



**GEOTECHNICAL INVESTIGATION REPORT
FOR THE PROPOSED FACTORY COMPLEX
AT MALANPUR MPIDC INDUSTRIAL AREA,
GWALIOR, MADHYA PRADESH**

**NAGADI CONSULTANTS
PRIVATE LIMITED**

REGISTERED OFFICE :

Bangalore :

1016, Dr. Rajkumar Road, 4th Block,
Rajajinagar, Bangalore - 560 010
Tel : 080 - 23156076 Fax : 080 - 23303007
E-mail : bangalore@nagadi.co.in

REGIONAL OFFICE :

New Delhi :

106/1D Kishangarh, Vasant Kunj
New Delhi - 110 070
Tel : 011 - 26891980 Fax : 011 - 26897403
E-mail : delhi@nagadi.co.in

Chennai :

61C, East Coast Road, Thruvanmiyur
Chennai - 600 041
Tel : 044 - 2447870 Fax : 044 - 24488957
E-mail : chennai@nagadi.co.in

Secunderabad :

60, Manovikasnagar, Opp. NIMH,
Secunderabad - 500 009
Tel : 040 - 2775 446 Fax : 040 - 27751194
e-mail : secunderabad@nagadi.co.in

Client:

Space Geo Tech, "Sri Guru Krupa",
#985, 18th A Main, 66th Cross,
5th Block, Rajajinagar,
Bangalore - 560010

Website : nagadi.co.in

Job No. : **G(D) 4550**

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GEOTECHNICAL INVESTIGATION REPORT for the Proposed Factory Complex at Malanpur MPIDC Industrial Area, Gwalior, Madhya Pradesh

EXECUTIVE SUMMARY

Space Geo Tech, "Sri Guru Krupa", Bangalore - 560010 are the Consultants for the proposed project at Malanpur, MPIDC Industrial Area, Gwalior.

The proposed structures are Factory Buildings.

The scope of work for these structures as specified by the clients consisted of conducting boreholes in soil / rock strata down to a maximum depth of about 10m below the existing ground level at twenty locations.

The results of the investigations have indicated the presence of refusal/ rock strata in the form of Sandstone at a depth varying from the existing ground level to about 9.5m below the existing ground level. The subsoil strata generally consists of clayey sandy silt down to the depths of refusal/ rock strata except for occasional layers of sandy soils in between in a few boreholes.

The refusal/ rock strata consists of Brownish/whitish/ pinkish grey Sandstone . The rock is in different states of weathering down to the depths investigated.

Core recoveries ranging between almost 14% to 99% and RQD values ranging from almost nil to 74% have been observed at various depths in the boreholes.

Ground water table had not been encountered in any of boreholes down to the maximum depth investigated, during the period of field investigations i.e May 2023.

The N-values (N-values 12- 78) indicate that the the subsoil is generally medium dense down to the depths of refusal/ rock strata.

Considering the type of structures involved and the subsoil/rock characteristics as determined from the geotechnical investigations, Isolated/ Strip Footings have been recommended.



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Delhi : 011 (T) 26891980 (F) 26897403 delhi@nagadi.co.in
Bangalore : 080 (T) 23156076 (F) 23303007 bangalore@nagadi.co.in
Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
Secunderabad : 040 (T) 27754446 (F) 27751194 secunderabad@nagadi.co.in

Job No. : G(D) 4550

Sheet No. : 1

The following recommendations have been provided for various structures for the foundations resting on rock/ soil strata.

FOR ALL THE FOUNDATIONS OF AN ISOLATED STRUCTURE RESTING ON SOIL STRATA

Location/ Borehole No.	Depth of foundation (m) below EGL	Net A.B.P. (t/m ²) for Isolated/ Strip footing for widths of foundations		
		1.5	3	>4.5
BH1, BH2, BH3, BH4, BH5, BH6, BH7, BH10, BH13, BH14, BH20	1.5m below the EGL	16	19	23

EGL : Existing Ground Level

FOR ALL THE FOUNDATIONS OF AN ISOLATED STRUCTURE RESTING ON ROCK STRATA

Location/ Borehole No.	Depth of Foundation	Net A.B.P. (t/m ²) for Foundation Width >1.5m
BH8, BH9, BH11, BH12, BH15, BH17, BH18, BH19	minimum 0.3m in rock strata	50

EGL : Existing Ground Level

SOME OF THE FOUNDATIONS OF AN ISOLATED STRUCTURE RESTING ON SOIL STRATA AND SOME OF FOUNDATIONS RESTING ON ROCK STRATA

Net allowable bearing pressure of 14 t/m² can be adopted for foundations widths greater than 1.5m for foundations resting at a depth of 1.5m below the existing ground level in soil strata and at a minimum depth of 0.3m in rock strata.



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Bangalore : 080 (T) 23156076 (F) 23303007 bangalore@nagadi.co.in
Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
Secunderabad : 040 (T) 27754446 (F) 27751194 secunderabad@nagadi.co.in

Job No. : G(D) 4550

Sheet No. : 2

Precaution :

For foundations resting in soil strata, foundation surface must be compacted heavily. If any loose pockets are observed, the same shall be filled with brickbats/gravel and compacted. Foundations can subsequently be placed over such a prepared surface.

For foundations resting on rock strata, loose pockets if encountered shall be removed and backfilled with concrete. A levelling course of concrete shall be laid and construction of foundations can be taken up subsequently.



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Delhi : 011 (T) 26891980 (F) 26897403 delhi@nagadi.co.in
Bangalore : 080 (T) 23156076 (F) 23303007 bangalore@nagadi.co.in
Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
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Job No. : G(D) 4550

Sheet No. : 3

1.0 INTRODUCTION

- 1.1 Space Geo Tech, "Sri Guru Krupa", #985, 18th A Main, 66th Cross, 5th Block, Rajajinagar, Bangalore - 560010 are the Consultants for the proposed project at Malanpur MPIDC Industrial Area, Gwalior, Madhya Pradesh.
- 1.2 To design the substructures for the proposed structures of the Factory Complex , adequate information regarding the subsoil conditions is required. For this purpose, detailed geotechnical investigations have been undertaken at the site of the proposed project.
- 1.3 This report contains the details of the geotechnical investigations conducted along with the results and analysis of the investigations and the recommendations thereof.
- 1.4 Geotechnical investigations for this purpose have been carried out as per the verbal authorization of the authorised signatory of Space Geo Tech. This authorization has been given in response to our offer no. NCD/Q/SGT/012/2022 dated 26th April 2023.

2.0 PROJECT DETAILS

2.1 Site Location

- 2.1.1 The site for the proposed project at Malanpur MPIDC Industrial Area, Gwalior, Madhya Pradesh and is situated at a distance of about 20 km from Gwalior Railway Station towards Bhind, Madhya Pradesh.

2.2 Site Layout and Topography

- 2.2.1 A schematic site plan showing the dimensions and other details of the site is enclosed in this report (fig.1a).
- 2.2.2 Maximum level differences of about 3m had been observed at the site, during the period of field investigations. However, the general level of the site had been observed to be about 2m below the adjacent road level.



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Delhi : 011 (T) 26891980 (F) 26897403 delhi@nagadi.co.in
Bangalore : 080 (T) 23156076 (F) 23303007 bangalore@nagadi.co.in
Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
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Job No. : G(D) 4550

Sheet No. : 4

2.2.3 About thirty percent area of the site in North - East direction had been observed to be under use for stone query purposes with level differences upto 5m.

2.2.4 Rock in outcrop had been observed to be visible in some portion of the site.

2.2.5 Vegetation in the form of grass and bushes had been observed at the site, during the period of field investigations.

2.2.6 The colour of the surface earth had been observed to be Yellow brown.

2.3 Seismic Zone

The present site is located in the Seismic Zone - II which is the zone of low seismicity, as per the seismic zoning map of India given in BIS code IS:1893 (Part1)-2016.

2.4 The Structure/s

2.4.1 The proposed structures are Factory Buildings.

2.4.2 The structures are understood to be framed ones and the construction to be of Reinforced Cement Concrete.

3.0 OBJECT OF INVESTIGATIONS

3.1 For designing the foundation system of the proposed structures, the following data are required :

- a) Type of foundation
- b) Depth below the ground level at which the foundation system is to be laid.
- c) Allowable bearing pressure at the foundation level.

3.2 To determine the above factors, the following information would be required:

- a) The subsoil/rock profile indicating thicknesses of the various soil/rock strata, to a depth within the influence zone below the foundations
- b) Engineering properties of the soil/rock strata at various levels



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Delhi : 011 (T) 26891980 (F) 26897403 delhi@nagadi.co.in
Bangalore : 080 (T) 23156076 (F) 23303007 bangalore@nagadi.co.in
Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
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Job No. : G(D) 4550

Sheet No. : 5

- c) Physical characteristics of the soil/rock strata
- d) Variation of strength of soil/rock strata with depth

3.3 For evaluating the above parameters, field investigations and laboratory investigations on the soil/rock samples collected during the field investigations, have been carried out.

3.4 The results from these investigations have been analysed to provide the recommendations for the design of foundations.

4.0 SCOPE OF INVESTIGATIONS

4.1 The scope of investigations as stipulated by the client consists of :

- a) Conducting boreholes in soil/ rock strata at twenty locations down to a maximum depth of 10m below the existing ground level.
- b) Conducting chemical analysis on soil samples.
- c) Conducting relevant laboratory tests on soil / rock samples recovered.
- d) Preparation and submission of a technical report in three copies containing the details of the tests carried out, their analysis and recommendations regarding the foundation system to be adopted.

4.2 The following operations were to be undertaken while progressing the boreholes:

- a) Conducting standard penetration tests at regular intervals in soil strata.
- b) Recovering undisturbed soil samples from various levels of the subsoil strata.
- c) Recovering rock core samples in rock strata.
- d) Recording ground water table levels, if met with.

5.0 FIELD INVESTIGATIONS

5.1 Preliminary Details

5.1.1 Field investigations had been carried out between 1st May 2023 and 9th May 2023.



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Delhi : 011 (T) 26891980 (F) 26897403 delhi@nagadi.co.in
 Bangalore : 080 (T) 23156076 (F) 23303007 bangalore@nagadi.co.in
 Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
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Job No. : G(D) 4550

Sheet No. : 6

5.1.2 A Schematic site plan/ Google map image showing the test locations has been given in fig. 1a.

5.1.3 Photographs showing view of the site and work under progress are given in figs. 1b & 1c.

5.2 Boreholes

5.2.1 The locations, termination depths and depths at which the refusal/ rock strata had been encountered in all the twenty boreholes are as follows :

BH No.	Termination Depth (m) below EGL	Depth (m) of Refusal/ rock strata below EGL	Coordinates (m)	
			North	East
BH1	6.5	3.5	2916825	227991
BH2	3.5	3.5	2916800	228043
BH3	3.9	3.9	2916773	228097
BH4	10	7	2916744	228156
BH5	3.5	3.5	2916710	228233
BH6	10	8.5	2916679	228300
BH7	5	5	2916636	228348
BH8	4.2	1.2	2916711	228388
BH9	3.3	0.3	2916739	228354
BH10	6.5	3.5	2916768	228296
BH11	2.5	2.5	2916808	228218
BH12	4	1	2916844	228149
BH13	5	5	2916880	228080
BH14	9.5	9.5	2916912	228018
BH15	4.5	0	2916984	228053
BH16	3.3	0.3	2916935	228098
BH17	4.5	0	2916908	228170
BH18	4.5	0	2916982	228202
BH19	4.5	0	2916991	228116



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Delhi : 011 (T) 26891980 (F) 26897403 delhi@nagadi.co.in
Bangalore : 080 (T) 23156076 (F) 23303007 bangalore@nagadi.co.in
Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
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Job No. : G(D) 4550

Sheet No. : 7

BH No.	Termination Depth (m) below EGL	Depth (m) of Refusal/ rock strata below EGL	Coordinates (m)	
			North	East
BH20	5	5	2916820	228112

- 5.2.2 The boreholes had been progressed by Shell and Auger method down to the refusal/ rock depths that is depths beyond which the boreholes could not be progressed by this method.
- 5.2.3 Drilling in refusal/ rock strata had been carried out in some of the boreholes, so as to ensure that adequate information regarding the rock strata below the likely foundation level is obtained.
- 5.2.4 Drilling in refusal/ rock strata had been carried out down to a maximum depth of 9.5m below the existing ground level, by rotary drilling machine using double tube core barrel fitted with appropriate diamond bits of Nx size.
- 5.2.5 In the soil strata, Standard Penetration Tests (SPT) had been conducted at 1.5m intervals. Disturbed soil samples recovered from split spoon samplers had been retained for identification purposes. However, Standard Penetration Test had also been conducted at occasional depths in weathered rock strata for the confirmation of refusal/ rock strata.
- 5.2.6 Undisturbed soil samples had been recovered by thin walled tube samplers conforming to IS : 2132. These tubes had an area ratio of less than 10%.
- 5.2.7 The diameter of undisturbed soil samples was 50mm and the length was 45cm.
- 5.2.8 The ends of sample tubes had been sealed by wax to prevent loss / ingress of moisture. Disturbed soil samples had been enclosed in polythene bags.
- 5.2.9 In the rock strata, the rock core samples, where recovered from the boreholes had been preserved in the core boxes with proper marking on each sample and the borelogs had been maintained appropriately.



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Delhi : 011 (T) 26891980 (F) 26897403 delhi@nagadi.co.in
Bangalore : 080 (T) 23156076 (F) 23303007 bangalore@nagadi.co.in
Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
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Job No. : G(D) 4550

Sheet No. : 8

5.2.10 Soil / rock samples had been transported to the laboratory for testing purposes.

5.2.11 Ground water table had not been encountered in any of the the boreholes down to the maximum depth investigated i.e. 9.5m below the existing ground level, during the period of field investigations May 2023.

