth was recorded as depth of water table.

4.6 Ground water samples were collected from bore holes in an airtight clean bottle, properly labeled, sealed and sent to the laboratory of its chemical analysis test. Before collecting ground water sample, it was ensured that no external water was added before collection of sample.

4.7 Soil sample ware collected from bore holes as per approved schedule and chemical test were conducted on it in the laboratory.

5.0 Electrical Resistivity Tests

Electrical resistivity of the soil at the site was determined at the specified locations. The earth resistivity test is used for shallow subsurface exploration by means of electrical measures made at the ground surface. Resistivity measurements were made by driving electrode about 15 cm in to the ground at pre-selected electrode spacing. The test procedure was in accordance with IS: 3043:1987. The electrode spacing of 0.5, 1, 2, 5,7, 10 & 15 m were used. The results of ERT's are attached in illustration part of this report.

6.0 Laboratory Testing

6.1 Grain Size Analysis

For this purpose an oven dry pulverized soil sample is sieved through the set of sieves 20mm, 10mm, 4.75mm, 2.0m, 1.0m, 600micron, 300micron, 150micron and 75micron. The amounts of soil retained on each sieve are noted down. The % retained, cumulative % retained and % passing are computed by these retained weights.

If the % passing 75 micron sieve is appreciable, Hydrometer method is used to find the % fraction of particle sizes from 75micron to 2micron.

6.2 Liquid Limit

For liquid limit Casagrande apparatus is used. For this test air dry soil sample passing 425micron is taken and mixed with distilled water to give a stiff and homogeneous paste and is left for sufficient time for maturing in an air light container.

A portion of the above paste is kept in the cup of Casagrande apparatus, a groove is cut with groove cutting tool and blows are imported by turning the handle at the rate of 2 revolutions per second. The numbers of blows are counted till the continuous contact of the bottom of the groove occurs.

Few quantity of soil from the close portion of the groove after the contact occurs, are taken and its water content is determined by over drying method.

The liquid limit (WL) is computed by the equation.

$$W_l=W_n(n/25)e$$

Where Wn=water content (% corresponding to n blows)
e = 0.092 for soils with $W_L<50$
= 0.12 for soils with $W_L>50$

6.3 Plastic Limit

For this test sample is prepared in the same way as for liquid limit test. A ball is formed of sub sample weighting about 5 gm. This ball is rolled between the fingers of one hand and the glass plate with pressure sufficient to reduce the mass into a thread of about 3 mm in 5 to 10 complete forward and back movements. When a diameter of 3 mm is reached, soil is again remolded into a ball.
The process of rolling and remolding is repeated until the thread starts just crumbing at a diameter of 3 mm.

The crumbled thread is immediately transferred to an airtight container for determination of its moisture content by oven drying method.

This water content is termed as plastic limit. (W_P)

6.4 Plasticity Index

The plasticity index Ip is given by

$$I_p=W_L-W_P$$

6.5 Water Content

For this test the soil sample of known quantity (W_m) is taken in a container. The container with this soil sample is placed in an oven for drying at 105-110ºc for 16-24 hours. After drying the dry sample is again weighed to determine the dry weight of sample (W_d)

The moisture content is computed by the following equation:

$$W_n=(W_m-W_d)/W_d$$

6.6 Dry Density & Bulk Density

For determination of bulk density, a sample of known volume ‘V’ is extracted from the undisturbed sample. Its bulk weight ‘W’ and moisture content ‘Wn’ is determined by oven drying method.

The bulk density is determined by following equation

$$\gamma_b=W/V$$

and dry density by

$$\gamma_d=\gamma_b/(1+W_n)$$

6.7 Specific Gravity

The specific gravity of soil sample is determined by density bottle method. For this test 5-10g (w_2) sample of oven dry, cool soil is taken in 50ml capacity density bottle and its weight is noted down. The soil is covered with distilled water and left for sufficient period for suitable soaking. The entrapped air is removed by vacuum. The soil in bottle is filled full with water and it is noted down as w_3. The mass of empty bottle (w_1) and bottle with full distilled water also noted (w_4).

The specific gravity is found by the following equation.

$$G=w_2-w_1/[(w_2-w_1)-(w_3-w_4)]$$

6.8 Direct Shear Test

For this test shear box test apparatus is used. The prepared specimen from remolded/undisturbed sample is placed carefully in the box. The plain grid is kept on top of the specimen with its serrations at right angles to the direction of shear. The upper porous stone is placed on the grid and loading pad on the stone. The box with specimen is gently placed in the container (water jacket). The specimen is submerged with water. The container is mounted with the shear box and the specimen inside, on the shearing machine. The upper part of the box is so adjusted that it touches the proving ring. The jack is brought forward to bear up against the box container. The proving ring dial gauge is set to read zero.

The steel ball is placed in the recess of the loading pad. The loading yoke is set in contact with the steel ball on the loading pad. Vertical displacement dial gauge to read zero in contact with the top of the yoke. The normal load is applied and any change in thickness of specimen is recorded. Shear displacement dial gauge is also set to read zero. The locking screw is now removed and two parts of the shear box are separated by advancing the spacing screws.

The specimen is sheared at constant rate of strain. The readings of the proving ring dial gauge are noted down every 15 seconds for the first one-minute and then every 30 seconds thereafter. The reading of change in the thickness dial gauge and shear displacement dial gauge are also recorded at the same time interval. The test is continued until the specimen fails. The specimen is assumed to fail when the proving ring dial gauge starts receding or at shear displacement of approximately 15% of the length takes place.

The soil is removed from the box and test is repeated on the identical specimen under increased normal load.

For consolidated undrained test the specimen is prepared and set in the apparatus as above and after submergence, the specimen is allowed to consolidate fully under normal loads. The specimen is then sheared as in undrained test. At the end of the test, the specimen is removed and its final water content is determined. The test is repeated on other identical specimen in similar way under increasing normal loads.

For drained test, after completion of consolidation under a particular normal load, specimen is sheared at a slow rate to allow the pore water inside the specimen drain out. Final water content of failed specimen is determined. The test is repeated on other identical specimen after consolidation under increasing normal loads.

6.9 Chemical Analysis of Subsoil Samples

The chemical analysis tests on subsoil sample indicates that the pH value, chloride content and sulphate content are within permissible limits and Ordinary Portland Cement or Portland Slag Cement or Portland Pozzolana Cement can be used for RCC work. The minimum cement content and maximum free water-cement ratio shall be maintained as per IS: 456, 2000. Refer to the Test results attached in this report.

7.0 Findings Of Geotechnical Investigation

The classification of subsoil strata met at this site was done according to IS: 1498-1970. The test results can be summarized as below-

Borehole wise Summary

BH-1:

The subsoil strata from 0.0 to 0.5 m consist of filled up soil with gravel underlain by silty fine sand/fine sand to the finally explored depth of 15.00 m.

BH-2:

The subsoil strata from 0.0 to 0.4 m consist of filled up soil with gravel underlain by silty fine sand/fine sand to the finally explored depth of 15.00 m.

Table no. 1
Bore Hole Wise Details Of Subsoil Strata.

Depth,m		Soil Classification	Range of N value	Soil properties
From	To			
0.00	0.50	Filled up	-	-
0.50	10.00	Silty fine sand	16-50	DST c=0.00 kg/cm^2, Ø=30 º
10.00	15.00	Fine sand	64-86	DST c=0.00 kg/cm^2, Ø=32 º
WATER TABLE: Not Encountered				

The layer wise properties of the subsoil strata encountered at this site and used in design are given in following table no. 2.

Table No. 2
Layerwise Properties of Subsoil Strata

Depth, m		Soil Classification	Effective unit Weight, gm/cc	Shear Parameters	
From	To			C (kg/cm^2)	Ø (degree)
0.00	0.50	Filled up	1.60	-	-
0.50	10.00	Silty fine sand	1.85	0.00	30
10.00	15.00	Fine sand	1.90	0.00	32

The Detail description of subsoil strata encountered along with various laboratory test results are presented in the respective soil profile in Appendix-A of this report.

The subsoil profile depicting the distribution of the various subsoil strata along the alignment along with N values (observed/corrected) and other strength parameters with depth are given in subsoil profile enclosed with this report.

The SPT Curve & Table (No/Nc), Grain Size Analysis Curve, Mohr Circle Diagrams etc. are enclosed with this report.

Ground Water

The ground water table was not encountered in the borehole below existing ground surface during boring activities at site. However, as the surface water may percolate in heavy rainy season hence for the design purposes effect of ground water table can be considered at 5.0 m from ground surface.

8.0 Proposed Depth & Type Of Foundations

As discussed in Section 7.0, filled up soil was met to 0.4~0.5 m depth and silty sand/fine sand is encountered at the site below the fill to maximum explored depth of 15.0 m. Open foundations for the proposed facilities may bear at or below 2.0~3.0 m depth .

We recommend isolated / raft foundation at the minimum foundation embedment depth of 2.0 below EGL for the planned structure.

8.1 Computation of Safe /Allowable Bearing Capacity

Shear and settlement failure criteria as per IS: 6403- 1981, IS: 8009 (part-1)-1976 and IS: 1904-1986 have been considered to compute the safe / allowable bearing capacity of underlying soil strata for proposed structure.

