

GEOTECHNICAL REPORT

PROPOSED STAFF RESIDENTIAL BUILDING
PROJECT AT PLOT NO. 53/11, 12, 13, 14,
OLD RAJENDER NAGAR,
NEW DELHI

SUBMITTED TO:

SALWAN EDUCATION TRUST

Block 53, Old Rajender Nagar, New Delhi – 110 060

Project No. 22080

Dated. July, 2022

Revision-0

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July 5th , 2022

Project No. 22080

Salwan Education Trust

Block 53, Old Rajender Nagar,
New Delhi – 110 060

Sub: Final Report on Soil Investigation work for Proposed Staff Residential Building Project at Plot No. 53/11, 12, 13, 14, Old Rajender Nagar, New Delhi

We have carried out the soil investigation work accordance with your Work Order No. SET/654/2022 dated April 4th, 2022. We thank you for your business and hope that you are satisfied with our services rendered.

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

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

Yours faithfully,
RAO GEOTECHNICAL CONSULTANTS LLP



(G.R.RAO)



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1.0 INTRODUCTION

1.1 Project Description

This soil investigation work, whose results are being presented herewith, has been carried out for Proposed Staff Residential Building Project at Plot No. 53/11, 12, 13, 14, Old Rajender Nagar, New Delhi. We understand that the proposed project shall consists of Stilt + 4 storeys with single basement.

Borehole locations were shown to us by the client representative. A Layout plan indicates the borehole locations is illustrated on the Plate No. 1.

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 two (2) boreholes to specified depth or refusal ($N > 100$) whichever encountered earlier), observing ground water table levels, conducting required field and laboratory tests and their analysis.
3. 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.

3.0 LABORATORY TESTS

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

Laboratory Test	IS Code Referred
Bulk Density	By calculations
Natural Moisture Content	IS : 2720 (Part-2)-1973, RA-2010
Specific Gravity	IS : 2720 (Part-3)-1980, RA-2007
Grain Size Analysis	IS : 2720 (Part-4)-1985, RA-2010
Liquid Limit and Plastic Limit	IS : 2720 (Part-5)-1985, RA-2010
Consolidated Drained Direct Shear Test	IS : 2720 (Part-13)-1986, RA-2010

4.0 GENERAL SITE CONDITIONS

4.1 Site Stratigraphy

A heterogenous fill was met at the site to about 0.5 m below EGL. Below fill, silty sand / sandy silt was met at the site to about 7.5-11.0 m depth and underlain by refusal (N>100) strata to the maximum explored depth of 11.1 m below EGL. The boreholes were terminated on the refusal (N>100) strata.



The field SPT N-values range from 3 to 7 to about 2 m depth, indicating loose strata condition and range from 9 to 14 to about 4.5 m depth below EGL. Further, SPT N-values range from 14 to 29 to about 9 m depth and range from 36 to 75 to about 11.0 m depth below EGL.

All test results are presented on the individual soil profiles on Sheet No. 2 to 4. A summary of the borehole profiles is illustrated on Sheet No. 5. Plots of field and corrected SPT values versus depth are presented on Sheet No. 6 & 7, respectively.

4.2 Groundwater

Based on our measurements in the completed boreholes, groundwater was not met to the maximum explored depth of 11.1 m below EGL during the period of our field investigations (June, 2022). Fluctuations may occur in the measured ground levels due to seasonal variations in rainfall, surface evaporation rates.

5.0 **FOUNDATION ANALYSIS**

5.1 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.

5.2 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. Raft foundation is also a suitable foundation scheme for the basement area.

Our recommended values of net and corresponding gross allowable bearing pressures at various depths for open / raft foundation are presented in Section 6.0.

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.



5.3 Method of Analysis

Bearing capacity analysis for open foundations has been done in general accordance with IS: 6403-1981. The bearing capacity equation used is as follows:

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

where:

Q = lateral load

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

ζ_c, ζ_q, ζ_γ = Shape factors.

For Strip footings, ζ_c = ζ_q = ζ_γ = 1

For Square footing, ζ_c = 1.3, ζ_q = 1.2, ζ_γ = 0.6

d_c, d_q, d_γ = Depth factors

For φ ≤ 10, d_c = 1 + 0.2 tan (45+φ/2) D/B, d_q = d_γ = 1

For φ > 10, d_q = d_γ = 1 + 0.1 tan (45+φ/2) D/B

Appropriate values have been substituted into the bearing capacity equation given above to compute the safe net bearing capacity. The values have been checked to determine the settlement of the foundation under the safe bearing pressure. The allowable bearing pressure has been taken as the lower of the two values computed from the bearing capacity shear failure criterion as well as that computed from the tolerable settlement criterion.

Settlement analysis has been performed based on the SPT values in accordance with Clause 9.1.4 of IS 8009 (Part 1)-1976 RA 2003 Fig.9.

6.0 RECOMMENDATIONS

The following table presents our recommended values of net and corresponding gross allowable bearing pressures for the open / raft foundations bearing at the recommended depths:

Foundation Type	Foundation Depth below EGL, m	Recommended Net Allowable Bearing Pressure, T/m ²		Corresponding Gross Allowable Bearing Pressure, T/m ²		Suggested Modulus of Subgrade Reaction (k), KN/m ³
		Total Settlement = 50 mm	Total Settlement = 75 mm	Total Settlement = 50 mm	Total Settlement = 75 mm	
Open Foundation	3.0	12.0	-	-	-	2400
	4.0	15.0	-	-	-	3000



Foundation Type	Foundation Depth below EGL, m	Recommended Net Allowable Bearing Pressure, T/m ²		Corresponding Gross Allowable Bearing Pressure, T/m ²		Suggested Modulus of Subgrade Reaction (k), KN/m ³
		Total Settlement = 50 mm	Total Settlement = 75 mm	Total Settlement = 50 mm	Total Settlement = 75 mm	
Raft Foundation	3.0	14.5	21.8	19.5	26.7	3800
	4.0	16.0	24.0	22.7	30.7	4500

The recommended values include a bearing capacity safety factor of 2.5. The appropriate net bearing pressures may be selected for the deflection/settlement as computed from soil-structure interaction.