6.0 LABORATORY INVESTIGATIONS

6.1 Tests on soil and rock samples from boreholes

6.1.1 The soil samples brought to the laboratory had been subjected to various tests to determine the following properties :

- a) Type and gradation of soil
- b) Consistency limits
- c) Density and water content
- d) Shear strength parameters

6.1.2 In order to determine the above properties, the following tests have been conducted :

- a) Sieve analysis on coarse grained soil fraction
- b) Hydrometer analysis on fine grained soil fraction
- c) Triaxial compression tests
- d) Maximum and minimum dry densities
- e) Density and water content determination tests
- f) Liquid and plastic limits

6.1.3 The rock samples brought to the laboratory had been subjected to various tests to determine the following properties :

- a) Unit weight
- b) Porosity
- c) Water absorption



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Delhi : 011 (T) 26891980 (F) 26897403 delhi@nagadi.co.in
Bangalore : 080 (T) 23156076 (F) 23303007 bangalore@nagadi.co.in
Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
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Job No. : G(D) 4550

Sheet No. : 9

- d) Unconfined compressive strength
- e) Point load strength index

6.2 Chemical Analysis

6.2.1 The soil samples collected from the boreholes had been tested to determine the pH-value and the presence of salts harmful to reinforced cement concrete construction namely Chloride and Sulphate contents.

7.0 RESULTS & ANALYSIS

7.1 Presentation of Results

7.1.1 The results of the borehole investigations and of the laboratory investigations conducted on the soil/ rock samples collected from the boreholes, have been presented in the form of soil profile tables and rock profile tables.

7.1.2 The soil profile tables indicate the following:

- a) Standard penetration test values at various depths
- b) Soil description identifying the type of soil
- c) Grain size analysis indicating composition of subsoil
- d) Atterberg Limits
- e) Natural density and water content
- f) Triaxial test results

7.1.3 The rock profile tables indicate the following :

- a) Strata description identifying the type of rock strata
- b) Number of core pieces of different sizes and thereupon the core recovery
- c) Rock quality designation (RQD)
- d) Rock properties like unit weight and water absorption
- e) Unconfined compressive strength of the rock



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Delhi : 011 (T) 26891980 (F) 26897403 delhi@nagadi.co.in
 Bangalore : 080 (T) 23156076 (F) 23303007 bangalore@nagadi.co.in
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Job No. : G(D) 4550

Sheet No. : 10

- f) Point load strength of the rock

7.2 Soil/Rock Profile

7.2.1 A perusal of the data presented in the soil and rock profile tables indicates the presence of the following three soil/rock strata at the site :

- a) Stratum - I : Clayey sandy silt with occasional gravel
 b) Stratum - II : Silty sand with occasional clay and gravel
 c) Stratum - III : Brownish/ whitish/ pinkish grey Sandstone

7.2.2 The depths at which these three strata have been encountered in the twenty boreholes are as follows :

BH. No.	Strata (depth in m : from : to)		
	Stratum - I	Stratum - II	Stratum - III
1	0 - 3.5	N.E.	3.5 - 6.5
2	0 - 3.5	N.E.	N.E.
3	0 - 3.9	N.E.	N.E.
4	0 - 3.9	3.9 - 7	7 - 10
5	0 - 3.5	N.E.	N.E.
6	0 - 2.4 3.9 - 8.5	2.4 - 3.9	8.5 - 10
7	0 - 5	N.E.	N.E.
8	0 - 1.2	N.E.	1.2 - 4.2
9	0 - 0.3	N.E.	0.3 - 3.3
10	0 - 3.5	N.E.	3.5 - 6.5
11	0 - 2.5	N.E.	N.E.
12	0 - 1	N.E.	1 - 4
13	1.5 - 3	0.0 - 1.5 3 - 5	N.E.
14	0 - 4.3 6.9 - 9.5	4.3 - 6.9	N.E.



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 Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
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Job No. : G(D) 4550

Sheet No. : 11

BH. No.	Strata (depth in m : from : to)		
	Stratum - I	Stratum - II	Stratum - III
15	N.E.	N.E.	0 - 4.5
16	0 - 0.3	N.E.	0.3 - 3.3
17	N.E.	N.E.	0 - 4.5
18	N.E.	N.E.	0 - 4.5
19	N.E.	N.E.	0 - 4.5
20	0 - 5	N.E.	N.E.

N.E. : not encountered

7.2.3 The above results show that :

- Stratum - I consisting predominantly of silty soils with varying percentage of clay and sand, has been encountered down to a maximum depth of 9.5m below the existing ground level
- Stratum - II predominantly of sandy soils with significant percentages of silt and clay, has been encountered in occasional layers down to a maximum depth of 7m below the existing ground level in some boreholes.
- Stratum - III consisting of rock strata in the form of Whitish/ pinkish grey Sandstone, has been encountered between almost at the ground level to a maximum depth of about 9.5m below the existing ground level.

7.3 Soil Composition

7.3.1 The grain size distributions of the soil samples at various depths have been presented in the form of grain size analysis curves in figs. 5a to 5e.

7.3.2 The variations in the grain size distributions in the two strata (except Stratum - III i.e. rock strata) in the twenty boreholes are as follows



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Delhi : 011 (T) 26891980 (F) 26897403 delhi@nagadi.co.in
Bangalore : 080 (T) 23156076 (F) 23303007 bangalore@nagadi.co.in
Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
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Job No. : G(D) 4550

Sheet No. : 12

a) Stratum - I : Clayey sandy silt with occasional gravel

BH. No.	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
1	4 - 7	34 - 35	45 - 50	11 - 14
2	7 - 13	30	46 - 49	11 - 14
3	10 - 18	23 - 35	45 - 46	10 - 13
4	13 - 19	26 - 27	42 - 49	12
5	6 - 22	29 - 33	37 - 46	12 - 15
6	0 - 5	23 - 43	44 - 48	9 - 15
7	2 - 18	25 - 44	45 - 52	9 - 12
8		N.E.		
9	-	-	-	-
10	2 - 10	25 - 36	47 - 49	15 - 16
11	7	37	43	13
12	-	-	-	-
13	6	27	53	14
14	0 - 13	19 - 44	39 - 67	10 - 12
15		N.E.		
16	-	-	-	-
17		N.E.		
18		N.E.		
19		N.E.		
20	5 - 29	22 - 29	31 - 53	11 - 21

N.E. : not encountered

b) Stratum - II : Silty sand with occasional clay and gravel

BH. No.	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
4	3 - 10	44 - 54	36 - 43	0 - 10
6	10	57	33	0
8	-	-	-	-



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Bangalore : 080 (T) 23156076 (F) 23303007 bangalore@nagadi.co.in
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Job No. : G(D) 4550

Sheet No. : 13

BH. No.	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
13	2 - 12	51	37 - 38	0 - 9
14	15 - 39	45 - 47	26 - 38	0

This stratum has been encountered only in these boreholes

7.3.3 The above results indicate that :

- Stratum - I consists of about 31% to 67% of silt, 19% to 44% of sand and 9% to 21% of clay with occasional gravel.
- Stratum - II consists of about 26% to 43% of sand, 44% to 57% of silt with rest of the soil matrix consisting of clay and gravel.

7.4 Natural Density and Water Content

7.4.1 The natural bulk densities, water contents and dry densities of the subsoil in the boreholes wherein undisturbed soil samples have been collected, vary as follows :

BH. No.	Bulk Density (g/cm ³)	Water Content (%)	Dry Density (g/cm ³)
1	2.02 - 2.05	12.1 - 23.5	1.64 - 1.84
2	1.96 - 1.98	15.1 - 17.6	1.68 - 1.70
3	1.8	8.1	1.67
4	1.74 - 1.90	2.8 - 13.2	1.68 - 1.72
5	1.98 - 2.08	12.1 - 14.9	1.72 - 1.86
6	1.95 - 2.04	8.7 - 14.0	1.75 - 1.87
7	2.04 - 2.10	15.1 - 16.5	1.75 - 1.81
8	1.9	6.6	1.78
10	2.02 - 2.03	10.4 - 11.6	1.74 - 1.84
11	1.84	6.9	1.72
13	1.78 - 2.09	6.2 - 17.6	1.68 - 1.79
14	1.90 - 2.17	6.1 - 13.8	1.74 - 1.91
20	1.90 - 2.03	7.3 - 10.6	1.77 - 1.84



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Job No. : G(D) 4550

Sheet No. : 14

7.4.2 The variations in the dry densities of the soil have also been presented in the form of plots of dry density vs depth for the boreholes conducted, in figs. 3a to 3c.

7.4.3 The above results indicate that the subsoil where encountered is generally in a medium dense state down to the depths of refusal/ rock strata.

7.5 Atterberg Limits

7.5.1 The Atterberg limits indicate that the subsoil is generally low plastic down to the depths of refusal/ rock strata.

7.6 Standard Penetration Tests Values (N-values)

7.6.1 The observed Standard Penetration Test values (N-values) vary between 12 and 78 as indicated in the soil profile tables and as also shown in the figs. 4a & 4b wherein the observed N-values have been plotted with respect to depth.

7.6.2 The above results indicate that the subsoil is generally in a medium dense state down to the depths of refusal/ rock strata.

7.7 Rock Conditions

7.7.1 An analysis of the data provided in the rock profile tables indicates the following :

- a) The rock strata generally consists of Sandstone .
- b) The colour of the rock generally varies from Brownish/ whitish to pinkish grey down to the maximum depth investigated.
- c) Core recoveries ranging from 14% to 99%% have been observed at different depths in different boreholes.
- d) RQD values varying between almost nil to 74% have been observed at different depths in different boreholes.



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Delhi : 011 (T) 26891980 (F) 26897403 delhi@nagadi.co.in
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Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
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Job No. : G(D) 4550

Sheet No. : 15

- e) The rock strata has been observed to have a wide range of weathered states from highly weathered (generally recognised by nil to very low core recovery) to more or less in a moderately weathered state (generally recognised by higher core recovery and higher RQD) at different depths in different boreholes.
- f) Unit weight of the rock generally varies between 2.30 g/cm³ and 3.44 g/cm³.
- g) Porosity of the rock varies between 2.4 % and 5.1 %.
- h) Water absorption of the rock varies between 1.8% and 3.9%.
- i) Uniaxial compressive strength of the rock varies between 278 kg/cm² and 727 kg/cm². Low uniaxial compressive strength have been observed due to the fact that the rock strata consists of the trap rocks.
- j) Point load strength of the rock generally varies between 1040 kg/cm² and 1170 kg/cm². These tests are primarily conducted on rock samples where significant RQD has not been obtained.

7.8 Compiled Soil And Rock Profile

7.8.1 An overview of the results and their analysis has been presented in the form of a compiled soil and rock profile (figs. 2a & 2b).

7.8.2 The above figure shows the various strata encountered and their thicknesses in each of the boreholes and also gives the soil / rock composition and the observed N-values at various depths.

7.9 Chemical Analysis

7.9.1 The results of the chemical analysis conducted on soil samples collected from different boreholes, for determining the presence of any harmful salts which can have adverse effects on construction, are as follows :



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Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
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Job No. : G(D) 4550

Sheet No. : 16

Borehole no.	pH value	Chloride Content (ppm)	Sulphate Content (ppm)
BH1/ 0.9m	6	32	58
BH2/ 2.4m	6.5	35	62
BH3/ 1.5m	6.5	40	75
BH4/ 1.5m	7	32	84
BH4/ 3m	7	45	52
BH5/ 2.4m	7	38	64
BH6/ 1.5m	6.5	26	58
BH6/ 4.5m	6.5	22	72
BH7/ 0.9m	7	35	48
BH7/ 2.4m	6.5	36	56
BH10/ 0.9m	6.5	40	64
BH10/ 2.4m	6.5	46	58
BH11/ 0.9m	6.5	38	60
BH13/ 0.9m	7	28	80
BH13/3.9m	7	32	78
BH14/ 1.5m	6.5	42	52
BH14/4.5m	7	36	65
BH14/ 7.5m	6.5	30	64
BH20/0.9m	6.5	22	70
BH20/2.4m	6.5	32	65

IS LIMITS

<i>pH value</i>	<i>Not less than 6</i>
<i>Chloride content (ppm)</i>	<i>Maximum 500 ppm</i>
<i>Sulphate content (ppm)</i>	<i>Maximum 400 ppm</i>

7.9.2 The above results indicate that the soil water encountered at the site will not have any aggressive effect on normal concrete construction works.



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Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
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Job No. : **G(D) 4550**

Sheet No. : **17**

8.0 DESIGN CRITERIA

8.1 Design Parameters

8.1.1 The parameters required for the design of the foundation system for the proposed structures are:

- a) Type of foundation to be adopted
- b) Depth at which the foundations have to be laid
- c) Allowable bearing pressure on the soil/rock at the foundation level

8.1.2 On the basis of the analysis of the results of the investigations, the required design parameters have been arrived at as given in the following sections.

8.2 Type of Foundation

8.2.1 The type of foundation depends upon the following :

- a) Subsoil/rock conditions
- b) Type of structure
- c) Configuration of loading points
- d) Loading intensity on each column at the foundation level

8.2.2 The proposed structures are Factory Buildings. Considering this, medium heavy to heavy loads can be anticipated on the foundations.

8.2.3 The results of the investigations have indicated that the refusal/ rock strata in the form of Sandstone rock has been encountered at a depth varying between almost at the ground level and 9.5m below the existing ground level.

8.2.4 The subsoil strata down to the depths of refusal/ rock strata is generally in a medium dense state down to the depths of refusal/ rock strata.

8.2.5 In view of the above, the foundations for the proposed structures can be supported over

Isolated/ Strip Footings.