The safe/allowable bearing capacity from both criteria is given as follows:-

8.2 Shear Failure Criterion:

The net safe bearing capacity of sub-soil strata has been computed by considering average of general and local shear failure using the following equation for calculating the net ultimate bearing capacity.

$$Q_{nu} = 2/3\ C\ N'_c\ S_c\ d_c\ i_c + q\ (N_q' - 1)\ S_q d_q i_q + 1/2\ \gamma\ B N_\gamma' S_\gamma d_\gamma\ i_\gamma \times W'$$

The following lowest soil parameters at foundation depth level are selected from bore hole for calculations:

$C=0.0T/m^2$ $\quad Ø=30^\circ$

Average Shear Parameters are computed by the following equation by iteration:

$C_{av}=(C_1h_1+C_2h_2+--------+C_nh_n)/h$

$\tan Ø_{av}=(h_1 \tan Ø_1+h_2 \tan Ø_2+----------+h_n \tan Ø_n)/h$

where, $h =0.5\times B\times\tan(45+ Ø_{av}/2)$ below foundation level

and Ci, Øi, hi-cohesion, angle of friction and thickness of ith layer below foundation level and upto thickness h respectively.

Shape factors have been taken as follows:-

$S_c = S_q = 1 + 0.2\ B/L$, $S_\gamma = 1 – 0.4\ B/L$ (for raft footing)

$i_c=i_q=i_\gamma=1.0$

Effective density:-

0.00 m to 10.00 m	:	1.85 t/cu.m
10.00 m to 15.00 m	:	1.90 t/cu.m

Depth factors:

$d_c=1+0.2\times of/B \tan(45^o+ Ø_{av}/2)$

$d_q=d_\gamma=1$ to $0.1\times D_f/B \tan(45^o+ Ø_{av}/2)$

Water correction factor (w)' = 0.60

Factor of safety F.O.S=2.5

Using the above equation and parameters, the following values of net safe bearing capacity have been computed in following table no. 3.

Table no. 3

Net Safe Bearing Capacity Based On Shear Failure Criterion

Depth of foundation below natural ground level (m)	Type of foundation (m)	Width of footing (m)	Net safe bearing capacity (t/m^2)
2.00	Open	3.0 m	25.2
	Open	6.0 m	32.2
3.00	Open	3.0 m	38.4
	Open	6.0 m	44.2

8.3 Settlement Failure Criterion

The settlement of sandy layers below the foundation level and up to the zone of Influence are computed by using the chart of settlement vs SPT 'N' given on page 17 of IS 8009, part-I.

For Raft footings, the zone of influence below the foundation depth is considered equal to 2.0B, where B is the width of foundation. The total permissible settlements have been considered as 50 & 75 mm.

The soil parameters have been adopted from the following table no. 4.

Table no. 4

Settlement Parameters (N Observed)

Depth below Ground level (m)	N Observed
0.00-10.00	16-50
10.00-15.00	64-86

The values of net allowable pressure intensities computed based on the above selected soil parameters are given in following Table no. 5.

Table No. 5:
Net Allowable Pressure Intensity based on settlement failure criterion.

Depth of foundation below NGL (m)	Type of foundation (m)	Width of Foundation (m)	Net Allowable Pressure intensity (t/m^2)	
			S=50 mm	S=75 mm
2.00	Open	3.0 m	20.4	25.2*
	Open	6.0 m	22.9	32.2*
3.00	Open	3.0 m	22.0	33.0
	Open	6.0 m	24.3	36.5

*Restricted in shear.

9.0 Conclusion with Recommendations

On the basis of above Geotechnical investigation the following recommendations are suggested:

9.1 The subsoil strata at this site consist of filled up to 0.5 m depth underlain by sand. The subsoil strata have been described in detail in clause 7.0. .

9.2 On the basis of field and some laboratory test results, and analysis in clause 8.0, the lower values of net safe bearing capacity obtained from shear failure criterion and net allowable pressure intensity obtained from settlement failure criterion can be adopted for design purposes. The recommended value of net safe bearing capacities/net allowable pressure intensities for design purposes, are given in the following table no. 6:-

Table no. 6:
Recommended Values of Net SBC/API

Depth of foundation below NGL (m)	Type of foundation (m)	Width of Foundation (m)	Net Allowable Pressure intensity (t/m^2)	
			S=50 mm	S=75 mm
2.00	Open	3.0 m	20.4	25.2*
	Open	6.0 m	22.9	32.2*
3.00	Open	3.0 m	22.0	33.0
	Open	6.0 m	24.3	36.5

*Restricted in shear.

9.3 The chemical analysis tests on subsoil sample indicates that the Ordinary Portland Cement or Portland Slag Cement or Portland Pozzolana Cement can be used for RCC work. The minimum cement content and maximum free water-cement ratio shall be maintained as per IS: 456, 2000. refer to the Test Results attached in Appendix-A of this report.

9.4 The slope of the excavated pit may be kept upto 1 vertical on 0.8-1.0 horizontal during excavation. However, if space is constraint then suitably designed bracing and strutting system should be adopted.

9.5 As per IS 1893:2002, the site falls under earthquake Zone-IV. Water table is not met at to the final explored depth and SPT value exceeds 16 in the top layer . So in our opinion liquefaction may not likely to take place.

9.6 The above recommendations have been made on the basis of in situ tests and laboratory tests conducted on the samples collected from limited number of bore holes bored at the locations given by the client. If during construction, any unusual or abnormal features are noticed, these may be brought to the attention of Geotechnical Consultants for further suggestions.

10.0 Closure

We appreciate the opportunity to submit this Soil Investigation Report. The above recommendations have been made on the basis of in situ tests and laboratory tests conducted on the samples collected from the boreholes explored at the locations (as per location plan). If during excavation, any unusual or abnormal features are noticed, these may be brought to the attention of geotechnical consultant before proceeding with construction work for further suggestions.

For

MEGS Geo Engineering Service

Appendix-A

SOIL PROFILE

Project : Soil Investigation work for G.T Road Grid Substation in BSES Yamuna Power Limited	BH.No: 1 Location-Jhilmil	Dia of Borehole 150 mm	Start Date 3/8/2022	Borehole Depth, m
Client: BSES Yamuna Power Limited	Surface Elevation -	WATER TABLE : Not Encountered	Coordinates -	End Date 4/8/2022	15.0

SPT N-Value	Depth (m)	Sample No.	Symbol	SOIL DESCRIPTION	IS Symbol	Gradation Analysis				Silt Factor	Atterberg Limits			Specific Gravity	Natural Density gms/cm^3	Dry Density gms/cm^3	Water Content %	Shear Test		
						Gravel %	Sand %	Silt %	Clay %		Liquid %	Plastic %	Plasticity Index %					Test Type	Cohesion Intercept Kg/cm^2	Angle of Internal Friction
	0.00 0.50	DS1		Filled up soil with gravel	0.5 m															
20	1.50 1.95	SPT1		Light brown silty fine sand		0	79	21	0		Non-Plastic									
	2.50 2.80	DS2																		
23	3.00 3.45	SPT2												2.66						
30	4.50 4.95	SPT3				0	84	16	0		Non-Plastic									
	5.50 5.80	UDS1			SM										1.86	1.62	14.7	DST	0.0	31.4
35	6.00 6.45	SPT4																		
47	7.50 7.95	SPT5				0	82	18	0		Non-Plastic									
	8.50 8.80	UDS2												2.63	1.89	1.64	15.2	DST	0.0	32.1
52	9.00 9.45	SPT6		Light grey fine sand with gravel	9.0 m SP-SM	4	85	11	0											
56	10.50 10.95	SPT7									Non-Plastic									

SOIL PROFILE

Project : Soil Investigation work for G.T Road Grid Substation in BSES Yamuna Power Limited		BH.No: 1 Location-Jhilmil	Dia of Borehole 150 mm	Start Date 3/8/2022	Borehole Depth, m
Client: BSES Yamuna Power Limited	Surface Elevation -	WATER TABLE : Not Encountered	Coordinates -	End Date 4/8/2022	15.0

SPT N-Value	Depth (m)	Sample No.	Symbol	SOIL DESCRIPTION	IS Symbol	Gradation Analysis				Silt Factor	Atterberg Limits			Specific Gravity	Natural Density gms/cm^3	Dry Density gms/cm^3	Water Content %	Shear Test		
						Gravel %	Sand %	Silt %	Clay %		Liquid %	Plastic %	Plasticity Index %					Test Type	Cohesion Intercept Kg/cm^2	Angle of Internal Friction
	11.50 11.80	UDS3		Light grey fine sand											1.92	1.66	15.8	DST	0.0	32.8
64	12.00 12.45	SPT8			SP-SM	0	92	8	0											
73	13.50 13.95	SPT9									Non-Plastic			2.64						
82	15.00 15.45	SPT10			15.0 m	0	91	9	0											

SOIL PROFILE

Project : Soil Investigation work for G.T Road Grid Substation in BSES Yamuna Power Limited		BH.No: 2 Location-Jhilmil	Dia of Borehole 150 mm	Start Date 4/8/2022	Borehole Depth, m
Client: BSES Yamuna Power Limited	Surface Elevation -	WATER TABLE : Not Encountered	Coordinates -	End Date 5/8/2022	15.0

SPT N-Value	Depth (m)	Sample No.	Symbol	SOIL DESCRIPTION	IS Symbol	Gradation Analysis				Silt Factor	Atterberg Limits			Specific Gravity	Natural Density gms/cm^3	Dry Density gms/cm^3	Water Content %	Shear Test		
						Gravel %	Sand %	Silt %	Clay %		Liquid %	Plastic %	Plasticity Index %					Test Type	Cohesion Intercept Kg/cm^2	Angle of Internal Friction
	0.00 0.50	DS1		Filled up soil with gravel	0.4 m															
16	1.50 1.95	SPT1		Light brown silty fine sand		0	77	23	0		Non-Plastic									
	2.50 2.80	UDS1												2.65	1.84	1.61	14.4	DST	0.0	30.6
24	3.00 3.45	SPT2																		
29	4.50 4.95	SPT3				0	83	17	0		Non-Plastic									
	5.50 5.80	UDS2			SM										1.88	1.63	15.4			
59	6.00 6.45	SPT4				0	81	19	0		Non-Plastic									
55	7.50 7.95	SPT5												2.63						
	8.50 8.80	UDS3				0	85	15	0		Non-Plastic				1.89	1.64	15.5	DST	0.0	31.8
63	9.00 9.45	SPT6																		
77	10.50 10.95	SPT7			11.0 m															