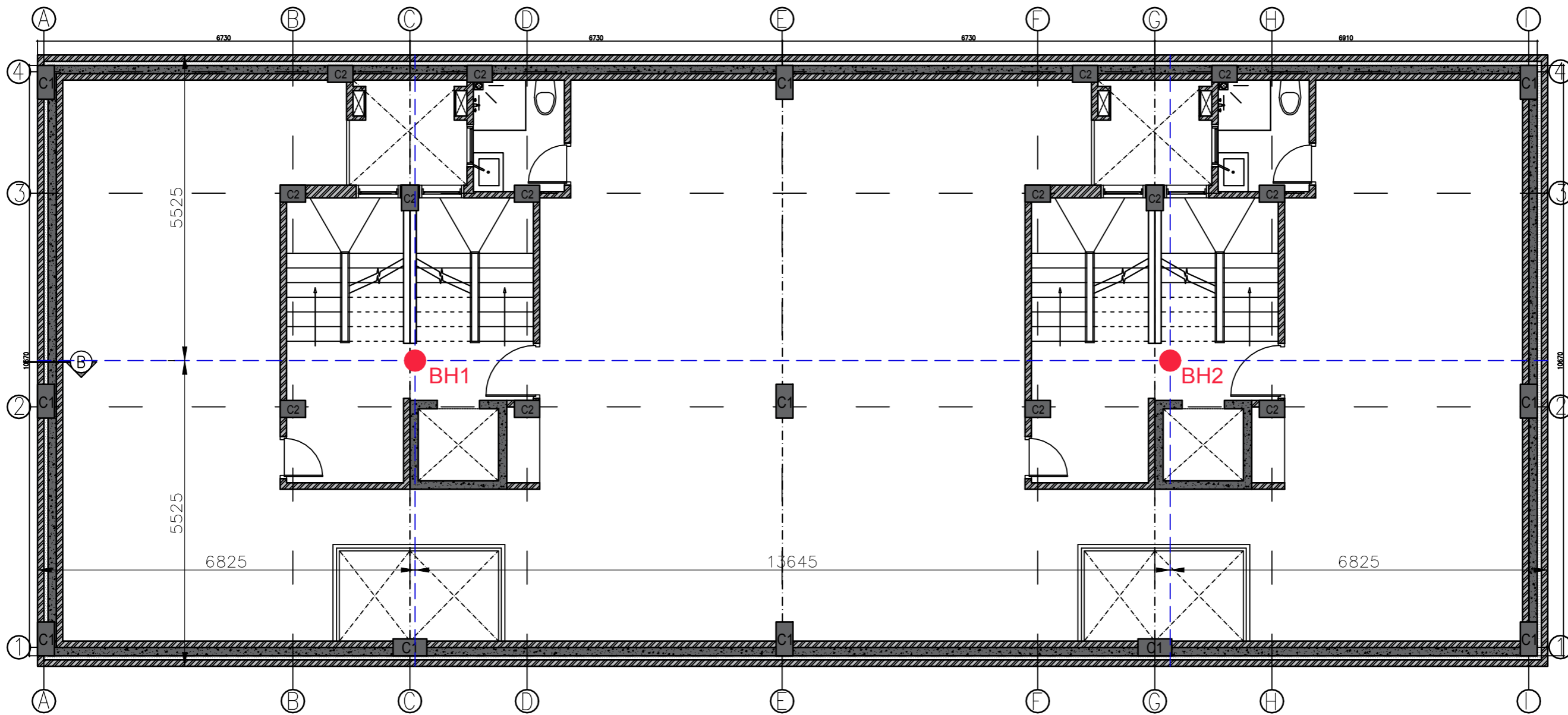
Net bearing pressure for foundations at intermediate depths may be interpolated linearly between the values given above. Fill placed above EGL should be treated as surcharge load. Foundation should be seated 0.5 into natural strata.

The soils at foundation level should be compacted thoroughly prior to construction to ensure that there are no loose soil pockets below the foundation.

The suggested modulus of sub grade reaction (k) has been computed based on empirical relationships as given in published literature and is applicable for 6 m size square footing at the centre of the loaded area.

7.0 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.



BOREHOLE LOCATION PLAN

- RECOMMENDED BORE HOLE POSITION**
1. THE RECOMMENDED DEPTH OF BORE HOLE (BH1 & BH2) FOR SOIL STRATA INVESTIGATION SHALL BE 10 METER FROM NGL
 2. THE RECOMMENDED TEST SHALL BE SPT TEST
 3. PROVIDE THE COMPLETE SOIL STRATA REPORT ALONG WITH SBC VALUE.
 4. PROVIDE THE WATER TABLE DEPTH.

PROJECT
STAFF RESIDENCE FOR SET ON PLOTS
53/11,12,13,14 AT RAJENDER NAGAR

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TITLE
BOREHOLE LOCATION PLAN

DRAWN BY	KUSH	DRAWING NO.	SHEET NO.
CHKD. BY	SHIV	ST-01	01
SCALE	SCALE TO FIT	REVISION NO.	
DATE	25.03.2022		
DRG. TYPE	WORKING	BLOCK:-	
JOB CODE			



Borehole Log (BH-1)

Location : Salwan School Campus, New Delhi

Ground Water Level : Not met

Drilling : Shell & Auger

Termination Depth : 11.1 m

Start Date : 18-Jun-22

Finish Date : 18-Jun-22

Scale

Depth, m	Sample Designation	Groundwater depth, m	SPT		Symbol	SOIL DESCRIPTION	Depth of Strata, (m)	Standard Penetration Test Results				Grain Size Analysis				Atterberg Limits			Specific Gravity	Density		Shear Tests		
			Field Value, N	Corrected Value, N"				Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Liquid (%)	Plastic (%)	Plasticity Index (%)	Bulk Density (gm/cm ³)	Dry Density (gm/cm ³)	Moisture Content (%)	Cohesion Intercept, 'c' (kg/cm ²)		Angle of Internal Friction, 'φ' (degrees)				
0.5	DS1	-																						
1.5	SPT1		7	10		Light brown silty sand (SM)																		
2.3	UDS1						3.0		0	64	33	3					2.65	1.61	1.49	8.3	0.0	27.0		
3.0	SPT2		9	11		Light brown sandy silt, no plastic (ML)			0	43	53	4												
4.5	SPT3		14	15			4.5		1	56	40	3												
5.3	UDS2																	1.65	1.51	9.2				
6.0	SPT4		14	14																				
7.5	SPT5		29	26		Light brown silty sand (SM)																		
8.3	UDS3																	1.71	1.54	10.8	0.0	30.0		
9.0	SPT6		36	30					3	66	29	2												



Borehole Log (BH-1)

