GEOTECHNICAL INVESTIGATION REPORT for the Proposed Warehouse at Village Silani, Sohna, Gurugram, Haryana

EXECUTIVE SUMMARY

Values Spaces Realtors (Sohna) Pvt Ltd. West Bengal - 700012 are in the process of constructing Warehouse Buildings at Village, Silani, Sohna, Gurugram, Haryana.

The proposed structures are Warehouse buildings.

The Geotechnical investigation programme has been undertaken at the site, as per the scope of investigations, stipulated by the client. The scope of work consisted of conducting boreholes in soil strata down to 24m depth at six locations and conducting california bearing ratio test on two soil samples collected from the site.

The borehole investigations indicate that the subsoil strata consists of silty sandy soils / sandy soils down to about 4m depth below the existing ground level beyond which the subsoil strata generally consists of clayey sandy silt down to the depth investigated except beyond 17m depth down the depth investigated wherein silty sandy soils have also been encountered in between. Additionally, occasional thin layers of silty sandy soils have also been encountered between 4m and 17m depths.

The N-values indicate that, subsoil is loose to medium dense (N-values 2 - 13) down to about 3m depth below which the subsoil is medium dense (N-values 7 -52) down to the depth investigated.

Ground water table had been encountered in all the boreholes at a depth of about 1m below the existing ground level, during the period of field investigations i.e March 2023.

The assessment of the susceptibility to liquefaction of the subsoil at site indicate that the subsoil down to about 4m 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.

The following safe pile capacities have been recommended for various diameters for 10m and 15m 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*
450	10	20	10	0.4	1.1
	15	35	15		
600	10	35	15	0.7	2.1
	15	55	25		
800	10	50	20	1.4	3.9
	15	90	40		

However, *for boundary wall and also minor structures* at ground level, Isolated/ Strip Footings, have also been recommended at a depth of 1.5m below the existing ground level, net allowable bearing pressures varying between 4 - 6 t/m^2 have been recommended for various widths of foundations for an allowable settlement of 50mm.

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.

For Isolated/ Strip Footings, 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.

1.0 INTRODUCTION

1.1 Values Spaces Realtors (Sohna) Pvt Ltd., P-40, New CIT Road, 40 Lu-Husn, Sarani, 4th Floor, Kolkata, West Bengal - 700012 are in the process of constructing Warehouse Buildings at Village, Silani, Sohna.

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 investigations have been carried out as per the authorization of authorised signatory of Values Spaces Realtors (Sohna) Pvt Ltd., vide their work order reference no. WOVSRS2200001 dated 13th March 2023. This authorization has been given in response to our offer no. NCD/Q/CCIL/128C/2022 dated 3rd March 2023.

2.0 PROJECT DETAILS

2.1 Site Location

2.1.1 The site for the proposed project is located at Village Silani, Tehsil Sohna, District Gurugram, Haaryana and is situated at a distance of about 10 km from Sohna towards Palwal, Haryana.

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 Photographs showing the view of the site and borehole under progress is given in fig. 1b of the report.

2.2.3 Maximum level differences of about 0.5m had been observed at the site, during the period of field investigation and the general level of the site had been observed to be about 0.5m below the near by main road level.

2.2.4 The boundaries of the site had been observed to be demarcated with boundary barbed wire fencing along its periphery.

2.2.5 High tension electric line had been observed be passing over the plot from eastern side to southern side of the plot.

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

2.2.7 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 the zone of high 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 Warehouse Buildings.

2.4.2 The structures are understood to be framed ones and that the construction is proposed 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 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 24m depth at six locations.

b) Conducting laboratory california bearing ratio test inclusive of modified proctor density test on two soil samples collected from the site.

c) Conducting relevant laboratory tests on soil 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 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 20th March 2023 and 28th March 2023.

5.1.2 A schematic site plan showing the test locations is given in fig. 1a.

5.2 Boreholes

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

5.2.2 Boreholes, BH1 to BH6 had been progressed down to the stipulated depth of 24m 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.

5.2.5 Undisturbed soil samples were recovered by thin walled tubes conforming to IS : 2132. These tubes had an area ratio of less then 10%.

5.2.6 The diameter of undisturbed soil samples was 50mm and the length was 45cm.

5.2.7 The ends of sample tubes were sealed by wax to prevent loss / ingress of moisture. Disturbed soil samples were enclosed in polythene bags.

5.2.8 The samples thus recovered were transported to the laboratory for testing purposes.

5.2.9 Ground water table had been encountered in all the boreholes at a depth varying between 0.8m and 1.3m below the existing ground level, during the period of field investigation i.e. March 2023.