SOIL PROFILE

Project : Soil Investigation work for G.T Road Grid Substation in BSES Yamuna Power Limited		BH.No: 2 Location-Jhilmil	Dia of Borehole 150 mm	Start Date 4/8/2022	Borehole Depth, m
Client: BSES Yamuna Power Limited	Surface Elevation -	WATER TABLE : Not Encountered	Coordinates -	End Date 5/8/2022	15.0

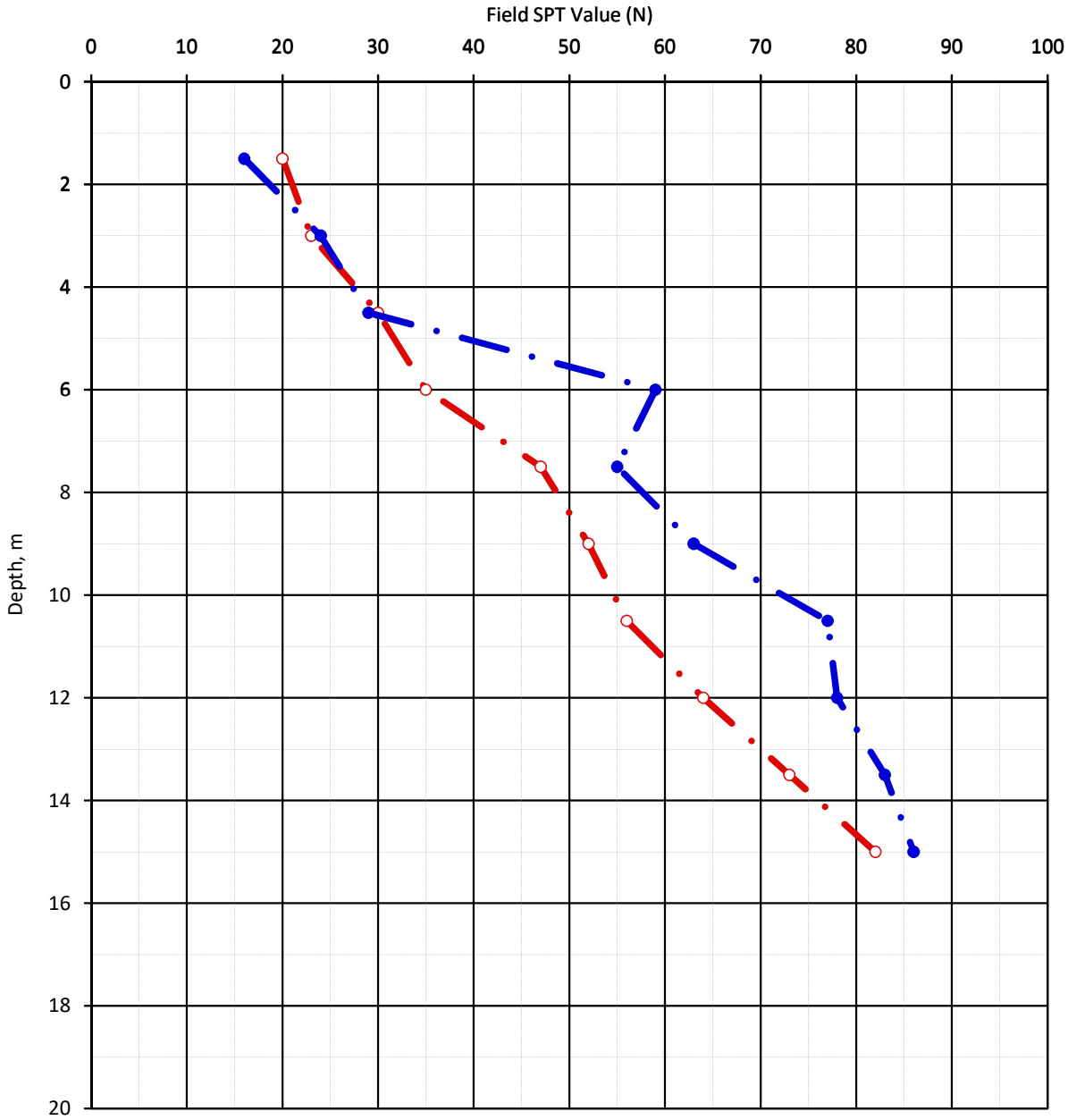
SPT N-Value	Depth (m)	Sample No.	Symbol	SOIL DESCRIPTION	IS Symbol	Gradation Analysis				Silt Factor	Atterberg Limits			Specific Gravity	Natural Density gms/cm^3	Dry Density gms/cm^3	Water Content %	Shear Test		
						Gravel %	Sand %	Silt %	Clay %		Liquid %	Plastic %	Plasticity Index %					Test Type	Cohesion Intercept Kg/cm^2	Angle of Internal Friction
	11.50 11.80	UDS4		Light grey fine sand		0	91	9	0		Non-Plastic			2.64	1.94	1.67	16.1	DST	0.0	32.5
78	12.00 12.45	SPT8			SP-SM															
83	13.50 13.95	SPT9				0	90	10	0		Non-Plastic									
86	15.00 15.45	SPT10			15.0 m									2.62						

MEGS GEO ENGINEERING SERVICE

Standard Penetration Test

Project: Soil Investigation work for G.T Road Grid Substation in BSES Yamuna Power Limited

Borehole Details			
Symbol	Borehole Number	Reduced Level	Location
	BH-1	-	Jhilmil
	BH-2	-	