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Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
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Job No. : G(D) 4550

Sheet No. : 18

8.3 Depth of Foundation

8.3.1 The depth at which the foundations should be laid, will be governed by the following criteria:

- a) There should be sufficient thickness of soil above the footings/foundations so that they are neither exposed or undermined by natural/manmade forces in the future.
- b) There should be sufficient thickness of soil/rock above the footings/foundations so that the bearing capacity of the soil/rock can be fully mobilised.
- c) Soil/rock beyond the level of footings/foundations should have the requisite strength to support the anticipated bearing pressures on the foundations without allowing the settlements of the footings/foundations to exceed the acceptable limits.
- d) Requirements of the type of structure.

8.3.2 Giving due consideration to above, the foundations of the proposed structures can be placed

- a) at a depth of ***minimum 0.3m in virgin rock strata.***
- b) at a depth of ***1.5m below the existing ground level, in soil strata***

8.3.3 The depths at which the refusal/ rock strata have been encountered in the boreholes at various locations has been given hereunder.

BH No.	Depth (m) of Refusal/ rock strata below EGL
BH1	3.5
BH2	3.5
BH3	3.9
BH4	7
BH5	3.5
BH6	8.5



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Job No. : G(D) 4550

Sheet No. : 19

BH No.	Depth (m) of Refusal/ rock strata below EGL
BH7	5
BH8	1.2
BH9	0.3
BH10	3.5
BH11	2.5
BH12	1
BH13	5
BH14	9.5
BH15	0
BH16	0.3
BH17	0
BH18	0
BH19	0
BH20	5

8.3.4 The excavations down to the above mentioned depths in soil strata can be carried out by ordinary methods by providing necessary side slopes.

8.4 Allowable Bearing Pressures

8.4.1 As the refusal/ rock strata has been encountered at a depth varying from the existing ground level (surface) to 9.5m below the existing ground level, there may be following three possibilities of the strata on which the foundations of a structure shall be placed.

- All the foundations of a structure are placed on soil strata
- All the foundations of a structure are placed on rock strata
- Some of the foundations of a structure are placed on soil strata and some of foundations may rest on the rock strata



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Delhi : 011 (T) 26891980 (F) 26897403 delhi@nagadi.co.in
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Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
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Job No. : **G(D) 4550**

Sheet No. : **20**

8.4.2 The allowable bearing pressure depends on the allowable settlement.

- a) An allowable settlement of 50mm has been considered to evaluate the allowable bearing pressure for ***Isolated/Strip Footings*** wherein all the foundations of an isolated structure are resting on soil strata.
- b) For all the foundations of an isolated structure resting on rock strata, the allowable bearing pressures on ***Isolated/Strip footings*** has been evaluated using the method based on the rock core strength as per the guidelines of Clause - 6 of IS: 12070 - 1987.
- c) For some of the foundations of an isolated structure resting on soil strata and some of the foundations resting on rock strata, the foundations resting on soil strata may undergo larger settlements as compared to the foundations resting on refusal/ rock strata. Therefore, to evaluate the allowable bearing pressure, the differential settlements between the various foundations of the isolated structure, resting on the two different types of strata, have to be ensured to be within acceptable limits. Hence, a lower allowable settlement of 25mm has been considered to evaluate the allowable bearing pressure.

8.4.3 Allowable bearing pressure has been evaluated by :

- a) Shear failure criterion using average soil data
- b) Settlement criterion taking SPT values

8.4.4 On the basis of the above, the following recommendations regarding the net allowable bearing pressures at the recommended depths for the various proposed structures, are being made:



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Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
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Job No. : G(D) 4550

Sheet No. : 21

a) **FOR ALL THE FOUNDATIONS OF AN ISOLATED STRUCTURE RESTING ON SOIL STRATA**

Location/ Borehole No.	Depth of foundation (m) below EGL	Net A.B.P. (t/m ²) for Isolated/ Strip footing for widths of foundations		
		1.5	3	>4.5
BH1, BH2, BH3, BH4, BH5, BH6, BH7, BH10, BH13, BH14, BH20	1.5m below the EGL	16	19	23

EGL : Existing Ground Level

b) **FOR ALL THE FOUNDATIONS OF AN ISOLATED STRUCTURE RESTING ON ROCK STRATA**

Location/ Borehole No.	Depth of Foundation	Net A.B.P. (t/m ²) for Foundation Width >1.5m
BH8, BH9, BH11, BH12, BH15, BH17, BH18, BH19	minimum 0.3m in rock strata	50

EGL : Existing Ground Level

c) **SOME OF THE FOUNDATIONS OF AN ISOLATED STRUCTURE RESTING ON SOIL STRATA AND SOME OF FOUNDATIONS RESTING ON ROCK STRATA**

Net allowable bearing pressure of 14 t/m² can be adopted for foundations widths greater than 1.5m for foundations resting at a depth of 1.5m below the existing ground level in soil strata and at a minimum depth of 0.3m in rock strata.



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Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
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Job No. : G(D) 4550

Sheet No. : 22

9.0 RECOMMENDATIONS

9.1 Type of Foundation

Isolated / Strip Footings

9.2 Depth of foundations & Allowable Bearing Pressures

a) FOR ALL THE FOUNDATIONS OF AN ISOLATED STRUCTURE RESTING ON SOIL STRATA

Location/ Borehole No.	Depth of foundation (m) below EGL	Net A.B.P. (t/m ²) for Isolated/ Strip footing for widths of foundations		
		1.5	3	>4.5
BH1, BH2, BH3, BH4, BH5, BH6, BH7, BH10, BH13, BH14, BH20	1.5m below the EGL	16	19	23

EGL : Existing Ground Level

b) FOR ALL THE FOUNDATIONS OF AN ISOLATED STRUCTURE RESTING ON ROCK STRATA

Location/ Borehole No.	Depth of Foundation	Net A.B.P. (t/m ²) for Foundation Width >1.5m
BH8, BH9, BH11, BH12, BH15, BH17, BH18, BH19	minimum 0.3m in rock strata	50

EGL : Existing Ground Level

c) SOME OF THE FOUNDATIONS OF AN ISOLATED STRUCTURE RESTING ON SOIL STRATA AND SOME OF FOUNDATIONS RESTING ON ROCK STRATA

Net allowable bearing pressure of 14 t/m² can be adopted for foundations widths greater than 1.5m for foundations resting at a depth of 1.5m below the existing ground level in soil strata and at a minimum depth of 0.3m in rock strata.



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Delhi : 011 (T) 26891980 (F) 26897403 delhi@nagadi.co.in
Bangalore : 080 (T) 23156076 (F) 23303007 bangalore@nagadi.co.in
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Job No. : G(D) 4550

Sheet No. : 23

9.3 Appendices

9.3.1 The typical calculation of allowable bearing pressure for foundations resting on soil strata has been shown in Appendix - A of this report.

9.3.2 The typical calculation of allowable bearing pressure for foundations resting on rock strata has been shown in Appendix - B of this report.

9.3.3 A list of IS Codes referred for providing the recommendations and that which might be required to implement the same is also enclosed in this report in Appendix - C.

9.4 Special Note

9.4.1 For foundations resting in soil strata, foundation surface must be compacted heavily. If any loose pockets are observed, the same shall be filled with brickbats/gravel and compacted. Foundations can subsequently be placed over such a prepared surface.

9.4.2 For foundations resting on rock strata, loose pockets if encountered shall be removed and backfilled with concrete. A leveling course of concrete shall be laid and construction of foundations can be taken up subsequently.

9.5 NOTE

The recommendations given in this report have been arrived at on the basis of design parameters which have been judiciously adopted by giving due consideration to the results of field and laboratory investigations as well as NAGADI's experience of over four decades in working in various types of soil and rock conditions all over India.



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Delhi : 011 (T) 26891980 (F) 26897403 delhi@nagadi.co.in
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Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
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Job No. : G(D) 4550

Sheet No. : 24

9.6 ***LIMITATIONS***

This Geotechnical investigation has been carried out at locations in the site chosen by the clients so as to represent the entire site. The recommendations provided in this report are hence valid only for these test locations. However, if there is any change in subsoil/ rock conditions and properties at places between or beyond chosen test locations, fresh investigations will have to be carried out at such locations.

Dr. N. Santosh Rao

Technical Director

For Nagadi Consultants Pvt. Ltd



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Bangalore	: 080 (T) 23156076 (F) 23303007	bangalore@nagadi.co.in
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Job No. : G(D) 4550

Sheet No. : 25

ANALYSIS FOR ALLOWABLE BEARING PRESSURE**Data**

(i) Soil Properties :

$$c \text{ (kg/cm}^2\text{)} = 0.11 \quad \phi = 28^\circ \quad \gamma \text{ (g/cm}^3\text{)} = 1.75$$

(ii) Depth of Foundation, D (m) = 1.5

(iii) Allowable Settlement, s (mm) = 50

Shear Failure Criterion (Ref. IS : 6403)

$$N_c' = 20.09 \quad N_q' = 10.41 \quad N_\gamma' = 10.87 \quad R_w' = 0.75 \quad R_w = 0.75$$

$$q_s = \frac{1}{3} \cdot (c \cdot N_c + \gamma \cdot D \cdot N_q \cdot R_w' + 0.5 \cdot \gamma \cdot B \cdot N_\gamma \cdot R_w) - \gamma \cdot D \cdot R_w$$

$$B \text{ (m)} \quad 1.5 \quad 3 \quad >4.5$$

$$q_s \text{ (t/m}^2\text{)} \quad 15.8 \quad 19.4 \quad 22.9$$

Settlement Criterion (Ref. IS : 8009)(i) *From N Values*

$$B \text{ (m)} \quad 1.5 \quad 3 \quad >4.5$$

$$H \text{ (m)} \quad 3 \quad 6 \quad 10$$

$$N_{av} \quad 18 \quad 20 \quad 22$$

$$q_a \text{ (kg/cm}^2\text{)} \quad 28 \quad 26.7 \quad 28.1$$

(ii) *From Triaxial Compression Tests*

$$q_a = \frac{s}{m_v \cdot H}$$

$$B \text{ (m)} \quad 1.5 \quad 3 \quad >4.5$$

$$H \text{ (m)} \quad 3 \quad 6 \quad 10$$

$$m_v \text{ (t/m}^2\text{)}^{-1} \quad - \quad - \quad -$$

$$q_a \text{ (t/m}^2\text{)} \quad - \quad - \quad -$$

ADOPT	B (cm)	1.5	3	>4.5
	q (t/m ²)	16	19	23

Note : q_s and q_a are NET VALUES, Weight of backfill etc. need not be added to the loading except in case of filling above original G.L.



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Delhi : 011 (T) 26891980 (F) 26897403 delhi@nagadi.co.in
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Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
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Job No. : G(D) 4550

Sheet No. : 26

TYPICAL ANALYSIS FOR ALLOWABLE BEARING PRESSURE FOR FOUNDATIONS RESTING ON ROCK

- A. The allowable bearing pressure has been evaluated from the core strength as per the guidelines of clause 6 of IS 12070 - 1987 as:

$$q_s = q_c \cdot N_j$$

Where q_c = average uniaxial compressive strength of rock cores

N_j = empirical coefficient depending in the spacing of discontinuities

- B. The empirical coefficient ' N_j ' is determined using the following formula :

$$N_j = \frac{3 + \frac{S}{B}}{10 \cdot \sqrt{1 + 300 \cdot \frac{\delta}{S}}}$$

where δ = Thickness of discontinuities/joints in cm

S = Spacing of discontinuities/joints in cm

B = Footing width in cm

- C. The results of the investigations have shown that below the likely foundation levels, the core recovery in the rock strata is typically in varying percentage. Accordingly, considering an average core recovery of 40%, the thickness of all discontinuities/joints will be 60% of the drill run. As on average the number of core pieces recovered in a drill run is about 10, the number of joints in the drill run can be considered as 10. Considering the number of discontinuities/joints as 10 in a drill run of 1.5m or 150cm, the thickness of discontinuities/joints works out to about $\delta = 9$ cm.



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Chennai	: 044 (T) 24487870 (F) 24488957	chennai@nagadi.co.in
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Job No. : G(D) 4550

Sheet No. : 27

- D. Similarly, considering the average number of core pieces recovered in a drill run as 15 and an average core recovery of 40%, the average core size or spacing of discontinuities/joints works out to $S = 6\text{cm}$.
- E. Considering the typical width of foundation 'B' as 2m or 200cm, the empirical coefficient ' N_j ' is determined to be $= 0.0143$.
- F. Average unconfined/uniaxial compressive strength ' q_c ' of the rock strata has been observed to be about 350 kg/cm^2 .
- G. Accordingly, the allowable bearing pressure on foundations resting on the rock strata is determined to be :

$$q_s = 350 \times 0.0143 = 5.00 \text{ kg/cm}^2$$

$$= 50 \text{ t/m}^2$$



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Job No. : G(D) 4550

Sheet No. : 28

LIST OF IS CODES

Field Investigation

1. IS : 1892 - 1979: Code of practice for sub surface investigations for foundations
2. IS : 2131 - 1981: Method of Standard Penetration Tests for soils (First revision)
3. IS : 2132 - 1986 : Code of practice for thin walled tube sampling of soils (Second revision)
4. IS : 11315 - 1985 (Part 11): Method for the quantitative descriptions of discontinuities in rock masses
5. IS : 11315 - 1995 (Part 12) : Quantitative description of discontinuities in rock mass methods.

Laboratory Tests

1. IS : 2720 - 1983 (Part 1) : Methods of test for soils: Preparation of dry soil samples for various tests (Second revision)
2. IS : 2720 - 1980 (Part 2) : Method of test for soils: Determination of water content (Second revision) Amendment 1
3. IS : 2720 - 1980 (Part 3/sec 1) : Method of Test for Soils : Determination of Specific Gravity : Fine Grained Soils. (First Revision)
4. IS : 2720 - 1980 (Part 3/Sec 2) : Method of test for soils : Determination of Specific Gravity : Fine, Medium & Coarse grained soils. (First



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Job No. : G(D) 4550

Sheet No. : 29

revision).