6.0 LABORATORY INVESTIGATIONS

6.1 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

6.2 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) Atterberg limits namely Liquid Limit and Plastic Limits

d) Natural Density and Water Content

e) Triaxial compression tests

6.3 Chemical Analysis

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

6.4 Modified Proctor Density Tests

6.4.1 The modified proctor density tests are conducted to determine the maximum dry densities and corresponding optimum moisture contents of the soil samples. The remoulded soil samples for the laboratory CBR tests have to be prepared at these maximum dry densities and optimum moisture contents.

6.4.2 The modified proctor density test is conducted on a representative portion of air dried soil sample finer than 20mm.

6.4.3 The test involves first mixing thoroughly the air dried soil sample with a fixed known amount of water and filling the mixed soil in a mould of 1000cm^3 capacity with base plate attached, in five different layers of approximately equal weight with simultaneous compaction of each layer by giving 25 blows from a standard 4.9kg hammer falling through a standard 45cm height above the soil surface with the blows being distributed uniformly over the surface of each layer.

6.4.4 The density and the water content of the soil in the mould is determined. This process is repeated by gradually increasing the water content of the soil by adding fixed quantities of water till the measured densities after compaction show a decrease with increase in water content.

6.4.5 The maximum dry density and optimum moisture content of the soil is then determined from a plot of the measured dry density vs the corresponding measured water content of the soil.

6.5 Laboratory California Bearing Ratio Tests

6.5.1 The soil samples for the determination of California Bearing Ratio had been collected from the specified locations (as indicated in fig. 1a) from a depth of 0.5m below the existing ground level.

6.5.2 The soil samples for the laboratory CBR tests are prepared in a standard CBR mould by compacting the soil having the optimum moisture content, to the maximum dry density obtained from the modified proctor density tests. To prepare such a soil sample for the laboratory CBR test, oven dried soil sample passing through 20mm of about 5kg weight is taken filled into the CBR mould in five layers by giving 55 blows for each layer from a

standard 4.9kg hammer falling through a standard height of 45cm. After preparation of the soil sample, the CBR mould containing the soil sample is kept submerged in water under a surcharge weight of 5kg for a period of 96 hours to facilitate soaking of the soil sample.

6.5.3 After 96 hours of soaking, the CBR mould containing the soil sample is taken out of the water and placed on a load frame wherein a plunger of 50mm dia is made to penetrate into the soil sample in the CBR mould at a displacement rate of 1.25mm/min. The load required to penetrate the plunger into the soil, is recorded corresponding to different penetration depths of the plunger.

6.5.4 A curve of loading intensity vs penetration is plotted. From the analysis of this curve the CBR values are determined as given below :

$$CBR\ value = \frac{P_T}{P_S} \times 100$$

where P_t = corrected loading intensity corresponding to the chosen penetration from the load penetration curve for the test

P_s = standard loading intensity for the same depth of penetration

7.0 RESULTS & ANALYSIS

7.1 Presentation of Results

7.1.1 The results of the borehole 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 : Silty sand with occasional clay and gravel

b) Stratum - II : Clayey sandy silt with occasional gravel/ sandy clayey silt

c) Stratum - III : Sand with silt and occasional gravel

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 - 5 8 - 11	5 - 8 11 - 18.4 21 - 24	18.4 - 21
2	8.4 - 9.9 17.4 - 20.4	3.9 - 8.4 9.9 - 17.4 20.4 - 24	0 - 3.9
3	0 - 3.7 16.8 - 18 21 - 24	3.7 - 16.8	18 - 21
4	0 - 2 5.8 - 6.9 10.2 - 11.4 13.3 - 14.4 17 - 24	4.3 - 5.8 6.9 - 10.2 11.4 - 13.3 14.4 - 17	2 - 4.3
5	2 - 3.7 8.2 - 9 17 - 21	0 - 2 3.7 - 8.2 9 - 17 21 - 24	N.E.

BH. No.	Strata (depth in m : from : to)		
	Stratum -I	Stratum -II	Stratum - III
6	0 - 2.4 17.2 - 20.4	3.9 - 17.2 20.4 - 24	2.4 - 3.9

N.E. : not encountered

7.2.3 The above results show that :

a) Stratum - I consisting predominantly of sandy soils with significant percentages of silt, has been encountered in random layers down to about 5m depth and also beyond 17m depth down to the depth investigated. However, this stratum has also been encountered in occasional thin layers between 5m depth and 17m depth below the existing ground level.

b) Stratum - II consisting predominantly of silty soils with varying percentages of clay and sand, has been encountered between 4m and 18m depths and also beyond a depth of about 21m down to the depth investigated i.e. 24m below the existing ground level.

c) Stratum - III consisting predominantly of sandy soils, has been encountered in occasional thin layers down to about 4m depth and also between 18m and 21m depths below the existing ground level.