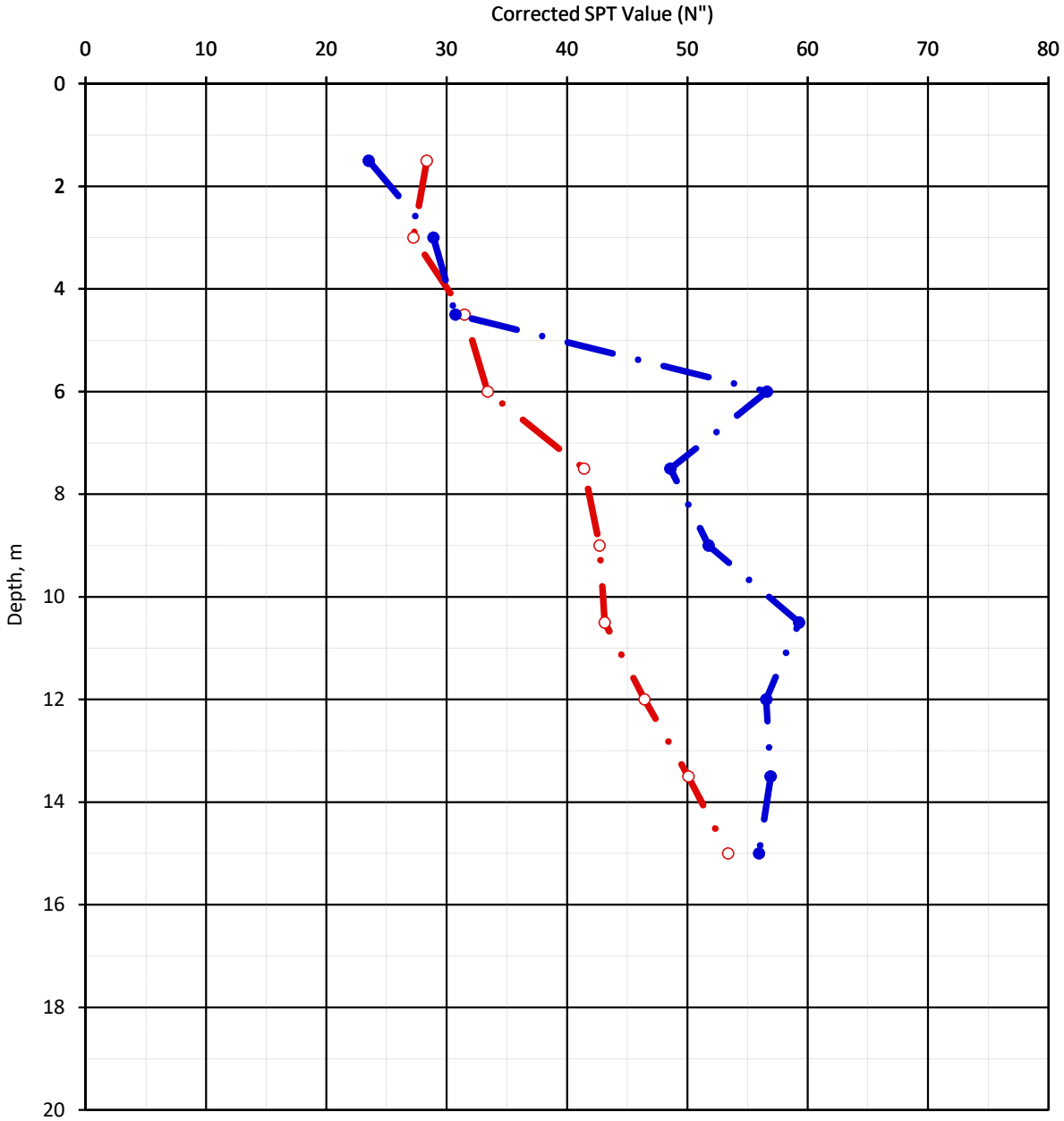
Field SPT Values vs. Depth

MEGS GEO ENGINEERING SERVICE

Standard Penetration Test

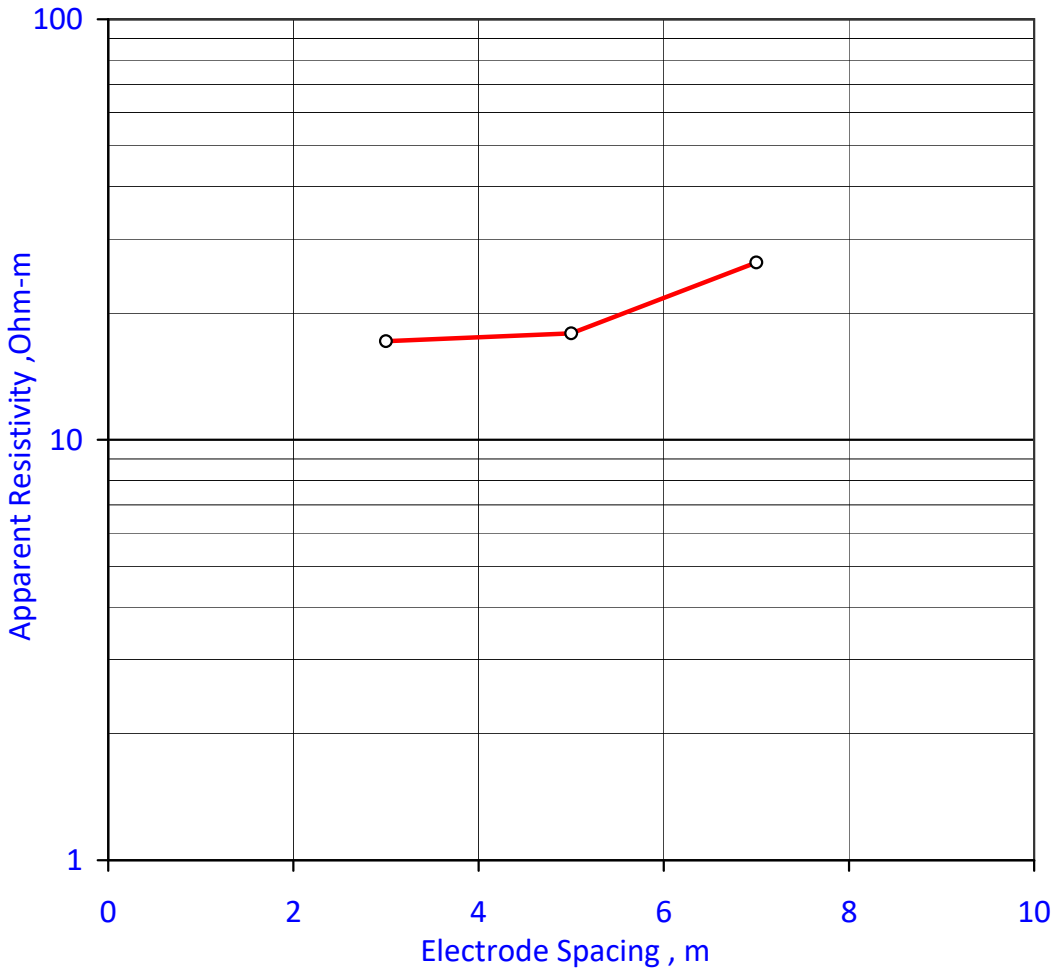
Project: Soil Investigation work for G.T Road Grid Substation in BSES Yamuna Power Limited

Borehole Details			
Symbol	Borehole Number	Reduced Level	Location
	BH-1	-	Jhilmil
	BH-2	-	



Corrected SPT Values vs. Depth

ELECTRICAL RESISTIVITY TEST NO - 1

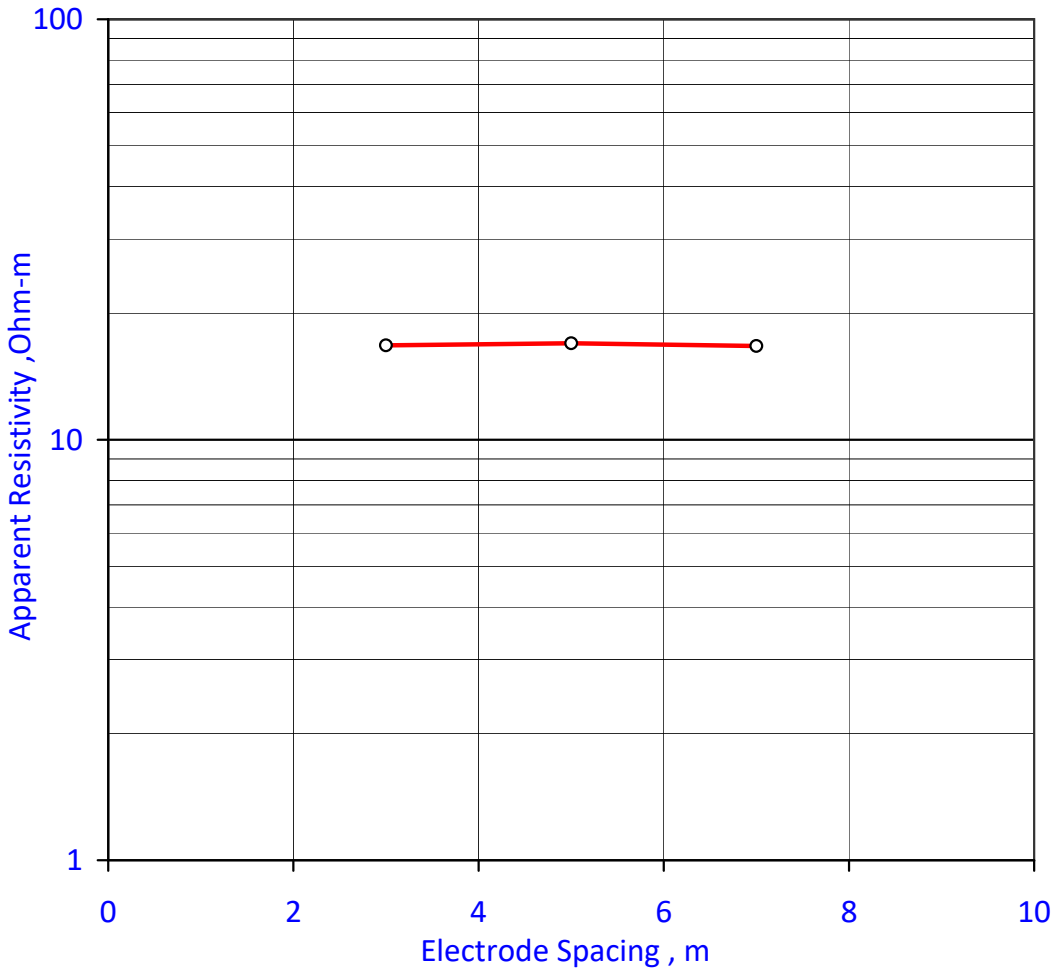


Electode Spacing,m	Apparent Resistivity, Ohm-m
3.0	17.2
5.0	17.9
7.0	26.4

Location : Jhilmil

Project: Soil Investigation work for G.T Road Grid Substation in BSES Yamuna Power Limited

ELECTRICAL RESISTIVITY TEST NO - 2

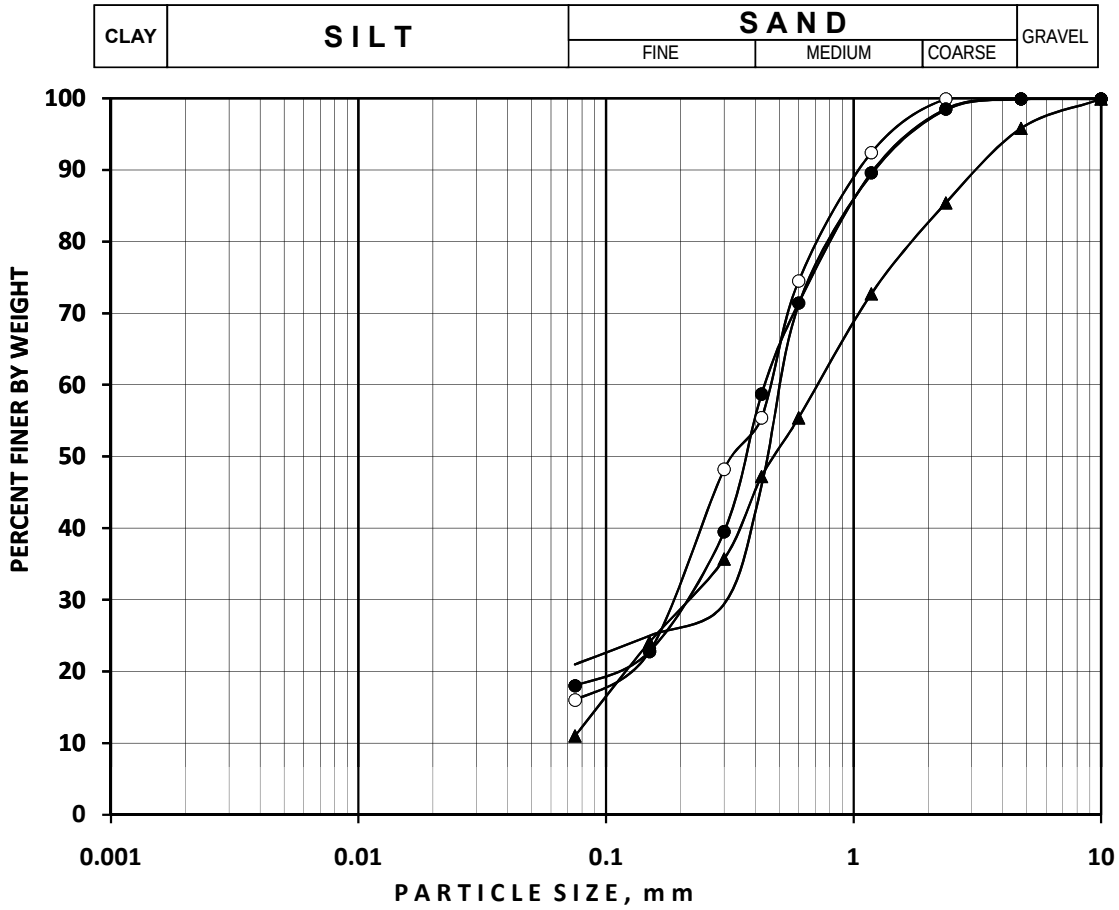


Electode Spacing,m	Apparent Resistivity, Ohm-m
3.0	16.8
5.0	17.0
7.0	16.7

Location : Jhilmil

Project: Soil Investigation work for G.T Road Grid Substation in BSES Yamuna Power Limited

