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**Proposed 120,000 KL Per Annum Paint Plant At
Plot No. A-1, A-2 At Gopalpur, U.P.S.I.C.
Industrial Area, Sikandrabad, District
Bulandshahr, Uttar Pradesh - 203205**

Client:

Shalimar Paints Limited,
A1 & A2, UPSIDC.
Industrial Area, 203205,
Bulandshahr, Uttar Pradesh

Website : nagadi.co.in

Job No. : **G(D) 4518**

Date : 16.01.23

**GEOTECHNICAL INVESTIGATION REPORT for the Proposed 120,000
KL Per Annum Paint Plant At Plot No. A-1, A-2 At Gopalpur, UPSIC
Industrial Area, Sikandrabad, District Bulandshahr, Uttar Pradesh - 203205**

EXECUTIVE SUMMARY

Shalimar Paints Ltd. are in the process of expansion of existing plant at Sikandrabad, District-Bulandshahr, Uttar Pradesh - 203205.

The proposed structures are Factory Buildings.

The Geotechnical investigation programme has been undertaken at the site, as per the scope of investigation, stipulated by the client. The scope of work consisted of conducting boreholes in soil strata down to 20m depth at six locations, conducting electrical resistivity test at two locations and excavation of trial pits down to 4m depth at two locations.

The results of the field investigations indicate that the subsoil strata consists of clayey sandy silt down to about 5m depth below the existing ground level beyond which the subsoil strata predominantly consists of sandy soils down to the depth of investigations.

The N-values (N-values 7 - 32) indicate that the subsoil is loose to medium dense down to about 9m depth below which the subsoil is medium dense (N-values 22 - 48) down to the depth investigated.

Ground water table had been encountered at a depth of about 4m below the existing ground level, during the period of field investigations, i.e December 2022.

The assessment of the susceptibility to liquefaction of the subsoil at site indicate that the subsoil between 4m and 9m depth is susceptible to liquefaction.

Considering the type of structures involved and the subsoil characteristics as determined from the geotechnical investigations, **Straight Bored Pile foundations** have been recommended.



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The following safe pile capacities have been recommended for various diameters and effective lengths of piles.

<i>Pile Dia (mm)</i>	<i>Pile Effective Length (m)</i>	<i>Pile Vertical Load Capacity (tons)</i>	<i>Uplift Capacity of pile (tons)</i>	<i>Safe Lateral Capacity (tons)</i>	
				<i>Free Head</i>	<i>Fixed Head</i>
600	15	40	15	0.1	0.4
	20	60	30		
800	15	70	30	0.3	0.8
	20	100	50		

Precautions :

For Straight Bored Piles, after reaching the required depth in the pile bores, 15cm thick layer of gravel should be placed and compacted at the bottom so that the slush formed at the bottom is diminished.



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1.0 INTRODUCTION

- 1.1 Shalimar Paints Limited, A1 & A2, UPSIDC Industrial Area, 203205, Bulandshahr, Uttar Pradesh are in the process of constructing 120,000 KL Per Annum Paint Plant within their existing plant at Plot No. A-1, A-2 at Gopalpur, U.P.S.I.C. Industrial Area, District Bulandshahr, Sikandrabad, Uttar Pradesh - 203205.
- 1.2 To design the substructures for the proposed structures, adequate information regarding the subsoil conditions is required. For this purpose, detailed geotechnical investigations have been undertaken at the site of the proposed structures.
- 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 The geotechnical investigation has been carried out as per the authorization of the authorised signatory of Shalimar Paints Limited vide their work order reference no. 4800002544 dated 28th December 2022. This authorization has been given in response to our offer no. NCD/Q/SPL/143/2022 dated 21st December 2022.

2.0 PROJECT DETAILS

2.1 Site Location

- 2.1.1 The site for the proposed project is located with in the premises of existing plant of Shalimar Paints at Plot No. A-1, A-2 at Gopalpur, UPSIC Industrial Area, District Bulandshahr, Sikandrabad, Uttar Pradesh - 203205 which itself is situated at a distance of about 0.7 km from Tel - Mill bus stop towards village Gopalpur, District Bulandshahr, Sikandrabad, Uttar Pradesh - 203205.



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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 0.5m had been observed at the site, during the period of field investigations. However, the general level of the site had been observed to be almost same as that of internal factory roads.

2.2.3 A few industrial structures had been observed to be existing at the site, during the period of field investigations which are apparently to be demolished for the new construction of proposed factory buildings.

2.2.4 A high tension (HT) electric line had been observed to be passing from South - East to North - West direction, almost over the middle portion of the site.

2.2.5 Vegetation in the form of grass and occasional trees 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 Yellowish brown.

2.3 **Seismic Zone**

2.3.1 The present site is located in the Seismic Zone - IV which is an area of high seismic activity and earthquake intensity, 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 is proposed to be of Reinforced Cement Concrete.



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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 profile indicating thickness of the various soil strata, to a depth within the influence zone below the foundations
- b) Engineering properties of the soil strata at various levels
- c) Physical characteristics of the soil strata
- d) Variation of strength of soil strata with depth

3.3 For evaluating the above parameters, field investigations and laboratory investigations on the soil 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 strata down to 20m depth at six locations.
- b) Conducting electrical resistivity tests at two locations.
- c) Excavating Trial Pits at two locations.
- d) Conducting relevant laboratory tests on soil samples recovered.



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- e) 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 1.5/3m intervals.
b) Recovering undisturbed soil samples from various levels of the subsoil strata.
c) 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 29th December 2022 and 3rd January 2023.

5.1.2 A schematic site plan showing the test locations are given in fig. 1a of the report.

5.1.3 Photographs showing view of the site and work under progress are given in fig. 1b to 1d of this report.

5.2 Boreholes

5.2.1 All the boreholes were progressed by shell and auger method. Casing pipe were used to stabilize the sides of the boreholes below water table level.

5.2.2 Boreholes BH1 to BH6 had been conducted down to the stipulated depth of 20m below the existing ground level.

5.2.3 The diameter of the boreholes was 150/100mm.

5.2.4 Standard penetration tests were conducted at 1.5/3m intervals. Disturbed soil samples recovered from split spoon samplers were retained for identification purposes.



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- 5.2.5 Undisturbed soil samples were recovered by thin walled tubes conforming to IS : 2132. These tubes had an area ratio of less than 10%.
- 5.2.6 The ends of sample tubes were sealed by wax to prevent loss/ ingress of moisture. Disturbed soil samples were enclosed in polythene bags.
- 5.2.7 The samples thus recovered were transported to the laboratory for testing purposes.
- 5.2.8 Ground water table had been encountered in all the boreholes at a depth varying between 4m and 4.3m below the existing ground level, during the period of field investigations i.e December 2022 - January 2023.
- 5.3 Electrical Resistivity Test**
- 5.3.1 Electrical resistivity tests (ERT1 and ERT2) had been carried out at two locations. These tests have been conducted using Wenner's four electrode method as per IS : 3043.
- 5.3.2 In this test, four electrodes had been driven into the ground surface along a straight line at equal intervals. The tests involves the passing of a current through the outer two electrodes called the current electrodes and the measurement of the voltage difference between the two inner electrodes called the potential electrodes. The ratio of the voltage difference measured to the current passed gives the resistance. An soil megger had been used to determine the resistance directly, at the site. The resistance had been so determined for various electrode spacings.
- 5.3.3 In the present case, the depth of electrodes had been maintained at 15cms. The spacings of electrodes adopted had been 1,2,3,4,5,6,7,8,9 and 10m. However, in present case due to space constraint, the spacing of electrodes had to be restricted maximum between 2m and 5m distance in all the eight directions except for few directions wherein the spacing of the electrodes had reached to maximum 10m spacing.



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5.3.4 The above procedure had been repeated for eight different directions at selected location, as per the standard procedure.

5.3.5 The electrical resistivity of the soil which is a function of the resistance determined is calculated for each electrode spacing used. A plot of soil resistivity vs distance is then prepared which invariably indicates an average constant value of the soil resistivity at larger electrode spacings. This average constant value of the soil resistivity is taken as the resistivity for that direction.

5.3.6 The electrical resistivity of the soil depends on the density, water content, grain size distribution etc. of the soil.

5.4 Trial Pits

5.4.1 Two Trial Pits viz TP1 & TP2 of 2m × 2m size had been excavated down to 4m depth below the existing ground level at two different locations.

6.0 LABORATORY INVESTIGATIONS

6.1 Tests on Soil Samples from Boreholes

6.2 The soil samples brought to the laboratory were subjected to various tests to determine the following properties :

- a) Type of soil and its gradation
- b) Consistency limits
- c) Natural Bulk Density & Water Content
- d) Strength parameters like cohesion, angle of shearing resistance

6.3 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) Atterberg Limits namely Liquid and Plastic Limits



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- d) Natural Density and Water Content
- e) Triaxial compression tests

6.4 Chemical Analysis

6.4.1 The chemical analysis has been conducted only on water and soil samples collected from the boreholes 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 boreholes investigations have been presented in the form of soil 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

7.2 Soil Profile

7.2.1 A perusal of the data presented in the soil profile tables indicates that the subsoil mainly consists of the following three strata in the six boreholes:

- a) Stratum - I : Clayey sandy silt with occasional gravel / sandy clayey silt
- b) Stratum - II : Silty sand with occasional clay and gravel
- c) Stratum - III : Sand with traces of silt and occasional gravel/ sand with silt



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7.2.2 The thickness of the three strata in the six boreholes are as follows :

BH. No.	Strata (depth in m : from : to)		
	Stratum - I	Stratum - II	Stratum - III
1	0 - 6.5 16.5 - 19.7	6.5 - 9.7	9.7 - 16.5 19.7 - 20
2	0 - 5.7	N.E.	5.7 - 20
3	0 - 5.2	N.E.	5.2 - 20
4	0 - 6.9	N.E.	6.9 - 20
5	0 - 6.7	6.7 - 8.2	8.2 - 20
6	0 - 3.9	N.E.	3.9 - 20

N.E. : not encountered

7.2.3 The above results show that :

- a) Stratum - I consisting of predominantly of silty soils with varying percentages of clay and sand has been encountered down to about 6.9m depth below the existing ground level. Additionally, this stratum has also been encountered between 16.5m and 19.7m depth, only in borehole BH1.
- b) Stratum - II consisting predominantly of sandy soils with significant percentages of silt, has been encountered between 6.5m and 9.7m depths, only in boreholes BH1 and BH5.
- c) Stratum - III consisting predominantly of sandy soils, is predominant beyond a depth of about 5.5m down to the depth investigated except for occasional thin layers of Stratum - I between 16.5m and 19.7m depths, only in borehole BH1.

7.3 Soil Composition

7.3.1 The grain size distributions of the soil samples in the six boreholes have been presented in the form of grain size analysis curves in figs. 7a to 7j.



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7.3.2 The variations in the grain size distributions in each of the three strata in the six boreholes are as follows:

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

BH. No.	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
1	0 - 32	12 - 52	41 - 75	2 - 20
2	0 - 2	15 - 23	57 - 75	2 - 26
3	0	16 - 49	49 - 69	2 - 24
4	0 - 42	13 - 48	30 - 75	2 - 10
5	0 - 11	11 - 36	56 - 70	2 - 25
6	6 - 9	16 - 17	57 - 68	9 - 18

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

BH. No.	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
1	0	71 - 76	24 - 29	0
5	0	70	30	0

This stratum has been encountered only in these two boreholes.

c) Stratum - III : Sand with traces of silt and occasional gravel/ sand with silt

BH. No.	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
1	0 - 2	80 - 96	4 - 20	0
2	0 - 4	89 - 98	2 - 7	0
3	0 - 2	86 - 97	2 - 12	0
4	0	80 - 98	2 - 20	0
5	0	83 - 98	2 - 17	0
6	0 - 3	89 - 98	2 - 11	0



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7.3.3 The above results indicate that :

- a) Stratum - I consists of about 30% to 75% of silt, 11% to 52% of sand with rest of the matrix consisting of clay and occasional gravel.
- b) Stratum - II consists of about 70% to 76% of sand and 24% to 30% of silt.
- c) Stratum - III consists of an average of about 89% of sand and 11% of silt with occasional gravel.

7.4 Natural Density and Water Content

7.4.1 The natural bulk densities, water contents and dry densities of soil samples collected at various depths in six boreholes vary as follows :

BH. No.	Bulk Density (g/cm ³)	Water Content (%)	Dry Density (g/cm ³)
1	1.93 - 2.02	10.7 - 25.9	1.63 - 1.74
2	1.93 - 2.05	13.6 - 24.1	1.64 - 1.70
3	1.98 - 2.06	16.2 - 23.9	1.65 - 1.70
4	1.99 - 2.08	19.1 - 24.1	1.64 - 1.70
5	1.97 - 2.09	13.4 - 23.8	1.61 - 1.81
6	1.96 - 2.03	16.9 - 26.7	1.57 - 1.68

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

7.4.3 As undisturbed soil samples could not be obtained in sandy soil stratum below the water table level, the results for the densities and water contents of the subsoil of these depths are not available.



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7.5 Atterberg Limits

7.5.1 The Atterberg limits indicate that the subsoil is generally low plastic down to about 6m depth below the existing ground level except occasional thin layers of medium plastic soils at shallow depths. Subsoil beyond a depth of about 6m is predominantly non - plastic down to the depth investigated. Additionally, low - plastic soils have also been encountered between 16.5m and 19.7m depths, only in borehole BH1. The variation in the Atterberg limits in the Stratum - I are as follows:

- a) Liquid limit (LL) % : 25 - 38
- b) Plastic limit (PL) % : 15 - 23

7.6 Standard Penetration Test Values (N-values)

7.6.1 The observed Standard Penetration Test values (N-values) vary between 7 and 48 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 depths.

7.6.2 The above results indicate that the subsoil is in a loose to medium dense state down to about 9m depth below which the subsoils is in a medium dense state down to the depth investigated.

7.7 Triaxial Test Results

7.7.1 The results of triaxial tests are indicated in the respective soil profile tables. These results have been considered in providing the recommendations. The results of the triaxial tests in the form of shear strength parameters i.e. angle of internal resistance (ϕ) and cohesion (c) varies as follows :

- a) Angle of internal resistance : $23^\circ - 27^\circ$
- b) Cohesion (kg/cm^2) : 0.03 - 0.12



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7.8 Compiled Soil Profile

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

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

7.9 Chemical Analysis

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

a) Water Samples

Borehole (BH)/ Depth (m)	pH value	Chloride Content (ppm)	Sulphate Content (ppm)
BH1	7	45	82
BH2	6.5	53	78
BH3	7	73	69
BH4	7	64	62
BH5	7	77	84
BH6	6.5	56	65

b) Soil Samples

Borehole (BH)/ Depth (m)	pH value	Chloride Content (ppm)	Sulphate Content (ppm)
BH1	6.5	28	35
BH2	6.5	22	31
BH3	6.5	35	42
BH4	7	18	32



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Borehole (BH)/ Depth (m)	pH value	Chloride Content (ppm)	Sulphate Content (ppm)
BH5	6.5	44	35
BH6	7	29	38

IS LIMITS

pH value	Not less than 6
Chloride content (ppm)	Maximum 500 ppm
Sulphate content (ppm)	Maximum 400 ppm

7.9.2 The above result indicate that water and soil encountered at site will not have any aggressive effect on normal concrete construction work.

7.10 Electrical Resistivity Tests

7.10.1 The results of the Electrical Resistivity Tests (ERT) are analysed as given below.

7.10.2 The electrical resistivity is calculated using the following expression :

$$\rho = 2 \cdot \pi \cdot S \cdot R$$

where ρ = resistivity of the soil in Ω -m

S = spacing of electrodes in m

R = measured resistance or megger reading in Ω

7.10.3 Polar plot of the electrical resistivity vs measured in eight directions have been given in figs. 5a & 5b.

7.10.4 The values of electrical resistivity obtained from the polar plot is given below :

Test Location	Electrical Resistivity, Ω -m
ERT1	24.4
ERT2	28.7



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7.11 Trial Pits

7.11.1 Trial pits of 2m × 2m area had been excavated down to 4m depth below the existing ground level. The subsoil strata predominantly consists of Yellowish brown clayey sandy silt / sandy clayey silt down to the depth excavated.

7.11.2 Photographs showing view of the excavated trial pits TP1 and TP2 have been given in figs. 6a & 6b.

7.11.3 Disturbed and undisturbed soil samples were collected to conduct various laboratory tests.

7.11.4 The grain size distributions, atterberg limits and in-situ properties of the soil samples collected from different depths in the Trial Pits are given below :

TP No.	Depth (m)	Grain Size Analysis				Atterberg Limits		In-situ Properties	
		Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	Density (g/cm ³)	WC (%)
TP1	0.5	0	17	60	23	38	24	-	-
	1.0	-	-	-	-	-	-	1.82	16.1
	1.5	2	14	58	26	43	25	-	-
	2.0	-	-	-	-	-	-	1.99	19.5
	2.5	0	11	69	20	39	23	-	-
	3.0	-	-	-	-	-	-	2.08	27.5
	3.5	0	27	63	10	31	20	-	-
	4.0	-	-	-	-	-	-	2.06	25.2
TP2	0.5	-	-	-	-	-	-	1.79	17.2
	1.0	0	13	59	25	41	25	-	-
	1.5	-	-	-	-	-	-	1.96	17.3
	2.0	0	13	71	16	33	22	-	-
	2.5	-	-	-	-	-	-	1.99	19.4
	3.0	0	13	57	30	39	24	-	-
	3.5	-	-	-	-	-	-	1.97	19.9



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TP No.	Depth (m)	Grain Size Analysis				Atterberg Limits		In-situ Properties	
		Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	Density (g/cm ³)	WC (%)
	4.0	0	9	77	14	34	22	-	-

8.0 ANALYSIS OF LIQUEFACTION SUSCEPTIBILITY

- 8.1.1 Analysis of the susceptibility to liquefaction of the subsoil at the site has been carried out in the form of a comparison of the shear stress induced/developed in event of an earthquake with the in-situ shear resistance of the subsoil at various depths in the different boreholes.
- 8.1.2 This method has been found to be very reliable and is used as one of the main criteria in almost all countries. The shear stress induced/developed at different depths during an earthquake depends upon the overburden pressure and the soil characteristics while the shear resistance is calculated based on the N-values and other soil properties for a maximum repeated strain of 2%.
- 8.1.3 The shear stress induced/developed and the shear resistance offered by the soil are evaluated in terms of the Cyclic Stress Ratio (CSR) and the Cyclic Resistance Ratio (CRR) respectively. The CSR is the ratio of the shear stress developed to the effective overburden pressure at various depths while the CRR is the ratio of the shear resistance of the soil to the effective overburden pressure at various depths. The analysis of variation of the CSR and the CRR with depth based on the results of each of the boreholes conducted, have been given in figs. C1 to C6 of this report.
- 8.1.4 The soil will liquefy in the depth zones where the CSR exceeds the CRR i.e. where the shear stress developed exceeds the shear resistance or in other words, where the factor of safety defined as the ratio of the CRR to CSR, is less than 1.
- 8.1.5 From the above analysis, it can be observed that subsoil down to about 12m depth is susceptible to liquefaction.



