GEOTECHNICAL REPORT

PROPOSED GRID 66/11KV GIS SUBSTATION
DTC CLUSTER, OKHLA,
NEW DELHI

SUBMITTED TO:

M/S. BSES RAJDHANI POWER LIMITED
DTC Cluster, Okhla, New Delhi

Project No. 23065 Dated. July, 2023 Revision-0

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July 13th, 2023 Project No. 23065

M/s. BSES Rajdhani Power Limited
DTC Cluster, Okhla,
New Delhi

Sub: **Final Report on Geotechnical Investigation Work for Proposed Grid 66/11kv GIS Substation DTC Cluster, Okhla, New Delhi**

We have carried out the geotechnical investigation for captioned project. We thank you for the Opportunity you give to us and hope that you are satisfied with our services rendered.

This Final Report presents our findings based on the geotechnical investigations 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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ILLUSTRATIONS

1.0 INTRODUCTION

1.1 Project Description

This Geotechnical Investigation Work, whose results are being presented herewith, has been carried out work for Proposed Grid 66/11kv GIS Substation DTC Cluster, Okhla, New Delhi. We understand that the proposed structure shall consist of Ground + 1-2 storeys without basement.

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 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 the specified depth, 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. Preparation and submission of technical report in triplicate.

2.0 FIELD INVESTIGATIONS

2.1 Soil Boring

The soil boring of 150 mm diameter were progressed using a rotary drilling through soil formation was performed using heavy-duty, hydraulic skid–mounted rotary drill rig. Where caving of the borehole occurred, casing was used to keep the borehole stable. The work was performed in general accordance with IS: 1892-1979 RA-2007. Standard Penetration Test (SPT) was performed in the soil at regular intervals as described in Section 2.2.

2.2 Standard Penetration Tests (SPT)

Standard Penetration Tests (SPT) were conducted in the boreholes at 1.5 m depth intervals in the soil by connecting a split spoon sampler to 'A' rod 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 RA 2002.

The SPT 'N'-values are described as follows:-

1. The number of blows for each 15 cm of penetration of the split spoon sampler is recorded.

2. 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.

3. The cumulative number of blows required to penetrate the balance 30 cm of the 45 cm split spoon sampler is termed the SPT value or the 'N' value. For example, a SPT value reported as "20" means that 20 blows were imparted to penetrate the split spoon sampler by the last 30 cm.

4. Where the number of blows required to penetrate the balance 30 cm of the split spoon sampler exceeds 100, the number of blows is presented along with the corresponding penetration. For example, an SPT value reported as "101 / 5 cm" means that 101 blows were imparted to penetrate the split spoon sampler by 5 cm after the first 15 cm initial (seating) penetration.

5. Where refusal (N>100) to further penetration of the split spoon sampler is encountered in the first 15 cm of seating penetration itself, SPT test could not be completed and "*Ref*" is indicated in the bore logs, along with the penetration achieved. For example, an SPT value reported as "Ref / 5 cm" means that more than 100 blows were imparted to penetrate the split spoon sampler by a total of 5 cm only and the 15 cm seating penetration could not be achieved.

Disturbed samples were collected from the split spoon sampler after conducting SPT. The samples were preserved in transparent polythene bags, and transported to our laboratory for laboratory testing.

2.3 Rock Drilling

Rotary drilling through rock formation was performed using heavy-duty, hydraulic skid–mounted rotary drill rig. The drilling rig has a hydraulic feed and is driven by a bevel gear system run by a 28 HP Perkins engine. The drill chuck has four jaws to accommodate NW size drill rod.

Drilling and sampling of the rock was performed using an NX size double tube core barrel. A 32–carat diamond impregnated bit was used to drill through rock strata/refusal. The bit was attached to the end of a core barrel, which is connected to the machine by a string of NW drill rods and rotated by the drilling machine.

Water was circulated through the drill rods to the bottom of the hole. The water serves the purpose of lubrication, cooling and protection of the diamond drill bit in addition to flushing the cuttings out of the hole. A reciprocating pump was used to circulate the water. While drilling through soft rock that is likely to collapse, NX size casing was installed. The casing with a diamond shoe bit was used to assist the casing to advance.

The percent core recovery and Rock Quality Designation (RQD) was measured for each core run. The percent core recovery is defined as the percent ratio of the cumulative length of core sample recovered to the total length of the core run. The Rock Quality Designation (RQD) is defined as the ratio of the cumulative length of core pieces 10 cm or longer to the total length of the core run, expressed as percentage. The Rock mass Rating (RMR), an engineering parameter that assists in assessing the rock quality and behavior is also presented on the individual rock profiles.