LABORATORY :
MEGS GEO ENGINEERING SERVICE



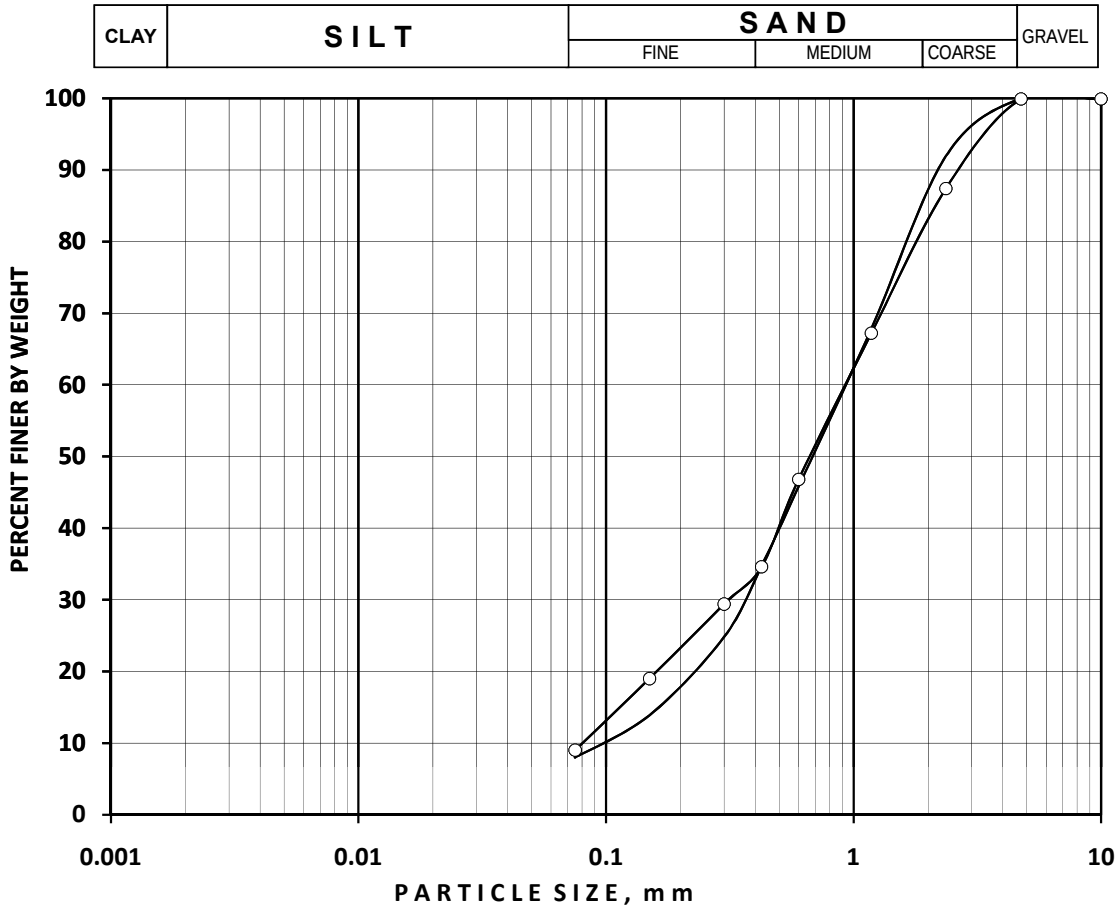
SYMBOL	BORE HOLE	DEPTH m	DESCRIPTION	GRAVEL %	SAND %	SILT %	CLAY %	D_{60}	D_{10}	C_u
——	1	1.5	Silty fine sand (SM)	0	79	21	0	0.523		
—○—○—	1	4.5	Silty fine sand (SM)	0	84	16	0	0.467		
—●—●—	1	7.5	Silty fine sand (SM)	0	82	18	0	0.443		
—▲—▲—	1	9.0	Fine sand with gravel (SP-SM)	4	85	11	0	0.754		

GRAIN SIZE ANALYSIS

Location: JHILMIL

Project: Soil Investigation work for G.T Road Grid Substation in BSES Yamuna Power Limited

LABORATORY :
MEGS GEO ENGINEERING SERVICE



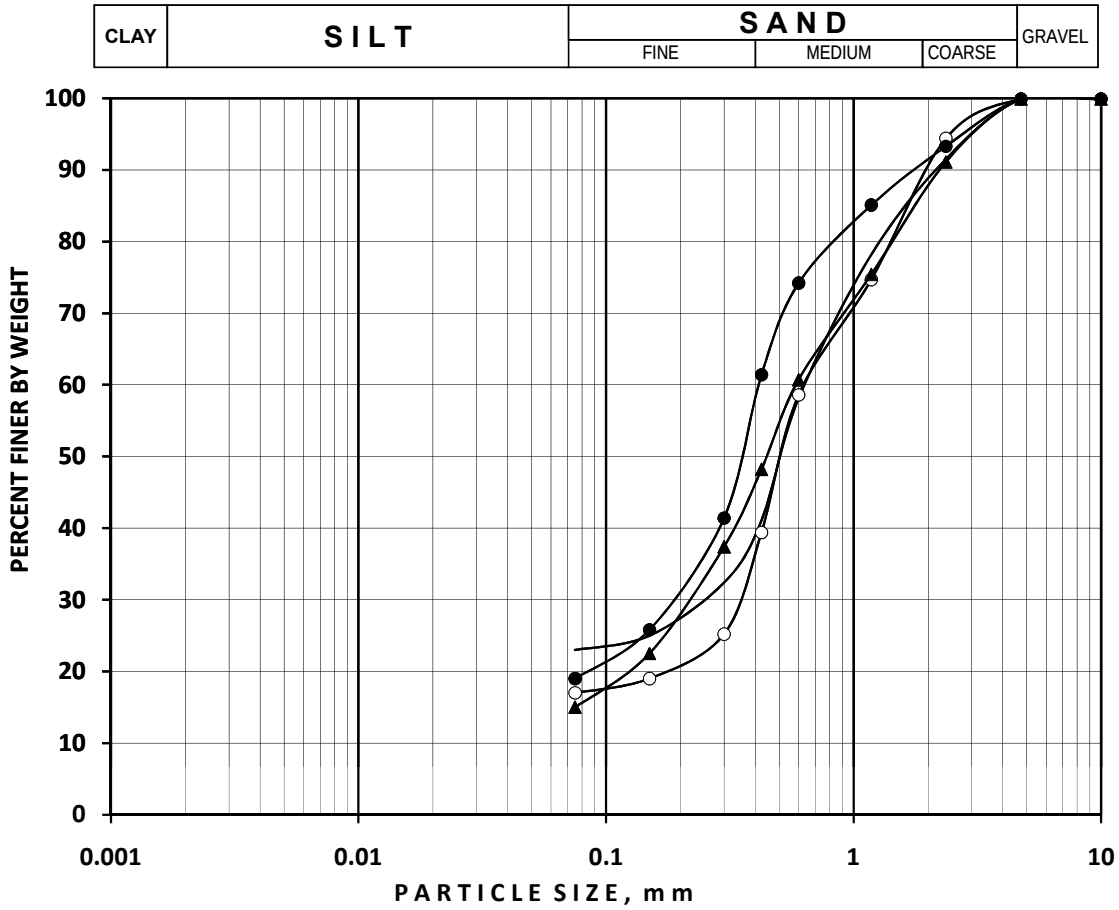
SYMBOL	BORE HOLE	DEPTH m	DESCRIPTION	GRAVEL %	SAND %	SILT %	CLAY %	D_{60}	D_{10}	C_u
———	1	12.0	Fine sand (SP-SM)	0	92	8	0	0.974	0.100	9.70
—○—○—	1	15.0	Fine sand (SP-SM)	0	91	9	0	0.975	0.083	11.82

GRAIN SIZE ANALYSIS

Location: JHILMIL

Project: Soil Investigation work for G.T Road Grid Substation in BSES Yamuna Power Limited