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8.1.6 Considering the above and also that the site is located in Seismic Zone - IV of seismic zoning map of India, the subsoil between 4m and 9m depth can be considered to be susceptible to liquefaction. Hence shallow foundations are not feasible, the proposed structures shall have to be supported over Straight Bored Pile foundations.

9.0 DESIGN CRITERIA

9.1 Design Parameters

9.1.1 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

9.1.2 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.

9.2 Type of Foundation

9.2.1 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

9.2.2 The proposed structures are Factory buildings.

9.2.3 Considering the above, medium heavy loads can be anticipated on the foundations.

9.2.4 The results of the investigations have shown that the subsoil below the likely founding is in a loose to medium dense state down to about 9m depth below which the subsoil is medium dense state down to the depth investigated.



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9.2.5 As mentioned in the earlier sections, the subsoil strata down to about 9m depth has been considered to be susceptible to liquefaction.

9.2.6 In view of the above, the proposed structures can be supported over ***Straight Bored Pile foundations.***

9.3 Depth of Pile Foundation

9.3.1 The minimum depth of pile foundations depends upon the following factors :

- a) Top filled-up strata / loose soil, if any
- b) Adequate depth of soil strata below the founding level of the pile foundations of requisite strength to mobilize the safe end bearing capacity
- c) Adequate depth of soil strata above the founding level of the pile foundations of requisite strength to mobilize the safe friction capacity.

9.3.2 Taking the above into consideration, the pile foundations for the proposed structures shall be made to rest at a depth greater than 17m below the existing ground level. Accordingly, considering the cut-off level of the piles as 1m below the existing ground level and effective length of piles of 15m and 20m, the founding levels of the piles will be about 16m and 21m respectively, below the existing ground level.

9.3.3 The soil encountered at the founding levels of the pile foundations will be ***Grey sandy soil.***

9.4 Pile Capacities

9.4.1 Load carrying capacities of bored pile foundation have been analysed and given for piles having various diameters and effective lengths.

9.4.2 The parameters considered for the analysis of the pile capacities are given below :

S. No.	Parameter	Value/s
1	Effective length (m)	15 & 20
2	Cohesion (kg/cm ²)	0.05



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S. No.	Parameter	Value/s
3	Angle of shearing resistance	27°
4	Submerged density (g/cm ³)	0.8
5	SPT Value at pile tip	18 & 20
6	Factor of safety	2.5

9.4.3 Considering the above parameters, the following safe pile capacities have been recommended for various diameters and effective lengths of piles.

Pile Dia (mm)	Pile Effective Length (m)	Pile Vertical Load Capacity (tons)	Uplift Capacity of pile (tons)	Safe Lateral Capacity (tons)	
				Free Head	Fixed Head
600	15	40	15	0.1	0.4
	20	60	30		
800	15	70	30	0.3	0.8
	20	100	50		

9.4.4 The typical calculations of safe pile capacity and safe uplift pile capacity have been given in Appendix - A.

9.4.5 The typical calculations of safe lateral capacity of the pile have been given in Appendix-B.

9.4.6 The group action of piles depends upon the number of piles in the group and their arrangement. Therefore, the efficiency factor for each pile group can be considered and checked as per the relevant BIS codes.

9.5 Special Note

9.5.1 The investigations have been conducted down to a depth of 20m below the existing ground level. As the piles of 20m effective length will rest at a depth of about 21m below the existing ground level, the recommendations for the same have been provided considering the similar subsoil conditions down to a minimum depth of about 25m below the existing ground level.



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9.5.2 After reaching the required depth in the pile bore, 15cm thick layer of gravel should be placed and compacted at the bottom so that the slush formed at the bottom is diminished.

10.0 RECOMMENDATIONS

10.1 Type of Foundations

Straight Bored Pile foundations

10.2 Depth of Foundations

Considering the cut-of level of the piles as 1m below the existing ground level and for effective lengths of pile of 15m and 20m , the piles shall rest at a depth of about 16m and 21m, respectively below the existing ground level.

10.3 Safe Pile capacities

Pile Dia (mm)	Pile Effective Length (m)	Pile Vertical Load Capacity (tons)	Uplift Capacity of pile (tons)	Safe Lateral Capacity (tons)	
				Free Head	Fixed Head
600	15	40	15	0.1	0.4
	20	60	30		
800	15	70	30	0.3	0.8
	20	100	50		

10.4 Note

10.4.1 The investigations have been conducted down to a depth of 20m below the existing ground level. As the piles of 20m effective length will rest at a depth of about 21m below the existing ground level, the recommendations for the same have been provided considering the similar subsoil conditions down to a minimum depth of about 25m below the existing ground level .



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10.4.2 As the subsoil down to about 9m depth below the existing ground level has been considered to be susceptible to liquefaction, the frictional component down to this depth has been neglected for evaluating the pile capacities.

10.4.3 The above recommended safe pile capacities have been arrived at on the basis of provisions given in the BIS code IS:2911 (Part1/Sec2) - 2010 and can therefore, be used for design purposes. These pile capacities should be confirmed / validated by carrying out initial pile load test/s as per the provisions given in BIS code IS:2911 (Part-4) - 2013, prior to finalizing the working loads on the pile foundations.

10.4.4 For straight bored pile foundations, after reaching the required depth in the pile bore, 15cm thick layer of gravel should be placed and compacted at the bottom so that the slush formed at the bottom is diminished.

10.5 Appendices

10.5.1 An appendix sheet showing the typical analysis of vertical pile capacity and uplift pile capacity calculations have been given in Appendix - A of this report.

10.5.2 An appendix sheet showing the typical analysis of lateral pile capacities calculations have been given in Appendix - B of this report.

10.5.3 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.

10.6 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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10.7 LIMITATIONS

This geotechnical investigations have 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 conditions and properties at places between or beyond chosen test locations, fresh investigations will have to be carried out at such locations.

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CALCULATIONS FOR PILE CAPACITY

A.1 Methodology

- A.1.1 A typical calculation for the pile capacity has been given hereunder for a pile of diameter ‘D’ = 600mm and for a length of pile ‘L’ = 20m.
- A.1.2 The pile is designed primarily as an end bearing cum friction pile.
- A.1.3 The end bearing capacity has been determined based on observed N-values while the friction capacity has been determined as per the relevant provisions of the BIS code IS:2911(part1/sec4).
- A.1.4 For determining the end bearing capacity, the N- value at the level of the pile tip has been taken as 20.
- A.1.5 For determining the friction capacity, the average angle of shearing resistance ϕ has been taken as 27°.

A.2 DETERMINATION OF PILE CAPACITY

A.2.1 Pile end bearing capacity based on N-values

A.2.1.1 The ultimate end bearing capacity of the Bored pile foundation is determined as given below:

$$Q_{bu} = 10 \cdot N \cdot A_p$$

where N = N-value at the level of the pile tip

$$A_p = \frac{\pi \cdot D^2}{4} = \text{cross - sectional area of pile toe} = 2827 \text{ cm}^2$$

$$D = \text{diameter of pile shaft} = 600 \text{ mm}$$

A.2.1.2 Therefore, the ultimate end bearing capacity of the bored pile foundation is :



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$$Q_{bu} = 56.5 \text{ tons}$$

A.2.2 Pile friction capacity based on IS:2911 (Part 1/Sec 4)

A.2.2.1 The ultimate friction capacity of the pile is :

$$Q_{fu} = \pi \cdot D \cdot (L - L_1) \cdot \alpha \cdot c + \sum_1^n K \cdot P_{Di} \cdot \tan \delta \cdot A_{si}$$

where c = cohesion of the soil along the pile shaft = 0.05 kg/cm²

α = adhesion factor = 1

K = coefficient of earth pressure = 1

P_{Di} = effective overburden pressure at for the i^{th} layer = $\gamma \cdot d_i$

γ = submerged unit weight of soil below water table = 0.8 g/cm³

d_i = depth of the i^{th} layer from ground level

A_{si} = surface area of the pile stem in the i^{th} layer

δ = angle of wall friction between pile and soil

= ϕ = angle of shearing resistance of the soil = 27°

A.2.2.2 For calculation purposes, the submerged unit weight of the soil has been taken as the effective unit weight of the soil. The submerged unit weight considered is 0.8 g/cm³.

A.2.2.3 As per the IS provisions, the effective overburden pressure P_{Di} is limited to a value equivalent to a depth of overburden equal to 15 times the diameter of the pile.

A.2.2.4 The skin friction capacity ' Q_{fu} ' is determined as :

$$Q_{fu} = \pi \cdot d \cdot (L - L_1) \cdot \alpha \cdot c + K \cdot \tan \delta \cdot \left[\frac{1}{2} \cdot (\gamma \cdot 15 \cdot D) \cdot (15 \cdot D) \cdot (\pi \cdot D) + (\gamma \cdot 15 \cdot D) \cdot (L - 15 \cdot D) \cdot (\pi \cdot D) - \frac{1}{2} \cdot (\gamma \cdot L_1) \cdot (L_1) \cdot (\pi \cdot D) \right]$$



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For $L_1 > 15$ times the pile diameter D

$$Q_{fu} = \pi \cdot D \cdot (L - L_1) \cdot \alpha \cdot c + K \cdot \tan \delta \cdot [(\gamma \cdot 15 \cdot D) \cdot (L - L_1) \cdot (\pi \cdot D)]$$

A.2.2.5 The skin friction capacity ' Q_{fu} ' of the Bored pile foundation is :

$$Q_{fu} = 93.9 \text{ tons}$$

A.3 SAFE PILE CAPACITY

A.3.1 The safe pile capacity is determined by applying appropriate factors of safety to the ultimate values determined above. A factor of safety of 2.5 has been adopted for determination of the safe pile capacity.

A.3.2 Therefore, the safe pile capacity of Bored pile foundation is :

$$Q_s = \frac{Q_{bu} + Q_{fu}}{2.5}$$

Hence,

$$Q_s = 60.2 \text{ tons say } 60 \text{ tons}$$

A.4 SAFE UPLIFT CAPACITY

The safe uplift capacity of the pile is determined by applying appropriate factors of safety to the ultimate friction capacity of the pile as determined above. A factor of safety of 3 has been adopted for determination of the safe uplift pile capacity.

Hence,

$$\text{Safe.Uplift.Capacity} = \frac{Q_{fu}}{3}$$

$$Q_{su} = 31.3 \text{ tons say } 30 \text{ tons}$$



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TYPICAL CALCULATION OF LATERAL PILE LOAD CAPACITY

(As per IS : 2911 (Part1/Sec2) - 2010)

B.1 Methodology

B.1.1 A typical calculation for the lateral pile load capacity has been given hereunder for a pile of diameter 'D' = 600mm.

B.1.2 For determining the lateral pile load capacity, the depth of fixity of the piles or in other words, the equivalent cantilever length of the pile, has to be first determined. The depth of fixity is determined based on the modulus of horizontal subgrade reaction η_h value which in turn is considered based on the relative density/ soil consistency of the soil as observed in the boreholes conducted, as per table 3 of Annex - C of the BIS code IS:2911(part1/sec2).

B.1.3 Considering that the soil in is on an average in a loose to medium dense state, the modulus of horizontal subgrade reaction can be taken as $\eta_h = 2.1 \times 10^3 \text{ kN/m}^2$ or 0.21 kg/cm^3 applicable for submerged conditions (as ground water table is at a shallow depth), as per table 1 of Annex - C of the BIS code IS:2911(part1/sec2).

B.1.4 Considering the subsoil to be susceptible to liquefaction down to about 9m depth below the existing ground level, in the event of earthquake the restraint provided by the soil against lateral load on the pile will almost nil within this depth. Hence the pile length of about 8m below cut off level (i.e. 1m below the existing ground level) will behave like cantilever (i.e. $e = 8\text{m}$).

B.2.2 The stiffness factor T is calculated as per C - 2.3.1 of Annex - C of the BIS code IS:2911(part1/sec2) , as given below:

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$$\text{Stiffness factor} = T = 5 \sqrt{\frac{EI}{\eta_h}}$$

Stiffness factor = T = 2.44 m

B.2.3 Hence, the equivalent cantilever length or in other words the depth of fixity (L_e) of the pile works out to be based on stiffness factor (T) and the plot given in fig.4 in C - 3 of Annex - C of the BIS code IS:2911(part1/sec2)

$$L_e = 1.9 \times T = 1.9 \times 2.44 = 4.64\text{m (for free head condition)}$$

$$L_e = 2.2 \times T = 2.2 \times 2.44 = 5.38\text{m (for fixed head condition)}$$

B.1.4 The lateral pile load capacity is then determined as the horizontal force required for causing the allowable horizontal deflection of the pile head when considering the pile as a cantilever.

B.1.5 For calculation purposes, the concrete of pile has been considered to be of M30 grade.

B.1.6 For the determination of the lateral pile load capacity, the allowable horizontal deflection of the pile head has been considered as 5mm based on the provisions of clause 7.4 of BIS code IS:2911 (Part4) - 1985.

B.3 Determination of Lateral Pile Load Capacity

B.3.1 The horizontal deflection of the pile head, is determined by the following equations :

$$y = \frac{Q_L \cdot (e + z_f)^3}{3 \cdot E \cdot I} \text{ (for free head condition)}$$

$$y = \frac{Q_L \cdot (e + z_f)^3}{12 \cdot E \cdot I} \text{ (for fixed head condition)}$$

where,



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e = cantilever length above ground/ bed to the point of load application

z = depth to point of fixity

B.3.2 The flexural rigidity 'E·I' of the pile section has to be then determined by taking into account the flexural rigidity provided by the reinforcement. For this purpose, the moment of inertia 'I' is determined by taking into account the area of reinforcement along with the appropriate value of modular ratio 'm'.

B.3.3 The elastic modulus of concrete is determined as :

$$E = 5000 \cdot \sqrt{f_{ck}}$$

Where f_{ck} = characteristic strength of concrete = 30N/mm²

Hence, $E = 27,386 \text{ N/mm}^2$ or $273,860 \text{ kg/cm}^2$

B.3.4 The moment of inertia of the pile section is determined as :

$$I = \frac{\pi \cdot d^4}{64}$$

Hence, $I = 6361725123 \text{ mm}^4 = 636173 \text{ cm}^4$

B.3.2 Considering an allowable horizontal deflection of the pile head of 5mm, the lateral pile load capacity works out to be :

$Q_L = 0.1 \text{ tons}$ (for free head condition)

$Q_L = 0.4 \text{ tons}$ (for fixed head condition)



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STANDARD PROCEDURE FOR LIQUEFACTION ANALYSIS

(Reference : Annex F of IS 1893 Part 1- 2016)

D.1 EVALUATION OF CYCLIC STRESS RATIO (CSR)

$$CSR = (\tau_{av} / \sigma'_{vo}) = 0.65(a_{max} / g) \cdot (\sigma_{vo} / \sigma'_{vo}) \cdot r_d \quad (i)$$

where, $r_d = (1.0 - 0.00765z)$, for, $(z \leq 9.15m)$

$$r_d = (1.174 - 0.0267z)$$
, for, $(9.15m < z \leq 23m)$

D.2 EVALUATION OF LIQUEFACTION RESISTANCE (CRR)

$$CRR_{7.5} = f(N_1)_{60} \quad (ii)$$

$$i.e. CRR_{7.5} = \frac{1}{34 - (N_1)_{60}} + \frac{(N_1)_{60}}{135} + \frac{50}{[10 \cdot (N_1)_{60} + 45]^2} - \frac{1}{200}$$

D.2.1. Influence of Fine Content

$$(N_1)_{60cs} = \alpha + \beta(N_1)_{60}$$

where, $\alpha = 0$, for, $(FC \leq 5\%)$

$$\alpha = \exp[1.76 - (190 / FC^2)], \text{ for, } (5\% < FC < 35\%)$$

$$\alpha = 5, \text{ for, } (FC \geq 35\%)$$

$$\beta = 1, \text{ for, } (FC \leq 5\%)$$

$$\beta = [0.99 + (FC^{1.5} / 1,000)], \text{ for, } (5\% < FC < 35\%)$$

$$\beta = 1.2, \text{ for, } (FC \geq 35\%)$$



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D.2.1. Other Corrections

$$(N_1)_{60} = N_m C_N C_E C_B C_R C_S$$

D.3 NOTATIONS

Notation	Description
CSR	Cyclic Stress Ratio
CRR	Cyclic Resistance Ratio
σ_{vo}	Total Vertical Overburden Stresses
σ'_{vo}	Effective vertical overburden stresses
τ_{av}	Average horizontal shear stress acting on soil layer during shaking generated by given earthquake
a_{max}	Peak horizontal acceleration at ground surface
g	Acceleration of gravity
r_d	Stress reduction coefficient to account for flexibility in soil profile
z	Depth below ground surface (m)
$CRR_{7.5}$	Cyclic resistance ratio for $M_w = 7.5$ earthquakes
$(N_1)_{60}$	Corrected standard penetration resistance
$(N_1)_{60cs}$	$(N_1)_{60}$ adjusted to equivalent clean-sand value
N_m	Measured standard penetration resistance
C_N	Correction factor for overburden pressure applied to SPT
C_E	Correction factor for hammer energy
C_B	Correction factor for borehole diameter
C_R	Correction factor for drilling rod length
C_S	Correction factor for split spoon sampler without liners
α, β	Coefficients, that are functions of fines content, used to correct $(N_1)_{60}$ to $(N_1)_{60cs}$



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LIST OF IS CODES**Field Investigation**

1. IS : 1892 - 2021 : Code of practice for sub surface investigations for foundations (First revision)
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 : 3043 - 1987: Code of Practice of Earthing

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 revision).