5. IS : 2720 - 1985 (Part 4) : Method of test for soils : Grain size analysis (Second revision)
6. IS : 2720 - 1985 (Part 5) : Method of test for soils : Determination of liquid and plastic limit (Second revision)
7. IS : 2720 (Part 10) - 1973: Method of test for soils : Determination of shear strength parameters using Triaxial apparatus
8. IS: 4078 - 1980 : Code of practice for indexing and storage of drill cores (First Revision)
9. IS: 9143: 1976: Method for the determination of unconfined compressive strength of rock materials.
10. IS : 2720 -1987 (Part 26): Methods of tests for soils: Determination of pH value (Second revision).
11. IS :2720 - 1977 (Part 27): Methods of tests for soils: Determination of total soluble sulphate (First revision).
12. IS : 13030 : 1991 : Method of test for laboratory determination of water content, porosity, density and related properties of rock material.

Foundation Construction

1. IS : 1904 - 1986 : Code of practice for design and construction of foundation in soils: General requirements (Third revision)
2. IS : 6403 - 1981 : Code of practice for determination of bearing capacity of shallow foundations : First revision (Amendment 1)



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Job No. : G(D) 4550

Sheet No. : 30

3. IS : 8009 - 1976 (Part 1) : Code of practice for calculation of settlements of foundations : Shallow foundations subject to symmetrical static vertical loads (Amendment 2)
4. IS: 12070 - 1987 : Code of practice for design and construction of shallow foundations on rocks
5. IS : 13063 : 1991 : Code of practice for structural safety of buildings on shallow foundations.



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Delhi	: 011 (T) 26891980 (F) 26897403	delhi@nagadi.co.in
Bangalore	: 080 (T) 23156076 (F) 23303007	bangalore@nagadi.co.in
Chennai	: 044 (T) 24487870 (F) 24488957	chennai@nagadi.co.in
Secunderabad	: 040 (T) 27754446 (F) 27751194	secunderabad@nagadi.co.in

Job No. : G(D) 4550

Sheet No. : 31

SOIL PROFILE		Project : Proposed Project at Malanpur MPIDC Industrial Area, Gwalior											
		B.H. Location :		Water Table : N.E.		Term. Depth : 6.5m		B.H. No.: 1					
N - Value	Depth (m)	Soil Description	Grain Size Analysis				Atterberg Limits		In-situ properties		Triaxial Test		
			Clay (%)	Silt (%)	Sand (%)	Gravel (%)	Liquid (%)	Plastic (%)	Density (g/cm ³)	Water Cont (%)	Type	c (kg/cm ²)	φ (°)
			11	50	35	4	27	19	2.02	23.5	CD	0.12	27
			14	45	34	7	31	21	2.05	12.1			



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 Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
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Job No. : G(D)4550

Sheet No. : 1

SOIL PROFILE		Project : Proposed Project at Malanpur MPIDC Industrial Area, Gwalior											
		B.H. Location :		Water Table : N.E.		Term. Depth : 3.5m		B.H. No.: 2		Triaxial Test			
				Grain Size Analysis		Atterberg		In-situ					
Depth (m)	N - Value	Soil Description	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Liquid (%)	Plastic (%)	Density (g/cm ³)	Water Cont (%)	Type	c (kg/cm ²)	φ (°)
0.0									1.96	15.1			
0.9								20					
1.5	12	Brownish yellow clayey sandy silt with gravel	7	30	49	14	30						
2.4													
3.0	23	Brownish yellow clayey sandy silt with gravel	13	30	46	11	29	20	1.98	17.6	CD	0.13	26
3.5	35	Refusal/ rock strata (Brownish yellow Sandstone)											
	5cm												

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Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in	Secunderabad : 040 (T) 27754446 (F) 27751194 secunderabad@nagadi.co.in		Sheet No. : 3



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Delhi : 011 (T) 26891980 (F) 26897403 delhi@nagadi.co.in
 Bangalore : 080 (T) 23156076 (F) 23303007 bangalore@nagadi.co.in
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Job No. G(D)4550

Sheet No. : 3

SOIL PROFILE		Project : Proposed Project at Malanpur MPIDC Industrial Area, Gwalior																													
		B.H. Location :		Water Table : N.E.				Term. Depth : 3.9m		B.H. No.: 3																					
				Grain Size Analysis				Atterberg		In-situ		Triaxial Test																			
Soil Description		Clay (%)				Silt (%)		Sand (%)		Gravel (%)		Liquid (%)		Plastic (%)		Density (g/cm ³)		Water Cont (%)		Type		c (kg/cm ²)		φ (°)							
Depth (m)		0.0		0.9		1.5		2.4		3.0		3.9		13		46		23		18		10		26		18		1.80		8.1	
N - Value		13		46		15cm		28		5cm		Refusal/ rock strata (Brownish yellow Sandstone)																			



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Bangalore : 080 (T) 23156076 (F) 23303007 bangalore@nagadi.co.in

Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in

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 Bangalore : 080 (T) 23156076 (F) 23303007 bangalore@nagadi.co.in
 Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
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Job No. G(D)4550

Sheet No. :

4

 NAGADI		Project : Proposed Project at Malanpur MPIDC Industrial Area, Gwalior										
		B.H. Location :				Water Table : N.E.			Term. Depth : 10m		B.H. No.: 4	
N - Value	Depth (m)	Soil Description	Grain Size Analysis				Atterberg		In-situ		Triaxial Test	
			Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Liquid (%)	Plastic (%)	Density (g/cm ³)	Water Cont (%)	Type	ϕ (°) c (kg/cm ²)
16	0.0	Greyish brown clayey sandy silt with gravel	13	26	49	12	32	21	1.89	9.9		
	0.9											
	1.5											
	2.4	Greyish brown clayey sandy silt with gravel	19	27	42	12	25	17	1.90	13.2	CD	0.12
	3.0											
	3.9											
	4.5	Change of the strata	10	54	36	0	Low	Plastic	1.74	2.8	CD	0.09
	5.4	Yellowish brown silty sand with gravel										
	6.0	Yellowish brown clayey silty sand with gravel										
66 20cm	7.0	Refusal/ rock strata (Brownish grey Sandstone)	3	44	43	10	24	17	Tube	bent		

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 Bangalore : 080 (T) 23156076 (F) 23303007
 Chennai : 044 (T) 24487870 (F) 24488957
 Secunderabad : 040 (T) 27754446 (F) 27751194
 delhi@nagadi.co.in
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Job No. G(D)4550
 Sheet No. : 5

ROCK PROFILE						Project : Proposed Project at Malanpur MPIDC Industrial Area, Gwalior		Location :	
		B.H. Size : Nx		Water Table (m): N.E.		Term. Depth (m): 10		B.H. No. : 4	
Strata Description		No. of Core Pieces of Size (cm)		Core Recovery (%)		Run Time (min)		Unit Weight (g/cm ³)	
		>75				80		1170	
		25-75	0 0	14 34		90			
		10-25	0 0 1						
		<10	9 10						
Remarks		N=31/4cm at 8.5m depth Highly weathered rock							
Point Load Strength (kg/cm ²)									
Unconfined Compressive Strength (kg/cm ²)									
Water Absorption (%)		1.8							
Porosity (%)		2.4							
Unit Weight (g/cm ³)		2.45							
Depth (m)		7.0 8.5 10.0							



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Delhi : 011 (T) 26891980 (F) 26897403 delhi@nagadi.co.in

Bangalore : 080 (T) 23156076 (F) 23303007 bangalore@nagadi.co.in

Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in

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Sheet No. : 6

Project : Proposed Project at Malanpur MPIDC Industrial Area, Gwalior																														
SOIL PROFILE		B.H. Location :		Water Table : N.E.		Term. Depth : 3.5m		B.H. No.: 5																						
		Soil Description	Grain Size Analysis				Atterberg		In-situ		Triaxial Test																			
Depth (m)	N - Value		17	0.9	1.5	2.4	3.0	3.5	Refusal/ rock strata (Brownish yellow Sandstone)	32	5cm	20	25	17	2.08	12.1	CD	0.13	28											
																				Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Liquid (%)	Plastic (%)	Density (g/cm ³)	Water Cont (%)	Type	c (kg/cm ²)	φ (°)

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ROCK PROFILE	Project : Proposed Project at Malanpur MPIDC Industrial Area, Gwalior		Location :	
	B.H. Size : Nx		Term. Depth (m) : 10m	B.H. No. : 6
	Strata Description		Run Time (min)	80
			RQD (%)	0
			Core Recovery (%)	17
				100
				80
	60			
	No. of Core Pieces of Size (cm)		40	
	<10		20	
Depth (m)		8.5	10.0	
Remarks		Highly weathered rock		
Point Load Strength (kg/cm ²)		325		
Unconfined Compressive Strength (kg/cm ²)				
Water Absorption (%)		2.7		
Porosity (%)		3.7		
Unit Weight (g/cm ³)		2.42		



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 Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
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Job No. : G(D)4550
 Sheet No. : 9

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Job No. G(D)4550

Sheet No. : 10

Project : Proposed Project at Malanpur MPIDC Industrial Area, Gwalior									
SOIL PROFILE		B.H. Location :		Water Table : N.E.		Term. Depth : 4.2m		B.H. No.: 8	
		Soil Description		Grain Size Analysis		Atterberg		In-situ	
Clay (%)				Liquid (%)		Water Cont (%)		c (kg/cm ²)	
Silt (%)						Density (g/cm ³)			
Sand (%)									
Gravel (%)								φ (°)	
Depth (m)		0.0	0.9	1.2					
N - Value		32 ----- 4cm							
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		Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in							
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		Sheet No. : 11							

ROCK PROFILE		Project : Proposed Project at Malanpur MPIDC Industrial Area, Gwalior		Location :		
		B.H. Size : Nx		B.H. No. : 8		
		Strata Description		Remarks		
Depth (m)						
1.2	- Yellowish/ Sandstone	whitish/ pinkish grey			Highly weathered rock	
2.7	- Yellowish/ Sandstone	whitish/ pinkish grey			Moderately to more or less sound rock	
4.2	-					
Core Recovery (%) 100 80 60 40 20 31 87			Run Time (min)		4590	
			RQD (%)		774	
			Core Recovery (%)		3187	
			No. of Core Pieces of Size (cm)		>7525-7510-25<10	
			No. of Core Pieces of Size (cm)		0163	
			No. of Core Pieces of Size (cm)		12	
			No. of Core Pieces of Size (cm)		1	
			No. of Core Pieces of Size (cm)		6	
			No. of Core Pieces of Size (cm)		3	
			No. of Core Pieces of Size (cm)		12	
Unconfined Compressive Strength (kg/cm²)			601			
Water Absorption (%)			3.9			
Porosity (%)			4.8			
Unit Weight (g/cm³)			2.44			
Point Load Strength (kg/cm²)						



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Delhi : 011 (T) 26891980 (F) 26897403 delhi@nagadi.co.in

Bangalore : 080 (T) 23156076 (F) 23303007 bangalore@nagadi.co.in

Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in

Secunderabad : 040 (T) 27754446 (F) 27751194 secunderabad@nagadi.co.in

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Sheet No. : 12



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GEOTECHNICAL CONSULTANTS

Delhi : 011 (T) 26891980 (F) 26897403 delhi@nagadi.co.in
 Bangalore : 080 (T) 23156076 (F) 23303007 bangalore@nagadi.co.in
 Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in
 Secunderabad : 040 (T) 27754446 (F) 27751194 secunderabad@nagadi.co.in

Job No. : 4550
G(D)

Sheet No. : 12

SOIL PROFILE		Project : Proposed Project at Malanpur MPIDC Industrial Area, Gwalior									
		B.H. Location :		Water Table : N.E.		Term. Depth : 3.3m		B.H. No.: 9			
Depth (m)		Soil Description		Grain Size Analysis		Atterberg		In-situ		Triaxial Test	
						Liquid (%)		Density (g/cm ³)		c (kg/cm ²)	
Clay (%)		Plastic (%)				Water Cont (%)		Type			
Silt (%)		Liquid (%)				Density (g/cm ³)		c (kg/cm ²)			
Sand (%)		Gravel (%)		Clay (%)		Plastic (%)		Water Cont (%)		Type	
N - Value		31 3cm		Yellowish brown clayey sandy silt		Refusal/ rock strata (Brownish grey Sandstone)		Density (g/cm ³)		c (kg/cm ²)	

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ROCK PROFILE		Project : Proposed Project at Malanpur MPIDC Industrial Area, Gwalior		Location :							
B.H. Size : Nx		Water Table (m): N.E.		Term. Depth (m): 3.3m	B.H. No. : 9						
Strata Description	No. of Core Pieces of Size (cm)	Core Recovery (%)		Run Time (min)	Remarks						
		RQD (%)		Highly weathered rock							
		Core Recovery (%)				392					
		Core Recovery (%)					1.9				
	Core Recovery (%)		2.6								
	Core Recovery (%)							2.51			
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Project : Proposed Project at Malanpur MPIDC Industrial Area, Gwalior															
SOIL PROFILE		B.H. Location :		Water Table : N.E.				Term. Depth : 6.5m		B.H. No.: 10					
		Depth (m)	N - Value	Soil Description	Grain Size Analysis				Atterberg		In-situ		Triaxial Test		
						Clay (%)	Silt (%)	Sand (%)	Gravel (%)	Liquid (%)	Plastic (%)	Density (g/cm ³)	Water Cont (%)	Type	c (kg/cm ²)
		0.0													
		0.9									2.03	10.4			
		1.5	31	Greyish brown clayey sandy silt with gravel	16	49	25	10	31	20					
		2.4									2.02	11.6	CD	0.13	27
		3.0	22	Greyish brown clayey sandy silt with gravel			36	2	29	20					
		3.5	34 ----- 3cm	Refusal/ rock strata (Yellowish/ pinkish grey Sandstone)											



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Delhi : 011 (T) 26891980 (F) 26897403 delhi@nagadi.co.in