LABORATORY :
MEGS GEO ENGINEERING SERVICE



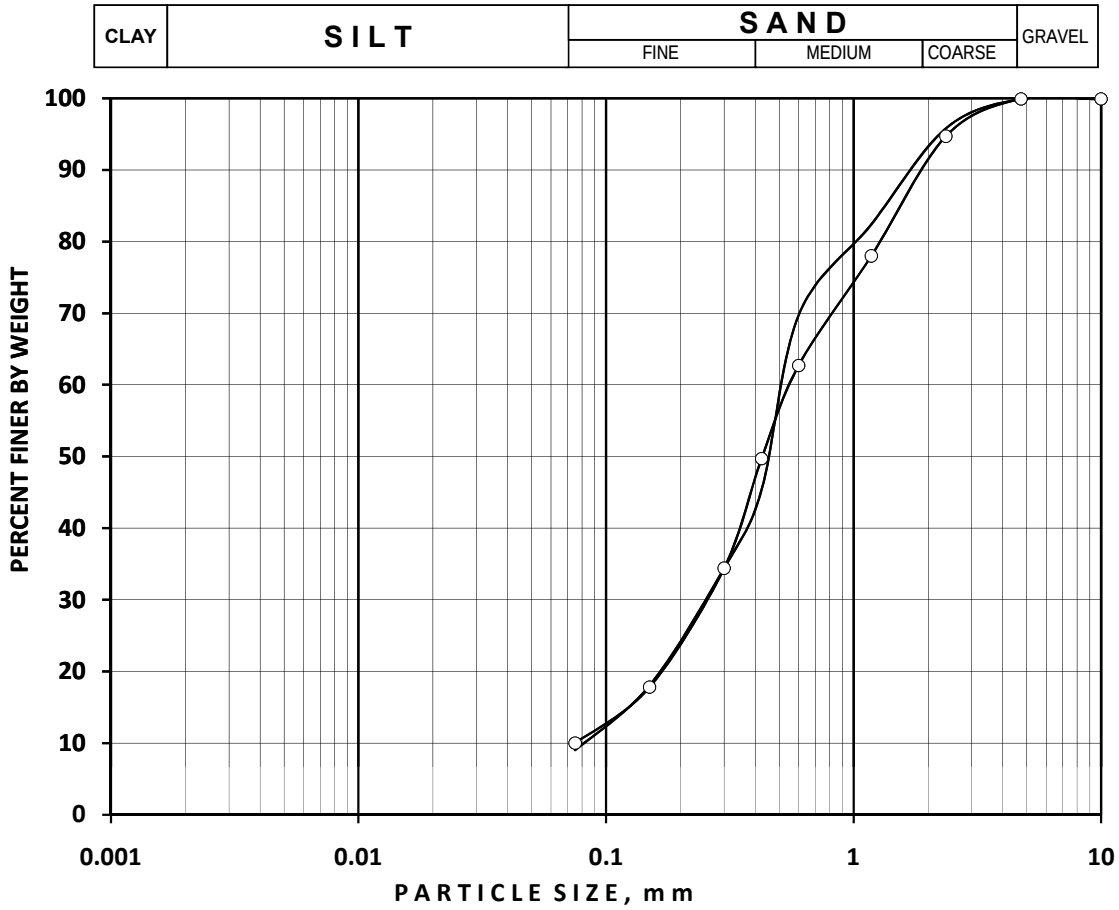
SYMBOL	BORE HOLE	DEPTH m	DESCRIPTION	GRAVEL %	SAND %	SILT %	CLAY %	D_{60}	D_{10}	C_u
——	2	1.5	Silty fine sand (SM)	0	77	23	0	0.655		
—○—○—	2	4.5	Silty fine sand (SM)	0	83	17	0	0.650		
—●—●—	2	6.0	Silty fine sand (SM)	0	81	19	0	0.416		
—▲—▲—	2	8.5	Silty fine sand (SM)	0	85	15	0	0.590		

GRAIN SIZE ANALYSIS

Location: JHILMIL

Project: Soil Investigation work for G.T Road Grid Substation in BSES Yamuna Power Limited

LABORATORY :
MEGS GEO ENGINEERING SERVICE



SYMBOL	BORE HOLE	DEPTH m	DESCRIPTION	GRAVEL %	SAND %	SILT %	CLAY %	D_{60}	D_{10}	C_u
	1	11.5	Fine sand (SP-SM)	0	91	9	0	0.530	0.083	6.37
	1	13.5	Fine sand (SP-SM)	0	90	10	0	0.564	0.075	7.52

GRAIN SIZE ANALYSIS

Location: JHILMIL

Project: Soil Investigation work for G.T Road Grid Substation in BSES Yamuna Power Limited

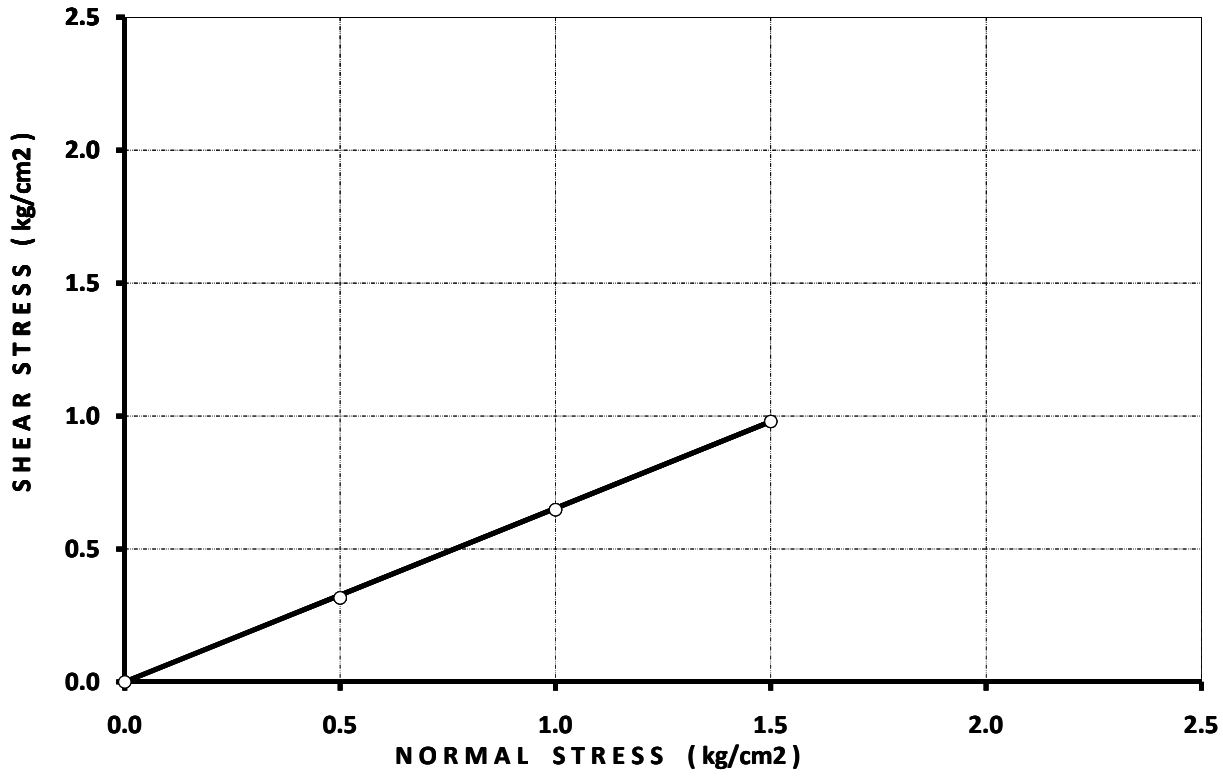
LABORATORY :
MEGS GEO ENGINEERING SERVICE

DRAINED DIRECT SHEAR TEST

Borehole No.	:	1
Depth, m	:	5.50
Type of test	:	Saturated Consolidated Drained

Dry Density gm/cc	"c" Value kg / cm^2	ϕ, Value DEGREE
1.62	0	31.4

Type of Soil : Silty sand



Project : Soil Investigation work for G.T Road Grid Substation in BSES Yamuna Power Limited

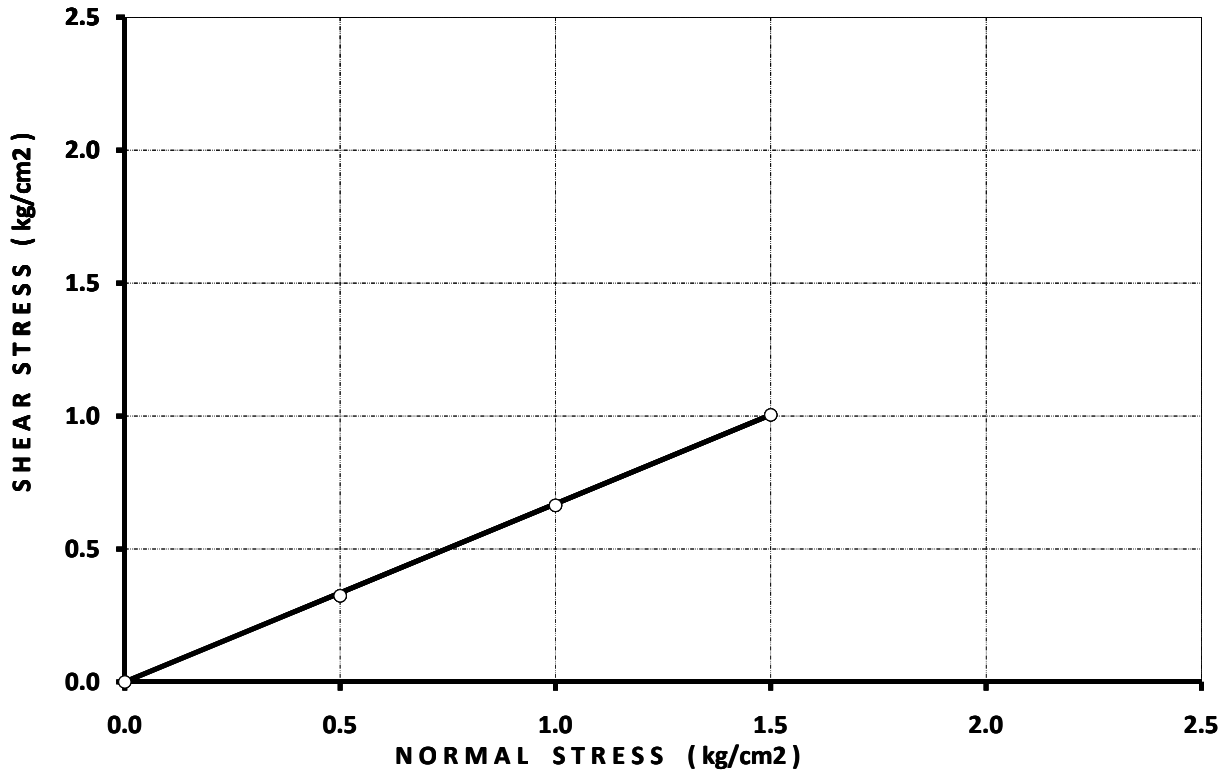
LABORATORY :
MEGS GEO ENGINEERING SERVICE

