PROJECT: REPORT ON

Soil Investigation work for Substation for BSES Yamuna Power Limited (Location-Faiz Road)

Prepared By:

MEGS GEO ENGINEERING SERVICE

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Prepared for:

BSES YAMUNA POWER LIMITED

CONTENTS

1.0 Introduction

M/s. BSES Yamuna Power Limited is planning to setup a grid substation at Faiz Road, 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 Faiz Road 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 & rock, in order to evaluate the stratigraphy at the site and to collect soil and rock core samples for laboratory testing.

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

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

3.0 Laboratory Tests

On rock core samples:

(a) Moisture content, porosity & density

(b) Specific gravity

(c) Unconfined compression test

(d) Point load strength index test

4.0 Site Exploration (Rotary Drilling)

Rotary drilling rigs having the capacity of drill up to 50 m depth has been used to drill through the rock stratum. The diamond bits were used to drill through weathered rock/hard rock stratum. Recovered cores were measured and percentage Core Recovery (CR) and Rock Quality Designation (RQD) has been calculated as under:

CR, % = (Total Core Length/Length of Run) x 100

RQD, % =
(Length of Cores > 101.6 mm (4 inches and above)/Length of Run) x 100

5.0 Laboratory Testing

5.1 Water absorption on rock samples

The water content of the rock samples were determined as ratio of water content absorbed by oven dried samples (105±3º) kept immersed for at least 24 hours with respect to its dry weight of rock samples.

Water absorption, W (%) = M_w/M_g

Where,
M_w= Pore water mass absorbed by sample
M_g= Grain Mass of oven dried sample.

5.2 Density on rock samples

Similar to density determination of soil sample, density of rock sample determined by mercury displacement method specified in IS: 13030-1991. The density of the rock is the weight per unit volume of the rock material.

5.3 Porosity on rock samples

The porosity of the rock sample is the ratio of voids to the total volume of the rock samples. The relation between Specific Gravity of rock (G), Dry Density of Rock (γ_d), Density of Water (γ_w) and porosity (η) can be expressed as –

$\eta = 1 - (\gamma d / G\ \gamma w)$

5.4 Unconfined compression strength

The Unconfined Compressive Strength of rock samples was determined using compressive testing machine as per method specified under IS: 9143-1979.

5.5 Point Load Strength Index

The point load strength index of rocks samples was determined by using compression testing machine with the conical loading platens as method specified under IS: 8764-1998.

6.0 Geomorphology

The ground water availability in NCT, Delhi is controlled by the hydrogeological situation characterized by occurrence of different landforms developed on different geological formations. Geomorphological map of Delhi is presented in Fig. 3.2. Entire area of NCT, Delhi can be grouped into three broad geomorphic units:

- Rocky surface
- Older Alluvial Plain
- Flood Plain of Yamuna River

Rocky Surface: The rocky surface represents structurally controlled relict linear ridges and isolated hillocks comprising of rocks of Delhi Supergroup and isolated hills mostly occurring in the south- and south-central parts, and extends from Mahipalpur to Wazirabad in the north. Towards south of Mahipalpur the ridge gets bifurcated, one arm extends towards Mandi and further south while the other arm takes a turn towards southeast and extends upto Tughlakabad- Greater Kailash-Nehru Place and Okhla. It attains a maximum elevation of 362 m above m.s.l. which gradually diminishes towards north where rocks are exposed on the western bank of Yamuna near Wazirabad.

Older Alluvial Plain: The gently undulatory terrain on either side of the rocky surface is described as Older Alluvial Plain. This surface is separated from the Yamuna Flood Plain by a bluff. Depending upon the morphological expressions / features, this unit is further divided into different subunits: (i) Najafgarh Older Alluvial Plain (ii) Delhi Older Alluvial Plain and (iii) Maidan Garhi Plain. Najafgarh Older Alluvial Plain occupying western and southwestern part of the region is partly covered by sand dunes and sandy sheets. The gently sloping surface including the covered pediment along the eastern flank of the ridge represents the Delhi Older Alluvial Plain. Maidan Garhi Plain is a relatively higher plain surface and forms part of Chhatarpur Basin. A narrow zone of badland has formed mostly along the western margins of structural ridges due to intense development of gullies and rills.