Details of rock samples collected and their respective core recovery / RQD values are presented on the rock profiles at various depths. The color of return water and the extent of water loss while drilling the borehole recorded on the boring logs may be used for an assessment of the nature of rock, water-tightness of joints and possible presence of interconnected channels / cavities.

2.4 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.

2.5 Electrical Resistivity Tests

Electrical resistivity of the substratum 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 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.

3.0 LABORATORY TESTS

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

Name of Test	IS Code No.
Porosity and Void Ratio	By Calculations
Specific Gravity	IS : 2720 (Part-3)-1980
Moisture Content, Density & Water absorption	IS : 13030-1991
Unconfined compressive strength	IS : 9143-1979, RA-2006
Point load strength index	IS : 8764-1998, RA-2008

4.0 GENERAL SITE CONDITIONS

4.1 Site Stratigraphy

The deposits at the site may be divided into two generalized strata as given below:

Stratum-I (Overburden): Fill
Stratum-II (Rock formation): Quartzite (Rock)

Stratum-I (Overburden): A heterogenous fill of sandy silt with concrete materials was met to about 1.5 m depth below EGL. Refusal (N >100) is encountered at the soil-rock interface.

Stratum-II (Rock formation): The rock formation of Stratum-II classifies as Quartzite. The rock is generally very weak to strong, very intensely to moderately fractured and completely to modertely weathered to the final explored depth of 6 m below EGL.

All test results are presented on the individual borelog profiles on Sheet No. 1 & 2. A summary of the borehole profiles is illustrated on Sheet No. 3.

4.2 Groundwater

Based on our measurements in the completed boreholes, groundwater was met at 1.3~1.4 m depth below EGL during the period of our field investigations (July, 2023).

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 configuration. The apparent resistivity values obtained have been analyzed to generate the polar curve. The polar curve is used to compute the mean resistivity.

Mean resistivity values at the electrical resistivity tests (ERT) location are summarized in the table below:

Test Designation	Mean Resistivity, ohm-m	Corrosion potential*	Presentation of Results
ERT-1	10.4	Severely Corrosive	Sheet No. 4

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

The above values 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.

6.0 FOUNDATION ANALYSIS AND RECOMMENDATIONS

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, field SPT values & laboratory test results, we are of the opinion that open foundations for the structures may bear on the rock formation.

Our recommended values of net allowable bearing pressures at minimum 2.0 m below existing ground level for open foundation are presented in Section 7.0.

6.3 Allowable Bearing Pressure

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

- Presumptive Values of safe bearing capacity as per Clause 5.2 of IS 12070-1987
- Based on RMR value as per Clause 5.3 of IS: 12070-1987.
- Bell Solution using Bearing Capacity Factors: "Foundations on Rock" by Duncan C. Wyllie (First Ed., 1992), Clause 5.2.4, pp. 120

We computed the safe bearing capacity from three methods mentioned above and recommended the minimum values from computed values.

7.0 RECOMMENDATIONS

The following table presents our recommended values of net allowable bearing pressures for open foundations bearing at 2.0-2.5 m depth below EGL.

Foundation Depth below EGL, m	Recommended Net Allowable Bearing Pressure, T/m²	Suggested Modulus of Subgrade Reaction, (K), kN/m³
2.0	25.0	20800
2.5	30.0	25000

The following points are highlighted with reference to the recommended bearing pressures given above:

1. Foundations on rock may experience total settlement of less than 10-12 mm.

2. The change in SBC for different foundation sizes is insignificant. Therefore, the recommended values may be considered applicable for all sizes of foundations including raft foundation.

3. Net bearing pressure for foundations bearing at intermediate depths may be interpolated linearly between the values given above.

4. For foundations on rock, all loose, weathered or fragmented rock should be removed so that foundation may bear on the firm rock.

5. The rock surface should be roughened and scarified so as to ensure a proper bond between rock and concrete.

6. The suggested modulus of sub-grade reaction (k) has been computed based on the net bearing pressure considering a corresponding foundation settlement of 12 mm. For a better estimate of foundation deformation characteristics, full scale footing load tests may be carried out on site.