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5. IS : 2720 - 1985 (Part 4) : Method of test for soils : Grain size analysis (Second revision)
6. IS : 2720 (Part 8) -1983: Determination of water content - dry density relation using heavy compaction. (First revision)
7. IS : 2720 - 1985 (Part 5) : Method of test for soils : Determination of liquid and plastic limit (Second revision)
8. IS 2720-1981 Part 12: Method of tests for soils : Determination of shear strength parameters using triaxial apparatus.
9. IS : 2720 - 1987 (Part16) Method of Tests for Soils: Laboratory Determination of California Bering Ratio (Second revision) (Reaffirmed - 2002)
10. IS : 2720 - 1986 (Part17) Method of Tests for Soils: Laboratory Determination of Permeability (Reaffirmed - 2002)
11. IS : 2720 -1987 (Part 26): Methods of tests for soils: Determination of pH value (Second revision).
12. IS :2720 - 1977 (Part 27): Methods of tests for soils: Determination of total soluble sulphate (First revision).

Foundation Construction

1. IS : 2911 - 1979 (P1/Sec 1): Code of practice for design and construction of pile foundations : concrete piles - Driven cast insitu (First revision) Amendment 2



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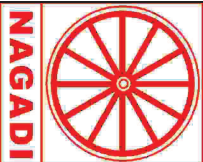
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Analysis of Susceptibility to Liquefaction for Borehole BH1

Depth (m)	a_{max}/g	σ_{vo}/σ'_{vo}	r_d	CSR	N_{obs}	C_N	C_E	C_B	C_R	C_S	$(N)_{60}$	FC (%)	α	β	$(N)_{60CR}$	CRR	FOS
0.9	0.24	1.000	0.999	0.156	8	1.70	1	1	0.75	1	10	48	5.00	1.200	17	0.181	1.16
2.4	0.24	1.048	0.998	0.163	7	1.52	1	1	0.8	1	9	85	5.00	1.200	16	0.170	1.04
3.9	0.24	1.300	0.997	0.202	10	1.19	1	1	0.85	1	10	45	5.00	1.200	17	0.181	0.89
5.4	0.24	1.447	0.996	0.225	13	1.07	1	1	0.95	1	13	77	5.00	1.200	21	0.228	1.02
6.9	0.24	1.543	0.995	0.239	17	0.99	1	1	0.95	1	16	24	4.18	1.108	22	0.242	1.01
8.4	0.24	1.610	0.994	0.250	20	0.92	1	1	0.95	1	18	29	4.64	1.146	25	0.292	1.17
9.9	0.24	1.660	0.910	0.236	37	0.87	1	1	1	1	32	21	3.78	1.086	39	0.500	2.12
11.4	0.24	1.699	0.870	0.230	35	0.82	1	1	1	1	29	12	1.55	1.032	31	0.500	2.17
12.9	0.24	1.730	0.830	0.224	41	0.78	1	1	1	1	32	12	1.55	1.032	35	0.500	2.23
14.4	0.24	1.755	0.790	0.216	40	0.75	1	1	1	1	30	14	2.20	1.042	33	0.500	2.31



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Sheet No:1

Analysis of Susceptibility to Liquefaction for Borehole BH2

Depth (m)	a_{max}/g	σ_{vo}/σ'_{vo}	r_d	CSR	N_{obs}	C_N	C_E	C_B	C_R	C_S	$(N)_{60}$	FC (%)	α	β	$(N)_{60CR}$	CRR	FOS
1.5	0.24	1.000	0.999	0.156	11	1.70	1	1	0.8	1	15	83	5.00	1.200	23	0.257	1.65
3	0.24	1.217	0.998	0.189	7	1.36	1	1	0.85	1	8	77	5.00	1.200	15	0.160	0.84
4.5	0.24	1.410	0.997	0.219	14	1.14	1	1	0.95	1	15	77	5.00	1.200	23	0.257	1.17
6	0.24	1.526	0.995	0.237	16	1.04	1	1	0.95	1	16	9	0.56	1.017	17	0.181	0.76
7.5	0.24	1.604	0.994	0.249	32	0.97	1	1	0.95	1	29	9	0.56	1.017	30	0.468	1.88
9	0.24	1.660	0.993	0.257	25	0.91	1	1	1	1	23	7	0.12	1.009	23	0.257	1.00
10.5	0.24	1.702	0.894	0.237	22	0.85	1	1	1	1	19	2	0.00	1.000	19	0.203	0.86
12	0.24	1.735	0.854	0.231	23	0.81	1	1	1	1	19	7	0.12	1.009	19	0.203	0.88
13.5	0.24	1.762	0.814	0.224	27	0.77	1	1	1	1	21	3	0.00	1.000	21	0.228	1.02
15	0.24	1.783	0.774	0.215	37	0.74	1	1	1	1	27	2	0.00	1.000	27	0.338	1.57



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Sheet No: 2

Analysis of Susceptibility to Liquefaction for Borehole BH3

Depth (m)	a_{max}/g	σ_{vo}/σ'_{vo}	r_d	CSR	N_{obs}	C_N	C_E	C_B	C_R	C_S	$(N)_{60}$	FC (%)	α	β	$(N)_{60CR}$	CRR	FOS
0.9	0.24	1.000	0.999	0.156	19	1.70	1	1	0.75	1	24	84	5.00	1.200	34	0.500	3.21
2.4	0.24	1.048	0.998	0.163	8	1.52	1	1	0.8	1	10	79	5.00	1.200	17	0.181	1.11
3.9	0.24	1.300	0.997	0.202	20	1.19	1	1	0.85	1	20	51	5.00	1.200	29	0.410	2.03
5.4	0.24	1.447	0.996	0.225	24	1.07	1	1	0.95	1	24	12	1.55	1.032	26	0.313	1.39
6.9	0.24	1.543	0.995	0.239	29	0.99	1	1	0.95	1	27	5	0.00	1.000	27	0.338	1.41
8.4	0.24	1.610	0.994	0.250	29	0.92	1	1	0.95	1	25	9	0.56	1.017	26	0.313	1.25
9.9	0.24	1.660	0.910	0.236	24	0.87	1	1	1	1	21	9	0.56	1.017	22	0.242	1.03
11.4	0.24	1.699	0.870	0.230	33	0.82	1	1	1	1	27	7	0.12	1.009	27	0.338	1.47
12.9	0.24	1.730	0.830	0.224	30	0.78	1	1	1	1	24	3	0.00	1.000	24	0.273	1.22
14.4	0.24	1.755	0.790	0.216	41	0.75	1	1	1	1	31	3	0.00	1.000	31	0.500	2.31



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Sheet No.3:

Analysis of Susceptibility to Liquefaction for Borehole BH4

Depth (m)	a_{max}/g	σ_{vo}/σ'_{vo}	r_d	CSR	N_{obs}	C_N	C_E	C_B	C_R	C_S	$(N)_{60}$	FC (%)	α	β	$(N)_{60CR}$	CRR	FOS
1.5	0.24	1.000	0.999	0.156	9	1.70	1	1	0.8	1	12	34	4.93	1.188	19	0.203	1.30
3	0.24	1.168	0.998	0.182	14	1.36	1	1	0.85	1	16	83	5.00	1.200	24	0.273	1.50
4.5	0.24	1.367	0.997	0.213	17	1.13	1	1	0.95	1	18	84	5.00	1.200	27	0.338	1.59
6	0.24	1.490	0.995	0.231	16	1.03	1	1	0.95	1	16	52	5.00	1.200	24	0.273	1.18
7.5	0.24	1.572	0.994	0.244	18	0.96	1	1	0.95	1	16	21	3.78	1.086	21	0.228	0.94
9	0.24	1.632	0.993	0.253	15	0.90	1	1	1	1	13	11	1.21	1.026	15	0.160	0.63
10.5	0.24	1.677	0.894	0.234	34	0.85	1	1	1	1	29	2	0.00	1.000	29	0.410	1.75
12	0.24	1.712	0.854	0.228	37	0.81	1	1	1	1	30	5	0.00	1.000	30	0.468	2.05
13.5	0.24	1.740	0.814	0.221	38	0.77	1	1	1	1	29	4	0.00	1.000	29	0.410	1.86
15	0.24	1.764	0.774	0.213	39	0.74	1	1	1	1	29	3	0.00	1.000	29	0.410	1.93



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Sheet NG4:

Analysis of Susceptibility to Liquefaction for Borehole BH5

Depth (m)	a_{max}/g	σ_{vo}/σ'_{vo}	r_d	CSR	N_{obs}	C_N	C_E	C_B	C_R	C_S	$(N)_{60}$	FC (%)	α	β	$(N)_{60CR}$	CRR	FOS
0.9	0.24	1.000	0.999	0.156	15	1.70	1	1	0.75	1	19	81	5.00	1.200	28	0.370	2.37
2.4	0.24	1.024	0.998	0.159	14	1.52	1	1	0.8	1	17	82	5.00	1.200	25	0.292	1.83
3.9	0.24	1.279	0.997	0.199	12	1.19	1	1	0.85	1	12	78	5.00	1.200	19	0.203	1.02
5.4	0.24	1.428	0.996	0.222	17	1.06	1	1	0.95	1	17	64	5.00	1.200	25	0.292	1.32
6.9	0.24	1.526	0.995	0.237	18	0.98	1	1	0.95	1	17	30	4.71	1.154	24	0.273	1.15
8.4	0.24	1.596	0.994	0.247	20	0.92	1	1	0.95	1	17	17	3.01	1.060	21	0.228	0.92
9.9	0.24	1.647	0.910	0.234	28	0.87	1	1	1	1	24	3	0.00	1.000	24	0.273	1.17
11.4	0.24	1.687	0.870	0.229	31	0.82	1	1	1	1	25	2	0.00	1.000	25	0.292	1.28
12.9	0.24	1.719	0.830	0.222	36	0.78	1	1	1	1	28	4	0.00	1.000	28	0.370	1.66
14.4	0.24	1.745	0.790	0.215	42	0.75	1	1	1	1	31	4	0.00	1.000	31	0.500	2.33



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Sheet No.5:

Analysis of Susceptibility to Liquefaction for Borehole BH6

Depth (m)	a_{max}/g	σ_{vo}/σ'_{vo}	r_d	CSR	N_{obs}	C_N	C_E	C_B	C_R	C_S	$(N)_{60}$	FC (%)	α	β	$(N)_{60CR}$	CRR	FOS
1.5	0.24	1.000	0.999	0.156	9	1.70	1	1	0.8	1	12	75	5.00	1.200	19	0.203	1.30
3	0.24	1.168	0.998	0.182	11	1.36	1	1	0.85	1	13	77	5.00	1.200	21	0.228	1.26
4.5	0.24	1.367	0.997	0.213	12	1.13	1	1	0.95	1	13	15	2.50	1.048	16	0.170	0.80
6	0.24	1.490	0.995	0.231	18	1.03	1	1	0.95	1	18	11	1.21	1.026	20	0.215	0.93
7.5	0.24	1.572	0.994	0.244	20	0.96	1	1	0.95	1	18	7	0.12	1.009	18	0.192	0.79
9	0.24	1.632	0.993	0.253	25	0.90	1	1	1	1	22	3	0.00	1.000	22	0.242	0.96
10.5	0.24	1.677	0.894	0.234	31	0.85	1	1	1	1	26	5	0.00	1.000	26	0.313	1.34
12	0.24	1.712	0.854	0.228	36	0.81	1	1	1	1	29	3	0.00	1.000	29	0.410	1.80
13.5	0.24	1.740	0.814	0.221	40	0.77	1	1	1	1	31	3	0.00	1.000	31	0.500	2.26
15	0.24	1.764	0.774	0.213	30	0.74	1	1	1	1	22	3	0.00	1.000	22	0.242	1.14



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Job No. : G(D)4518
 Sheet No. : 1

SOIL PROFILE		Project : Proposed Paint Plant Project at UPSIC Industrial Area, District Bulandshahr, Sikandrabad, Uttar Pradesh											
		B.H. Location :		Water Table : 4.2m		Term. Depth : 20m		B.H. No.: 1					
N - Value	Depth (m)	Soil Description	Grain Size Analysis				Atterberg Limits		In-situ properties		Triaxial Test		
			Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Liquid (%)	Plastic (%)	Density (g/cm ³)	Water Cont (%)	Type	c (kg/cm ²)	φ (°)
8	0.0	Yellowish brown clayey sandy silt with gravel	32	21	41	6	26	17	1.93	10.7	CD	0.1	24
	0.9												
7	1.5	Yellowish brown sandy clayey silt with gravel	3	12	65	20	29	20	1.97	16.4	CD	0.1	24
	2.4												
10	3.0	Yellowish brown clayey silty sand with gravel	3	52	41	4	25	16	2.02	23.1	CD	0.07	26
	3.9												
13	4.5	Yellowish brown clayey sandy silt	0	23	75	2	27	18	2.07	22.8	CD	0.07	26
	5.4												
17	6.0	Change of the strata	0	76	24	0	Non	Plastic	2.03	24.5	CD	0.07	26
	6.5												
20	6.9	Brownish Grey silty sand	0	71	29	0	Non	Plastic	2.03	24.5	CD	0.07	26
	7.5												
37	8.4	Brownish grey silty sand	0	71	29	0	Non	Plastic	2.03	24.5	CD	0.07	26
	9.0												
37	9.7	Change of the strata	0	80	20	0	Non	Plastic	2.03	24.5	CD	0.07	26
	9.9												



SOIL PROFILE		Project : Proposed Paint Plant Project at UPSIC Industrial Area, District Bulandshahr, Sikandrabad, Uttar Pradesh										
		B.H. Location :		Water Table : 4m		Term. Depth : 20m		B.H. No.: 2				
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	c (kg/cm ²)
22	10.5	Grey sand with traces of silt	0	98	2	0	Non	Plastic				
	11.4								Sample	slip		
23	12.0	Grey sand with traces of silt and gravel	2	91	7	0	Non	Plastic				
	12.9								Sample	slip		
27	13.5	Grey sand with traces of silt	0	97	3	0	Non	Plastic				
	14.4								Sample	slip		
37	15.0	Grey sand with traces of silt and gravel	4	94	2	0	Non	Plastic				
	15.9								Sample	slip		
40	16.5	Grey sand with traces of silt	0	98	2	0	Non	Plastic				
	17.4								Sample	slip		
47	18.0	Grey sand with traces of silt	0	98	2	0	Non	Plastic				
	20.0								Sample	slip		
		Observed 'N' Values										

Project : Proposed Paint Plant Project at UPSIC Industrial Area, District Bulandshahr, Sikandrabad, Uttar Pradesh

B.H. Location :

Water Table : 4.2m

Term. Depth : 20m

B.H. No.: 3

SOIL PROFILE

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	Type	c (kg/cm ²)	φ (°)	
19	0.0													
	0.9	Yellowish brown sandy clayey silt	0	16	60	24	37	22	1.98	16.2				
8	1.5													
	2.4	Yellowish brown clayey sandy silt	0	21	69	10	29	19	2.06	23.9				
	3.0													
20	3.9	Yellowish brown clayey sandy silt	0	49	49	2	25	15	1.99	20.3	CD	0.08	25	
	4.5													
	5.2	Change of the strata												
24	5.4	Grey sand with silt and gravel	2	86	12	0	Non	Plastic	Sample	slip				
	6.0													
29	6.9	Grey sand with traces of silt	0	95	5	0	Non	Plastic	Sample	slip				
	7.5													
29	8.4	Grey sand with traces of silt	0	91	9	0	Non	Plastic	Sample	slip				
	9.0													
24	9.9	Grey sand with traces of silt	0	91	9	0	Non	Plastic						



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Sheet No. : 5

Project : Proposed Paint Plant Project at UPSIC Industrial Area, District Bulandshahr, Sikandrabad, Uttar Pradesh

B.H. Location :

Water Table : 4.2m

Term. Depth : 20m

B.H. No.: 3

SOIL PROFILE

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	c (kg/cm ²)	φ (°)	
33	10.5													
	11.4	Grey sand with traces of silt	0	93	7	0	Non	Plastic	Sample	slip				
	12.0													
30	12.9	Grey sand with traces of silt and gravel	2	95	3	0	Non	Plastic	Sample	slip				
	13.5													
41	14.4	Grey sand with traces of silt	0	97	3	0	Non	Plastic	Sample	slip				
	15.0													
38	15.9	Grey sand with traces of silt and gravel	2	95	3	0	Non	Plastic	Sample	slip				
	16.5													
36	17.4	Grey sand with traces of silt and gravel	2	96	2	0	Non	Plastic	Sample	slip				
	18.0													
42	20.0	Grey sand with traces of silt	0	97	3	0	Non	Plastic	Sample	slip				
		Observed 'N' Values												