Flood Plain of river Yamuna: The low-lying flat surface representing the Flood Plain of river Yamuna occupying northern, northeastern and eastern parts of the NCT is an important geomorphic unit. North of Narela, the width of flood plain varies from 15 to 17 km. The wider Older Yamuna flood plain indicates lateral migration of river Yamuna over large areas. This belt has good potential for ground water development. It forms the erosional terrace. The Yamuna Active Flood Plain represents the wide belt bounded on both the sides by Eastern and

Western bunds and is naturally prone to annual/periodic floods being in the flood way and flood fringe zone of river Yamuna. It forms depositional terrace and is characterized by abandoned channels, cut-off meanders, meander scrolls, point bars and channel bars. Presence of number of cut- off meanders in the Yamuna Flood Plain suggests oscillatory shifting of river. The lakes near Bhalsawa, Kondli and Khichdipur are remnants of large meanders.

7.0 Geology

The rock formations exposed in the National Capital Territory of Delhi are mainly quartzite of the Alwar series of the Delhi Supergroup that are interbedded with thin micaceous schist bands. These rocks of Delhi area belong to the Alwar formation of Delhi Super group. Proterozoic rocks occur along the ridge, extending from Harchandpur (Haryana) in the South to Wazirabad (Delhi) in the North. Quaternary sediments directly overlie the Proterozoic rocks. The Stratigraphic succession of these rocks reviewed by Kachroo and Bagchi (1999 is tabulated below:

Holocene	Yamuna channel alluvium	Grey, fine to medium sand, grit with coarse sand, silt and clay	Point bars, channel deposits
	Yamuna Older Flood Plain & Terraces	Grey sand, coarse grit, pebble beds and minor clays	Palaeochannels, meander scrolls, oxbow lakes
	Older Alluvium	Sequence of sand-silt-clay with yellowish brown medium sand with silt, kankar with brown Aeolian sand	Abandoned channels, meander scrolls
----------Unconformity----------			
Neoproterozoic	Post Delhi Intrusives	Pegmatitic, tourmaline-quartz veins and quartz veins	
Mesoproterozoic	Delhi Supergroup	Ajabgarh Group – Bharkol Formatio	Quartzite with minor schist, tuff and ash beds

The highest is the erosional surface forming the top of denudational hills. The second surface is Older Alluvial plain and the third is depositional Younger Alluvial plain (Yamuna). The geomorphologic features have undergone changes due to widespread and uncontrolled urban activity. The geological map of Delhi is illustrated below:

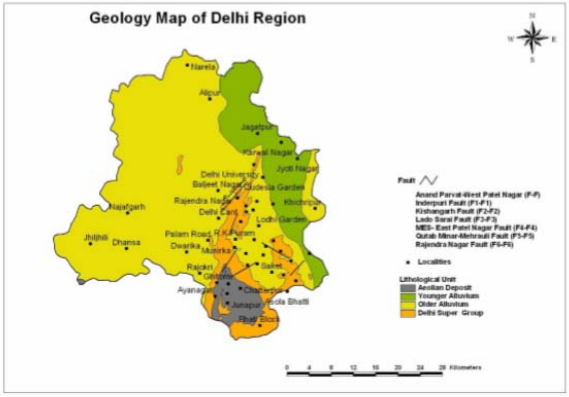


Fig 4.1: Geological map of NCT Delhi

The Quaternary deposits in the form of aeolian and alluvial deposits constitute the major repository of ground water in the area. In the East of the ridge, the thickness of unconsolidated sediments gradually increases away from the ridge. The aeolian deposits are mainly comprised of loam, silty loam and sandy loam. The bedrock is overlain by these deposits. Older alluvial deposits consist mostly of interbedded, lenticular and inter fingering deposits of clay, silt, and sand along with kankar. These deposits overlay the aeolian deposits and are in turn overlain by the newer alluvium, which occurs mostly in the flood plains of river Yamuna.

8.0 Seismology

The site area falls in Seismic **Zone-IV (Zone factor Z=0.24) as per IS: 1893 (Part-1)-2016** in the disaster-prone area map of the country. This means that it is a moderate damage risk zone. The maximum expected intensity of earthquakes in this zone is VII (MSK).