Location : Salwan School Campus, New Delhi

Ground Water Level : Not met

Drilling : Shell & Auger

Termination Depth : 11.1 m

Start Date : 18-Jun-22

Finish Date : 18-Jun-22

Scale

Depth, m	Sample Designation	Groundwater depth, m	SPT		Symbol	SOIL DESCRIPTION	Depth of Strata, (m)	Standard Penetration Test Results		Grain Size Analysis				Atterberg Limits			Specific Gravity	Density		Shear Tests	
			Field Value, N	Corrected Value, N"				Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Liquid (%)	Plastic (%)	Plasticity Index (%)	Bulk Density (gm/cm ³)	Dry Density (gm/cm ³)		Moisture Content (%)	Cohesion Intercept, 'c' (kg/cm ²)	Angle of Internal Friction, 'φ' (degrees)	
10.5	SPT7		75	60		Light brown silty sand (SM)	11.0														
11.0	SPT8		Ref	Ref		Weathered rock	11.1														



Borehole Log (BH-2)

Location : Salwan School Campus, New Delhi

Ground Water Level : Not met

Drilling : Shell & Auger

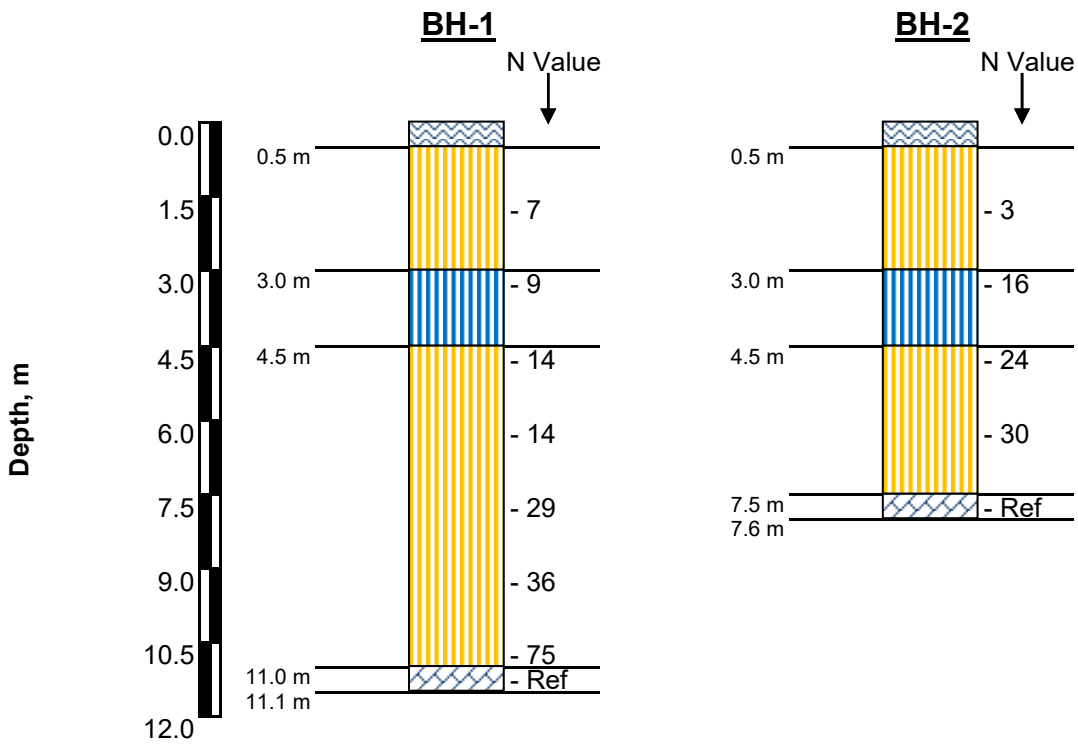
Termination Depth : 7.6 m

Start Date : 20-Jun-22

Finish Date : 20-Jun-22

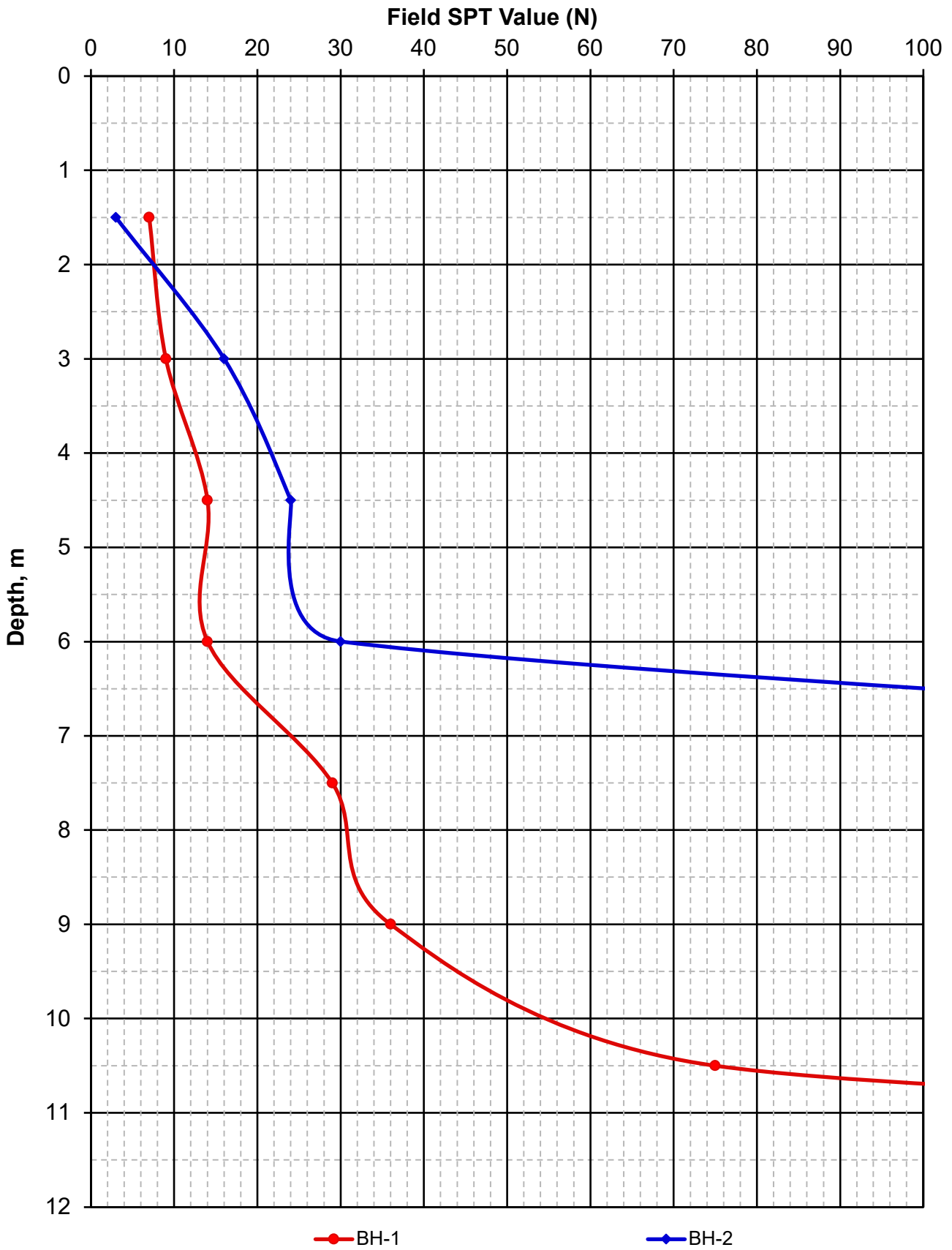
Scale