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Project : Proposed Paint Plant Project at UPSIC Industrial Area, District Bulandshahr, Sikandrabad, Uttar Pradesh

B.H. Location :

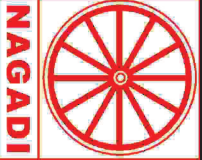
Water Table : 4.2m

Term. Depth : 20m

B.H. No.: 4

SOIL PROFILE

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	Type	c (kg/cm ²)	φ (°)
9	0.0	Yellowish brown gravelly clayey sandy silt	42	24	30	4	Low	Plastic	Tube	bent	CD	0.11	24
	0.9								1.5	1.99			
14	2.4	Yellowish brown clayey sandy silt	0	17	75	8	28	19	2.03	24.1	CD	0.11	24
	3.0								3.9	2.03			
17	4.5	Yellowish brown clayey sandy silt with gravel	3	13	74	10	29	20	2.08	20.3	CD	0.11	24
	5.4	Change of the strata							2.08	20.3			
16	6.0	Yellowish brown / br. grey clayey sandy silt	0	48	50	2	26	17	Sample	slip	CD	0.11	24
	6.9												
18	7.5	Grey sand with silt	0	80	20	0	Non	Plastic	Sample	slip	CD	0.11	24
	8.4												
15	9.0	Grey sand with silt	0	89	11	0	Non	Plastic	Sample	slip	CD	0.11	24
	9.9												



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Sheet No. : 7

Project : Proposed Paint Plant Project at UPSIC Industrial Area, District Bulandshahr, Sikandrabad, Uttar Pradesh

B.H. Location :

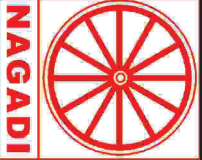
Water Table : 4.2m

Term. Depth : 20m

B.H. No.: 4

SOIL PROFILE

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	Type	c (kg/cm ²)	φ (°)
34	10.5	Grey sand with traces of silt	0	98	2	0	Non	Plastic					
	11.4								Sample	slip			
37	12.0	Grey sand with traces of silt	0	95	5	0	Non	Plastic					
	12.9								Sample	slip			
38	13.5	Grey sand with traces of silt	0	96	4	0	Non	Plastic					
	14.4								Sample	slip			
39	15.0	Grey sand with traces of silt	0	97	3	0	Non	Plastic					
	15.9								Sample	slip			
43	16.5	Grey sand with traces of silt	0	95	5	0	Non	Plastic					
	17.4								Sample	slip			
41	18.0	Grey sand with traces of silt	0	97	3	0	Non	Plastic					
	20.0								Sample	slip			
		Observed 'N' Values											



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Sheet No. : 8

Project : Proposed Paint Plant Project at UPSIC Industrial Area, District Bulandshahr, Sikandrabad, Uttar Pradesh

B.H. Location : Water Table : 4.3m Term. Depth : 20m B.H. No.: 5

SOIL PROFILE

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	Type	c (kg/cm ²)	φ (°)
15	0.0 0.9 1.5	Yellowish brown sandy clayey silt with gravel	2	17	56	25	36	23	1.99	15.7			
14	2.4 3.0	Yellowish brown clayey sandy silt	0	18	65	17	31	20	2.05	13.4	CD	0.12	24
12	3.9 4.5	Yellowish brown clayey sandy silt	11	11	70	8	28	18	2.09	23.8			
17	5.4 6.0 6.7	Yellowish brown clayey sandy silt Change of the strata	0	36	62	2	26	17	1.97	22.2	CD	0.08	25
18	6.9 7.5	Brownish grey silty sand	0	70	30	0	Non	Plastic	Sample	slip			
20	8.2 8.4 9.0	Change of the strata Grey sand with silt	0	83	17	0	Non	Plastic	Sample	slip			
28	9.9	Grey sand with traces of silt	0	97	3	0	Non	Plastic					



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Sheet No. : 9

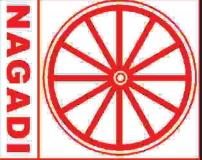
Project : Proposed Paint Plant Project at UPSIC Industrial Area, District Bulandshahr, Sikandrabad, Uttar Pradesh

B.H. Location : Water Table : 4.3m Term. Depth : 20m B.H. No.: 5

SOIL PROFILE

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	c (kg/cm ²)	φ (°)
31	10.5	Grey sand with traces of silt	0	98	2	0	Non	Plastic	Sample	slip			
	11.4								Sample	slip			
	12.0								Sample	slip			
36	12.9	Grey sand with traces of silt	0	96	4	0	Non	Plastic	Sample	slip			
	13.5								Sample	slip			
	14.4								Sample	slip			
42	15.0	Grey sand with traces of silt	0	96	4	0	Non	Plastic	Sample	slip			
	15.9								Sample	slip			
	16.5								Sample	slip			
44	17.4	Grey sand with traces of silt	0	97	3	0	Non	Plastic	Sample	slip			
	18.0								Sample	slip			
48	20.0	Grey sand with traces of silt	0	97	3	0	Non	Plastic	Sample	slip			

Observed 'N' Values



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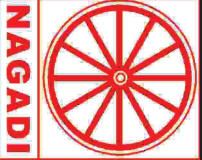
Sheet No. : 10

Project : Proposed Paint Plant Project at UPSIC Industrial Area, District Bulandshahr, Sikandrabad, Uttar Pradesh

B.H. Location : Water Table : 4.2m Term. Depth : 20m B.H. No.: 6

SOIL PROFILE

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	c (kg/cm ²)	φ (°)
9	0.0	Yellowish brown sandy clayey silt with gravel	9	16	57	18	32	22	1.97	20.8	CD	0.11	23
	0.9								1.96	16.9			
11	1.5	Yellowish brown clayey sandy silt with gravel	6	17	68	9	29	20	2.03	26.7	CD	0.03	25
	2.4								1.99	26.5			
12	3.0	Change of the strata	0	85	15	0	Non	Plastic	Sample	slip	CD	0.03	25
	3.9								Sample	slip			
18	4.5	Grey sand with silt	0	89	11	0	Non	Plastic	Sample	slip	CD	0.03	25
	5.4								Sample	slip			
20	6.0	Grey sand with traces of silt and gravel	2	91	7	0	Non	Plastic	Sample	slip	CD	0.03	25
	6.9								Sample	slip			
25	7.5	Grey sand with traces of silt	0	97	3	0	Non	Plastic	Sample	slip	CD	0.03	25
	8.4								Sample	slip			
	9.0	Grey sand with traces of silt	0	97	3	0	Non	Plastic	Sample	slip	CD	0.03	25
	9.9								Sample	slip			



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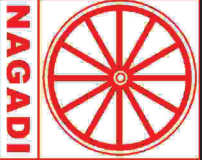
Sheet No. : 11

Project : Proposed Paint Plant Project at UPSIC Industrial Area, District Bulandshahr, Sikandrabad, Uttar Pradesh

B.H. Location : Water Table : 4.2m Term. Depth : 20m B.H. No.: 6

SOIL PROFILE

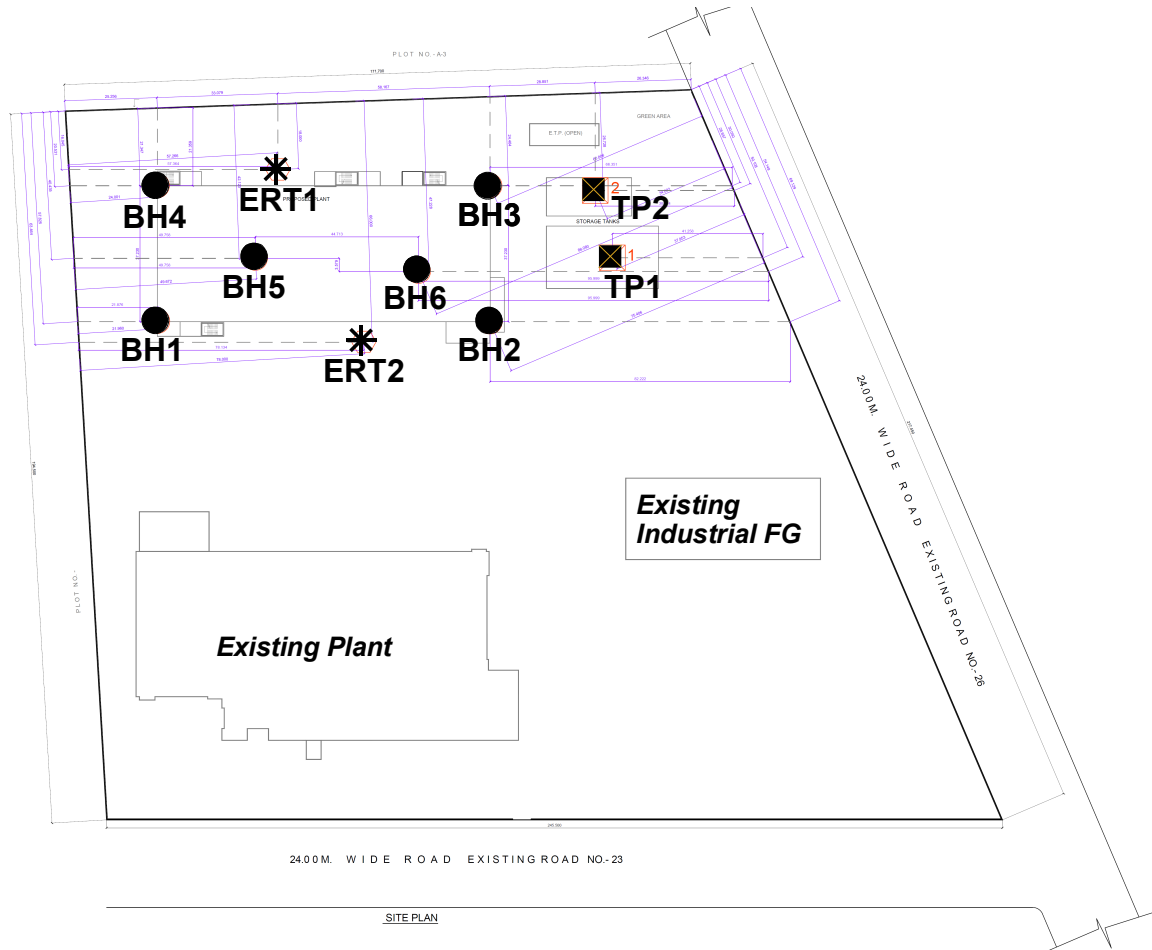
N - Value	Depth (m)	Soil Description	Grain Size Analysis				Atterberg		In-situ		Triaxial Test		
			Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Liquid (%)	Plastic (%)	Density (g/cm ³)	Water Cont (%)	Type	c (kg/cm ²)	φ (°)
31	10.5	Grey sand with traces of silt	0	95	5	0	Non	Plastic					
	11.4								Sample	slip			
36	12.0	Grey sand with traces of silt and gravel	2	96	2	0	Non	Plastic					
	12.9								Sample	slip			
40	13.5	Grey sand with traces of silt	0	98	2	0	Non	Plastic					
	14.4								Sample	slip			
30	15.0	Grey sand with traces of silt and gravel	3	95	2	0	Non	Plastic					
	15.9								Sample	slip			
39	16.5	Grey sand with traces of silt and gravel	2	96	2	0	Non	Plastic					
	17.4								Sample	slip			
45	18.0	Grey sand with traces of silt	0	98	2	0	Non	Plastic					
	20.0								Sample	slip			
		Observed 'N' Values											



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Sheet No. : 12



Legend

- Borehole (BH)
- * Electrical Resistivity Test (ERT)
- Trial Pit

SCHEMATIC SITE PLAN



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Job No. : G(D)4518

Sheet No. : 1a



**PHOTOGRAPHS SHOWING
VIEW OF THE SITE & BOREHOLES UNDER PROGRESS**



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Sheet No. : 1b



**PHOTOGRAPHS SHOWING
VIEW OF THE SITE & BOREHOLES UNDER PROGRESS**



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Job No. : G(D)4518

Sheet No. : 1c



**PHOTOGRAPHS SHOWING
ELECTRICAL RESISTIVITY TEST UNDER PROGRESS**

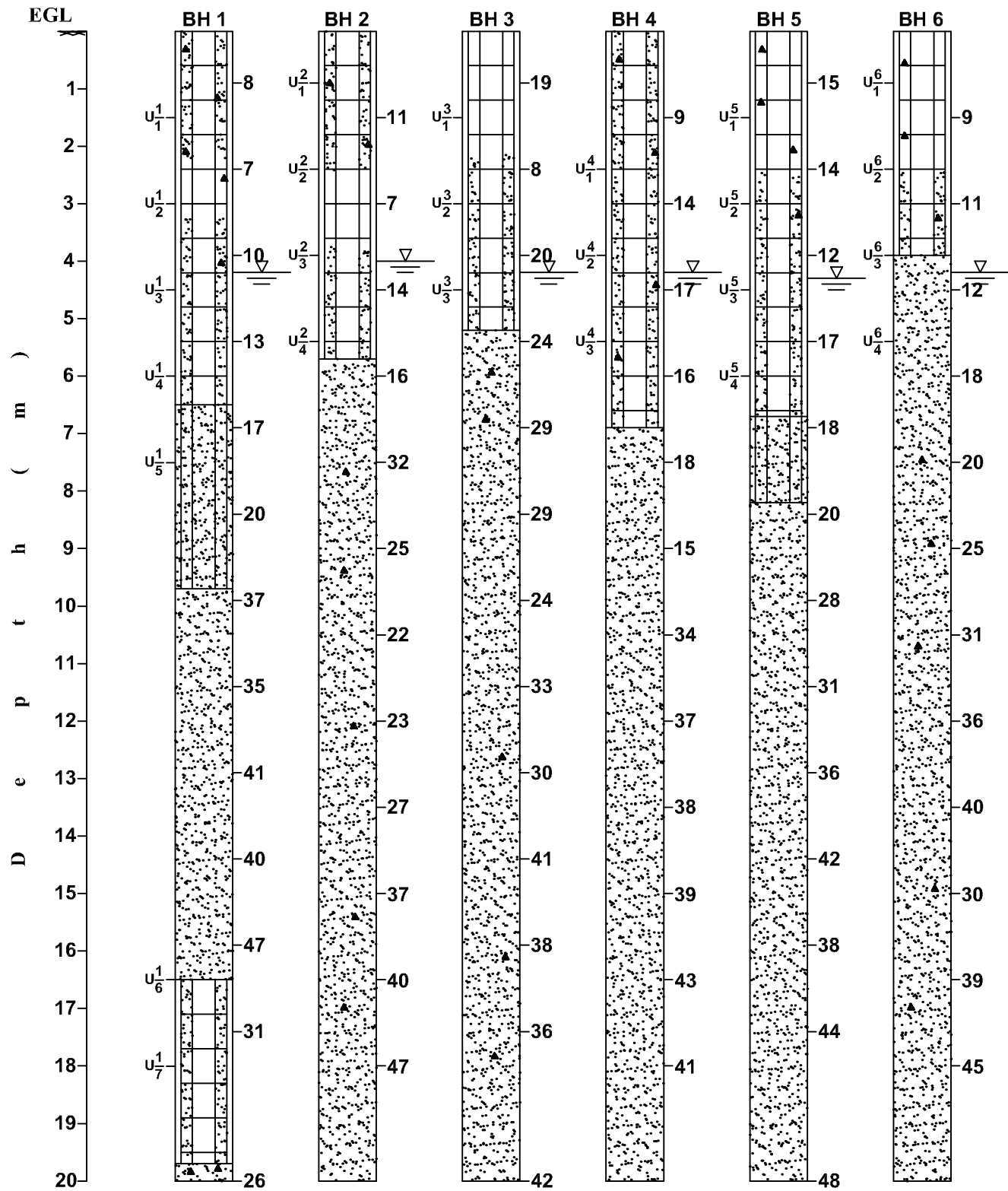


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Job No. : G(D)4518

Sheet No. : 1d



LEGEND



Yellowish brown clayey sandy silt with occasional gravel / sandy clayey silt
 (2-26)% (11-52)% (30-75)% (0-42)%



Brownish grey silty sand
 (24-30)% (70-76)%



Grey sand with silt and occasional gravel / sand with silt
 (80-98)% (2-20)% (0-4)%