9.0 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 material underlain by Quartzite rock to the finally explored depth of 10.5 m. A core recovery of 0-51% with RQD of 0-37% was met in rock strata.

BH-2:

The subsoil strata from 0.0 to 0.5 m consist of filled up material underlain by Quartzite rock to the finally explored depth of 15.0 m. A core recovery of 0-38% with RQD of 0-37% was met in rock strata.

Ground Water

The ground water table was not encountered in the borehole below existing ground surface during boring activities at site.

10.0 Proposed Depth & Type Of Foundations

As discussed in Section 6.0, filled up was met to 0.5 m depth and rock is encountered at the site below 0.5 m depth. Open foundations for the proposed facilities may bear on the rock strata.

Depending upon the visual examination of field strata, field and laboratory test results and the type of structure proposed at this site, the safe bearing capacity of sub-soil strata Raft footing/open foundation have been analyzed. Open foundations and raft foundations bearing on the rock formation are suitable foundation schemes. We recommend a minimum foundation embedment depth of about 1.0-2.5 m below the existing ground level**. Highly weathered and disintegrated rock has been treated as dense sand for purpose of analysis.**

The founding levels of structures should be decided based on the ground levels and the rock characteristics. It should be ensured that the foundations are seated on the natural undisturbed rock. Any loose pockets, soils, disturbed materials etc., encountered at founding levels should be removed and replaced by lean concrete.

10.1 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:-

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:

$C=0.0T/m^2$ $\quad \emptyset=35^\circ$

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

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

$\tan \emptyset_{av}=(h_1 \tan \emptyset_1+h_2 \tan \emptyset_2+----------+h_n \tan \emptyset_n)/h$

where, $h = 0.5 \times B \times \tan(45+ \emptyset_{av}/2)$ 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 0.50 m	:	1.60 t/cu.m
0.50 m to 3.00 m	:	2.00 t/cu.m
3.0 m to 15.00 m	:	2.20 t/cu.m

Depth factors:

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

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

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:

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)
1.0	Open	Width ≤ 3.0 m	36.8
1.5			48.9
2.0			61.6
2.5			75.0
1.0	Open/Raft	3.0 m ≥ Width ≤ 6.0 m	55.2
1.5			66.7
2.0			78.5
2.5			90.7

10.2 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 40 & 40 mm. Since the rock was met from 0.5 m depth, refusal was (N=50) has been taken for the analysis.

The values of net allowable pressure intensities computed based on the above selected soil parameters are given in following table:

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=25 mm	S=40 mm
1.0	Open	Width ≤ 3.0 m	20.0	32.0
1.5			23.0	36.8
2.0			26.0	41.6
2.5			30.0	48.0
1.0	Open/Raft	3.0 m ≥ Width ≤ 6.0 m	22.0	35.2
1.5			27.0	43.2
2.0			32.0	51.2
2.5			35.0	56.0

11.0 Conclusion with Recommendation

MEGS Geo Engineering Service conducted a geotechnical investigation for construction of of substation in Delhi. The following table presents our recommended values of net allowable bearing pressure for 3- 6 m wide foundation:

Depth of foundation below NGL (m)	Type of foundation (m)	Width of Foundation (m)	Net Allowable Pressure intensity (t/m^2)	
			S=25 mm	S=40 mm
1.0	Open	Width ≤ 3.0 m	20.0	32.0
1.5			23.0	36.8
2.0			26.0	41.6
2.5			30.0	48.0
1.0	Open/Raft	3.0 m ≥ Width ≤ 6.0 m	22.0	35.2
1.5			27.0	43.2
2.0			32.0	51.2
2.5			35.0	56.0

The following points are highlighted for the above bearing pressure:

1) A safety factor of 2.5 has been included for the bearing capacity tabulated above.
2) Total settlement of foundation designed for the above recommended bearing pressures is expected to be about 25 and 40 mm.
3) Layer wise properties of the encountered strata may be adopted given in enclosed sub-soil profiles.
4) The slope of the excavated pit may be kept upto 1 vertical on 0.20-0.30 horizontal during excavation
5) For foundations, all loose material should be removed so that foundations may bear on the natural undisturbed rock formation.
6) The rock surface should be roughened, scarified and watered thoroughly to ensure proper bond between rock and concrete.
7) The foundations should be seated at least 0.5 m into the rock formation.
8) The chemical analysis tests on subsoil sample indicate that the Ordinary Portland Cement or Portland Slag Cement or Portland Pozzolana Cement can be used for RCC work.
9) 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 Annexure-A illustration part of this report.
10) As per IS 1893:2002, the site falls under earthquake Zone-IV. Weathered rock was met at site to the final explored depth of 15.0 m, and water table was not met to the final explored depth of 15.0 m, which may not likely to liquefy. So in our opinion liquefaction may not likely to takeplace.

12.0 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

SUB SOIL PROFILE

Project: Soil Investigation work for Substation for BSES Yamuna Power Limited

Location: FAIZ ROAD

Bit Used: 32CT IMP

BH No.:	1
Start Date:	23-02-2025
End Date:	25-02-2025
RL, m:	-
Borehole Depth:	10.5 m
Water Table:	NIL
Boring Type:	Rotary
Size of Hole:	NX

SPT N-Value	Depth, m	Drill Run, m	Casing Size,m	Sample Type	Sample No.	Symbol	Description	Core Recovery,%	RQD,%	RMR Value	Colour of Return water	Water Loss	NMC,%	Water Absorption, %	Dry Density, gm/cm^3	Specific Gravity	Porosity	Point Load, Kg/cm^2	UCS, Kg/cm^2
	0.00		NX	DS-1			Filled up material: Sand intermixed with gravel, boulder etc.												
	0.50	0.50																	
	1.00			RK1				0	0										
Refusal	1.50	1.50																	
	2.00			SPT2			(2.0m)												
	2.50						Moderately weak to moderately strong grey Quartzite, moderately weathered	38	15										
	3.00	3.00		RK2			- moderately weak, 2.0 to 3.0 m												
	3.50						- moderately strong, 3.0 to 6.0 m												
	4.00							30	0										
	4.50	4.50		RK3							BROWN	PARTIAL							
	5.00		8.0 m																
	5.50							51	6										
	6.00	6.00		RK4															
	6.50																		
	7.00							42	34										
	7.50	7.50																	
	8.00																		
	8.50							41	37										
	9.00	9.00																	
	9.50																		
	10.00							32	31										
	10.50	10.50					10.5 m												

SUB SOIL PROFILE

Project: Soil Investigation work for Substation for BSES Yamuna Power Limited

Location: FAIZ ROAD | **Bit Used:** 32CT IMP

BH No.:	2
Start Date:	25-02-2025
End Date:	26-02-2025
RL, m:	-
Borehole Depth:	15.0 m
Water Table:	NIL
Boring Type:	Rotary
Size of Hole:	NX

SPT N-Value	Depth, m	Drill Run, m	Casing Size,m	Sample Type	Sample No.	Symbol	Description	Core Recovery,%	RQD,%	RMR Value	Colour of Return water	Water Loss	NMC,%	Water Absorption, %	Dry Density, gm/cm^3	Specific Gravity	Porosity	Point Load, Kg/cm^2	UCS, Kg/cm^2
	0.00		NX	DS-1			Filled up material: Sand intermixed with gravel, boulder etc.												
	0.50	0.50																	
	1.00			RK1			Very weak grey quartzite, highly fractured, highly weathered, disintegrated into coarse sand	0	0										
Refusal	1.50	1.50																	
	2.00							0	0										
	2.50			RK2															
	3.00	3.00								15									
	3.50																		
	4.00							0	0										
	4.50	4.50		RK3															
	5.00		7.5 m																
	5.50																		
	6.00	6.00		RK4				0	0										
	6.50						Moderately strong grey quartzite rock, moderatelt weathered												
	7.00							22	22	25	GREY	PARTIAL	0.68	1.32	2.72	2.80	0.059		315.4
	7.50	7.50																	
	8.00																		
	8.50							34	37										
	9.00	9.00								30									
	9.50																		
	10.00							38	31				0.47	1.08	2.75	2.84	0.065		417.4
	10.50	10.50					10.5 m												