Depth, m	Sample Designation	Groundwater depth, m	SPT		Symbol	SOIL DESCRIPTION	Depth of Strata, (m)	Standard Penetration Test Results				Grain Size Analysis				Atterberg Limits			Specific Gravity	Density		Shear Tests					
			Field Value, N	Corrected Value, N"				Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Liquid (%)	Plastic (%)	Plasticity Index (%)	Bulk Density (gm/cm ³)	Dry Density (gm/cm ³)	Moisture Content (%)	Cohesion Intercept, 'c' (kg/cm ²)		Angle of Internal Friction, 'φ' (degrees)							
0.5	DS1	-																									
1.5	SPT1		3	4	[Yellow vertical lines symbol]	Light brown silty sand (SM)																					
2.3	UDS1																										
3.0	SPT2		16	19		[Blue vertical lines symbol]	Light brown sandy silt, no plastic (ML)	3.0																			
4.5	SPT3		24	26	[Yellow vertical lines symbol]	Light brown silty sand (SM)	4.5																				
5.3	UDS2																										
6.0	SPT4		30	29																							
7.5	SPT5		Ref	Ref	[Blue hatched symbol]	Weathered rock	7.5																				
7.6							7.6																				

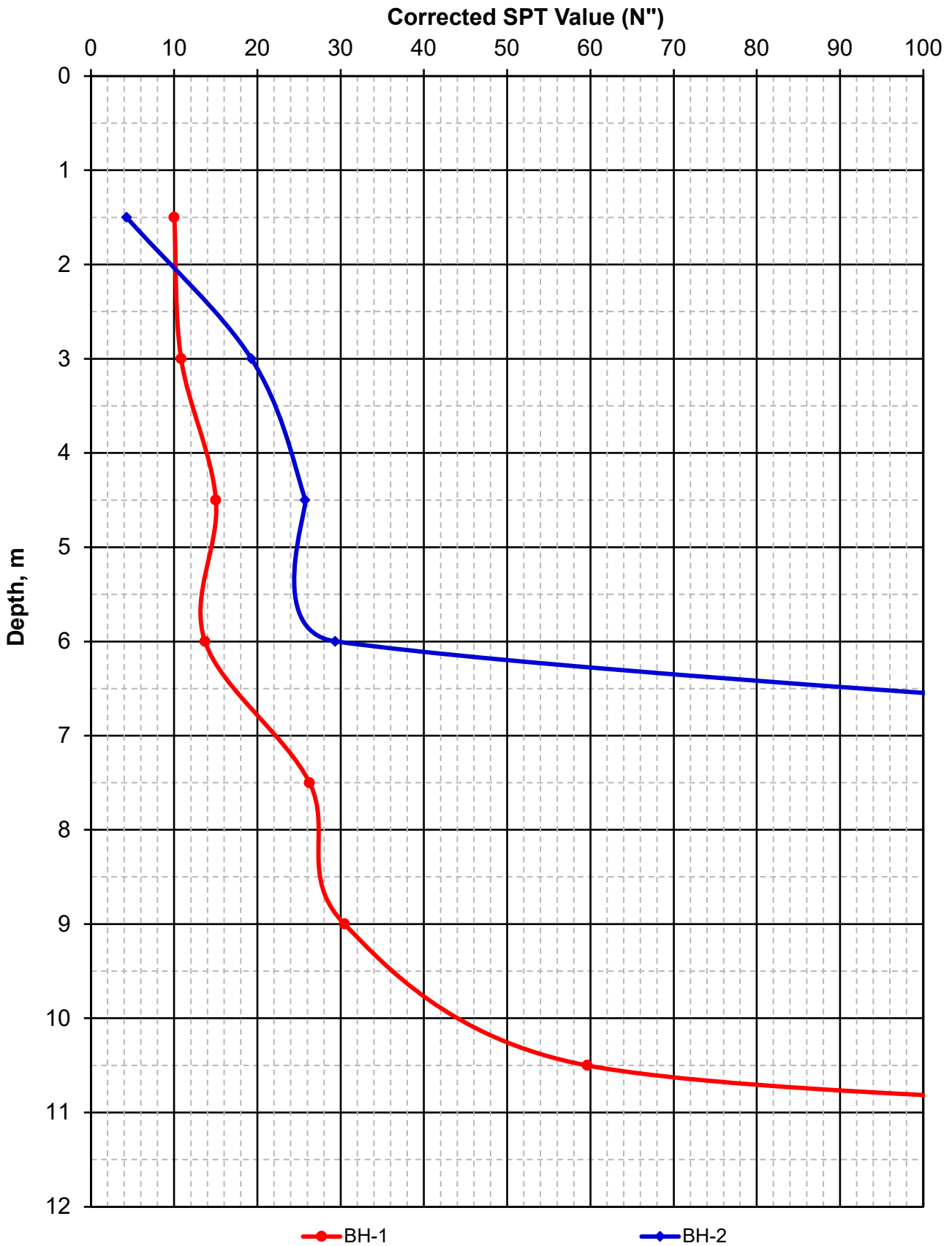


LEGEND	
SYMBOL	DESCRIPTION
	Fill-Cocrete
	Silty sand (SM)
	Sandy silt (ML)
	Completely Weathered Rock