42 Observed 'N' Values u₂¹ 2nd undisturbed soil sample of BH 1

∇ Ground Water table has been encountered as on January 2023

COMPILED SOIL PROFILE

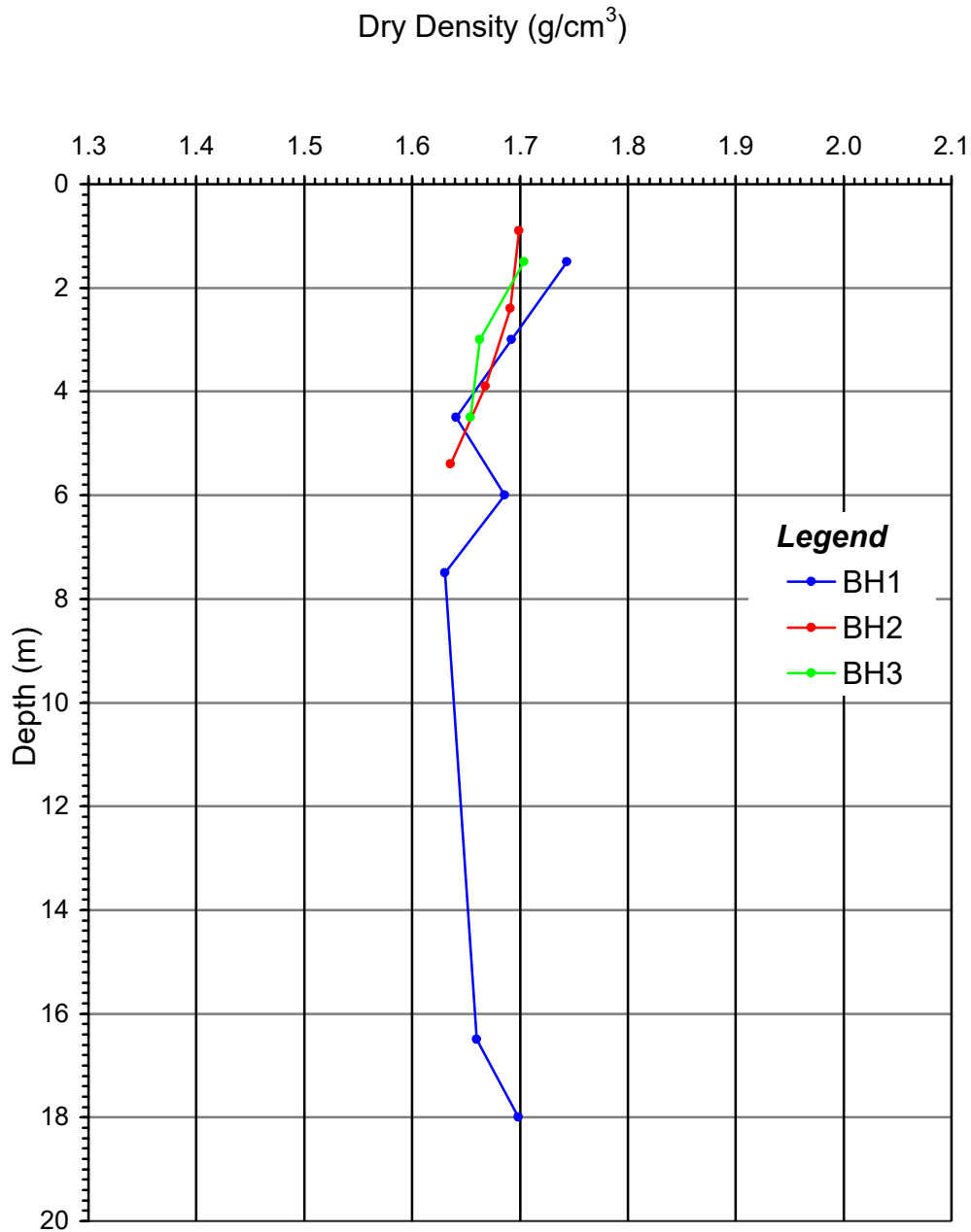


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Proposed Paint Plant Project at UPSIC Industrial Area,
 District Bulandshahr, Sikandrabad, Uttar Pradesh

Job No: G(D) 4518

Sheet No: 2



Dry Density vs Depth Curves

(Refer paragraph no. 7.4.2)

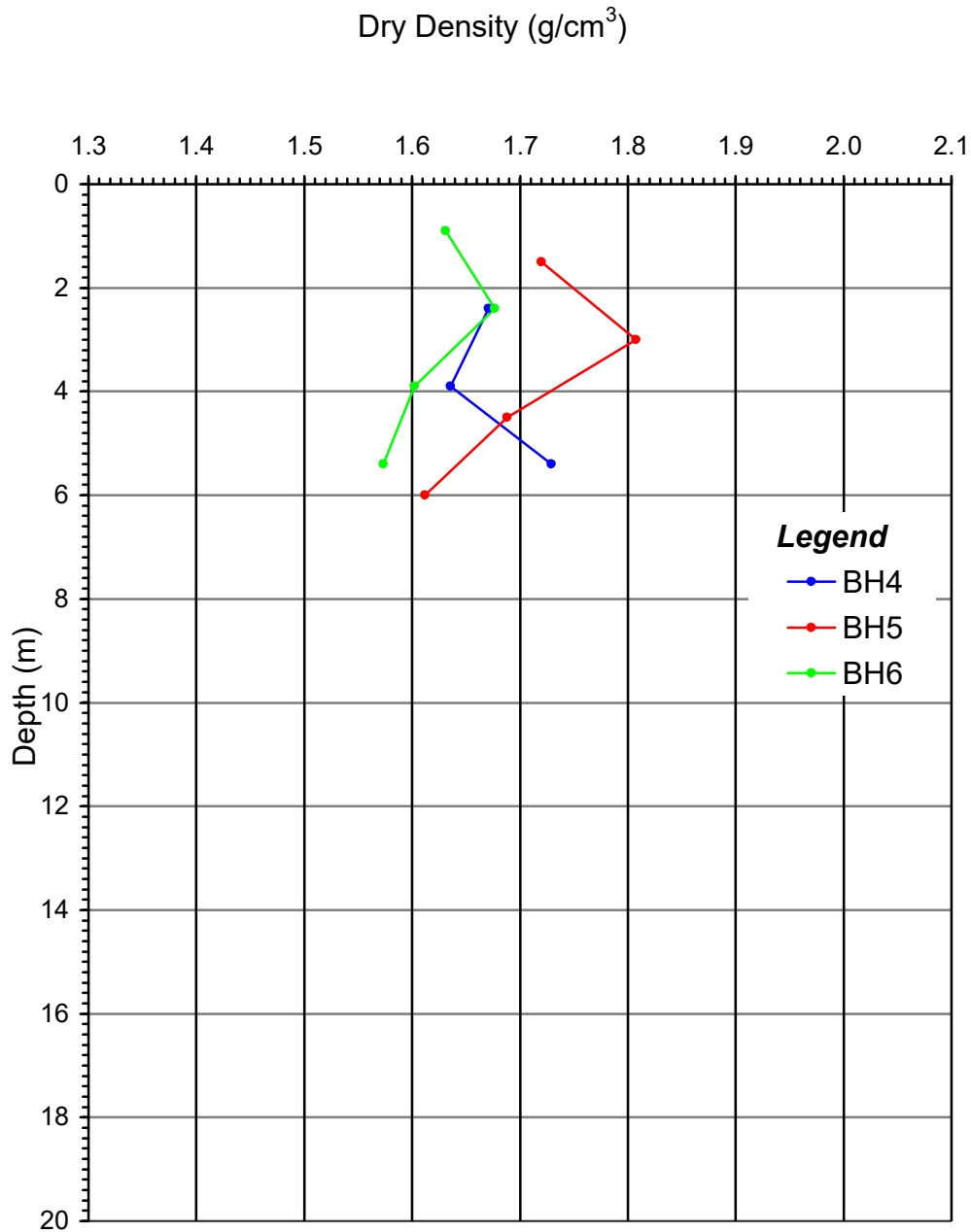


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Job No. G(D)4518

Sheet No. : 3a



Dry Density vs Depth Curves

(Refer paragraph no. 7.4.2)



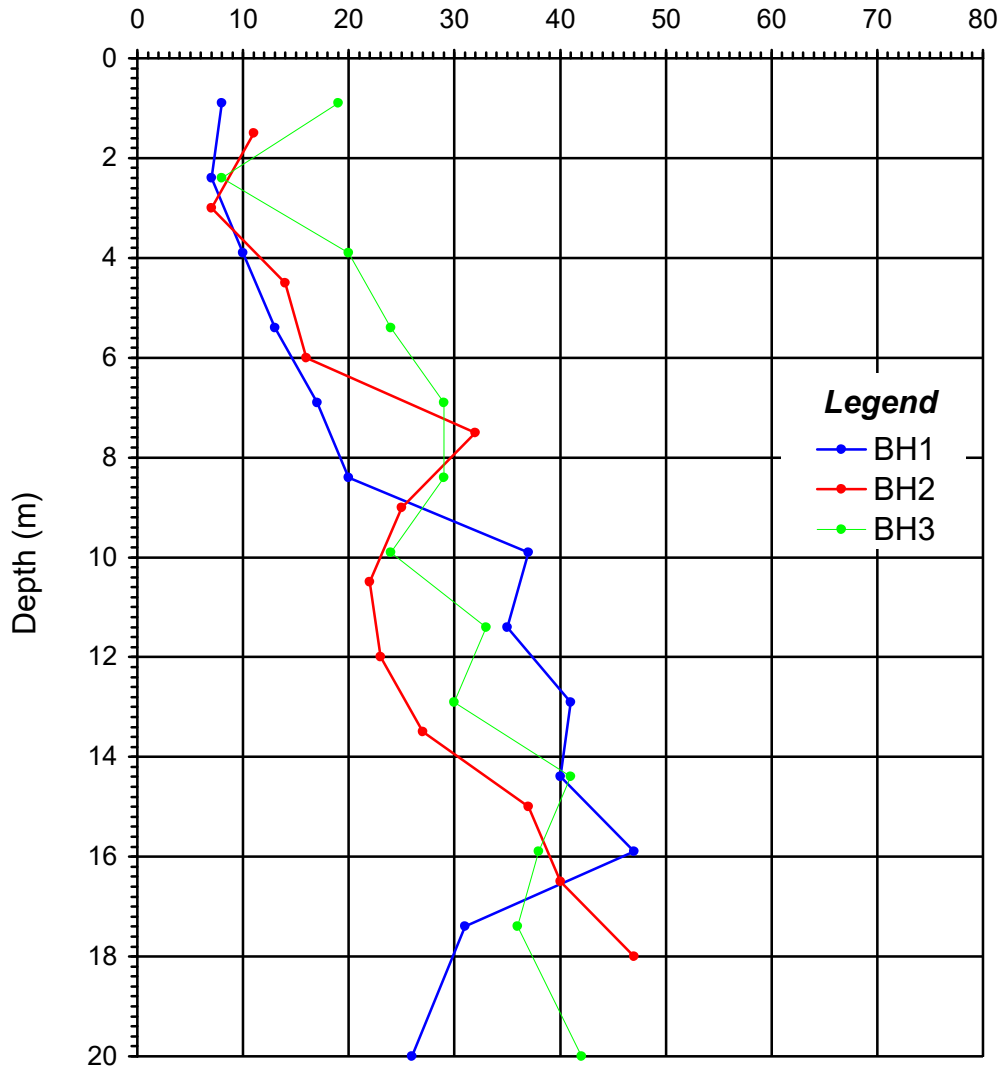
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Sheet No. : 3b

N - Values (Observed)



N - Values vs Depth Curves

(Refer paragraph no. 7.6.1)



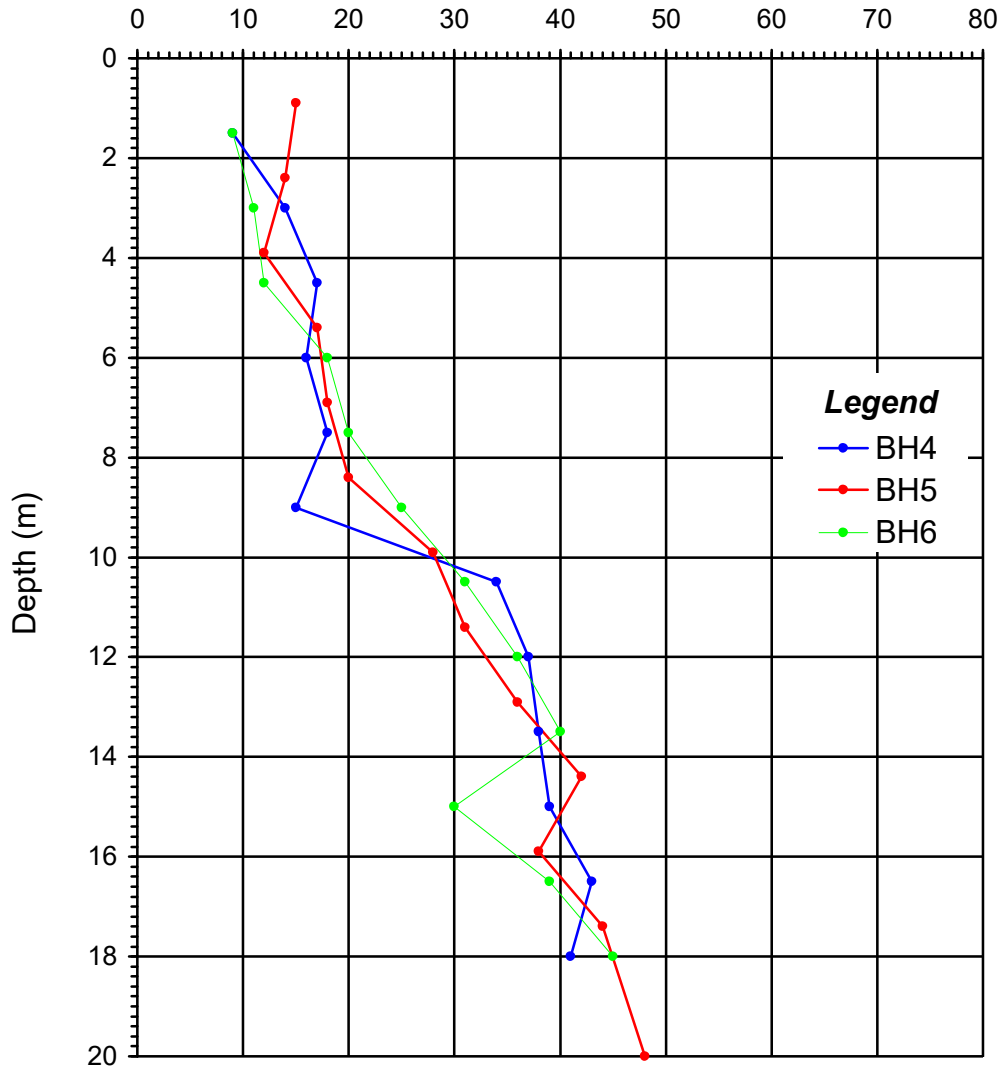
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Sheet No. : 4a

N - Values (Observed)



N - Values vs Depth Curves

(Refer paragraph no. 7.6.1)



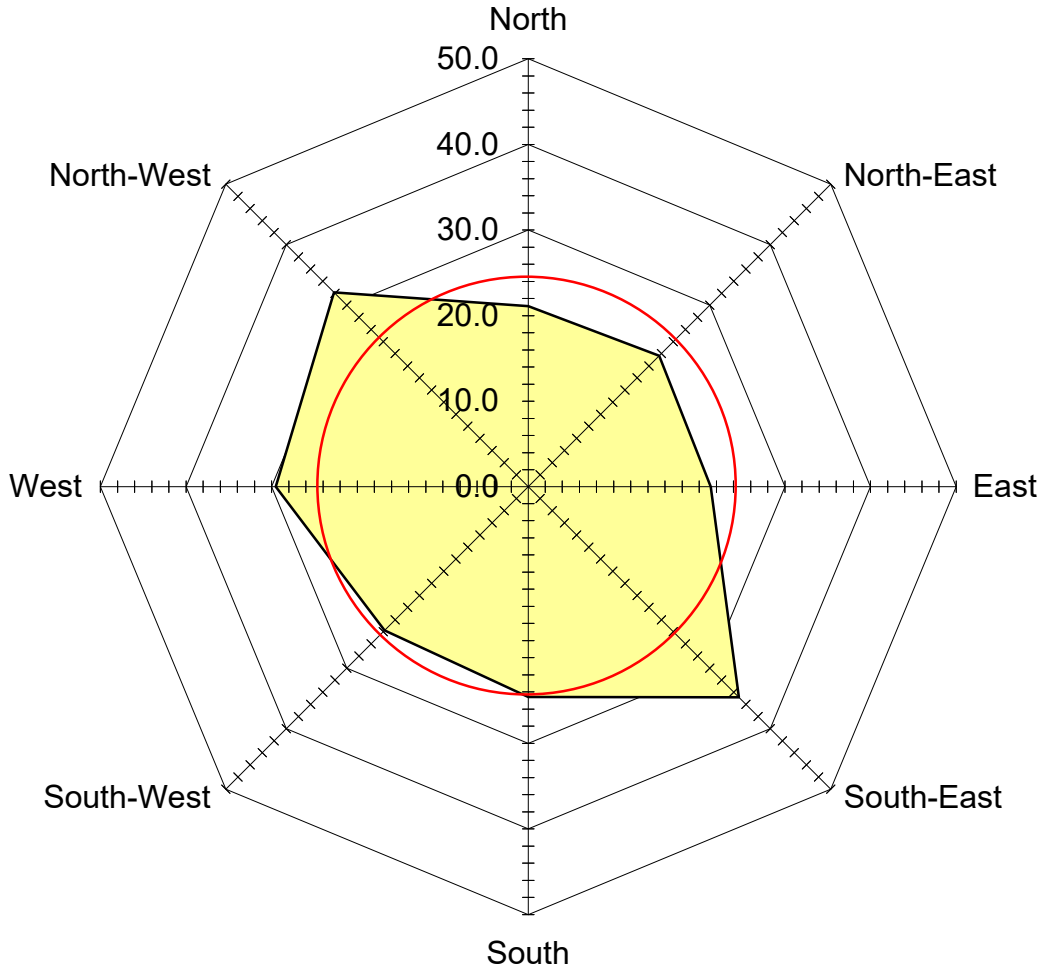
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Job No. G(D)4518

Sheet No. : 4b

Resistivity = radius of equivalent circle = 24.4 ohm-m



Polar Diagram

Electrical Resistivity Test - 1

(Refer paragraph no. 7.10.3)