7.3 Soil Composition

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

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

a) Stratum - I : Silty sand with occasional clay and gravel

BH. No.	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
1	0 - 2	69 - 75	24 - 31	0
2	0 - 2	25 - 55	30 - 33	0 - 10
3	2	47 - 74	24 - 35	0 - 16
4	0 - 4	59 - 79	21 - 37	0
5	0 - 11	51 - 68	28 - 44	0 - 5
6	0 - 20	56 - 63	24 - 32	0

b) Stratum - II : Clayey sandy silt with occasional gravel/sandy clayey silt

BH. No.	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
1	2 - 10	18 - 39	42 - 75	11 - 23
2	0 - 12	21 - 41	52 - 70	9 - 15
3	0 - 21	7 - 31	48 - 65	9 - 27
4	0 - 6	3 - 34	54 - 66	10- 40
5	0 - 10	6 - 33	51 - 75	8 - 32
6	0 - 9	10 - 41	47 - 71	8 - 12

c) Stratum - III : Sand with silt and occasional gravel

BH. No.	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
1	0	86	14	0
2	0	82 - 83	17 - 18	0
3	5	81	14	0
4	0	81	19	0
5		N.E.		
6	8	77	15	0

N.E. : not encountered

7.3.3 The above results indicate that :

a) Stratum - I consists of about 25% to 79% of sand and 21% to 44% of silt with occasional clay and gravel.

b) Stratum - II consists of about 42% to 75% of silt, 3% to 41% of sand with rest of the soil matrix consisting of clay and gravel.

c) Stratum - III consists of an average of about 85% of sand and 15% of silt with occasional gravel.

7.4 Natural Density and Water Content

7.4.1 The natural bulk densities, water contents and dry densities in the six boreholes vary as follows:

BH. No.	Bulk Density (g/cm^3)	Water Content (%)	Dry Density (g/cm^3)
1	1.96 - 2.07	18 - 24.4	1.60 - 1.75
2	1.86 - 2.11	19.5 - 23.9	1.56 - 1.76
3	1.87 - 2.12	18.9 - 24.6	1.55 - 1.76
4	1.90 - 2.09	17.9 - 28.6	1.55 - 1.77
5	1.92 - 2.14	18.2 - 25.8	1.56 - 1.82
6	1.91 - 2.16	17.4 - 27.0	1.52 - 1.73

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 The above results indicate that the subsoil is in a loose to medium dense state down to about 3m depth below which the subsoil is in a medium dense state down to the depth investigated.

7.5 Atterberg Limits

7.5.1 The Atterberg limits indicate that the subsoil is non-plastic down to about 4m depth beyond which subsoil is generally low plastic down to the depth investigated except beyond 17m depth down to the depth investigated wherein random layers of non plastic soil have also been encountered. Additionally, occasional thin layers of non plastic soil have also been encountered between 4m and 17m depths.

7.6 Standard Penetration Test Values (N-values)

7.6.1 The observed Standard Penetration Test values (N-values) vary between 4 and 52 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 3m depth below which the subsoil 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.

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 Modified Proctor Density Tests

7.9.1 Modified Proctor density tests have been conducted on the samples collected for the CBR tests from the specified locations, for the purpose of preparation of CBR samples.

7.9.2 The results of the Modified Proctor density test have been presented in the form of plots of dry density vs water content in figs. 5a & 5b.

7.9.3 The maximum dry densities and corresponding optimum moisture contents (OMC) determined from the above given tests for the various samples are as follows :

Test No.	Maximum Dry Density (g/cm^3)	Optimum Moisture Content (%)
1	9.4	2.03
2	9.6	2.03

7.9.4 The results of Modified Proctor density indicate that the top soil at the site has maximum dry density or Modified Proctor density varying between 9.4 g/cm^3 and 9.6g/cm^3 for optimum moisture content of 2.03% .

7.10 Laboratory CBR Tests

7.10.1 The results of the laboratory CBR tests conducted on soil samples prepared at the Modified Proctor densities and soaked for 96 hours, have been presented in the form of plots of load intensity vs penetration in figs. 6a & 6b.