Bangalore : 080 (T) 23156076 (F) 23303007 bangalore@nagadi.co.in

Chennai : 044 (T) 24487870 (F) 24488957 chennai@nagadi.co.in

Secunderabad : 040 (T) 27754446 (F) 27751194 secunderabad@nagadi.co.in

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NAGADI CONSULTANTS PRIVATE LIMITED
GEOTECHNICAL CONSULTANTS

Delhi : 011 (T) 26891980 (F) 26897403 delhi@nagadi.co.in
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Job No. G(D)4550

Sheet No. : 15

[illegible]

Project : Proposed Project at Malanpur MPIDC Industrial Area, Gwalior													
SOIL PROFILE		B.H. Location :		Water Table : N.E.		Term. Depth : 2.5m		B.H. No.: 11					
		Soil Description		Grain Size Analysis				Atterberg		In-situ		Triaxial Test	
Depth (m)				0.0	0.9	1.5	2.5	Brownish grey clayey sandy silt with gravel		Refusal/ rock strata (Brownish grey Sandstone)			
N - Value				28		27		3cm					



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Sheet No. : 17

SOIL PROFILE Project : Proposed Project at Malanpur MPIDC Industrial Area, Gwalior B.H. Location : Water Table : N.E. Term. Depth : 4m B.H. No.: 12		Soil Description Depth (m) N - Value		Grain Size Analysis Clay (%) Silt (%) Sand (%) Gravel (%)				Atterberg Plastic (%) Liquid (%)		In-situ Water Cont (%) Density (g/cm³)		Triaxial Test ϕ (°) c (kg/cm²) Type	
		Yellowish brown clayey sandy silt with gravel Refusal/ rock strata (Brownish grey Sandstone)		0.0 1.0				35 5cm					



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Sheet No. : 18

ROCK PROFILE		Project : Proposed Project at Malanpur MPIDC Industrial Area, Gwalior			Location :	
		B.H. Size : Nx		Water Table (m): N.E.	Term. Depth (m): 4m	B.H. No. : 12
Strata Description	Depth (m)	No. of Core Pieces of Size (cm)	Core Recovery (%)	Run Time (min)	Remarks	
				RQD (%)		
				100		
				80		
				60		
				40		
				20		
				>75		
				25-75		
				10-25		
<10						
Whitish/ yellow/ Sandstone	1.0	10	1	0	Highly weathered to moderately weathered rock	
Whitish/ yellow/ Sandstone	2.5	10	1	0		
	4.0	12	1	0		

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Sheet No. : 19	
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ROCK PROFILE						Project : Proposed Project at Malanpur MPIDC Industrial Area, Gwalior		Location :	
		B.H. Size : Nx		Water Table (m): N.E.		Term. Depth (m): 4.5m		B.H. No. : 15	
Strata Description		No. of Core Pieces of Size (cm)		Core Recovery (%)		Run Time (min)		Point Load Strength (kg/cm ²)	
Depth (m)		<10		20		RQD (%)		Unconfined Compressive Strength (kg/cm ²)	
0.0		24		56		90		479	
1.5		22		89		105		2.8	
3.0		8		83		100		3.9	
4.5		0		0		0		2.51	
		grey						Moderately weathered rock	
		brownish							
		reddish							
		Whitish/ Sandstone							
		grey							
		brownish							
		reddish							
		Whitish/ Sandstone							
		grey							
		brownish							
		reddish							
		Whitish/ Sandstone							



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Sheet No. : 22

SOIL PROFILE Project : Proposed Project at Malanpur MPIDC Industrial Area, Gwalior B.H. Location : Water Table : N.E. Term. Depth : 3.3m B.H. No.: 16		Soil Description Depth (m) N - Value		Grain Size Analysis Clay (%) Silt (%) Sand (%) Gravel (%)				Atterberg Plastic (%) Liquid (%)		In-situ Water Cont (%) Density (g/cm³)		Triaxial Test φ (°) c (kg/cm²) Type	
		Yellowish brown clayey sandy silt with gravel Refusal/ rock strata (Brownish grey Sandstone)		0.0 0.3		34 3cm							



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Sheet No. : 23

ROCK PROFILE		Project : Proposed Project at Malanpur MPIDC Industrial Area, Gwalior		Location :	
B.H. Size : Nx		Water Table (m): N.E.		Term. Depth (m): 3.3m	
B.H. No. : 16		Point Load Strength (kg/cm ²)		Remarks	
Strata Description		Unconfined Compressive Strength (kg/cm ²)		Highly weathered rock	
Depth (m)		Water Absorption (%)		575	
0.3		Porosity (%)		2.8	
1.5		Unit Weight (g/cm ³)		3.9	
3.3		Run Time (min)		3.42	
		RQD (%)		75	
		Core Recovery (%)		0	
		100		0	
		80		28	
		60		32	
		40			
		20			
		>75			
		25-75		0	
		10-25		0	
		<10		12	
		Whitish/ yellowish/ pinkish grey Sandstone		14	
		Whitish/ yellowish/ pinkish grey Sandstone		0	
				0	



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Sheet No. : 24

ROCK PROFILE		Project : Proposed Project at Malanpur MPIDC Industrial Area, Gwalior				Location :									
		B.H. Size : Nx		Water Table (m): N.E.		Term. Depth (m): 4.5m	B.H. No. : 17								
		Strata Description	No. of Core Pieces of Size (cm)		Core Recovery (%)	Run Time (min)	RQD (%)	Unit Weight (g/cm ³)	Porosity (%)	Water Absorption (%)	Unconfined Compressive Strength (kg/cm ²)	Point Load Strength (kg/cm ²)	Remarks		
>75															
25-75															
10-25															
<10															
Depth (m)	0.0	- Pinkish/ whitish/ brownish Sandstone	grey	16	3	0	0	80	90	27	2.47	3.8	2.7	639	Moderately weathered to more or less sound rock
1.5	- Pinkish/ whitish/ brownish Sandstone	grey	10	2	1	0	86	105	46						
3.0	- Pinkish/ whitish/ brownish Sandstone	grey	7	1	1	0	88	110	73						
4.5	-														



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 Bangalore : 080 (T) 23156076 (F) 23303007 bangalore@nagadi.co.in
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G(D)

Sheet No. : 25



Job No. G(D)4550

Sheet No. : 28

SOIL PROFILE			Project : Proposed Project at Malanpur MPIDC Industrial Area, Gwalior										
			B.H. Location :		Water Table : N.E.		Term. Depth : 5m		B.H. No.: 20				
N - Value	Depth (m)	Soil Description	Grain Size Analysis				Atterberg		In-situ		Triaxial Test		
			Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Liquid (%)	Plastic (%)	Density (g/cm³)	Water Cont (%)	Type	c (kg/cm²)	φ (°)
13 17 22 34 5cm	0.0	Brownish yellow clayey sandy silt with gravel	9	25	45	21	34	22	2.00	10.6	CD	0.14	27
	0.9												
	1.5												
	2.4												
	3.0	Brownish yellow clayey sandy silt with gravel	5	22	53	20	35	22	2.03	10.6			
	3.9												
	4.5	Brownish yellow clayey sandy silt with gravel	29	29	31	11	26	18					
5.0	Refusal/ rock strata (Br. grey Sandstone)												



GOOGLE IMAGE SHOWING THE BOREHOLE LOCATION



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Chennai	: 044 (T) 24487870 (F) 24488957	chennai@nagadi.co.in
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**PHOTOGRAPH SHOWING
VIEW OF THE SITE AND BOREHOLE UNDER PROGRESS**



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**PHOTOGRAPH SHOWING
VIEW OF THE SITE AND BOREHOLE UNDER PROGRESS**



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Sheet No. : 1c



**PHOTOGRAPH SHOWING VIEW OF THE OUTCROP
ROCK FRAGMENTS AT EXISTING GROUND LEVEL**



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**PHOTOGRAPH SHOWING VIEW ROCK CORE SAMPLES FOR
UNIAXIAL COMPRESSIVE STRENGTH TEST**

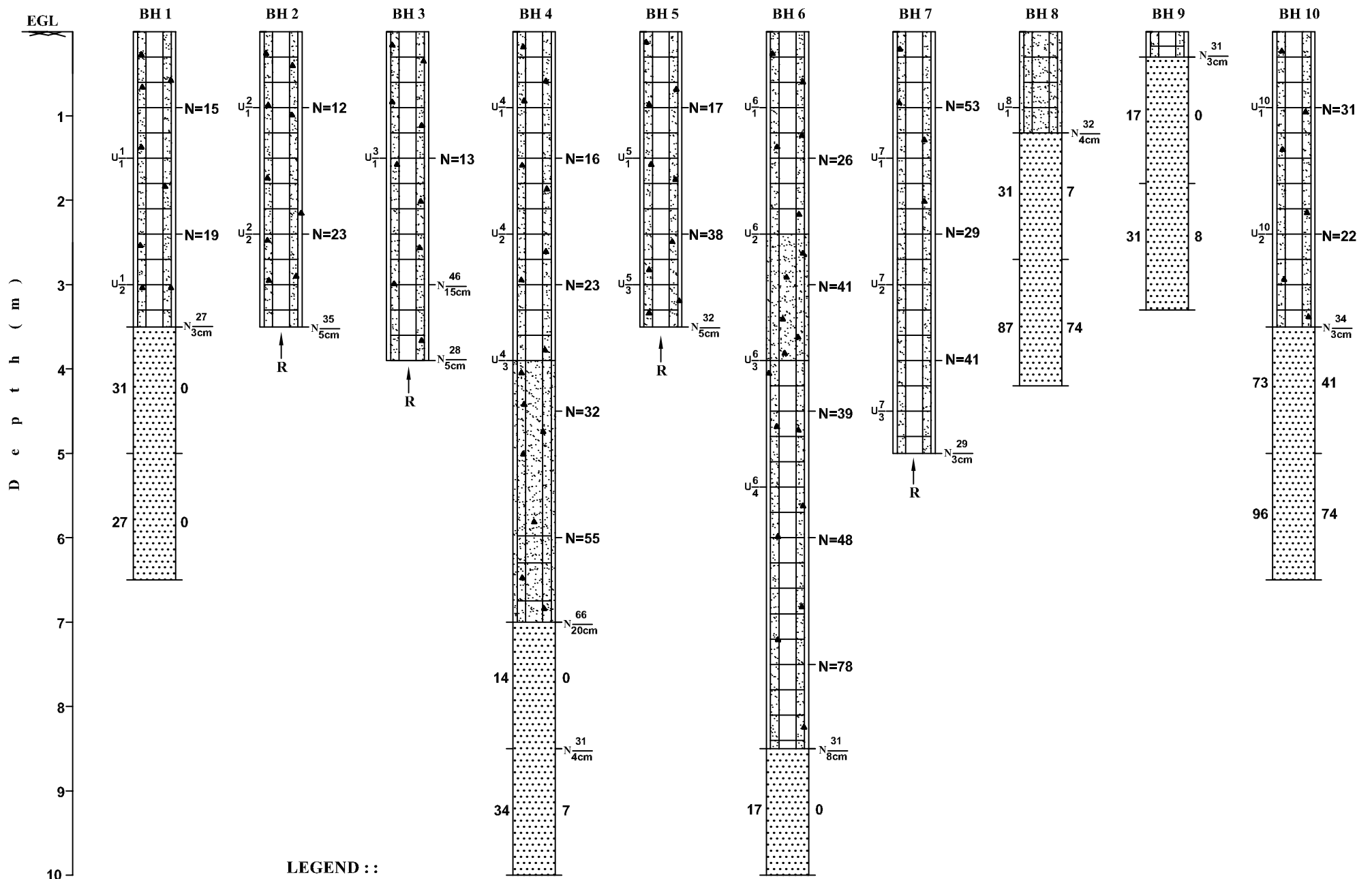


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LEGEND ::



Yellowish brown/ brownish grey clayey sandy silt with occasional gravel
(9-21)% (23-44)% (37-67)% (2-29)%



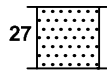
Yellowish brown/ brownish grey silty sand with occasional clay and gravel
(26-43)% (44-57)% (0-10)% (2-29)%



Brownish/ Whitish/ Pinkish grey Sandstone



R - Refusal / rock strata (Sandstone)



Core recovery(%)



RQD(%)



2nd undisturbed soil sample of BH 1



Observed 'N' Values



35 blows for 5cm. penetration

Ground Water table has been encountered as on May 2023.