8.0 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 Log (BH-1)

Location : DTC Cluster, Okhla, New Delhi

Ground Water Level : 1.4 m
Rock Level : 1.5 m
Termination Depth : 6 m

Drilling : Rotary Drilling
Start Date : 06-Jul-23
Finish Date : 09-Jul-23

Scale	Depth, m	Sample Designation	Serial No. of Cores	Core Recovery (%)	Rock Quality Designation (RQD) (%)	Symbol	ROCK DESCRIPTION	Depth of Strata, (m)	Percentage Core Recovery & RQD vs. depth (Core Recovery, RQD; 0 20 40 60 80 100)	Rock Mass Rating (RMR)	Return Water: Colour	Return Water: Loss	Laboratory Test Results: Core Sample No.	Specific Gravity	Density (gm/cc)	Water Absorption (%)	Void Ratio	Point Load Index (kg/cm^2)	Unconfined Compressive Strength (kg/cm^2)
	0.0	DS-1	-				Fill: Sandy silt with concrete materials	**1.5**											
	1.5	WS1	-	0	0		Very weak to weak, browinsh Quartzite, very intensely fractured, Completely to highly weathered			15	Brown	Partial							
	3.0	RK1	SP	3	0					16				2.66	2.18	5.60	0.22	-	-
	4.0	RK2	SP	8	0			**5.0**		16									
	5.0	RK3	1-5	13	0		Weak to moderately weak, brownish Quartzite, intensely fractured, highly weathered	**6.0**		18			3	2.78	2.35	2.60	0.18	3.6	-
																			-

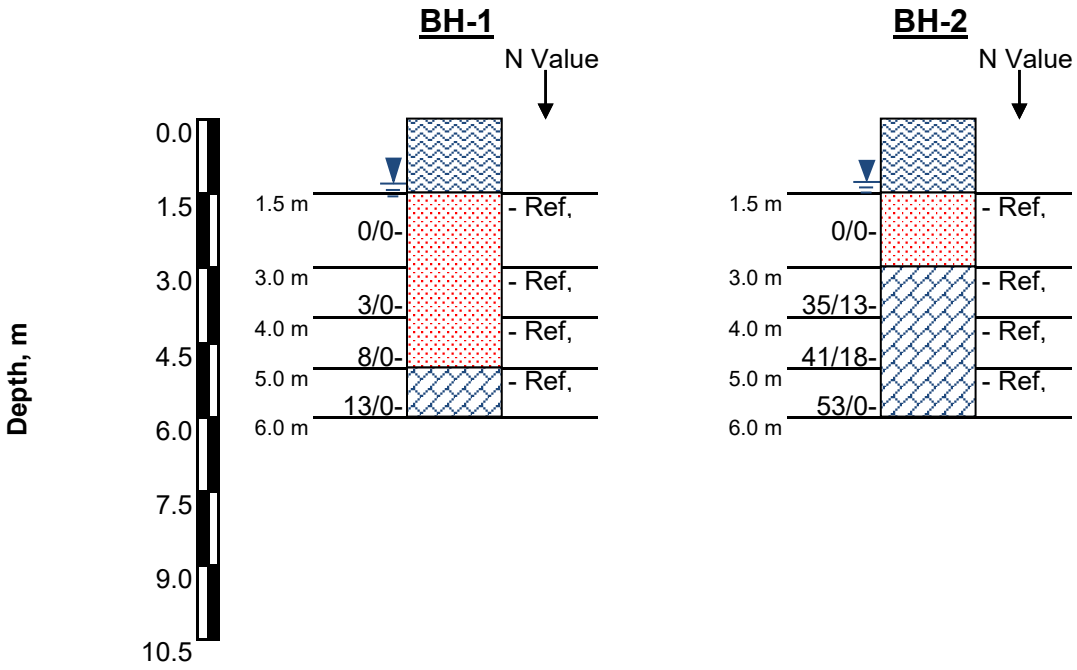
Borehole Log (BH-2)

Location : DTC Cluster, Okhla, New Delhi

Ground Water Level : 1.3 m
Rock Level : 1.5 m
Termination Depth : 6 m

Drilling : Rotary Drilling
Start Date : 10-Jul-23
Finish Date : 11-Jul-23

Scale	Depth, m	Sample Designation	Serial No. of Cores	Core Recovery (%)	Rock Quality Designation (RQD) (%)	Symbol	ROCK DESCRIPTION	Depth of Strata, (m)	Percentage Core Recovery & RQD vs. depth (Core Recovery, RQD; 0 20 40 60 80 100)	Rock Mass Rating (RMR)	Return Water: Colour	Return Water: Loss	Laboratory Test Results: Core Sample No.	Specific Gravity	Density (gm/cc)	Water Absorption (%)	Void Ratio	Point Load Index (kg/cm^2)	Unconfined Compressive Strength (kg/cm^2)
	0.0	DS-1	-				Fill: Sandy silt with concrete materials	**1.5**		0									
	1.5	WS1	-	0	0		Very weak, browinsh Quartzite, Completely weathered	**3.0**		15									
	3.0	RK1	1-2	35	13		Moderately weak to strong, brownish Quartzite, moderately fractured, highly to moderately weathered			20	Brown	Partial	1	2.81	2.42	2.60	0.16		130
	4.0	RK2	3-6	41	18					22									
	5.0	RK3	7-9	53	0			**6.0**		22			8	2.79	2.41	3.20	0.16	5.3	-