7.10.2 The laboratory CBR values corresponding to 2.5mm and 5mm penetration respectively, obtained after due corrections to the load intensity vs penetration plot, are as follows :

CBR No.	CBR 2.5mm	CBR 5mm
1	25.7	26.7
2	12.9	16.2

7.10.3 The above results indicate that the laboratory CBR values corresponding to 2.5mm penetration are lower than the laboratory CBR values at 5mm penetration. Hence, lower of the two values may be adopted for design purposes.

7.11 Chemical Analysis

7.11.1 The results of the chemical analysis conducted on water samples collected from the boreholes and a bore well existing at the site, for determining the presence of any harmful salts which can have adverse effects on concrete construction, are as follows :

Borehole no.	pH value	Chloride Content (ppm)	Sulphate Content (ppm)
BH1	7.5	508	371
BH3	7	>1000	1030
BH5	8.5	>1000	618
BH6	7.5	>1000	948

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

7.11.2 The above results of chemical analysis on water samples have exceeded the IS limits. Hence, the water encountered in the boreholes should not be used for concrete construction work.

7.12 *ANALYSIS OF LIQUEFACTION SUSCEPTIBILITY*

7.12.1 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.

7.12.2 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%.

7.12.3 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.

7.12.4 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.

7.12.5 From the above analysis, it can be observed that subsoil down to about 12m depth is susceptible to liquefaction.

7.12.6 However, as the subsoil strata beyond 4m depth down to the deeper depths generally consists of clayey sandy silt of low to medium plastic consistency even the water table is at shallow depth, susceptibility to liquefaction in this stratum can be considered as almost nil.

7.12.7 Considering the above and also that the site is located in Seismic Zone - IV of seismic zoning map of India, the subsoil down to about 4m depth has been 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.

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

8.2.3 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 3m depth below which the subsoil is medium dense state down to the depth investigated.

8.2.4 As mentioned in the earlier sections, the subsoil strata down to about 4m depth has been considered to be susceptible to liquefaction.

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

8.2.6 However, boundary wall and minor structures at ground level, can be supported over ***Isolated / Strip Footing***.

8.3 Depth of Pile Foundation

8.3.1 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.

8.3.2 Taking the above into consideration, the pile foundations for the proposed structures shall be made to rest at a depth greater than 12m below the existing ground level. Accordingly, considering the cut-off level of the piles as 2m below the existing ground level and effective length of piles of 10m and 15m, the founding levels of the piles will be about 12m and 17m respectively, below the existing ground level.

8.3.3 The soil encountered at the founding levels of the pile foundations will either be ***Yellowish brown clayey sandy silt or silty sand.***

8.4 Pile Capacities

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

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

S. No.	Parameter	Value/s
1	Effective length (m)	10 & 15
2	Cohesion (kg/cm²)	0.1
3	Angle of shearing resistance	24° & 25°
4	Submerged density (g/cm³)	0.8
5	SPT Value at pile tip	15 & 20
6	Factor of safety	2.5

8.4.3 Considering the above parameters, the following safe pile capacities have been recommended for various diameters for 10m and 15m 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*
450	10	20	10	0.4	1.1
	15	35	15		
600	10	35	15	0.7	2.1
	15	55	25		
800	10	50	20	1.4	3.9
	15	90	40		

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

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

8.4.6 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.

8.5 Special Note

8.5.1 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.

8.6 Depth of Isolated/ Strip Footings for Boundary Wall

8.6.1 The minimum depth of shallow foundations depends upon the following factors :

a) Top filled-up strata / loose soil, if any

b) Adequate depth of soil above founding level, to ensure mobilization of full safe bearing capacity

c) Adequate depth of soil strata below founding level of requisite strength to mobilize the safe bearing capacity

8.6.2 The results of the investigations have indicated that the subsoil is in a loose to medium dense state down to about 3m depth below which the subsoil is in a medium dense state down to the depth investigated.

8.6.3 Considering the above, the foundations for the boundary wall can be placed at a depth of ***1.5m below the existing ground level***.

8.6.4 The soil available at the founding level will be ***Yellowish brown silty sandy soil / sandy soil .***

8.7 Allowable Bearing Pressure for Boundary Wall

8.7.1 Allowable bearing pressure depends upon the allowable settlement. Allowable settlements of 50mm has been considered to evaluate the allowable bearing pressures for ***Isolated/Strip Footings***.