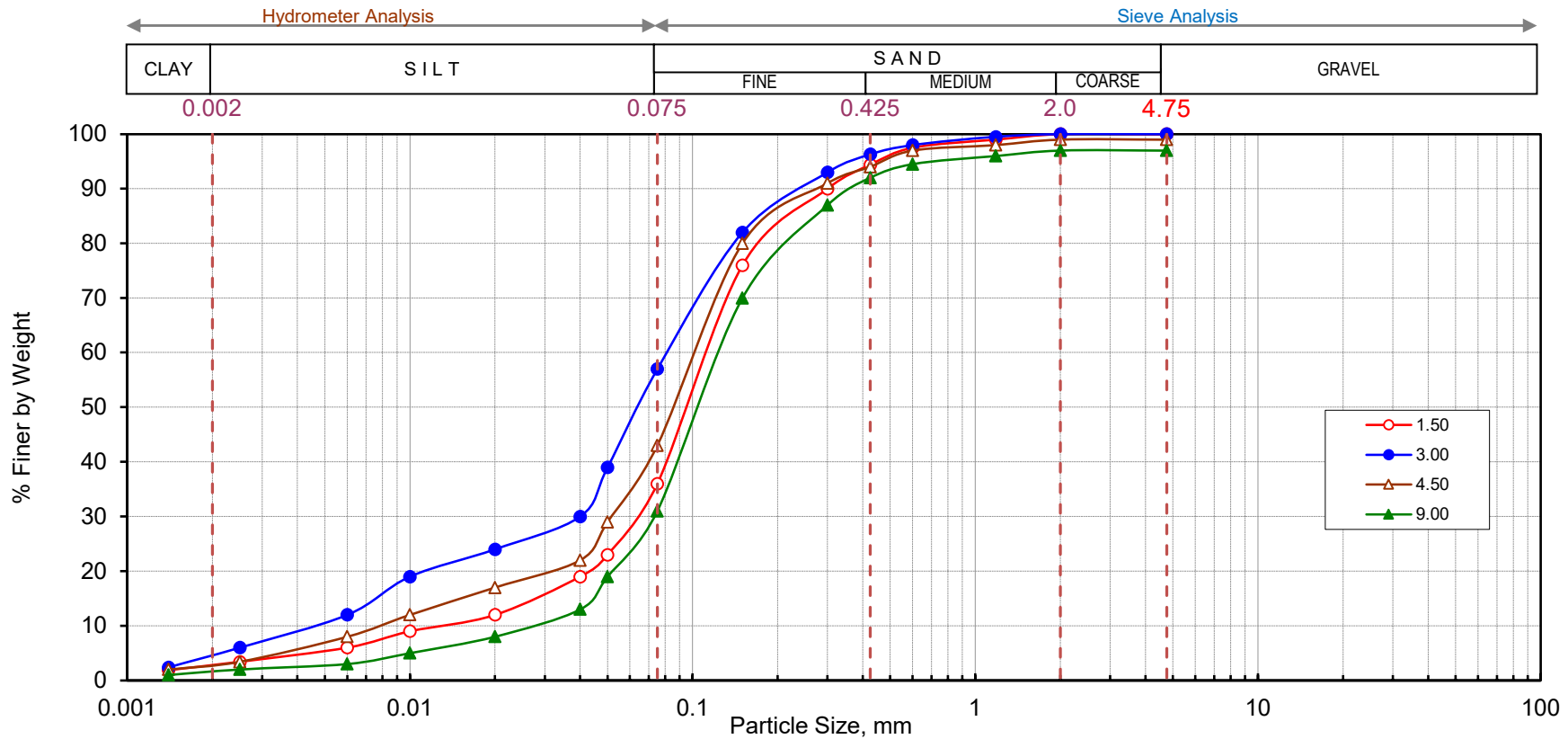
Cross Section of Boreholes



Plot of Field SPT-N value v/s depth

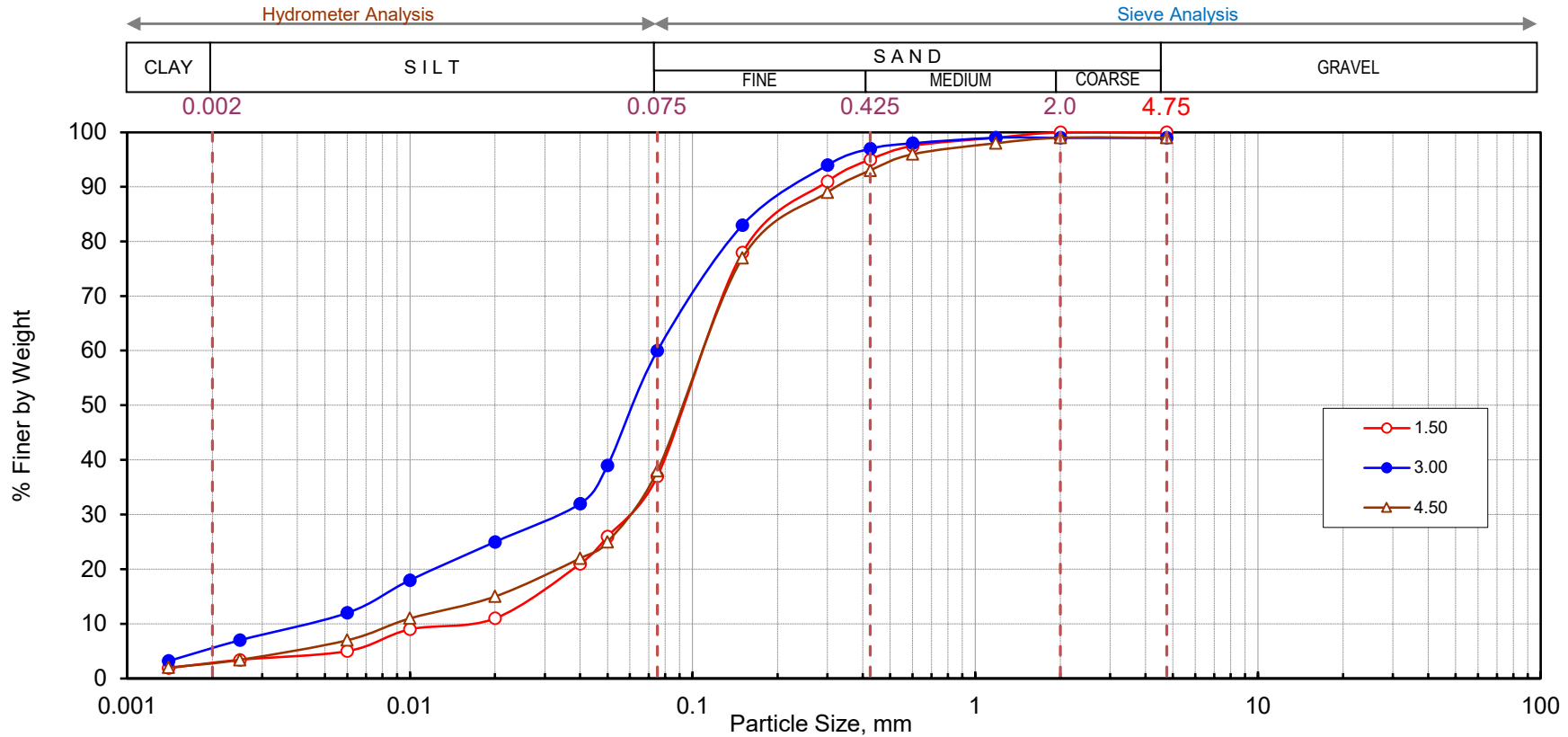


Plot of Corrected SPT-N'' value v/s depth



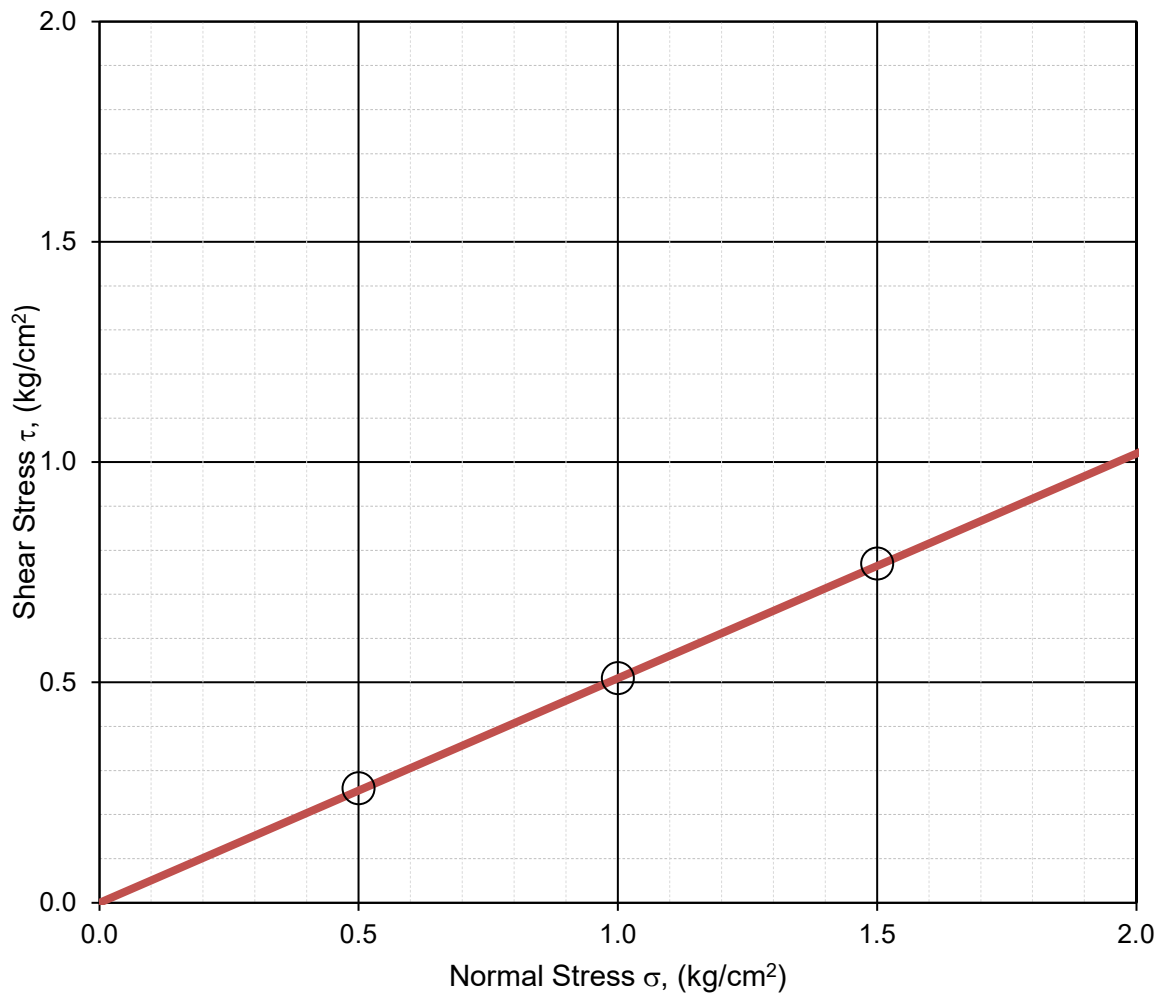
Sample Details				Test Results									
Location	Borehole Number	Sample Depth, m	Sample Description	Gravel %	Sand %	Silt %	Clay %		D ₆₀	D ₃₀	D ₁₀	C _u	C _c
Salwan School Campus, New Delhi	BH-1	1.50	Silty sand (SM)	0	64	33	3		0.120	0.063	0.013	9.0	2.52
	BH-1	3.00	Sandy silt (ML)	0	43	53	4		0.084	0.040	0.005	17.4	3.94
	BH-1	4.50	Silty sand (SM)	1	56	40	3		0.109	0.052	0.008	13.7	3.06
	BH-1	9.00	Silty sand (SM)	3	66	29	2		0.131	0.073	0.028	4.7	1.45

Grain Size Distribution



Sample Details				Test Results									
Location	Borehole Number	Sample Depth, m	Sample Description	Gravel %	Sand %	Silt %	Clay %		D ₆₀	D ₃₀	D ₁₀	C _u	C _c
Salwan School Campus, New Delhi	BH-2	1.50	Silty sand (SM)	0	63	34	3		0.117	0.059	0.015	7.8	1.99
	BH-2	3.00	Sandy silt (ML)	1	39	55	5		0.075	0.034	0.005	16.3	3.41
	BH-2	4.50	Silty sand (SM)	1	61	35	3		0.117	0.060	0.009	13.0	3.37