LEGEND	
SYMBOL	DESCRIPTION
	GW level
	Fill
	Completely Weatherd
	Quartzite (Rock)

Cross Section of Boreholes

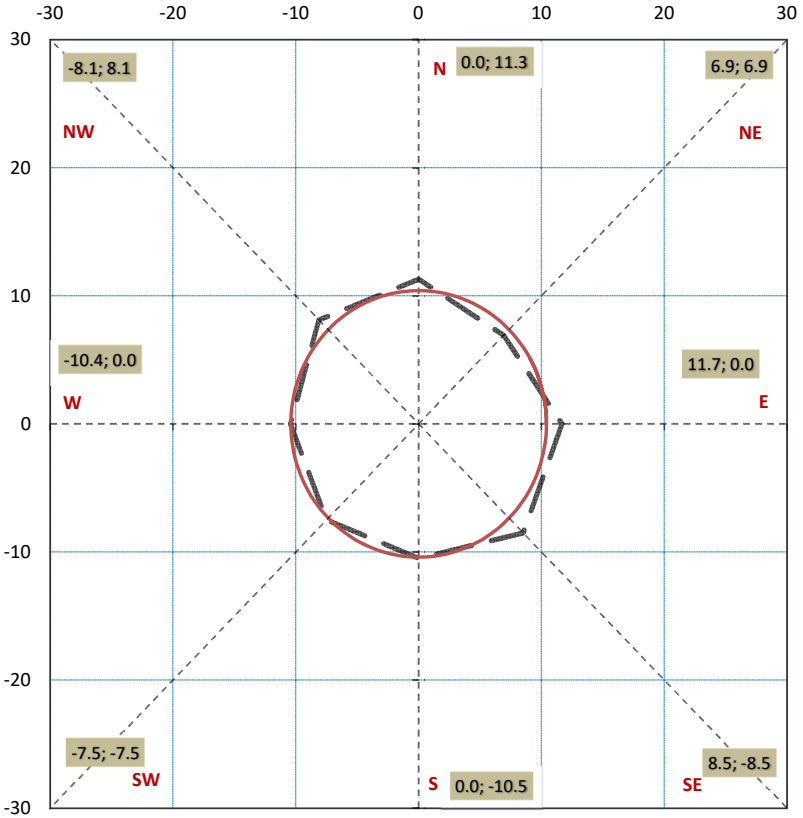
ELECTRICAL RESISTIVITY TEST RESULTS

IS: 3043-1987, RA-2006

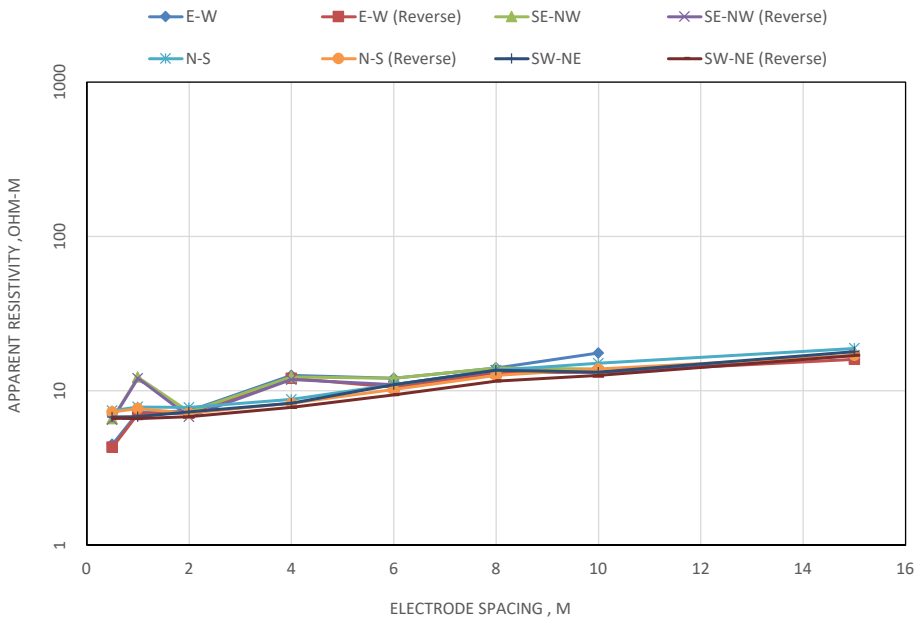
Test Details
Test Designation : ERT 01

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	4.5	4.3	6.6	6.5	7.4	7.3	6.8	6.6
1.0	7.2	7.1	12.3	12.1	7.9	7.7	6.8	6.6
2.0	7.4	7.2	7.3	6.8	7.8	7.2	7.3	6.8
4.0	12.6	12.1	12.3	11.8	8.8	8.3	8.3	7.8
6.0	12.1	10.6	12.1	10.9	10.9	10.2	10.9	9.4
8.0	14.1	13.1	14.1	13.6	13.6	12.6	13.6	11.6
10.0	17.6	13.2	13.8	13.2	15.1	13.8	13.2	12.6
15.0	17.9	16.0	17.9	17.0	18.8	17.0	17.9	17.0
Mean Resistivity	11.7	10.4	12.0	11.5	11.3	10.5	10.6	9.8

POLAR RESISTIVITY CURVE



MEAN RESISTIVITY VALUE = 10.4 ohm-m



Total Area of Polygon : 340

Radius of Equivalent Circle = Mean Resistivity : 10.4 ohm-m

TYPICAL CALCULATION

BEARING CAPACITY ANALYSIS FOR FOUNDATIONS ON ROCK
(as per IS 12070-1987 & International Practice)

Rock Type : Quartzite Rock
Core Recovery, % : 0
Width of Foundation, m : 3
Foundation Shape : square

Foundation Depth, m : 2
RQD, % : 0
Design Water Table, m : NOT MET
Factor of Saftey : 3

Presumptive Values of safe bearing capacity as per Clause 5.2 of IS 12070-1987

$q_{net\ safe} = q_s * c_{sub} * c_c * c_s$

$q_{net\ safe}$ = safe net bearing capacity
q_s = safe bearing capacity
c_{sub} = correction for saturation / submerged condition
c_s = correction for orientation of joints
c_c = correction for solution cavities (in limestone)