SUB SOIL PROFILE

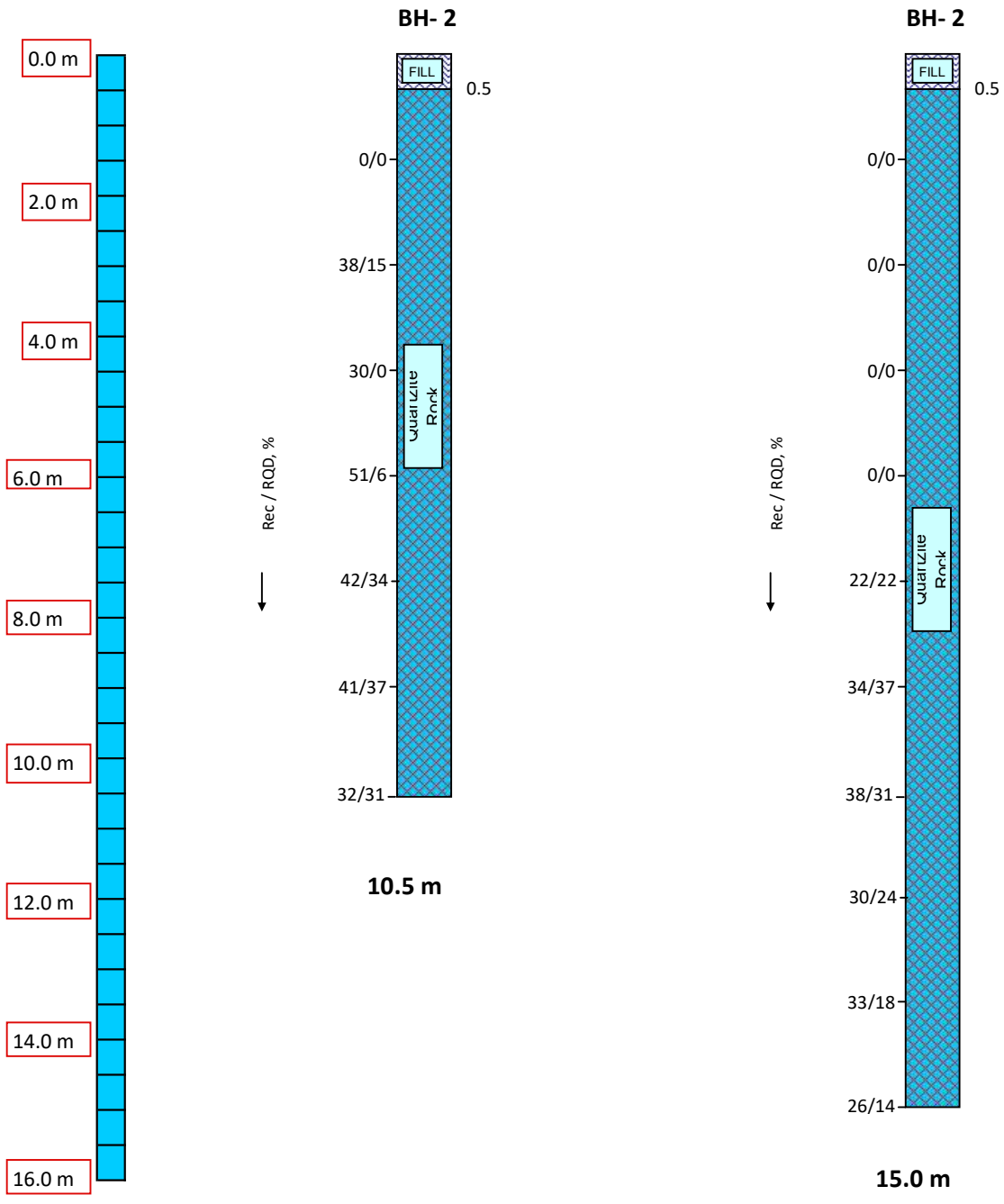
Project: Soil Investigation work for Substation for BSES Yamuna Power Limited