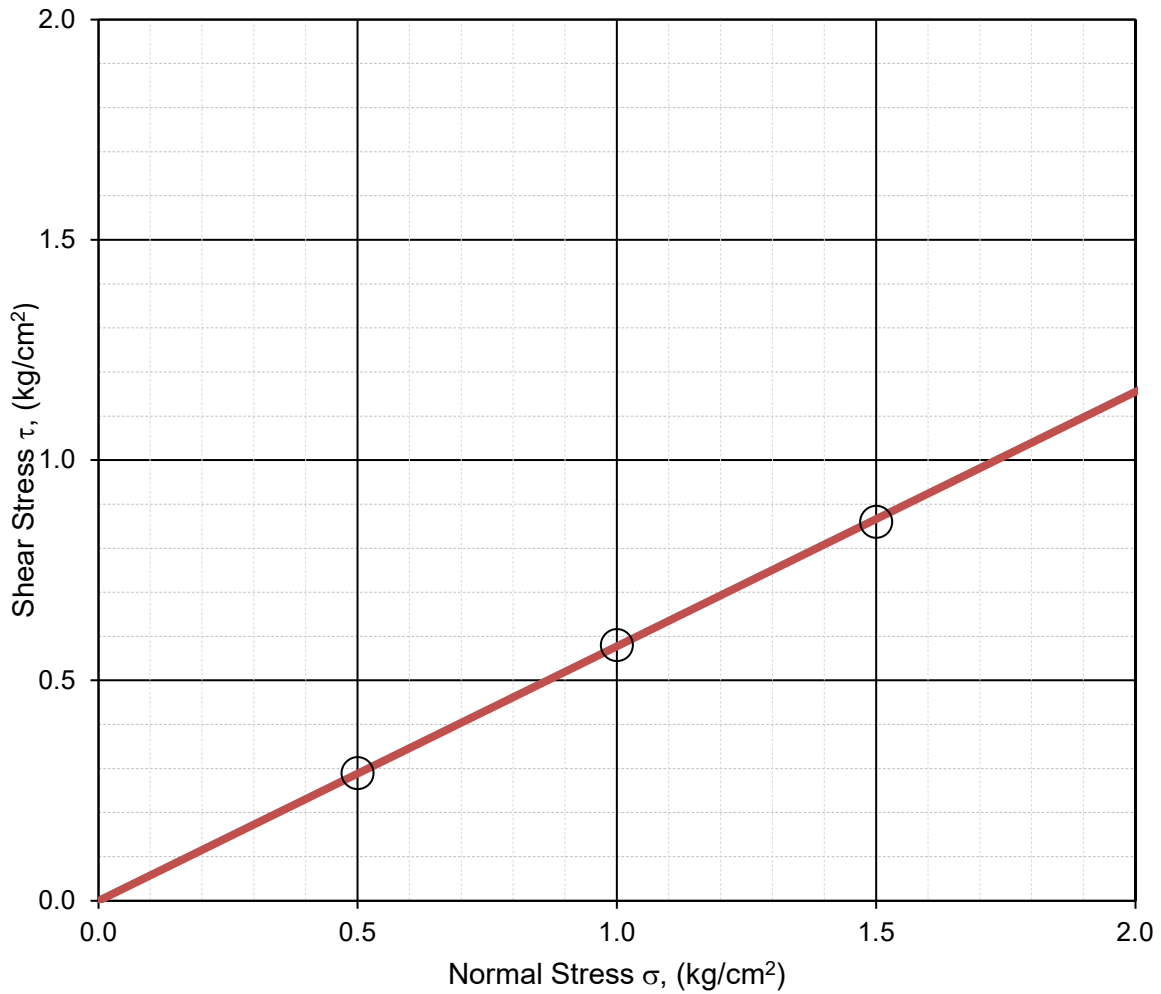
Grain Size Distribution



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

Cohesion Intercept, c (kg/cm²)	=	0
Angle of Internal Friction, ϕ (degrees)	=	27

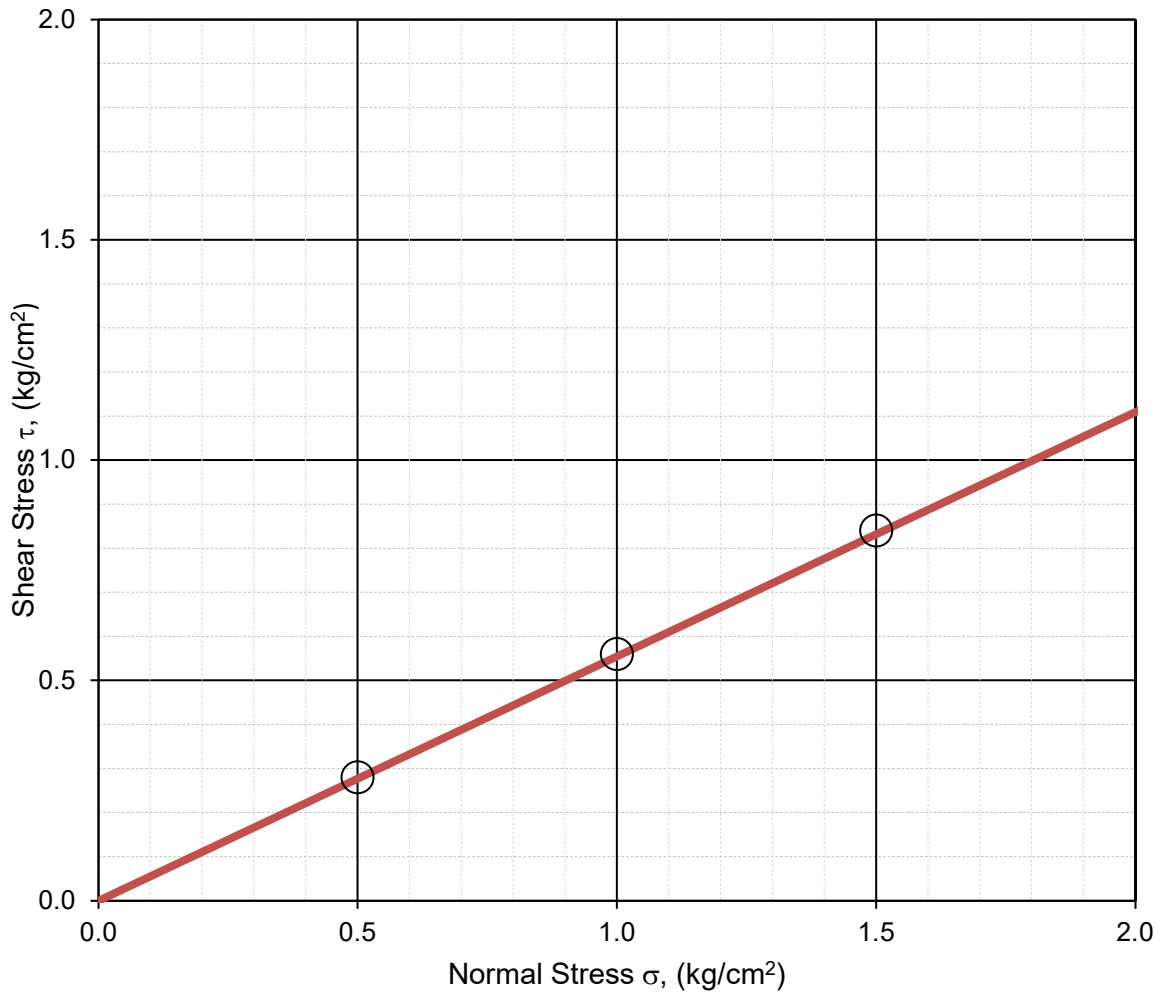
Consolidated Drained Direct Shear Test



Borehole No.	=	1
Sample Depth, m	=	8.25
Sample Description	=	Silty sand

Cohesion Intercept, c (kg/cm²)	=	0
Angle of Internal Friction, ϕ (degrees)	=	30

Consolidated Drained Direct Shear Test



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

Cohesion Intercept, c (kg/cm²)	=	0
Angle of Internal Friction, ϕ (degrees)	=	29

Consolidated Drained Direct Shear Test

TYPICAL CALCULATIONS

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

GENERAL SHEAR FAILURE		$N_c = 25.80$	Bulk Density Profile		
$c = 0.0$ T/m ²	$N_q = 14.72$	From, m	To, m	γ , T/m ³	
$\phi = 28.0$ degrees	$N_g = 16.72$	0.0	0.5	1.60	
		0.5	2.0	1.65	
LOCAL SHEAR FAILURE	$N_c' = 14.39$	2.0	4.5	1.70	
$c' = 0.0$ T/m ²	$N_q' = 6.10$	4.5	9.0	1.75	
$\phi' = 19.5$ degrees	$N_g' = 5.03$	9.0	11.0	1.85	
		11.0	12.0	2.00	