Presumptive Value of safe bearing capacity for design:

c_{sub} = 0.50 c_s = 0.60 qs = 85 T/m^2
c_c = 1.00
qnet safe = 25.5 T/m^2

Based on RMR value: Clause 5.3 of IS 12070-1987

Class of rock	I	III	III	IV	V
Description of rock	Very Good	Fair	Fair	Poor	Very Poor
RMR	100-81	60-41	60-41	40-21	20-0
$q_{net\ safe}$ (T/m^2)	600-448	280-141	280-141	135-48	45-30

RMR value for design = 15 Class of Rock: V Rock Description: Very Poor
qnet safe = 41.3 T/m^2

Bell Solution : Based on Interpreted c-ϕ Value of Rock & Bearing Capacity Factors

$q_{ult} = c\ N_c\ C_c + 0.5\ \gamma\ B\ N_\gamma\ C_\gamma + \gamma\ D\ N_q$

where
c= Cohesion of rock, T/m^2
B= width of foundation, m
N_c, N_q, N_γ = Bearing Capacity Factors which are a function of ϕ
C_c = 1.25 for square footing, 1.2 for circular footing
C_γ = 0.8 for square footing, 0.7 for circular footing
γ = Density of Rock, T/m^3
D= Depth of Foundation, m
q_{ult} = Ultimate Bearing Pressure, T/m^2
F = Factor of Safety

c, T/m^2 = 9.0 ϕ, Degree = 14.0
C_c = 1.25 C_γ = 0.8
Factor of Safety = 3.0
Overburden Pressure at Foundation Level, T/m^2: 3.58
Nϕ = 1.64 N_c = 6.74
Nγ = 2.14 Nq= 2.67

Computed Ultimate Bearing Capacity, q_{ult} = 91.0 T/m^2
Computed Safe Bearing Capacity, $q_{net\ safe}$ = 29.2 T/m^2

Bulk Density Profile		
Depth, m		γ, T/m^3
From	To	
0.0	1.5	1.7
1.5	4.5	2.2
4.5	6.0	2.7

Method of Analysis	Computed Safe Net Bearing Pressure, T/m^2
Presumptive method :	25.5
RMR value :	41.3
Bearing Capacity Factors :	29.2

Recommended value of Net Safe Bearing Pressure for Design: 25.0 T/m^2