DRAINED DIRECT SHEAR TEST

Borehole No.	:	1
Depth, m	:	8.50
Type of test	:	Saturated Consolidated Drained

Dry Density gm/cc	"c" Value kg / cm^2	ϕ, Value DEGREE
1.64	0	32.1

Type of Soil : Silty sand



Project : Soil Investigation work for G.T Road Grid Substation in BSES Yamuna Power Limited

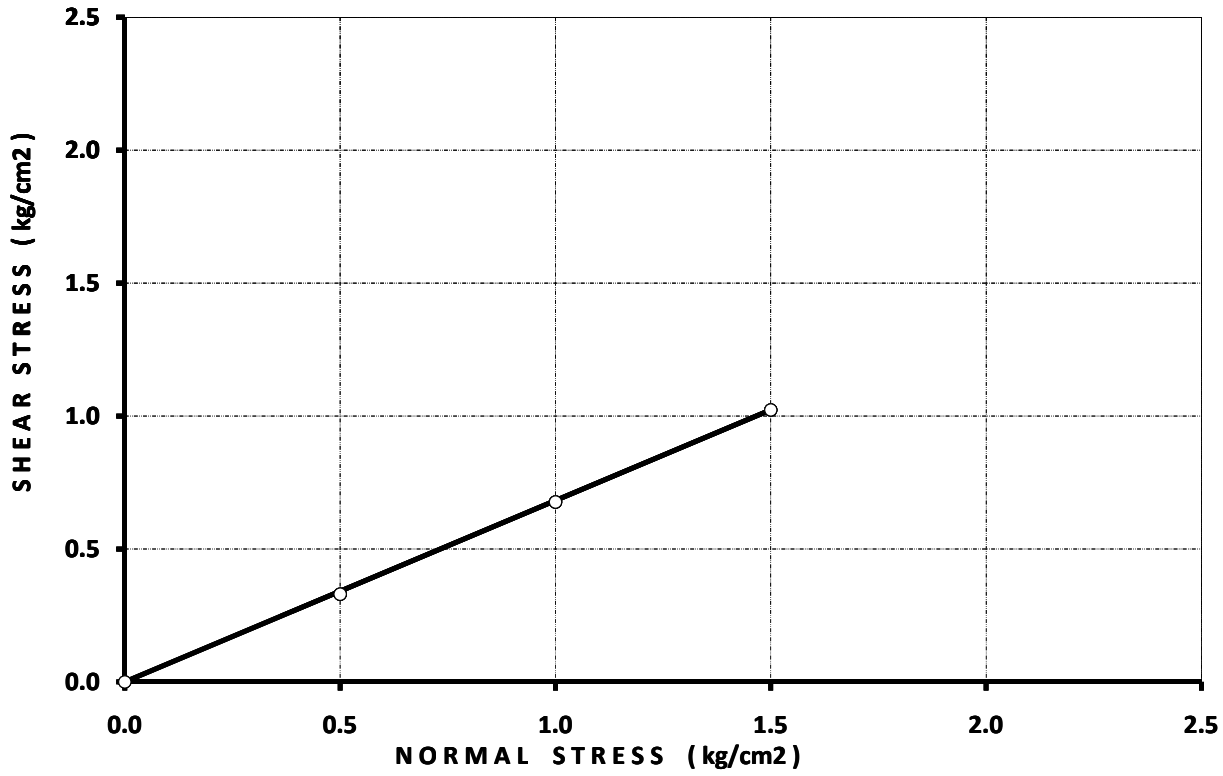
LABORATORY :
MEGS GEO ENGINEERING SERVICE

DRAINED DIRECT SHEAR TEST

Borehole No.	:	1
Depth, m	:	11.50
Type of test	:	Saturated Consolidated Drained

Dry Density gm/cc	"c" Value kg / cm^2	ϕ, Value DEGREE
1.66	0	32.8

Type of Soil : Fine sand



Project : Soil Investigation work for G.T Road Grid Substation in BSES Yamuna Power Limited

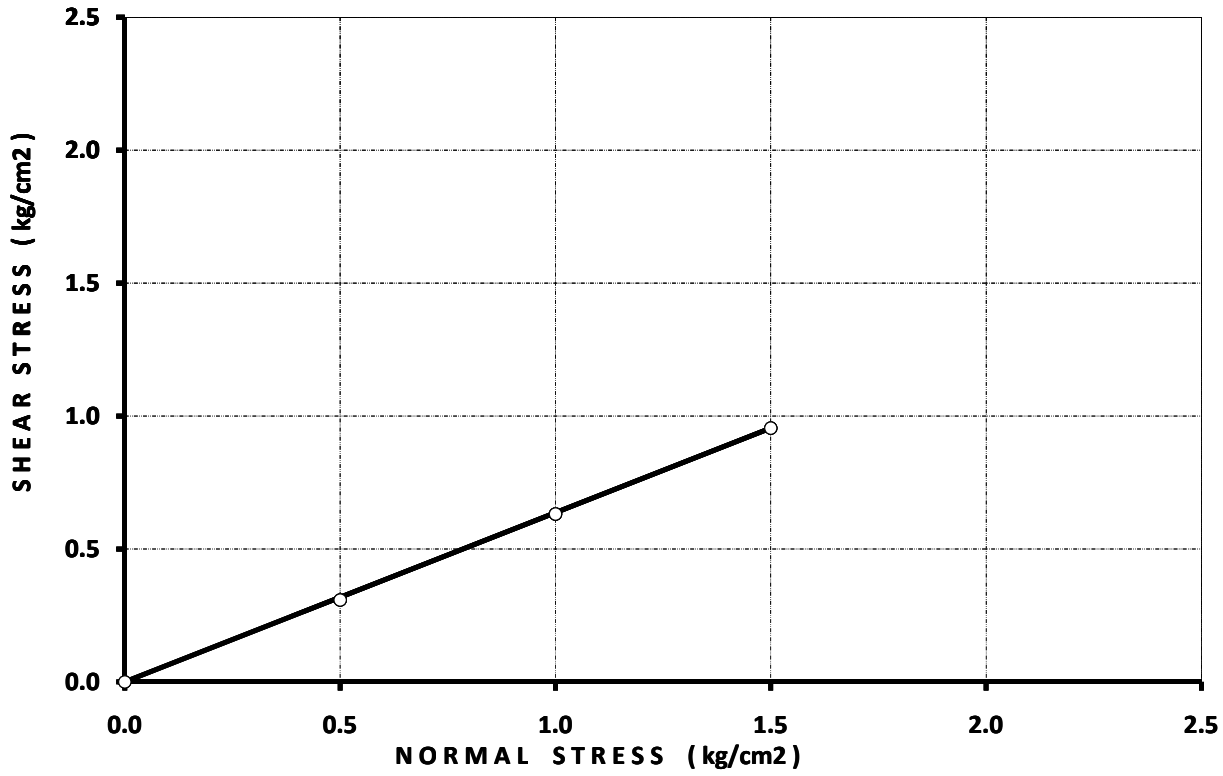
LABORATORY :
MEGS GEO ENGINEERING SERVICE

DRAINED DIRECT SHEAR TEST

Borehole No.	:	2
Depth, m	:	2.50
Type of test	:	Saturated Consolidated Drained

Dry Density gm/cc	"c" Value kg / cm^2	ϕ, Value DEGREE
1.61	0	30.6

Type of Soil : Silty sand



Project : Soil Investigation work for G.T Road Grid Substation in BSES Yamuna Power Limited

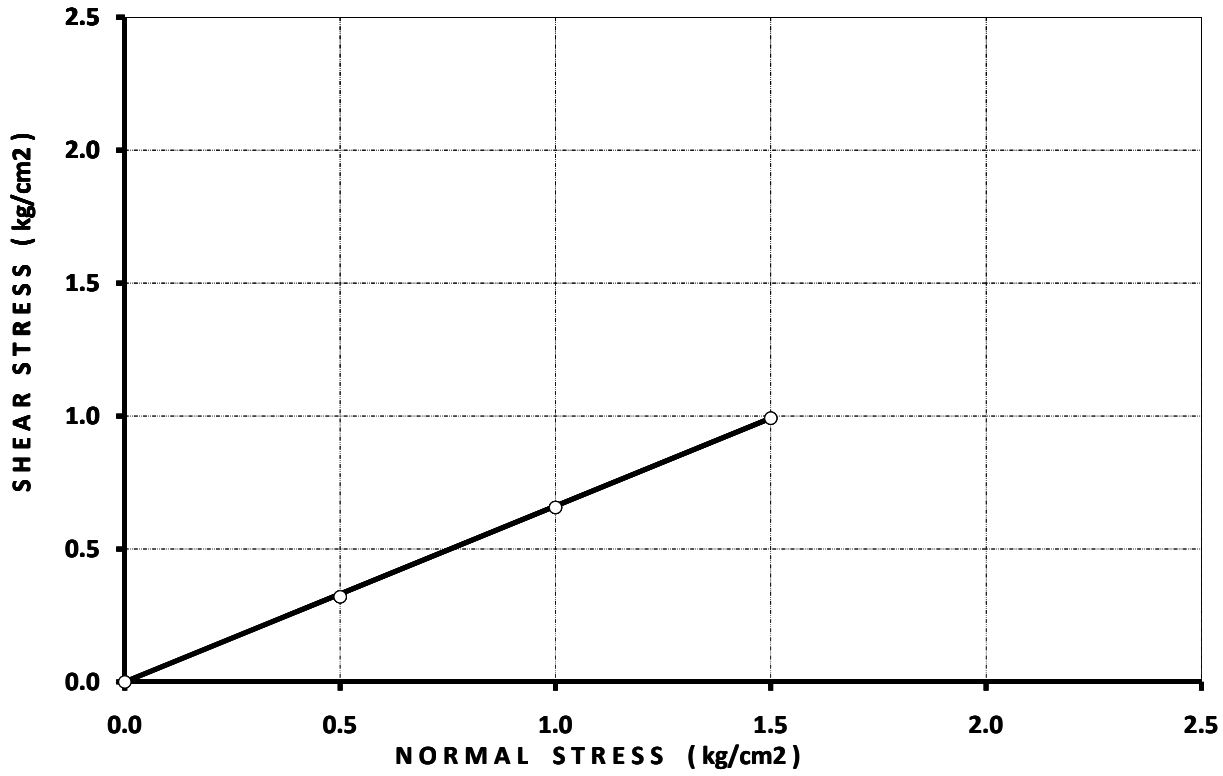
LABORATORY :
MEGS GEO ENGINEERING SERVICE