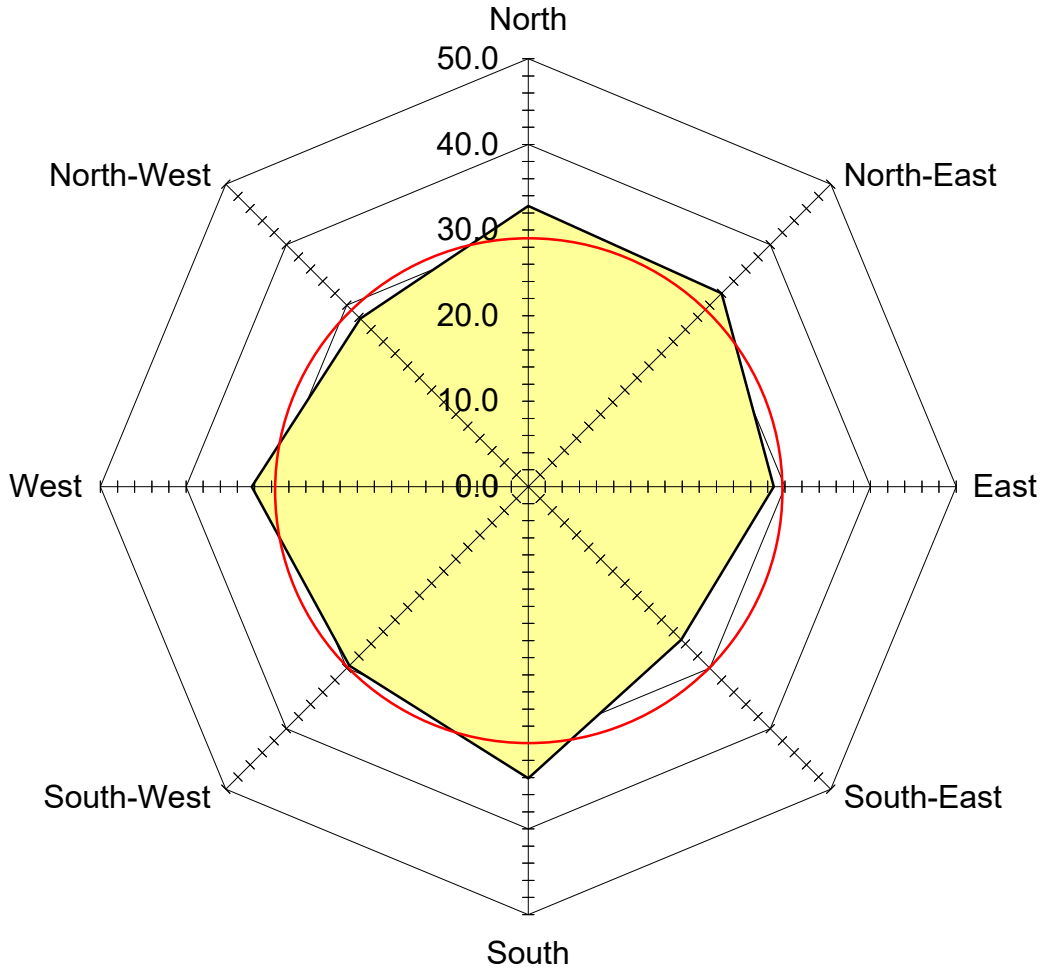
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Job No. : G(D) 4518

Sheet No. : 5a

Resistivity = radius of equivalent circle = 28.7 ohm-m



Polar Diagram

Electrical Resistivity Test - 2

(Refer paragraph no. 7.10.3)



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Job No. : G(D) 4518

Sheet No. : 5b



Trial Pit : ***TP1***
Size (m²) of Trial Pit : ***2×2 m²***
Depth (m) of Trial Pit : ***4 m***
Type of Subsoil : ***(Clayey sandy silt/sandy clayey silt with occasional gravel)***

CROSS-SECTION OF THE TRIAL PIT

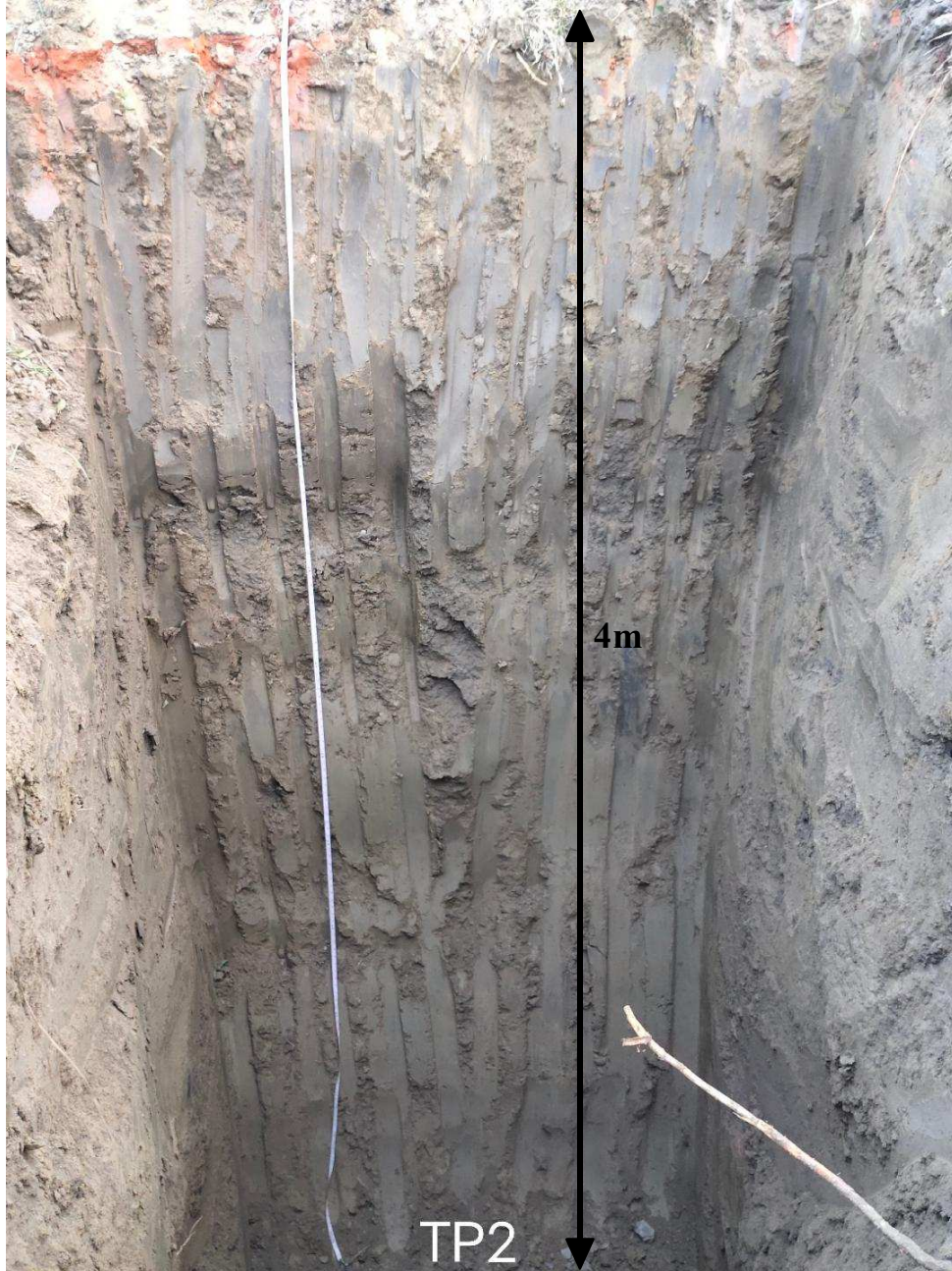


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Job No. : G(D)4518

Sheet No. : 6a



Trial Pit : ***TP2***
Size (m²) of Trial Pit : ***2×2 m²***
Depth (m) of Trial Pit : ***4 m***
Type of Subsoil : ***(Clayey sandy silt/sandy clayey silt with occasional gravel)***

CROSS-SECTION OF THE TRIAL PIT



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Job No. : G(D)4518

Sheet No. : 6b



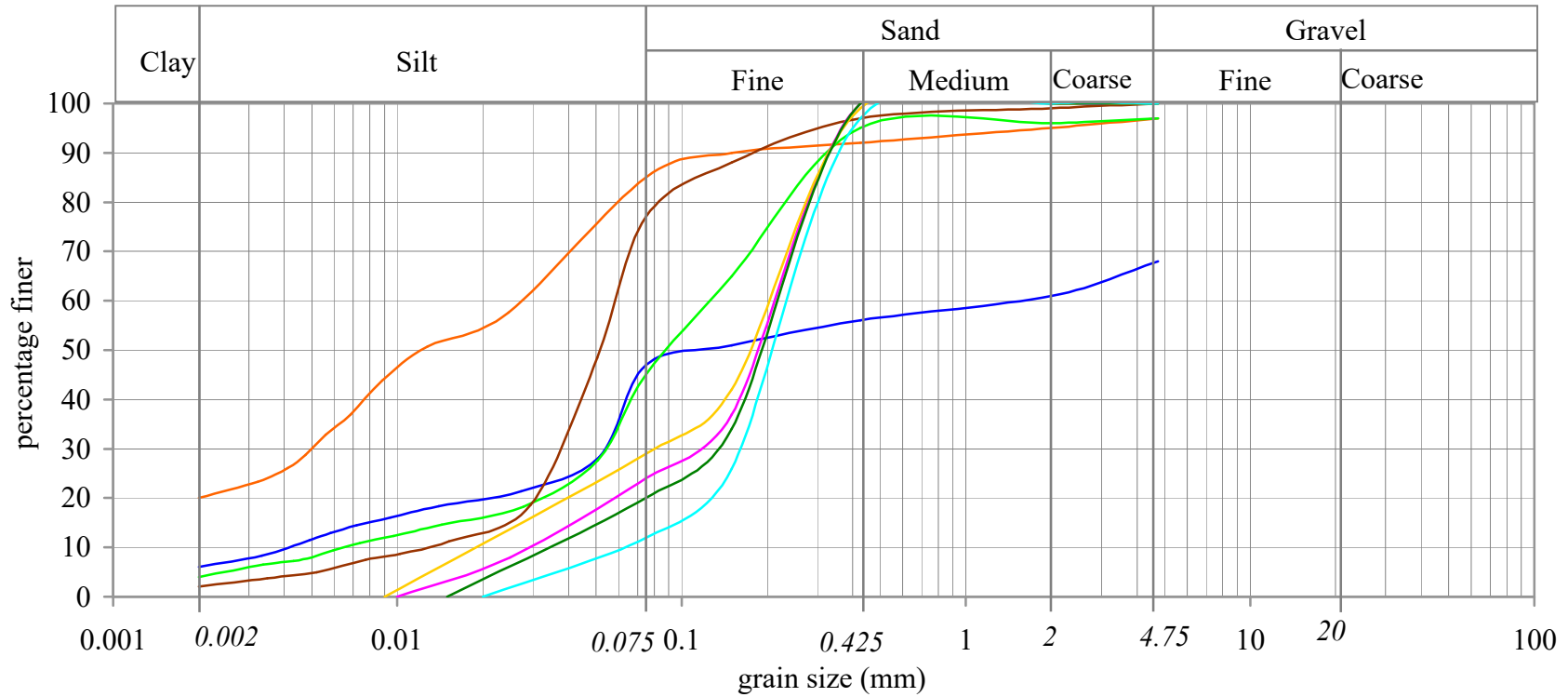
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Job No. : G(D)4518
 Sheet No. : 7a

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	32	21	41	6	1.6	0.0041	390.2
	1	2.4	Sandy clayey silt with gravel	3	12	65	20	0.027	-	-
	1	3.9	Clayey silty sand with gravel	3	52	41	4	0.13	0.0061	21.3
	1	5.4	Clayey sandy silt	0	23	75	2	0.059	0.013	4.5
	1	6.9	Silty sand	0	76	24	0	0.21	0.028	7.5
	1	8.4	Silty sand	0	71	29	0	0.21	0.019	11.1
	1	9.9	Sand with silt	0	80	20	0	0.22	0.032	6.9
	1	12.9	Sand with silt	0	88	12	0	0.23	0.061	3.8



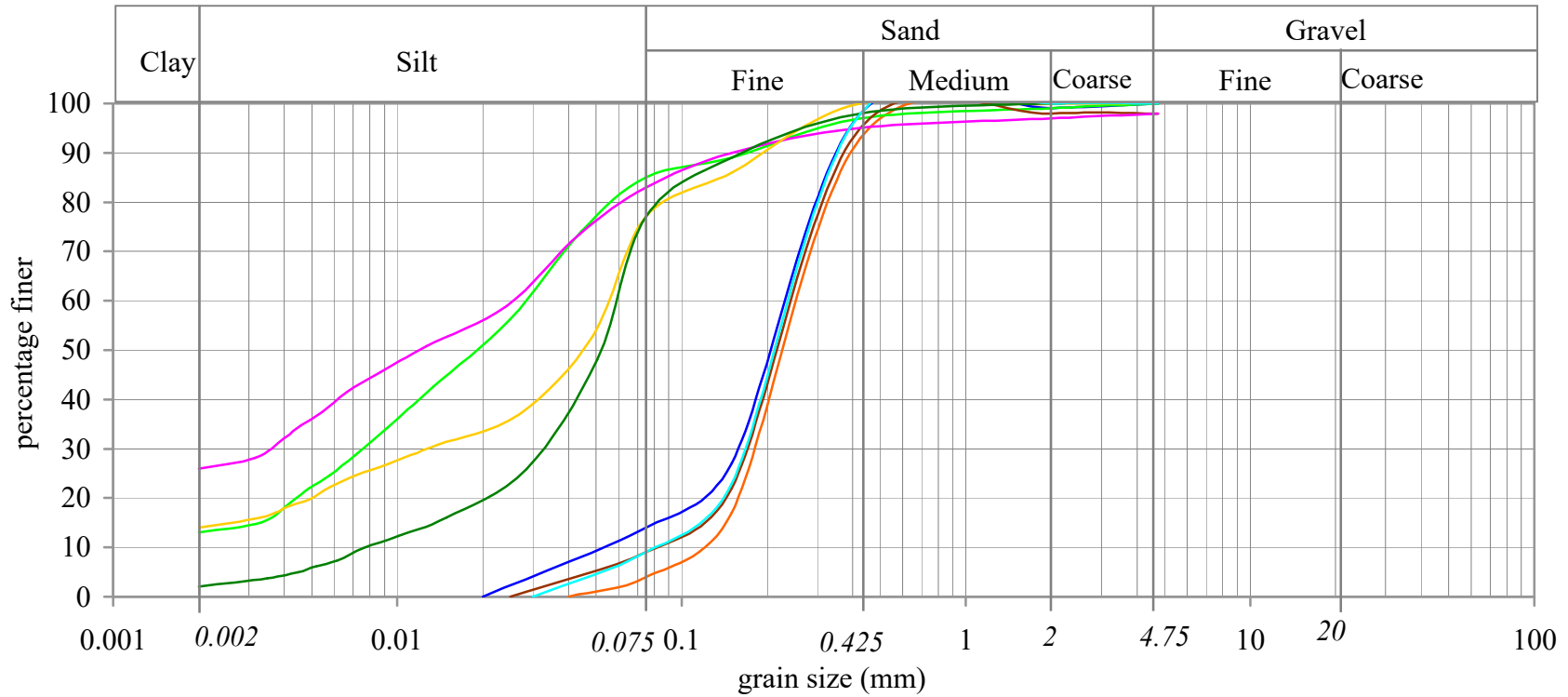
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Job No. : G(D)4518
 Sheet No. : 7b

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	14.4	Sand with silt	0	86	14	0	0.24	0.051	4.7
	1	15.9	Sand with traces of silt	0	96	4	0	0.26	0.12	2.2
	1	17.4	Clayey sandy silt	0	15	72	13	0.027	-	-
	1	20	Sand with traces of silt and gravel	2	89	9	0	0.25	0.081	3.1
	2	1.5	Sandy clayey silt with gravel	2	15	57	26	0.026	-	-
	2	3	Clayey sandy silt	0	23	63	14	0.058	-	-
	2	4.5	Clayey sandy silt	0	23	75	2	0.061	0.0075	8.1
	2	6	Sand with traces of silt	0	91	9	0	0.25	0.081	3.1



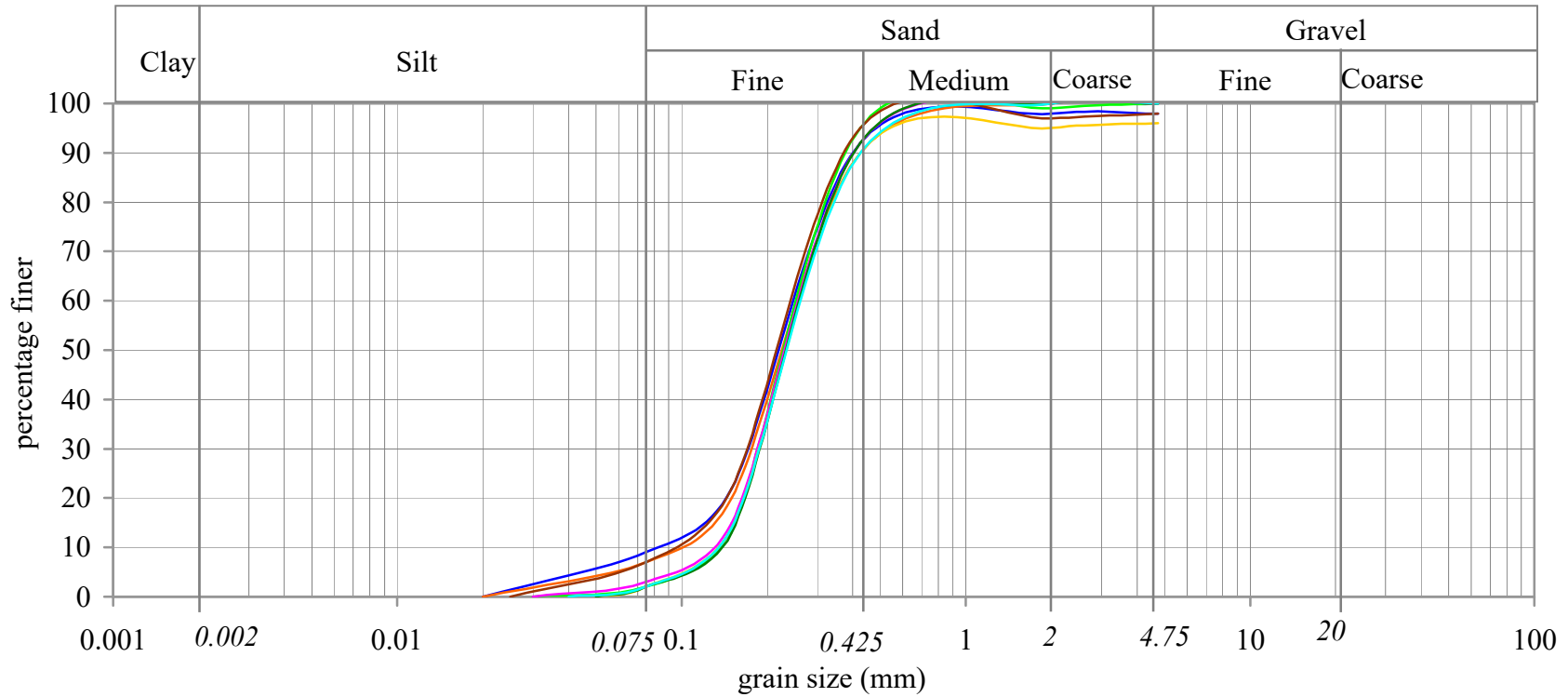
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 Sheet No. : 7c