8.7.2 Allowable bearing pressure has been evaluated by :

a) Shear failure criterion using average soil data

b) Settlement criterion taking SPT values

8.7.3 On the basis of the above analysis, the following recommendations regarding the net allowable bearing pressure are being made :

Net allowable bearing pressures (A.B.P.) for various widths of Isolated/Strip Footings for an allowable settlement of 50mm

Width of foundation (m)	*1.5*	*3*	*>4.5*
Net Allowable Bearing Pressure (t/m^2)	*4*	*5*	*6*

8.8 Note

8.8.1 As mentioned in the earlier sections, the subsoil strata down to about 4m depth has been considered to be susceptible to liquefaction. Hence, shallow foundations are not feasible. However, the above allowable bearing pressures have been given considering that in the event of an earthquake, there is a possibility that the foundations may under go differential settlements which may cause distress to the boundary wall and develop cracks. In such a case repair/ reconstruction of the boundary wall may have to be taken up accordingly

9.0 RECOMMENDATIONS

9.1 Type of Foundations

a) *Straight Bored Pile Foundations*

b) *Isolated/ Strip Footings (for Boundary wall and Minor Structures at ground level)*

9.2 Depth of Foundations

a) ***For Pile Foundations***

Considering the cut-of level of the piles as 2m below the existing ground level and for effective lengths of pile of 10m and 15m, the piles shall rest at a depth of about 12m and 17m respectively, below the existing ground level.

b) ***For Isolated/ Strip Footings (for Boundary Wall)***

1.5m below the existing ground level

9.3 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*
450	10	20	10	0.4	1.1
	15	35	15		
600	10	35	15	0.7	2.1
	15	55	25		
800	10	50	20	1.4	3.9
	15	90	40		

9.4 Allowable Bearing pressure

9.4.1 For boundary wall, Net allowable bearing pressure (A.B.P.) for various widths of Isolated/Strip Footings for an allowable settlement of 50mm

Width of foundation (m)	*1.5*	*3*	*>4.5*
Net Allowable Bearing Pressure (t/m^2)	*4*	*5*	*6*

9.4.2 The above allowable bearing pressures have been given considering that in the event of an earthquake, there is a possibility that the foundations may under go differential settlements which may cause distress to the boundary wall and develop cracks. In such a case repair/ reconstruction of the boundary wall may have to be taken up accordingly.

9.5 Notes

9.5.1 As the subsoil down to about 4m 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.

9.5.2 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.

9.6 Special Notes

9.6.1 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.

9.6.2 For Isolated/ Strip Footings, 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.

9.7 Appendices

9.7.1 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.

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

9.7.3 An appendix sheet showing the typical procedure for Liquefaction Analysis has been given in Appendix - C of this report.

9.7.4 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 - D.

9.8 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.

9.9 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.

Dr. N. Santosh Rao

Technical Director

*For **Nagadi Consultants Pvt. Ltd***

Appendix -A

(refer para no. 10.6.1)

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' = 10m.

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 15.

A.1.5 For determining the friction capacity, the average angle of shearing resistance ϕ has been taken as 24°.

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

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

D = diameter of pile shaft = 600 mm

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

Q_{bu} = 42.4 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 = 0.1 kg/cm^2

α = adhesion factor = 0.75

K = coefficient of earth pressure = 1

P_{Di} = effective overburden pressure at for the ith layer = $\gamma.d_i$

γ = submerged unit weight of soil below water table = 0.8 g/cm^3

d_i = depth of the ith layer from ground level

A_{si} = surface area of the pile stem in the ith layer

δ = angle of wall friction between pile and soil

= ϕ = angle of shearing resistance of the soil = 24^o

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/cm^3.

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 :

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

For $L_1 >$ *15 times the pile diameter D*

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

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

Q_{fu} = 43.2 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 = 34.2 tons say 35 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,

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

Q_{su} = 15.8 tons say 15 tons

Appendix -B

(refer para no. 10.6.2)

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 $\eta_h = 1.2 \times 10^3$ kN/m^2 or 0.12 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 4m 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 2m below cut off level (i.e. 2m below the existing ground level) will behave like cantilever (i.e. e =2m).

B.2 Stiffness Factor and Depth of Fixity

B.2.1 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:

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

Stiffness factor = T = 2.71 m

B.2.2 The equivalent cantilever length or in other words the depth of fixity ($\mathbf{L_e}$) 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)

$\mathbf{L_e = 1.9 \times T = 1.9 \times 2.71 = 5.14m}$ (for free head condition)

$\mathbf{L_e = 2.2 \times T = 2.2 \times 2.71 = 5.95m}$ (for fixed head condition)

B.2.3 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.2.4 For calculation purposes, the concrete of pile has been considered to be of M30 grade.