COMPILED SOIL/ ROCK PROFILE



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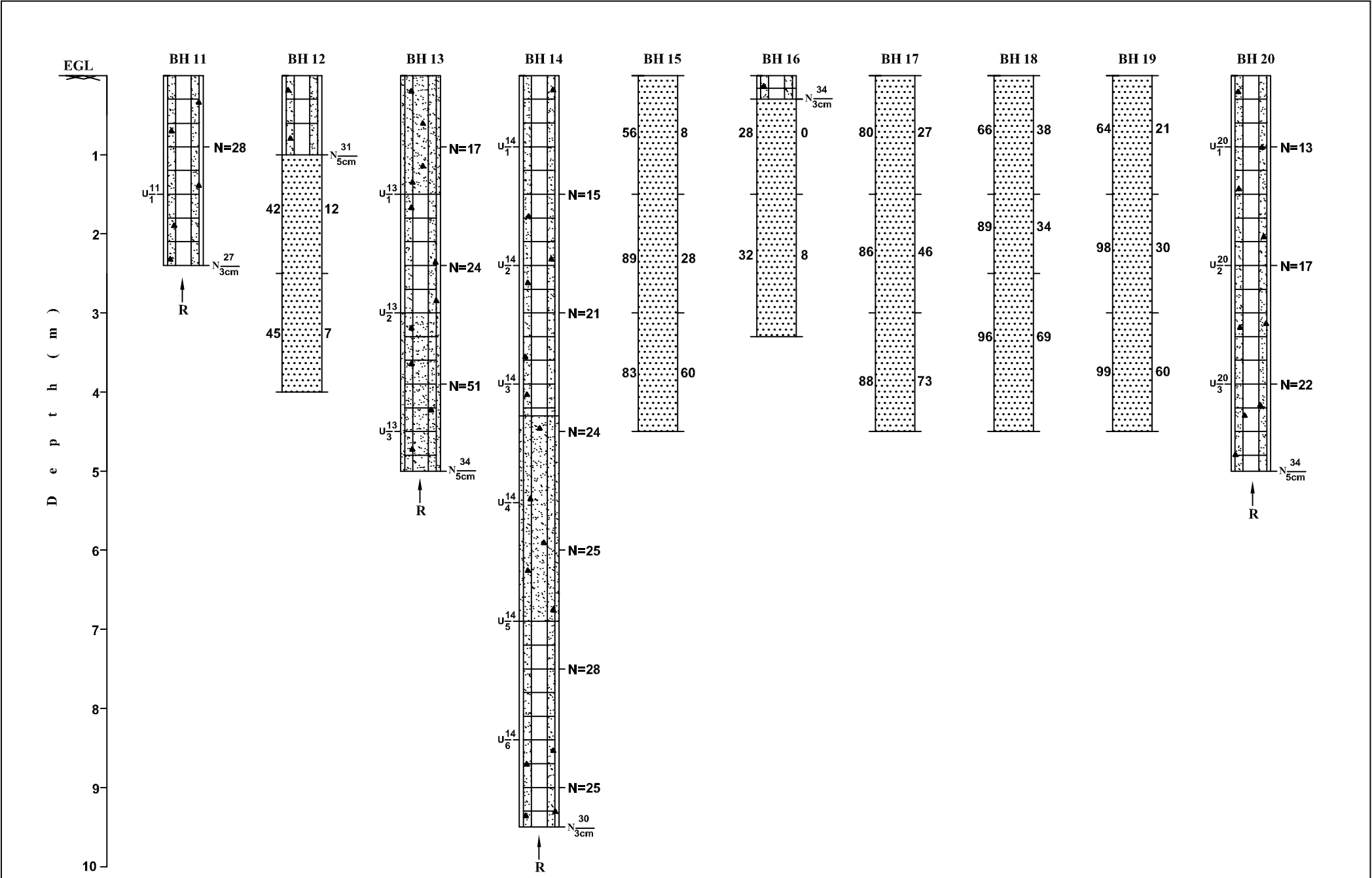
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Proposed Factory Complex at Malanpur
MPIDC Industrial Area, Gwalior, Madhya Pradesh

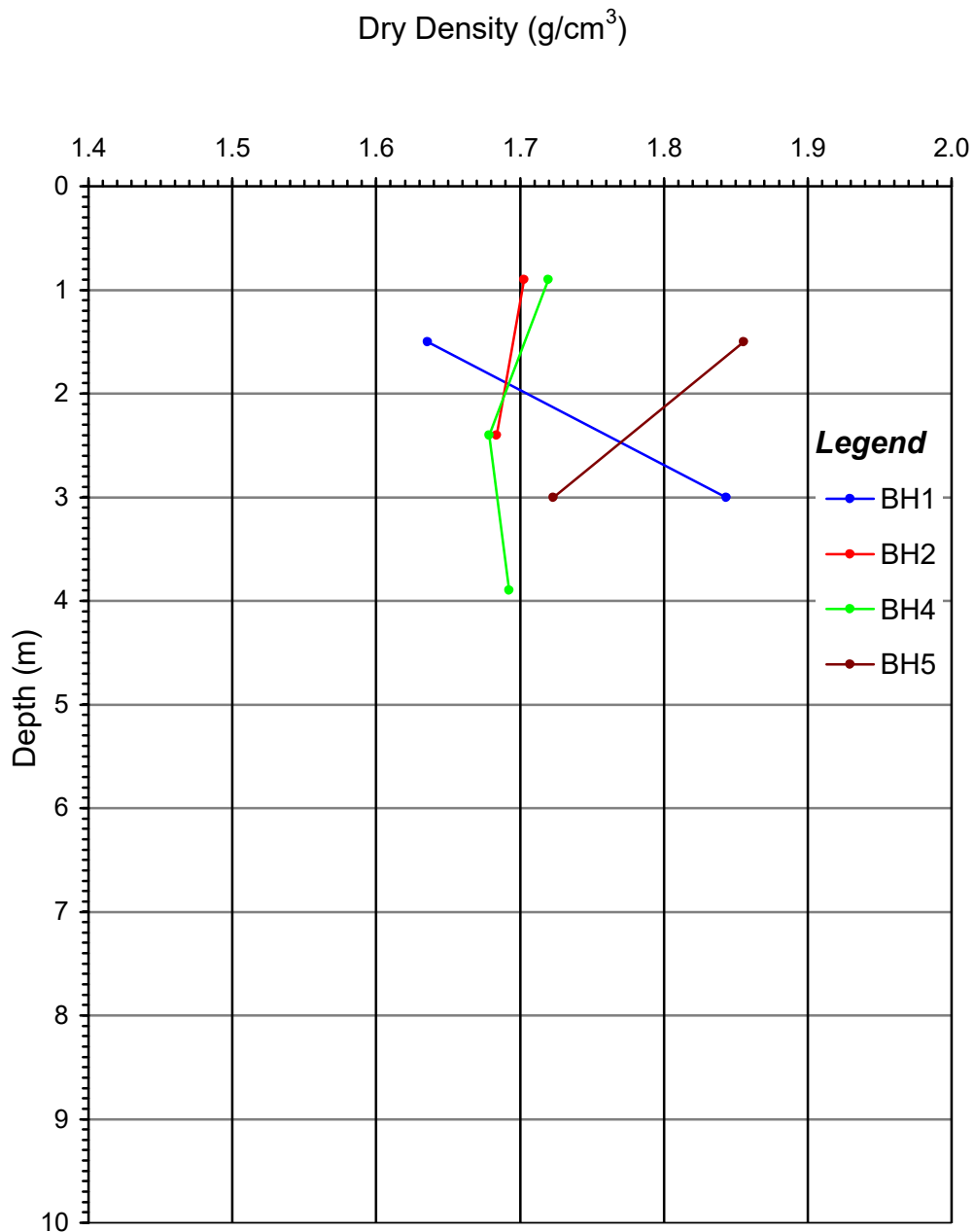
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Sheet No: 2a



For Legend Refer Sheet No. 2a

COMPILED SOIL/ ROCK PROFILE



Dry Density vs Depth Curves
(Refer paragraph no. 7.4.2)

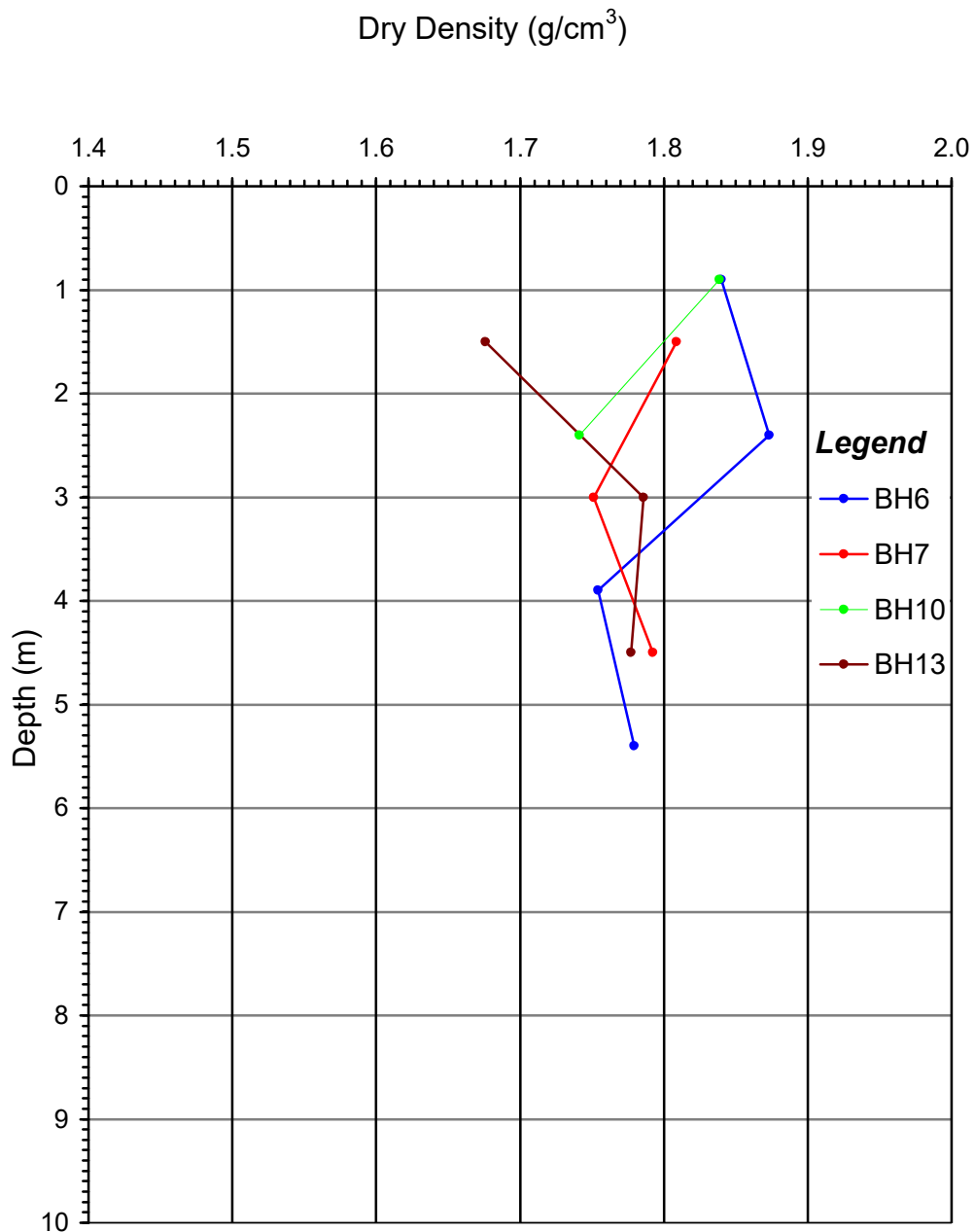


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Dry Density vs Depth Curves
(Refer paragraph no. 7.4.2)

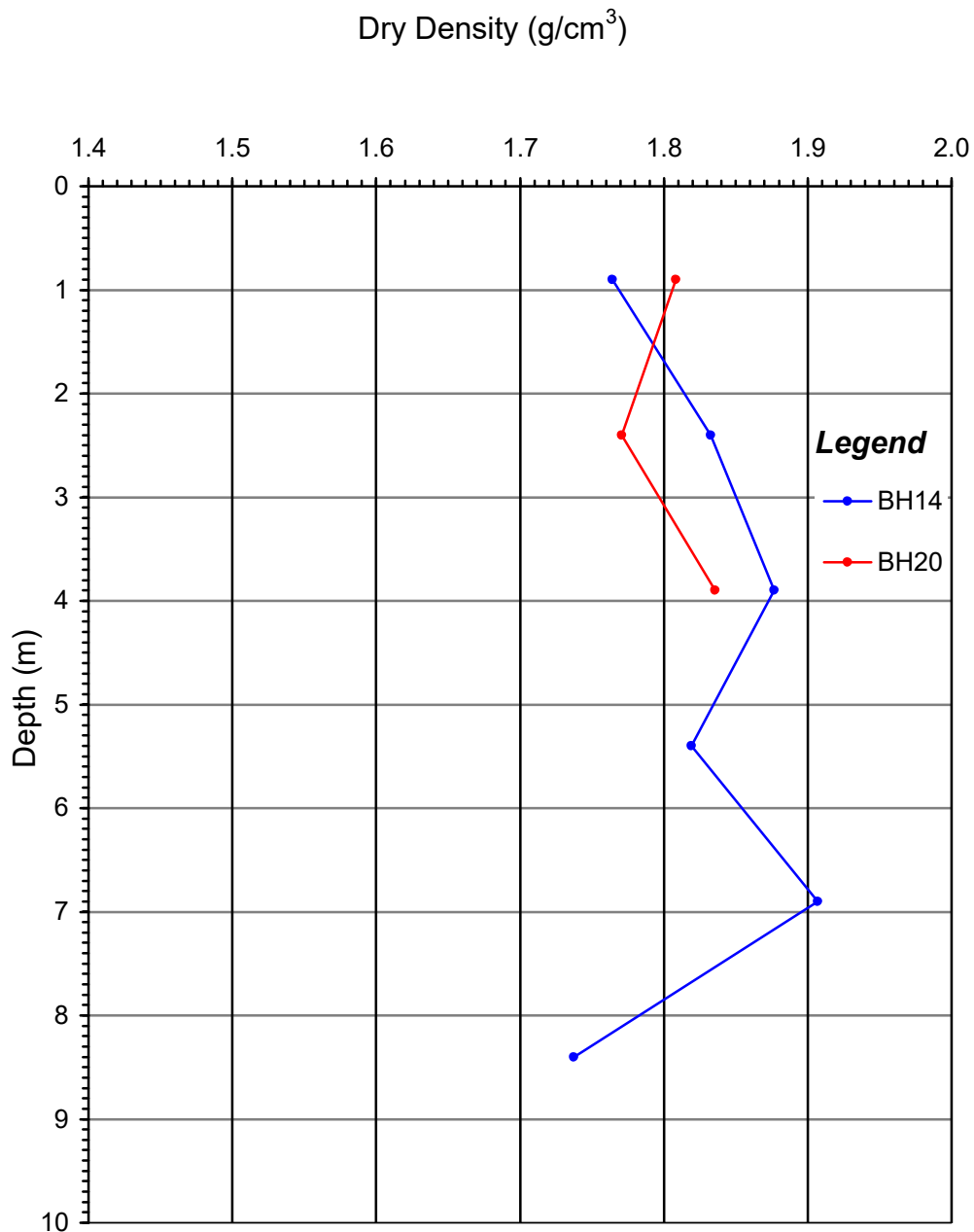


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Dry Density vs Depth Curves
(Refer paragraph no. 7.4.2)