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
	2	7.5	Sand with traces of silt and gravel	2	89	9	0	0.25	0.081	3.1
	2	9	Sand with traces of silt	0	93	7	0	0.24	0.11	2.2
	2	10.5	Sand with traces of silt	0	98	2	0	0.25	0.14	1.8
	2	12	Sand with traces of silt and gravel	2	91	7	0	0.24	0.095	2.5
	2	13.5	Sand with traces of silt	0	97	3	0	0.25	0.14	1.8
	2	15	Sand with traces of silt and gravel	4	94	2	0	0.24	0.14	1.7
	2	16.5	Sand with traces of silt	0	98	2	0	0.25	0.15	1.7
	2	18	Sand with traces of silt	0	98	2	0	0.24	0.15	1.6



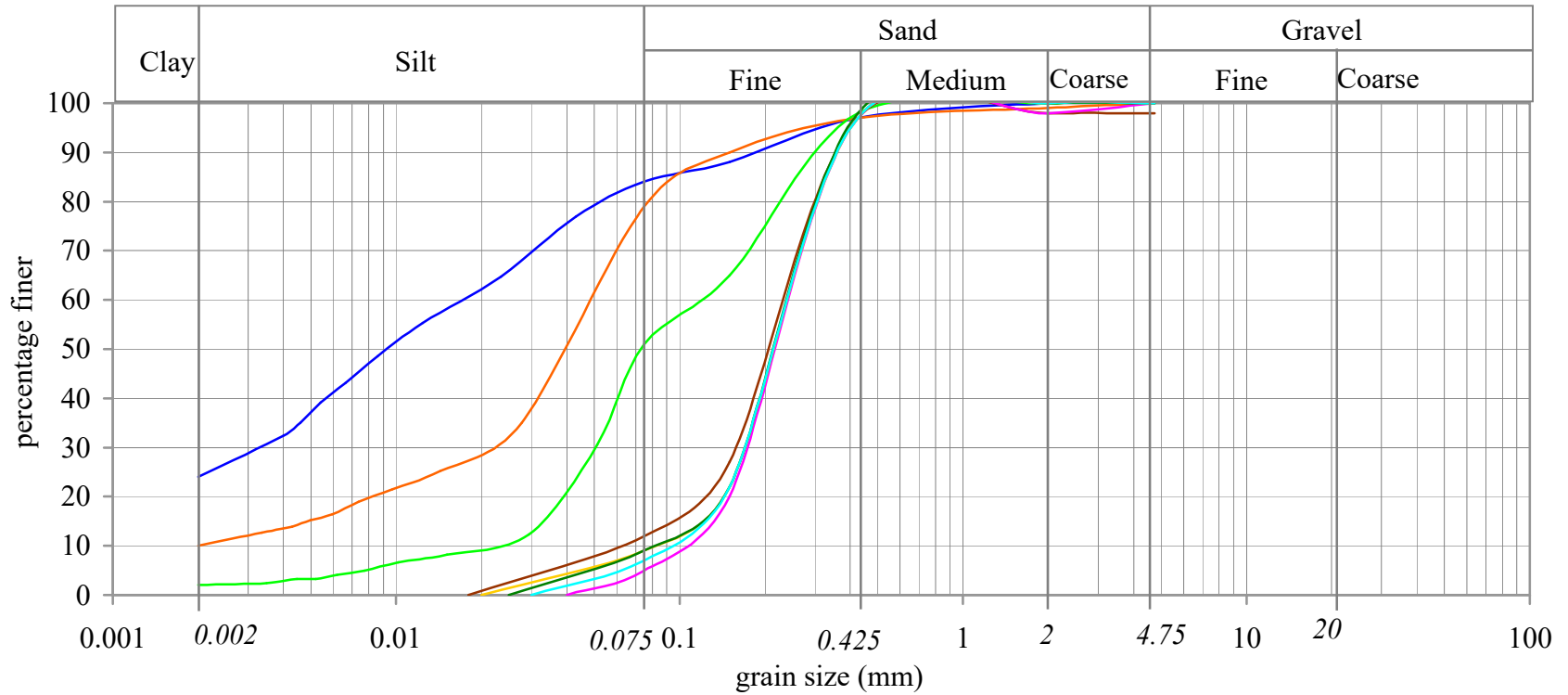
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Job No. : G(D)4518
 Sheet No. : 7d

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
	3	0.9	Sandy clayey silt	0	16	60	24	0.017	-	-
	3	2.4	Clayey sandy silt	0	21	69	10	0.049	0.002	24.5
	3	3.9	Clayey sandy silt	0	49	49	2	0.13	0.023	5.7
	3	5.4	Sand with silt and gravel	2	86	12	0	0.25	0.061	4.1
	3	6.9	Sand with traces of silt	0	95	5	0	0.24	0.11	2.2
	3	8.4	Sand with traces of silt	0	91	9	0	0.24	0.085	2.8
	3	9.9	Sand with traces of silt	0	91	9	0	0.25	0.082	3.0
	3	11.4	Sand with traces of silt	0	93	7	0	0.24	0.091	2.6



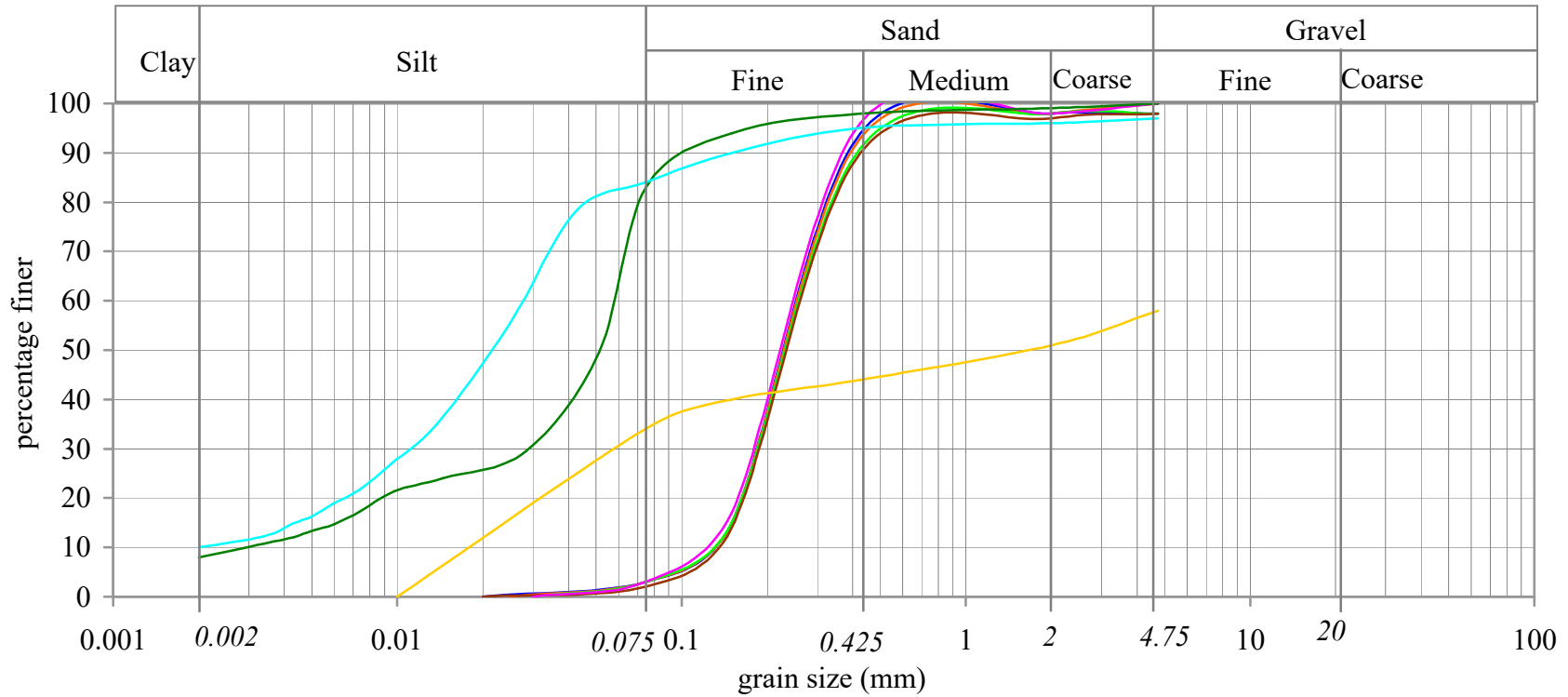
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Job No. : G(D)4518
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Grain Size Analysis Curves (refer paragraph no. 7.3.1)



Line Style	Bore hole	Depth (m)	Description	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	d ₆₀	d ₁₀	C _u
	3	12.9	Sand with traces of silt and gravel	2	95	3	0	0.25	0.14	1.8
	3	14.4	Sand with traces of silt	0	97	3	0	0.24	0.15	1.6
	3	15.9	Sand with traces of silt and gravel	2	95	3	0	0.25	0.14	1.8
	3	17.4	Sand with traces of silt and gravel	2	96	2	0	0.24	0.15	1.6
	3	20	Sand with traces of silt	0	97	3	0	0.24	0.14	1.7
	4	1.5	Gravelly sandy silt	42	24	34	0	-	0.019	-
	4	3	Clayey sandy silt	0	17	75	8	0.059	0.0028	21.1
	4	4.5	Clayey sandy silt with gravel	3	13	74	10	0.028	0.002	14.0



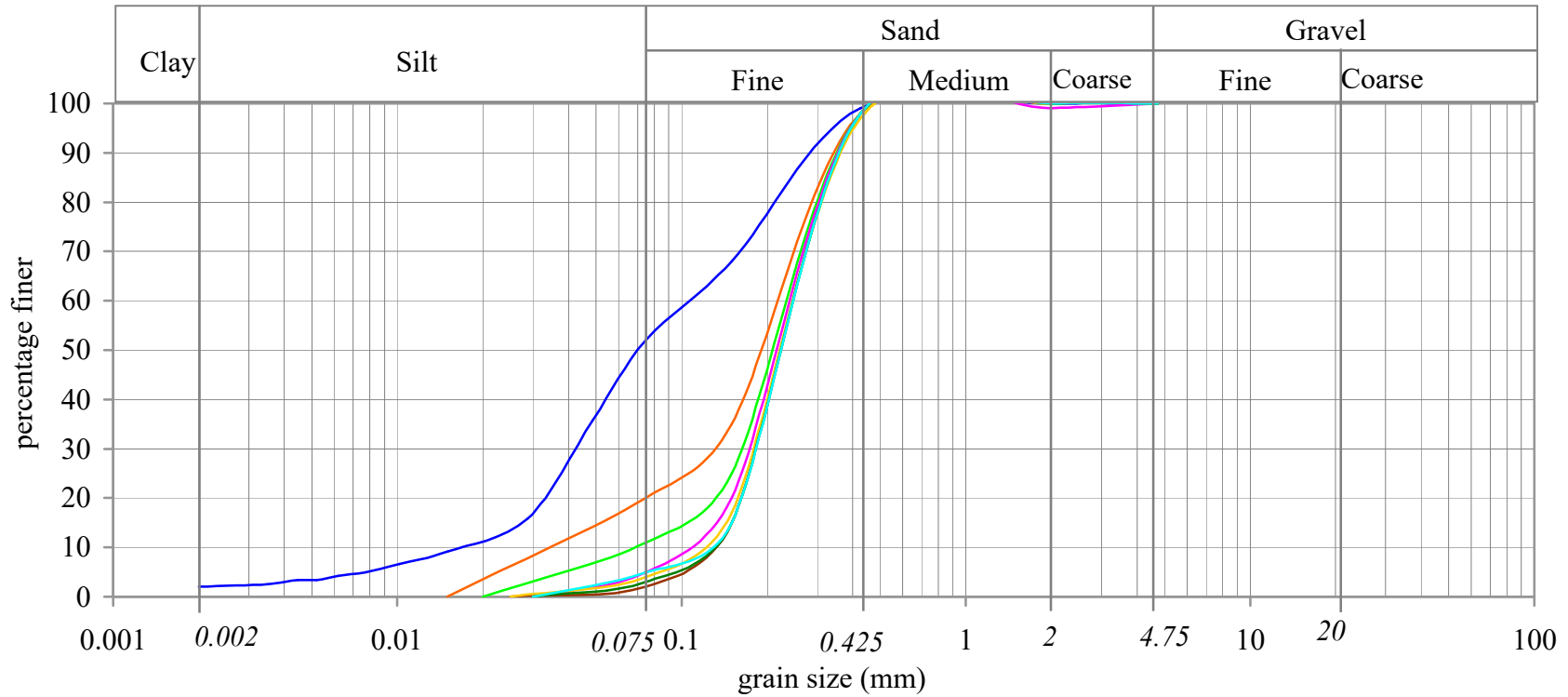
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Job No. : G(D)4518
 Sheet No. : 7f

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	6	Clayey sandy silt	0	48	50	2	0.11	0.017	6.5
	4	7.5	Sand with silt	0	80	20	0	0.22	0.035	6.3
	4	9	Sand with silt	0	89	11	0	0.24	0.068	3.5
	4	10.5	Sand with traces of silt	0	98	2	0	0.25	0.14	1.8
	4	12	Sand with traces of silt	0	95	5	0	0.24	0.11	2.2
	4	13.5	Sand with traces of silt	0	96	4	0	0.25	0.14	1.8
	4	15	Sand with traces of silt	0	97	3	0	0.24	0.15	1.6
	4	16.5	Sand with traces of silt	0	95	5	0	0.24	0.14	1.7



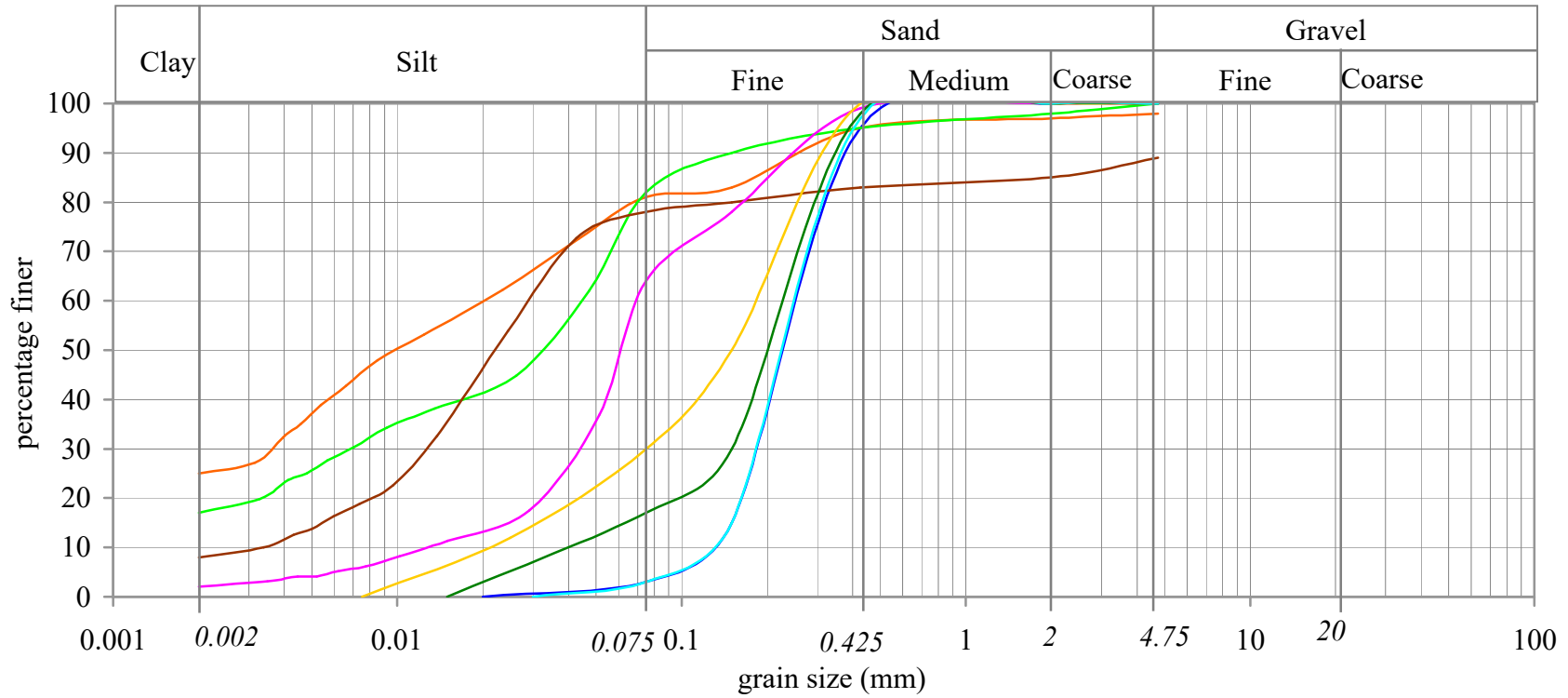
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Grain Size Analysis Curves (refer paragraph no. 7.3.1)