BH No.: 2 | **Borehole Depth:** 15.0 m
Start Date: 25-02-2025 | **Water Table:** NIL
End Date: 26-02-2025 | **Boring Type:** Rotary
Location: FAIZ ROAD | **Bit Used:** 32CT IMP | **RL, m:** - | **Size of Hole:** NX

SPT N-Value	Depth, m	Drill Run, m	Casing Size,m	Sample Type	Sample No.	Symbol	Description	Core Recovery,%	RQD,%	RMR Value	Colour of Return water	Water Loss	NMC,%	Water Absorption, %	Dry Density, gm/cm^3	Specific Gravity	Porosity	Point Load, Kg/cm^2	UCS, Kg/cm^2
	11.00						Moderately strong grey quartzite rock, moderatelt weathered												
	11.50							30	24				0.52	1.15	2.73	2.82	0.067		425.7
	12.00	12.00								30									
	12.50										GREY	PARTIAL							
	13.00							33	18										
	13.50	13.50																	
	14.00						Moderately weak grey quartzite rock, severely weathered												
	14.50									25									
	15.00	15.00						26	14				0.38	1.02	2.74	2.81	0.051		419.6

MEGS GEO ENGINEERING SERVICE

Project : Soil Investigation work for Substation for BSES Yamuna Power Limited (Location - FAIZ ROAD)



Summary of Boreholes

CHEMICAL TEST RESULTS

SOIL-WATER EXTRACT :

Borehole No.	Depth, (m)	Sulphate Content (SO_3) ,%	Chloride Content ,%	pH Value
1	0.00	0.07	0.03	7.9
2	0.00	0.09	0.05	8.2

Location-FAIZ ROAD

Project-Soil Investigation work for Substation for BSES Yamuna Power Limited

Appendix-B

Bearing capacity as per shear criteria (Typical Calculation)

The bearing capacity equation is as follows:

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

Foundation Depth= 2.0 m

Foundation Width = 6 m

Failure Criteria- Average of Local and General Shear Failure

FOS = 2.5,

C' = 0.0 T/m^2, ϕ' = 35 degree - General Shear Failure

c = 0.0 T/m^2, ϕ = 25 degree - Local Shear Failure

N_c = 46.12, N_q = 33.30, N_γ = 48.03 (IS 6403, Table-1, Clause-5.1.1)-General Shear Failure

N_c' = 20.75, N_q' = 10.69, N_γ' = 10.91 -Local Shear Failure

ζ_c = 1.30, ζ_q = 1.20, ζ_γ = 0.80 (IS 6403, Table-2, Section-5.1.2.1)

d_c = 1.10, d_q = 1.05, d_γ = 1.05 (IS 6403, Section-5.1.2.2)- General Shear Failure

d_c' = 1.08, d_q' = 1.04, d_γ' = 1.04 - Local Shear Failure

R_w = 0.60 q = 3.80 T/m^2 γ= 2.00 T/m^3 B= 6 m

Putting in the above formula, we get

$q_{net\ safe}$= 124.6 (General Shear Failure)

$q_{net\ safe}$= 32.5 (Local Shear Failure)

Taking average of both the values (i.e General and local shear failure)

$q_{net\ safe}$= 78.5 T/m^2

Settlement Analysis (Typical Calculation)

Foundation width = 6 m

Depth of foundation = 2.0 m

Water Table = NIL

Design N-value = 50

Settlement @ 1kg/cm2 for 6 m width footing at N -50 (S_1) (IS:8009-Part-1-1979, clause-9.2.2.1, Figure-9) = 0.0056 m = 5.6 mm

Correction for saturation Rw = 0.6 (water table – NIL)

Corrected S_2 = S_1/R_w - 5.6/0.6

S_2 = 9.3 mm

Now Rigidity Factor = 0.8

Fox's Depth Factor, D_f = 0.91

Total computed Settlement = S_2 x Rigidity Factor x Depth Factor

= 9.3 x 0.8 x 0.91
= 6.77 mm @ 1 Kg/cm^2
= 21.6 mm @3.2 kg/cm^2

Net Allowable Bearing Pressure for **21.6 mm (<25 mm) settlement** = 3.2 kg/cm^2 or **32.0 T/m^2**