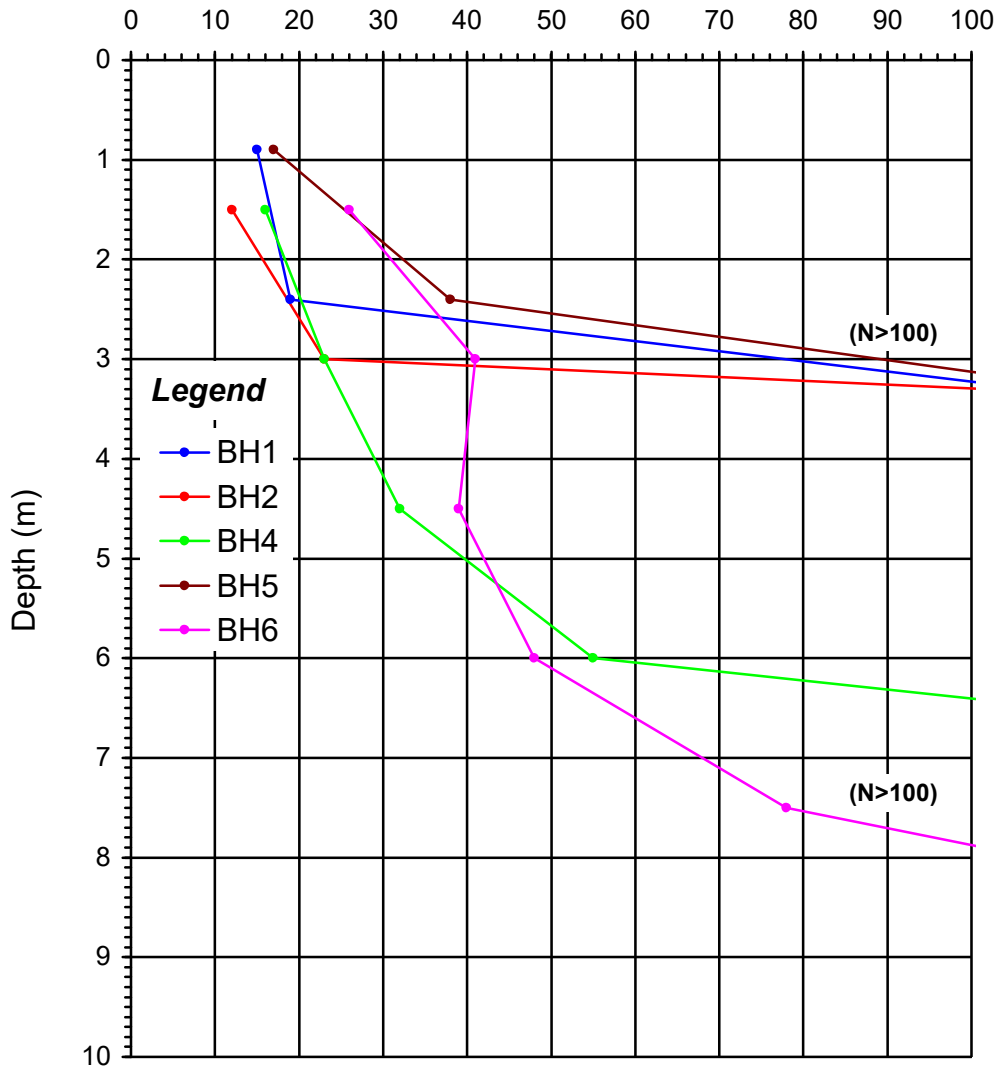
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N - Values (Observed)



N - Values vs Depth Curves

(Refer paragraph no. 7.6.1)



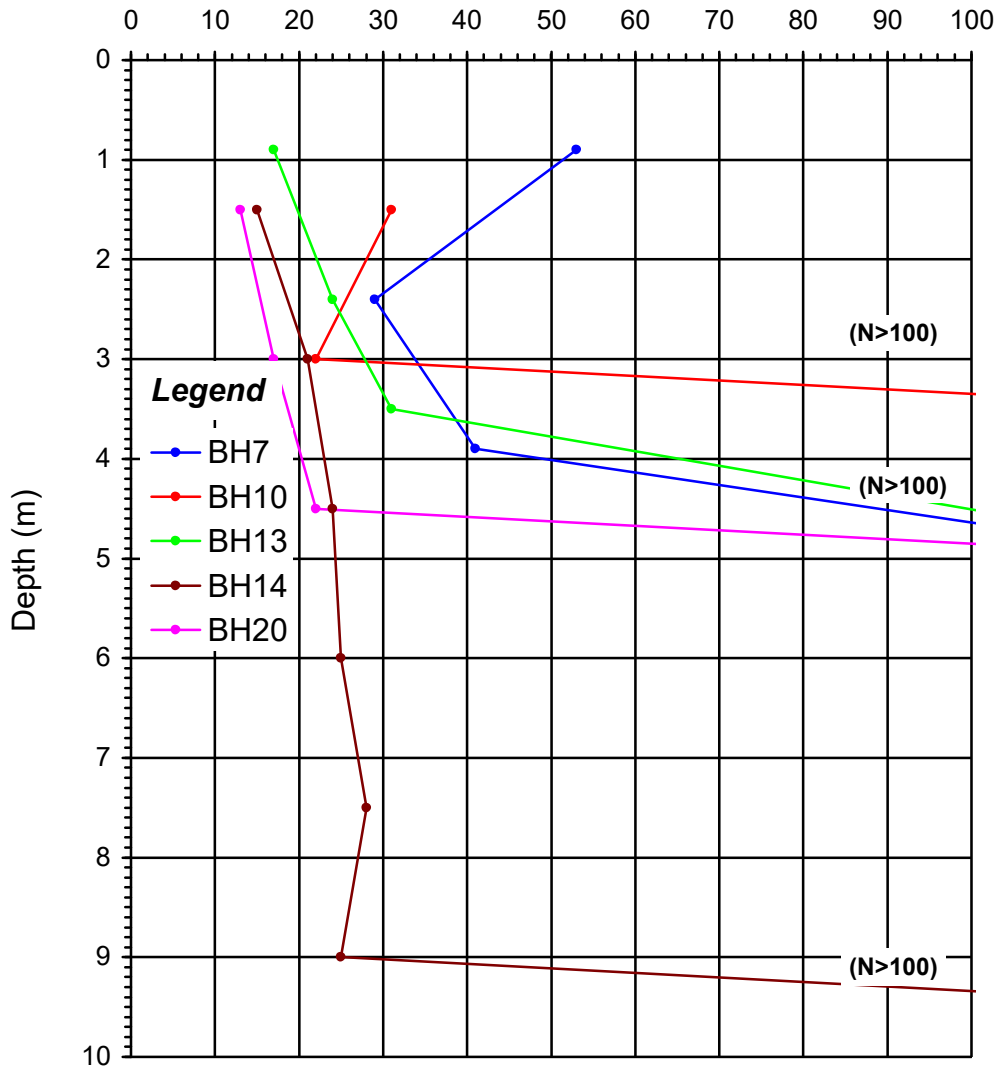
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Sheet No. : 4a

N - Values (Observed)



N - Values vs Depth Curves

(Refer paragraph no. 7.6.1)



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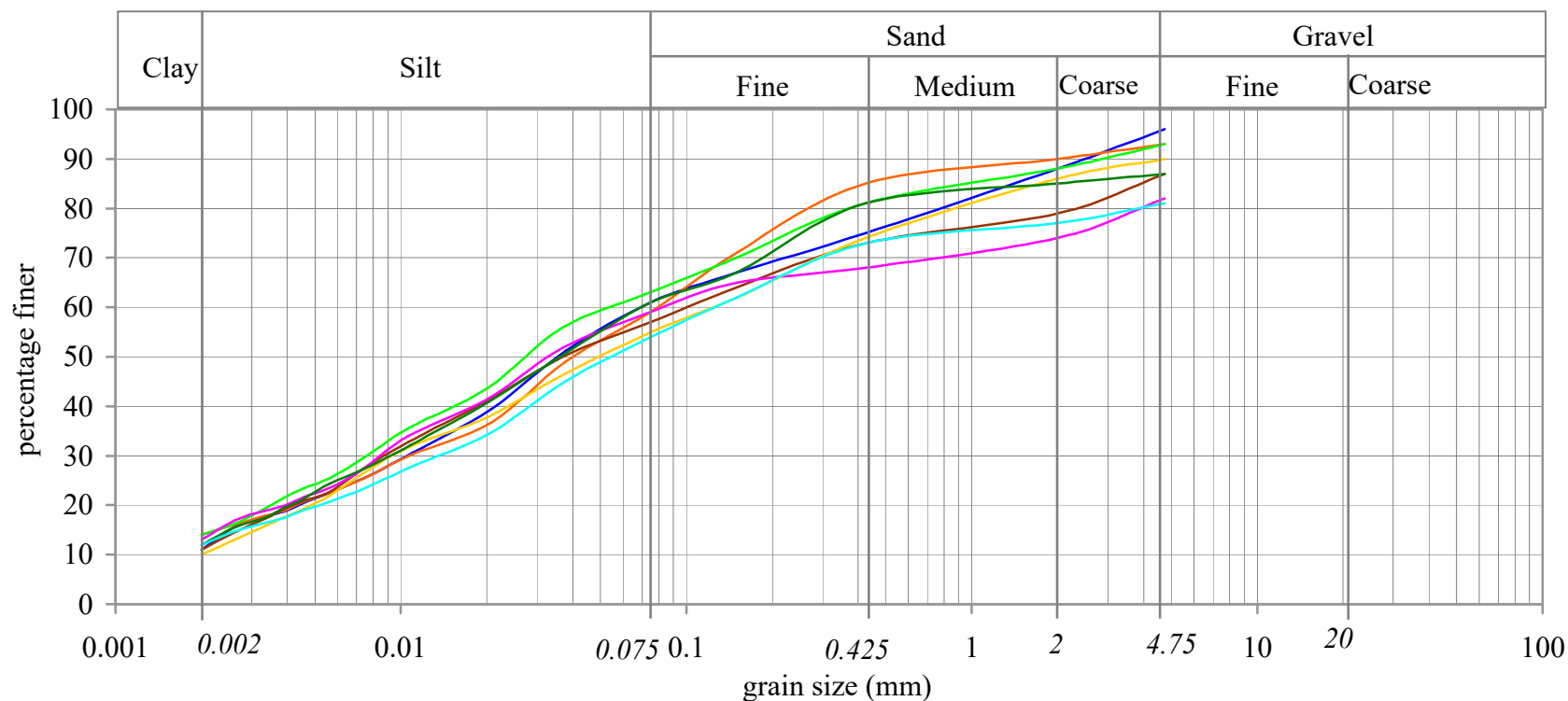
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Grain Size Analysis Curves (refer paragraph no. 7.3.1)



Line Style	Bore hole	Depth (m)	Description	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	d ₆₀	d ₁₀	C _u
—	1	0.9	Clayey sandy silt with gravel	4	35	50	11	0.068	-	-
—	1	2.4	Clayey sandy silt with gravel	7	34	45	14	0.075	-	-
—	2	1.5	Clayey sandy silt with gravel	7	30	49	14	0.055	-	-
—	2	3	Clayey sandy silt with gravel	13	30	46	11	0.095	-	-
—	3	0.9	Clayey sandy silt with gravel	18	23	46	13	0.081	-	-
—	3	2.4	Clayey sandy silt with gravel	10	35	45	10	0.12	0.002	60.0
—	4	1.5	Clayey sandy silt with gravel	13	26	49	12	0.069	-	-
—	4	3	Clayey sandy silt with gravel	19	27	42	12	0.12	-	-