Line Style	Bore hole	Depth (m)	Description	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	d ₆₀	d ₁₀	C _u
	4	18	Sand with traces of silt	0	97	3	0	0.25	0.13	1.9
	5	0.9	Sandy clayey silt with gravel	2	17	56	25	0.021	-	-
	5	2.4	Clayey sandy silt	0	18	65	17	0.045	-	-
	5	3.9	Clayey sandy silt with gravel	11	11	70	8	0.029	0.0032	9.1
	5	5.4	Clayey sandy silt	0	36	62	2	0.07	0.013	5.4
	5	6.9	Silty sand	0	70	30	0	0.19	0.021	9.0
	5	8.4	Sand with silt	0	83	17	0	0.23	0.049	4.7
	5	9.9	Sand with traces of silt	0	97	3	0	0.25	0.13	1.9



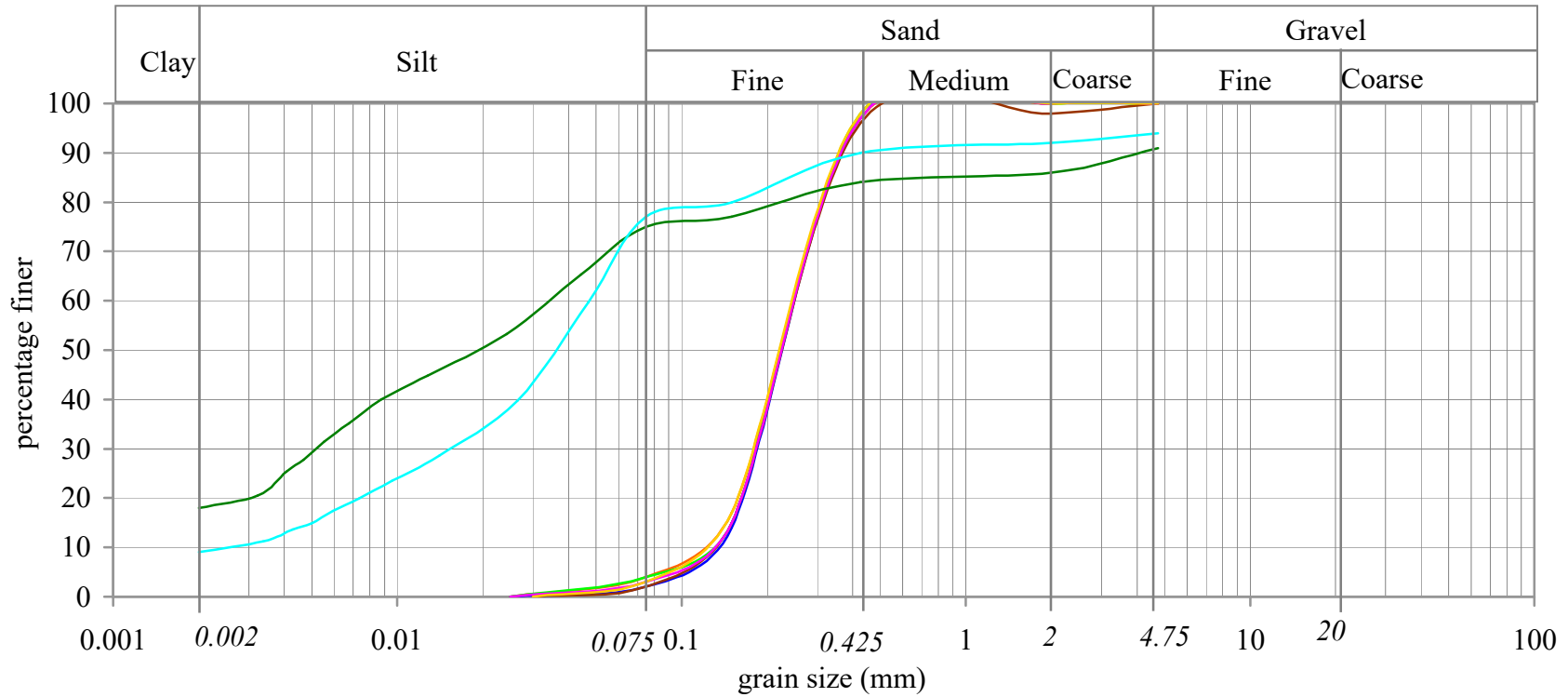
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Job No. : G(D)4518
 Sheet No. : 7h

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
	5	11.4	Sand with traces of silt	0	98	2	0	0.25	0.14	1.8
	5	12.9	Sand with traces of silt	0	96	4	0	0.24	0.13	1.8
	5	14.4	Sand with traces of silt	0	96	4	0	0.25	0.14	1.8
	5	15.9	Sand with traces of silt	0	98	2	0	0.24	0.15	1.6
	5	17.4	Sand with traces of silt	0	97	3	0	0.25	0.14	1.8
	5	20	Sand with traces of silt	0	97	3	0	0.24	0.14	1.7
	6	1.5	Sandy clayey silt with gravel	9	16	57	18	0.035	-	-
	6	3	Clayey sandy silt with gravel	6	17	68	9	0.049	0.0026	18.8



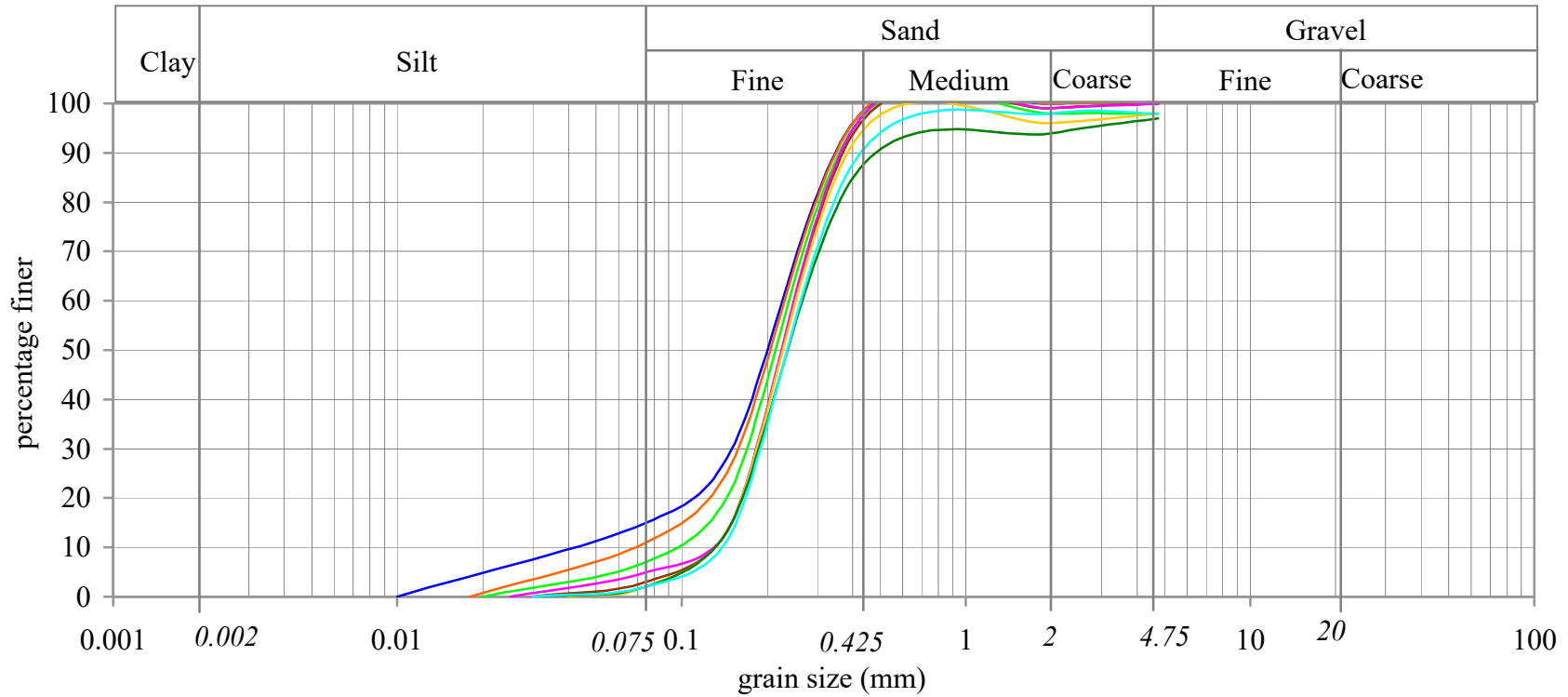
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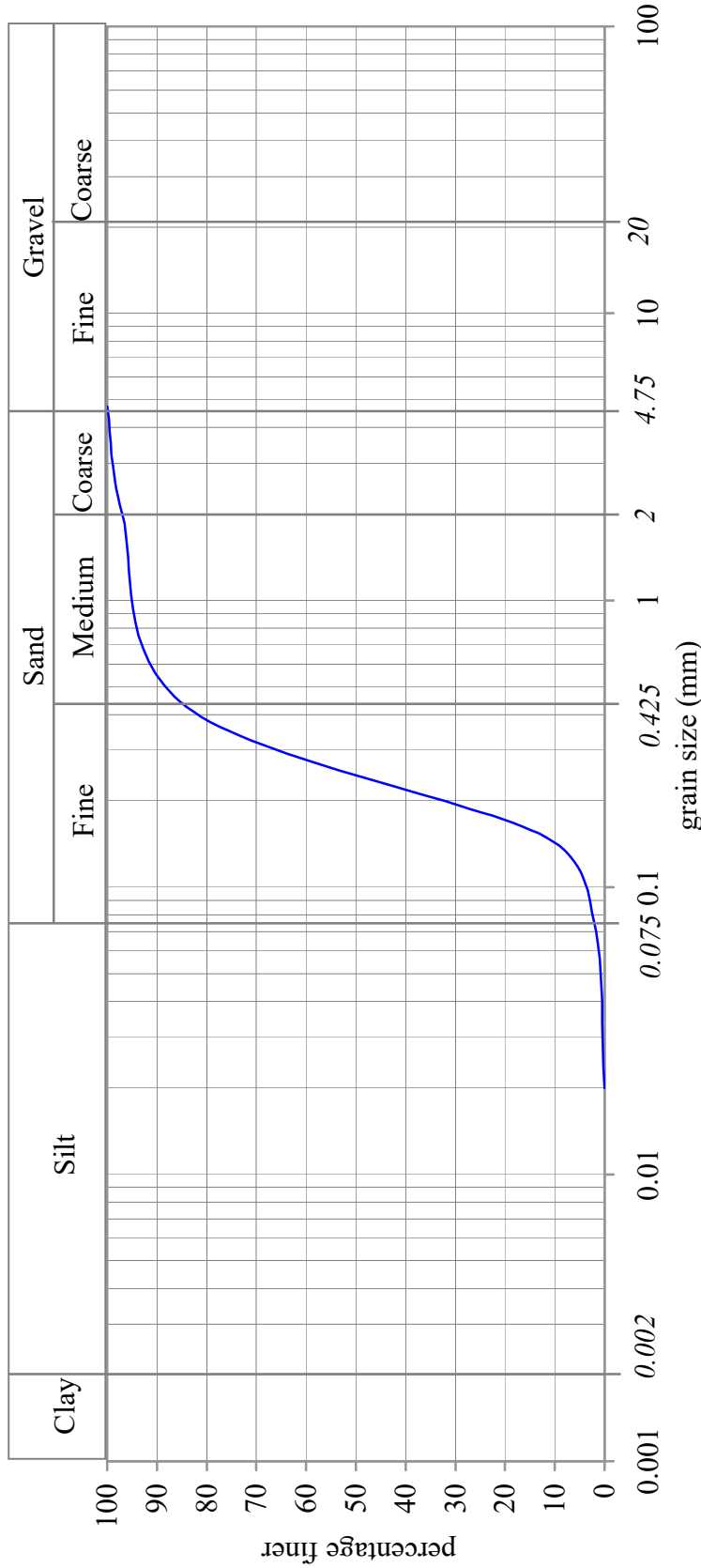
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 Sheet No. : 71

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	4.5	Sand with silt	0	85	15	0	0.23	0.041	5.6
	6	6	Sand with silt	0	89	11	0	0.25	0.068	3.7
	6	7.5	Sand with traces of silt and gravel	2	91	7	0	0.24	0.095	2.5
	6	9	Sand with traces of silt	0	97	3	0	0.24	0.13	1.8
	6	10.5	Sand with traces of silt	0	95	5	0	0.25	0.14	1.8
	6	12	Sand with traces of silt and gravel	2	96	2	0	0.25	0.13	1.9
	6	15	Sand with traces of silt and gravel	3	95	2	0	0.26	0.14	1.9
	6	16.5	Sand with traces of silt and gravel	2	96	2	0	0.27	0.14	1.9

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	18	Sand with traces of silt	0	98	2	0	0.28	0.15	1.9



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Job No. : G(D)4518

Sheet No. : 7j



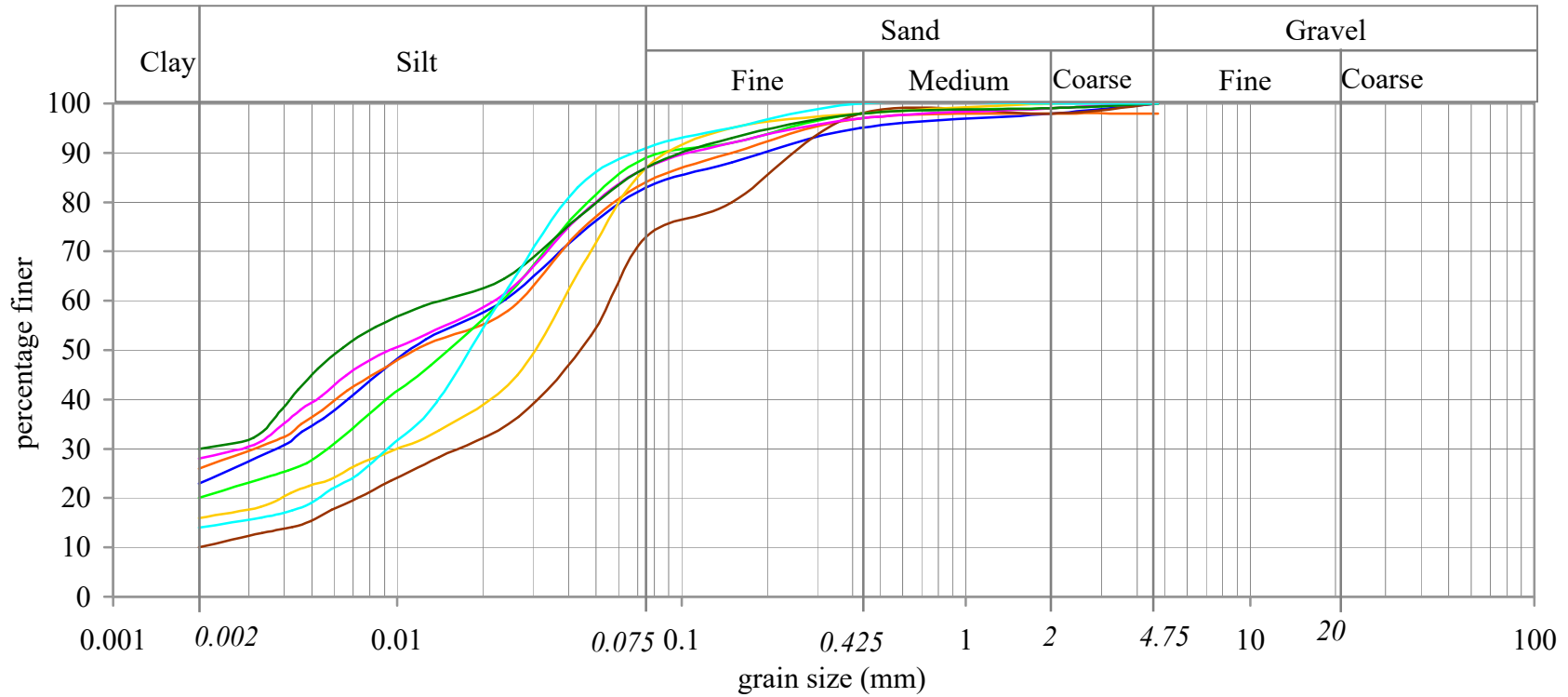
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Job No. : G(D)4518
 Sheet No. : 7K

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
Blue line	TP1	0.5	Sandy clayey silt	0	17	60	23	0.022	-	-
Orange line	TP1	1.5	Sandy clayey silt with gravel	2	14	58	26	0.027	-	-
Green line	TP1	2.5	Sandy clayey silt	0	11	69	20	0.023	-	-
Brown line	TP1	3.5	Clayey sandy silt	0	27	63	10	0.055	-	-
Magenta line	TP2	1	Sandy clayey silt	0	13	59	28	0.023	-	-
Yellow line	TP2	2	Sandy clayey silt	0	13	71	16	0.039	-	-
Dark Green line	TP2	3	Sandy clayey silt	0	13	57	30	0.015	-	-
Cyan line	TP2	4	Sandy clayey silt	0	9	77	14	0.023	-	-