B.2.5 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 :

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

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

where,

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/mm^2

Hence, E = 27,386 N/mm^2 or 273,860 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 mm^4 = 636173 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 = 0.7 tons (for free head condition)

Q_L = 2.1 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)

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

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

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

D.2 EVALUATION OF LIQUEFACTION RESISTANCE (CRR)

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

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

D.2.1. Influence of Fine Content

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

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

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

$\alpha = 5, for, (FC \ge 35\%)$

$\beta = 1, for, (FC \le 5\%)$

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

$\beta = 1.2, for, (FC \ge 35\%)$

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 $(N_1)_{60cs}$

Appendix - D

(refer para no. 10.6.4)

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)

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).
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

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	2.000	0.999	**0.312**	2	1.70	1	1	0.75	1	3	25	4.29	1.115	8	**0.096**	***0.31***
2.4	0.24	2.000	0.998	**0.311**	8	1.70	1	1	0.8	1	11	24	4.18	1.108	16	**0.170**	***0.55***
3.9	0.24	2.000	0.997	**0.311**	10	1.44	1	1	0.85	1	12	27	4.48	1.130	18	**0.192**	***0.62***
5.4	0.24	2.000	0.996	**0.311**	10	1.26	1	1	0.95	1	12	77	5.00	1.200	19	**0.203**	***0.65***
6.9	0.24	2.000	0.995	**0.310**	18	1.13	1	1	0.95	1	19	92	5.00	1.200	28	**0.370**	***1.19***
8.4	0.24	2.000	0.994	**0.310**	13	1.04	1	1	0.95	1	13	30	4.71	1.154	20	**0.215**	***0.69***
9.9	0.24	2.000	0.910	**0.284**	27	0.96	1	1	1	1	26	31	4.77	1.163	35	**0.500**	***1.76***
11.4	0.24	2.000	0.870	**0.271**	27	0.90	1	1	1	1	24	59	5.00	1.200	34	**0.500**	***1.84***
12.9	0.24	2.000	0.830	**0.259**	28	0.85	1	1	1	1	24	77	5.00	1.200	34	**0.500**	***1.93***
14.4	0.24	2.000	0.790	**0.246**	25	0.81	1	1	1	1	20	75	5.00	1.200	29	**0.410**	***1.67***
15.9	0.24	2.000	0.749	**0.234**	34	0.77	1	1	1	1	26	62	5.00	1.200	36	**0.500**	***2.14***
17.4	0.24	2.000	0.709	**0.221**	38	0.74	1	1	1	1	28	59	5.00	1.200	39	**0.500**	***2.26***
20	0.24	2.000	0.640	**0.200**	52	0.69	1	1	1	1	36	14	2.20	1.042	40	**0.500**	***2.50***

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	2.000	0.999	**0.312**	4	1.70	1	1	0.8	1	5	17	3.01	1.060	8	**0.096**	***0.31***
3	0.24	2.000	0.998	**0.311**	13	1.56	1	1	0.85	1	17	18	3.23	1.066	21	**0.228**	***0.73***
4.5	0.24	2.000	0.997	**0.311**	15	1.34	1	1	0.95	1	19	79	5.00	1.200	28	**0.370**	***1.19***
6	0.24	2.000	0.995	**0.311**	16	1.19	1	1	0.95	1	18	69	5.00	1.200	27	**0.338**	***1.09***
7.5	0.24	2.000	0.994	**0.310**	14	1.08	1	1	0.95	1	14	59	5.00	1.200	22	**0.242**	***0.78***
9	0.24	2.000	0.993	**0.310**	19	0.99	1	1	1	1	19	30	4.71	1.154	27	**0.338**	***1.09***
10.5	0.24	2.000	0.894	**0.279**	20	0.93	1	1	1	1	19	64	5.00	1.200	28	**0.370**	***1.33***
12	0.24	2.000	0.854	**0.266**	19	0.87	1	1	1	1	17	67	5.00	1.200	25	**0.292**	***1.10***
13.5	0.24	2.000	0.814	**0.254**	20	0.83	1	1	1	1	17	70	5.00	1.200	25	**0.292**	***1.15***
15	0.24	2.000	0.774	**0.241**	24	0.79	1	1	1	1	19	73	5.00	1.200	28	**0.370**	***1.53***
16.5	0.24	2.000	0.733	**0.229**	25	0.75	1	1	1	1	19	71	5.00	1.200	28	**0.370**	***1.61***
18	0.24	2.000	0.693	**0.216**	42	0.72	1	1	1	1	30	43	5.00	1.200	41	**0.500**	***2.31***