Factor of safety (FOS) = **2.5**
 Design Water Table Depth = **Not Met**
 R_w factor: Calculate (C) based on water table depth / Fixed Value(V) for worst condition = **V**
 R_w factor for design = **0.6**
 Depth factor to be considered? = **Y**
 For computation of Depth Factor, depth below GL to be ignored to account for loose soils, poorly compacted backfill above foundation, scour etc. = **2.0**

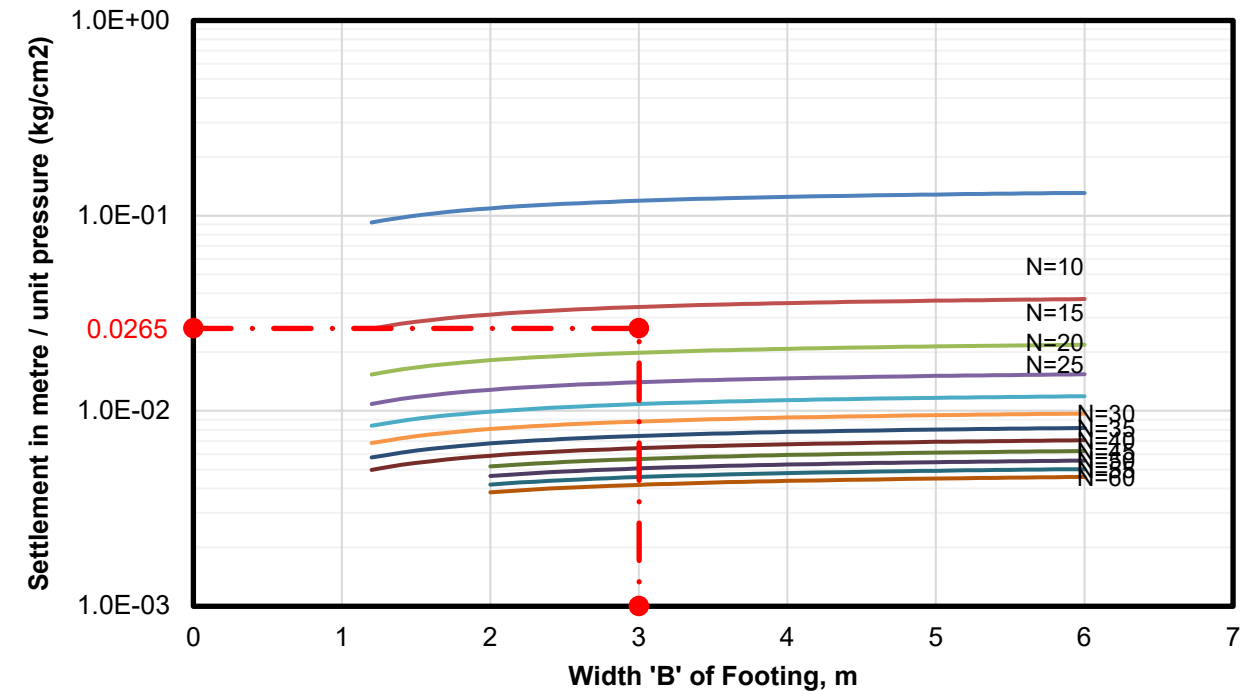
A. Bearing capacity analysis for shallow foundations as per IS 6403-1981

$$q_{net\ safe} = (1/FOS)\{cN_c z_c d_c + q(N_q - 1)z_q d_q + 0.5B\gamma N_g z_g d_g R_w\}$$

Foundation Size		Shape	Depth, m	Depth factors (GSF)			Depth factors (LSF)		
B, m	L, m			d_c	d_q	d_g	d_c	d_q	d_g
3.0	3.0	Square	3.0	1.11	1.06	1.06	1.09	1.05	1.05
3.0	3.0	Square	4.0	1.22	1.11	1.11	1.19	1.09	1.09
6.0	6.0	Square	3.0	1.06	1.03	1.03	1.05	1.02	1.02
6.0	6.0	Square	4.0	1.11	1.06	1.06	1.09	1.05	1.05

B. Settlement analysis for shallow foundations based on N-values as per IS:8009 (Part 1)-1976, Clause 9.1.4

$$q_{allowable} = \{(\Delta_{permissible} / \Delta_{unit}) * R_w\} / d_f * d_r$$



Foundation Dimensions B, m L, m		FOUNDATION SHAPE	Depth, m	R_w	Shape Factors			$q_{net\ safe}$, T/m ²		Safe Net Bearing Capacity T/m ² ①	Gross Bearing Capacity (Safe) T/m ²	Design N-Value	Design Net Bearing Pressure, T/m ² ②	Settlement @ 1kg/cm ² (as read off from graph), mm	Fox's Depth Factor, d_f	Rigidity Factor, d_r	Computed Settlement, mm	Recommended Net Allowable Bearing Pressure, T/m ² - min. of ① & ②
					z_c	z_q	z_g	GSF	LSF									
3.0	3.0	Square	3.0	0.60	1.30	1.20	0.80	43.3	15.4	29.3	34.3	12.0	12.0	26.5	0.91	1.0	48.1	12.0
3.0	3.0	Square	4.0	0.60	1.30	1.20	0.80	58.2	20.6	39.4	46.1	14.0	15.0	21.7	0.80	1.0	43.4	15.0
6.0	6.0	Square	3.0	0.60	1.30	1.20	0.80	50.9	17.6	34.3	39.2	13.0	14.5	26.2	0.96	0.8	48.7	14.5
6.0	6.0	Square	4.0	0.60	1.30	1.20	0.80	64.3	22.5	43.4	50.0	14.0	16.0	23.8	0.91	0.8	46.1	16.0