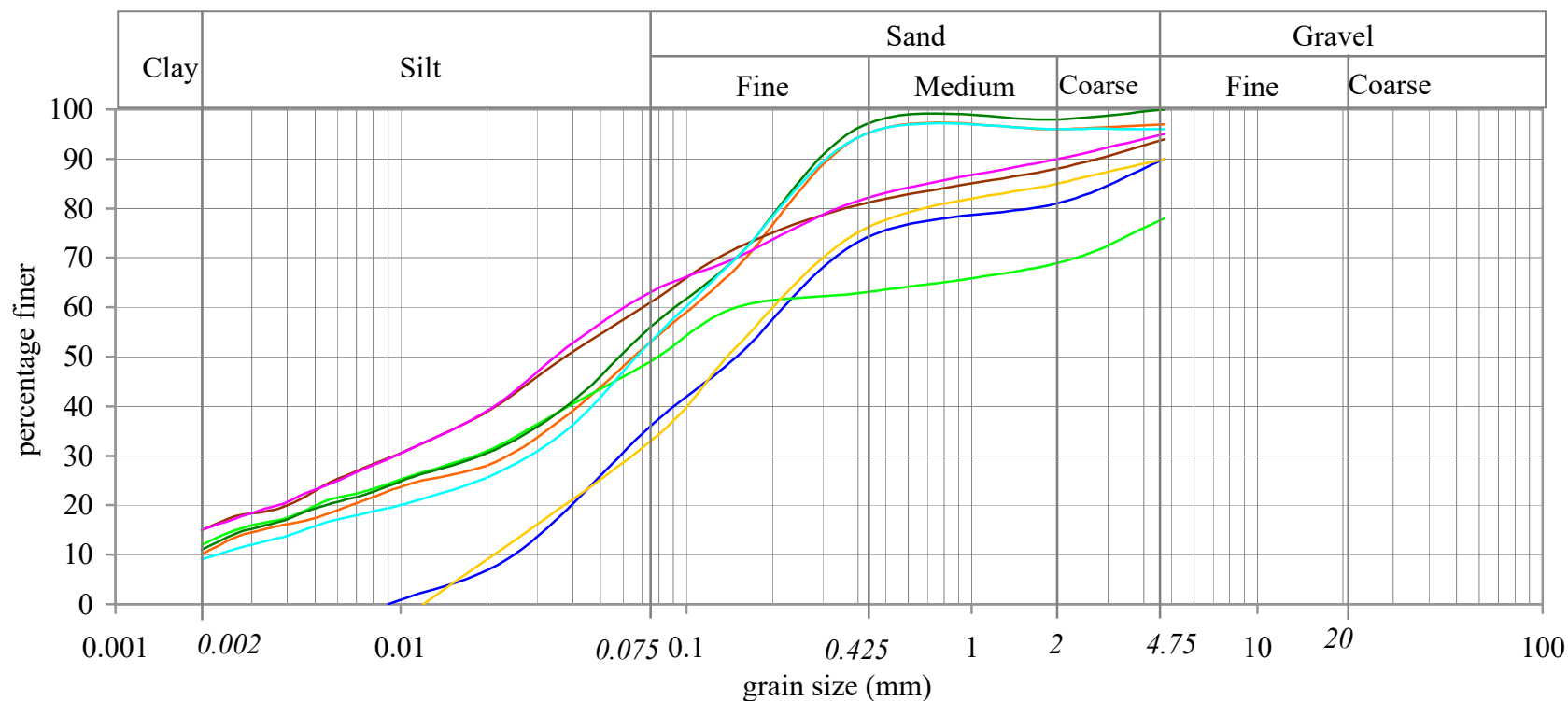


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Chennai : 044 (T) 24487870 (F) 24488957
Secunderabad : 040 (T) 27754446 (F) 27751194

delhi@nagadi.co.in
bangalore@nagadi.co.in
chennai@nagadi.co.in
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Grain Size Analysis Curves (refer paragraph no. 7.3.1)



Line Style	Bore hole	Depth (m)	Description	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	d ₆₀	d ₁₀	C _u
	4	4.5	Silty sand with gravel	10	54	36	0	0.21	0.023	9.1
	4	6	Clayey silty sand with gravel	3	44	43	10	0.11	0.002	55.0
	5	0.9	Clayey sandy silt with gravel	22	29	37	12	0.15	-	-
	5	2.4	Clayey sandy silt with gravel	6	33	46	15	0.07	-	-
	6	1.5	Clayey sandy silt with gravel	5	32	48	15	0.061	-	-
	6	3	Silty sand with gravel	10	57	33	0	0.19	0.021	9.0
	6	4.5	Clayey sandy silt	0	44	45	11	0.081	-	-
	6	6	Clayey sandy silt with gravel	4	43	44	9	0.1	0.0022	45.5

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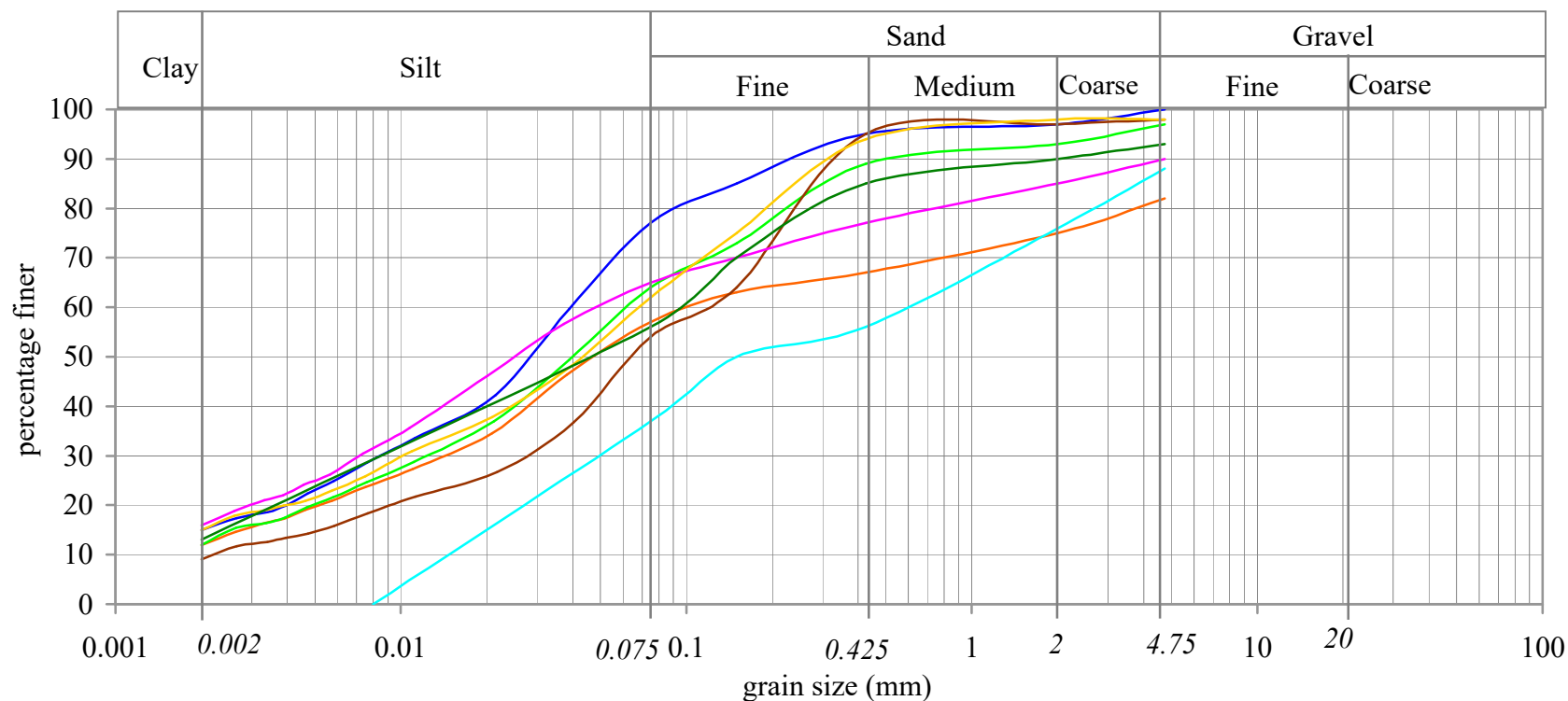


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Bangalore : 080 (T) 23156076 (F) 23303007
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delhi@nagadi.co.in
bangalore@nagadi.co.in
chennai@nagadi.co.in
secunderabad@nagadi.co.in

Grain Size Analysis Curves (refer paragraph no. 7.3.1)



Line Style	Bore hole	Depth (m)	Description	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	d ₆₀	d ₁₀	C _u
	6	7.5	Clayey sandy silt	0	23	62	15	0.039	-	-
	7	0.9	Clayey sandy silt with gravel	18	25	45	12	0.099	-	-
	7	2.4	Clayey sandy silt with gravel	3	33	52	12	0.061	-	-
	7	3.9	Clayey sandy silt with gravel	2	44	45	9	0.13	0.0022	59.1
	10	1.5	Clayey sandy silt with gravel	10	25	49	16	0.048	-	-
	10	3	Clayey sandy silt with gravel	2	36	47	15	0.067	-	-
	11	0.9	Clayey sandy silt with gravel	7	37	43	13	0.081	-	-
	13	0.9	Silty sand with gravel	12	51	37	0	0.9	0.015	60.0

Job No. : G(D)4550

Sheet No. : 5c



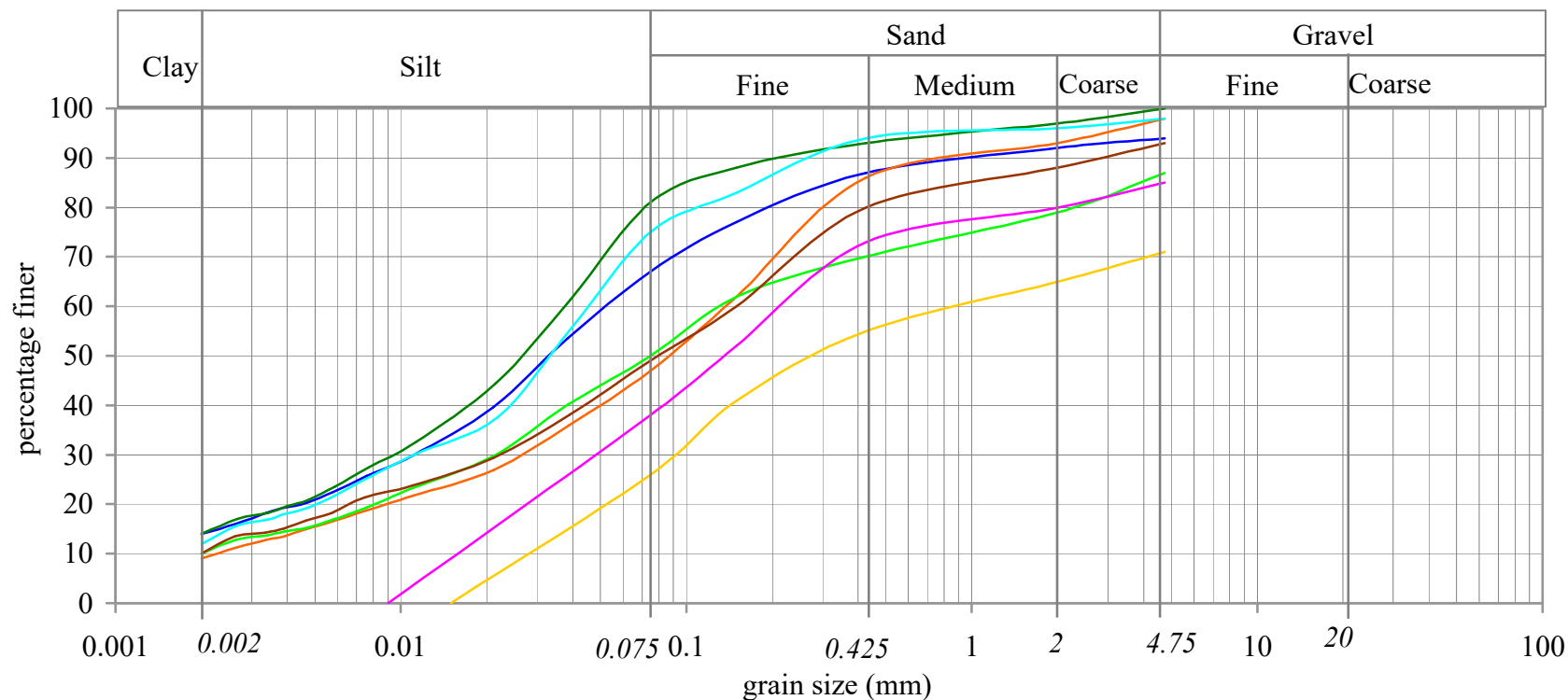
NAGADI CONSULTANTS PRIVATE LIMITED
GEOTECHNICAL CONSULTANTS

Delhi : 011 (T) 26891980 (F) 26897403
Bangalore : 080 (T) 23156076 (F) 23303007
Chennai : 044 (T) 24487870 (F) 24488957
Secunderabad : 040 (T) 27754446 (F) 27751194

delhi@nagadi.co.in
bangalore@nagadi.co.in
chennai@nagadi.co.in
secunderabad@nagadi.co.in

Job No. : G(D)4550
Sheet No. : 5d

Grain Size Analysis Curves (refer paragraph no. 7.3.1)



Line Style	Bore hole	Depth (m)	Description	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	d ₆₀	d ₁₀	C _u
	13	2.4	Clayey sandy silt with gravel	6	27	53	14	0.051	-	-
	13	3.9	Clayey silty sand with gravel	2	51	38	9	0.15	0.0022	68.2
	14	1.5	Clayey sandy silt with gravel	13	37	40	10	0.13	0.002	65.0
	14	3	Clayey silty sand with gravel	7	44	39	10	0.15	0.002	75.0
	14	4.5	Silty sand with gravel	15	47	38	0	0.21	0.017	12.4
	14	6	Silty sand with gravel	29	45	26	0	0.85	0.029	29.3
	14	7.5	Clayey sandy silt	0	19	67	14	0.039	0.002	19.5
	14	9	Clayey sandy silt with gravel	2	23	63	12	0.045	0.002	22.5

The figure is a semi-logarithmic plot of grain size distribution. The x-axis represents grain size in millimeters (mm) on a log scale from 0.001 to 100. The y-axis represents the percentage of soil finer than a given grain size, ranging from 0 to 100. The plot is divided into several regions based on soil classification: Clay (0.001 to 0.002 mm), Silt (0.002 to 0.075 mm), Sand (0.075 to 4.75 mm, subdivided into Fine, Medium, and Coarse), and Gravel (4.75 to 100 mm, subdivided into Fine and Coarse). Three curves are plotted: an orange curve (finest soil), a blue curve (medium soil), and a green curve (coarsest soil). The orange curve starts at approximately 20% finer at 0.002 mm and reaches about 95% finer at 4.75 mm. The blue curve starts at approximately 20% finer at 0.002 mm and reaches about 90% finer at 4.75 mm. The green curve starts at approximately 12% finer at 0.002 mm and reaches about 70% finer at 4.75 mm.

Grain Size (mm)	Orange Curve (%)	Blue Curve (%)	Green Curve (%)
0.002	20	20	12
0.0075	35	35	20
0.03	60	60	30
0.075	75	65	42
0.1	80	68	44
0.425	90	78	60
1	92	82	63
2	93	85	65
4.75	95	90	70

[illegible]