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Job No. : G(D)4539

Sheet No. : C2

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	2.000	0.999	**0.312**	2	1.70	1	1	0.75	1	3	51	5.00	1.200	9	**0.104**	***0.33***
2.4	0.24	2.000	0.998	**0.311**	4	1.70	1	1	0.8	1	5	24	4.18	1.108	10	**0.113**	***0.36***
3.9	0.24	2.000	0.997	**0.311**	9	1.46	1	1	0.85	1	11	62	5.00	1.200	18	**0.192**	***0.62***
5.4	0.24	2.000	0.996	**0.311**	12	1.27	1	1	0.95	1	15	74	5.00	1.200	23	**0.257**	***0.83***
6.9	0.24	2.000	0.995	**0.310**	14	1.14	1	1	0.95	1	15	90	5.00	1.200	23	**0.257**	***0.83***
8.4	0.24	2.000	0.994	**0.310**	15	1.04	1	1	0.95	1	15	69	5.00	1.200	23	**0.257**	***0.83***
9.9	0.24	2.000	0.910	**0.284**	21	0.97	1	1	1	1	20	67	5.00	1.200	29	**0.410**	***1.45***
11.4	0.24	2.000	0.870	**0.271**	24	0.91	1	1	1	1	22	70	5.00	1.200	31	**0.500**	***1.84***
12.9	0.24	2.000	0.830	**0.259**	28	0.86	1	1	1	1	24	74	5.00	1.200	34	**0.500**	***1.93***
14.4	0.24	2.000	0.790	**0.246**	31	0.81	1	1	1	1	25	84	5.00	1.200	35	**0.500**	***2.03***
15.9	0.24	2.000	0.749	**0.234**	28	0.77	1	1	1	1	22	82	5.00	1.200	31	**0.500**	***2.14***
17.4	0.24	2.000	0.709	**0.221**	40	0.74	1	1	1	1	30	32	4.83	1.171	40	**0.500**	***2.26***
20	0.24	2.000	0.640	**0.200**	46	0.69	1	1	1	1	32	14	2.20	1.042	36	**0.500**	***2.50***

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	2.000	0.999	**0.312**	4	1.70	1	1	0.8	1	5	27	4.48	1.130	10	**0.113**	***0.36***
3	0.24	2.000	0.998	**0.311**	8	1.65	1	1	0.85	1	11	19	3.43	1.073	15	**0.160**	***0.51***
4.5	0.24	2.000	0.997	**0.311**	7	1.39	1	1	0.95	1	9	82	5.00	1.200	16	**0.170**	***0.55***
6	0.24	2.000	0.995	**0.311**	17	1.22	1	1	0.95	1	20	22	3.93	1.093	26	**0.313**	***1.01***
7.5	0.24	2.000	0.994	**0.310**	9	1.11	1	1	0.95	1	9	97	5.00	1.200	16	**0.170**	***0.55***
9	0.24	2.000	0.993	**0.310**	8	1.02	1	1	1	1	8	64	5.00	1.200	15	**0.160**	***0.52***
10.5	0.24	2.000	0.894	**0.279**	11	0.95	1	1	1	1	10	37	5.00	1.200	17	**0.181**	***0.65***
12	0.24	2.000	0.854	**0.266**	22	0.89	1	1	1	1	20	67	5.00	1.200	29	**0.410**	***1.54***
13.5	0.24	2.000	0.814	**0.254**	23	0.84	1	1	1	1	19	21	3.78	1.086	24	**0.273**	***1.08***
15	0.24	2.000	0.774	**0.241**	24	0.80	1	1	1	1	19	95	5.00	1.200	28	**0.370**	***1.53***
16.5	0.24	2.000	0.733	**0.229**	25	0.76	1	1	1	1	19	77	5.00	1.200	28	**0.370**	***1.61***
18	0.24	2.000	0.693	**0.216**	32	0.73	1	1	1	1	23	21	3.78	1.086	29	**0.410**	***1.90***