DRAINED DIRECT SHEAR TEST

Borehole No.	:	2
Depth, m	:	8.50
Type of test	:	Saturated Consolidated Drained

Dry Density gm/cc	"c" Value kg / cm^2	ϕ, Value DEGREE
1.64	0	31.8

Type of Soil : Silty sand



Project : Soil Investigation work for G.T Road Grid Substation in BSES Yamuna Power Limited

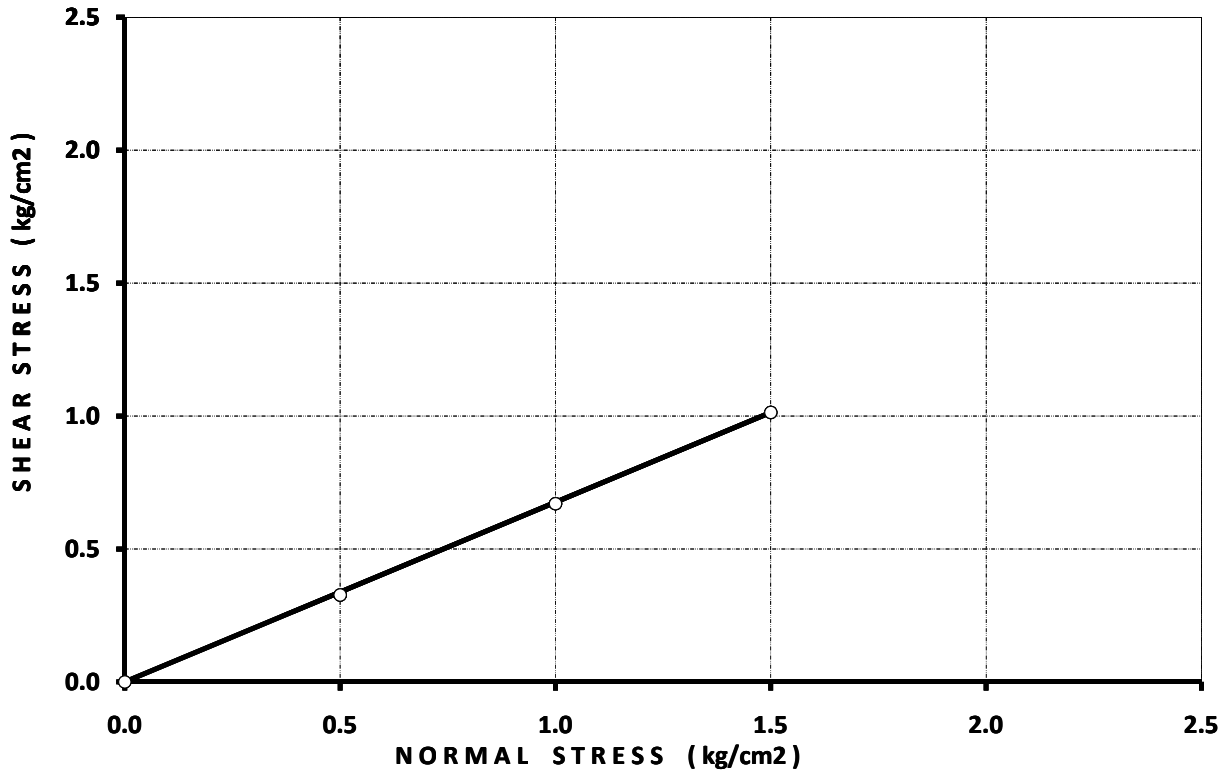
LABORATORY :
MEGS GEO ENGINEERING SERVICE

DRAINED DIRECT SHEAR TEST

Borehole No.	:	2
Depth, m	:	11.50
Type of test	:	Saturated Consolidated Drained

Dry Density gm/cc	"c" Value kg / cm^2	ϕ, Value DEGREE
1.67	0	32.5

Type of Soil : Fine sand



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CHEMICAL TEST RESULTS

Test on Soil-Water Extract				
Borehole No.	**Depth (m)**	**pH Value**	**Chloride Content ,%**	**Sulphate Content ,%**
BH-1	3.00	7.85	0.03	0.13
BH-2	4.50	7.74	0.02	0.11

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Appendix -B
Sample Calculation

MEGS Geo Engineering Service

BEARING CAPACITY ANALYSIS

Calculation as per IS 6403-1981

The bearing capacity equation is as follows :

$$q_{net\ safe} = (1/FS)\{cN_c\zeta_c d_c + q(N_q-1)\zeta_q d_q + 0.5B\gamma N_\gamma \zeta_\gamma d_\gamma R_w\}$$

where:

Soil parameters :

c =	0.00	T/m^2	ϕ =	30.0	degrees	GENERAL SHEAR FAILURE				Density Profile	
c' =	0.00	T/m^2	ϕ'=	21.1	degrees	LOCAL SHEAR FAILURE				Depth, m	g
General Shear Failure :			N_c =	30.14	N_q =	18.40	N_γ =	22.40	From	To	T/m^3
Local Shear Failure :			N_c' =	15.87	N_q' =	7.11	N_γ' =	6.24	0.0	0.5	Fill
									0.5	10.0	1.85
Factor of safety =	2.5								10.0	15.0	1.90

Design Water Table depth = 5.0 m

Rw = 0.60

Depth to be ignored due to fill: 0.5 m

FAILURE CRITERIA : **Average** **OF LOCAL & GENERAL SHEAR FAILURE**

Foundation Dimensions		FOUN-DATION SHAPE	Depth,m	R_w	Shape Factors			Depth factors (GSF)			Depth factors (LSF)			$q_{net\ safe}$, T/m^2		Safe Net Bearing Capacity T/m^2
B, m	L, m				ζ_c	ζ_q	ζ_γ	d_c	d_q	d_γ	d_c'	$d_{q'}$	d_γ'	GSF	LSF	
3.0	3.0	*Square*	2.0	0.60	1.30	1.20	0.80	1.00	1.09	1.09	1.00	1.07	1.07	38.2	12.3	25.2
6.0	6.0	*Square*	2.0	0.60	1.30	1.20	0.80	1.00	1.04	1.04	1.00	1.04	1.04	49.1	15.3	32.2
3.0	3.0	*Square*	3.0	0.60	1.30	1.20	0.80	1.00	1.14	1.14	1.00	1.12	1.12	57.8	18.9	38.4
6.0	6.0	*Square*	3.0	0.60	1.30	1.20	0.80	1.00	1.07	1.07	1.00	1.06	1.06	67.0	21.4	44.2

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MEGS Geo Engineering Service

Settlement based on N-value

Calculation as per IS : 8009 (Part I) - 1976

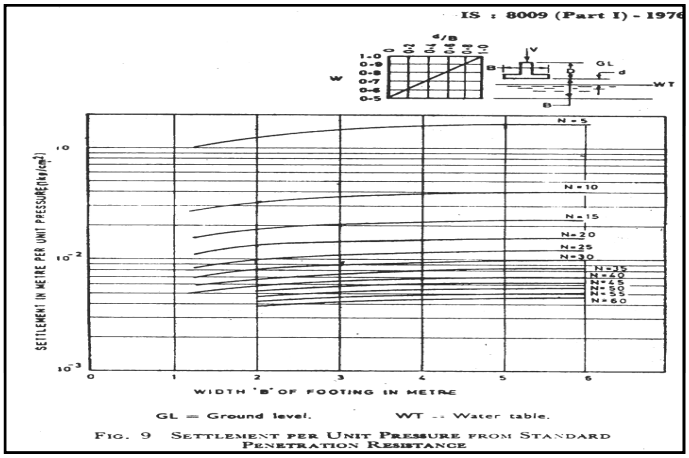

FIG. 9 SETTLEMENT PER UNIT PRESSURE FROM STANDARD PENETRATION RESISTANCE

Depth of Design Water Table: 5.0 m

Rw factor : 0.6

Depth to be ignore due to fill: 0.5 m

Tolerable Total Settlement : **50** mm

Foundation Width,m	Foundation Length,m	Foundation Depth,m	Shape	Design **N-value**	Settlement @ 1kg/cm^2 (as read off from graph), mm	R_w	Fox's Depth Factor, d_f	Rigidity Factor, d_r	Net Allowable Bearing Pressure, T/m^2
3.0	3.0	2.0	Square	16.0	18.4	0.60	1.00	0.8	**20.4**
6.0	6.0	2.0	Square	19.0	16.4	0.60	1.00	0.8	**22.9**
3.0	3.0	3.0	Square	17.0	17.0	0.60	1.00	0.8	**22.0**
6.0	6.0	3.0	Square	20.0	15.4	0.60	1.00	0.8	**24.3**

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Appendix-C
Borehole Photos

BH-1

BH-2