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Job No. : G(D)4539

Sheet No. : C4

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	2.000	0.999	**0.312**	2	1.70	1	1	0.75	1	3	69	5.00	1.200	9	**0.104**	***0.33***
2.4	0.24	2.000	0.998	**0.311**	9	1.70	1	1	0.8	1	12	31	4.77	1.163	19	**0.203**	***0.65***
3.9	0.24	2.000	0.997	**0.311**	8	1.46	1	1	0.85	1	10	92	5.00	1.200	17	**0.181**	***0.58***
5.4	0.24	2.000	0.996	**0.311**	16	1.27	1	1	0.95	1	19	71	5.00	1.200	28	**0.370**	***1.19***
6.9	0.24	2.000	0.995	**0.310**	9	1.14	1	1	0.95	1	10	97	5.00	1.200	17	**0.181**	***0.58***
8.4	0.24	2.000	0.994	**0.310**	7	1.04	1	1	0.95	1	7	49	5.00	1.200	13	**0.141**	***0.45***
9.9	0.24	2.000	0.910	**0.284**	8	0.97	1	1	1	1	8	64	5.00	1.200	15	**0.160**	***0.56***
11.4	0.24	2.000	0.870	**0.271**	19	0.91	1	1	1	1	17	63	5.00	1.200	25	**0.292**	***1.08***
12.9	0.24	2.000	0.830	**0.259**	29	0.86	1	1	1	1	25	74	5.00	1.200	35	**0.500**	***1.93***
14.4	0.24	2.000	0.790	**0.246**	26	0.81	1	1	1	1	21	82	5.00	1.200	30	**0.468**	***1.90***
15.9	0.24	2.000	0.749	**0.234**	30	0.77	1	1	1	1	23	80	5.00	1.200	33	**0.500**	***2.14***
17.4	0.24	2.000	0.709	**0.221**	31	0.74	1	1	1	1	23	28	4.56	1.138	31	**0.500**	***2.26***
20	0.24	2.000	0.640	**0.200**	38	0.69	1	1	1	1	26	30	4.71	1.154	35	**0.500**	***2.50***

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	2.000	0.999	**0.312**	2	1.70	1	1	0.8	1	3	24	4.18	1.108	8	**0.096**	***0.31***
3	0.24	2.000	0.998	**0.311**	9	1.63	1	1	0.85	1	12	15	2.50	1.048	15	**0.160**	***0.51***
4.5	0.24	2.000	0.997	**0.311**	10	1.38	1	1	0.95	1	13	59	5.00	1.200	21	**0.228**	***0.73***
6	0.24	2.000	0.995	**0.311**	11	1.22	1	1	0.95	1	13	81	5.00	1.200	21	**0.228**	***0.73***
7.5	0.24	2.000	0.994	**0.310**	16	1.10	1	1	0.95	1	17	90	5.00	1.200	25	**0.292**	***0.94***
9	0.24	2.000	0.993	**0.310**	2	1.01	1	1	1	1	2	59	5.00	1.200	7	**0.088**	***0.28***
10.5	0.24	2.000	0.894	**0.279**	9	0.94	1	1	1	1	8	57	5.00	1.200	15	**0.160**	***0.57***
12	0.24	2.000	0.854	**0.266**	11	0.89	1	1	1	1	10	67	5.00	1.200	17	**0.181**	***0.68***
13.5	0.24	2.000	0.814	**0.254**	19	0.84	1	1	1	1	16	71	5.00	1.200	24	**0.273**	***1.08***
15	0.24	2.000	0.774	**0.241**	26	0.80	1	1	1	1	21	83	5.00	1.200	30	**0.468**	***1.94***
16.5	0.24	2.000	0.733	**0.229**	28	0.76	1	1	1	1	21	77	5.00	1.200	30	**0.468**	***2.04***
18	0.24	2.000	0.693	**0.216**	32	0.73	1	1	1	1	23	32	4.83	1.171	32	**0.500**	***2.31***

SOIL PROFILE

Project : Proposed Warehouse at NH-919, Silani, Haryana - 12210

B.H. Location : | Water Table : 1.1m | Term. Depth : 24m | B.H. 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	Φ (°)
	0.0												
2	0.9	Yellowish brown silty sand	0	75	25	0	Non	Plastic					
	1.5								Sample	slip			
8	2.4	Yellowish brown silty sand with gravel	2	74	24	0	Non	Plastic					
	3.0								1.98	22.4			
10	3.9	Yellowish brown silty sand	0	73	27	0	Non	Plastic					
	4.5								1.96	22.2	CD	0.06	24
	5.0	Change of the strata											
10	5.4	Yellowish brown clayey sandy silt with gravel	3	20	62	15	32	21					
	6.0								2.00	23.5			
18	6.9	Yellowish brown sandy clayey silt	0	8	75	17	36	23					
	7.5								1.97	22.6			
	8.0	Change of the strata											
13	8.4	Yellowish brown silty sand	0	70	30	0	Non	Plastic					
	9.0								2.07	19.9	CD	0.07	26
27	9.9	Yellowish brown silty sand	0	69	31	0	Non	Plastic					
	10.5								1.98	20.0			
	11.0	Change of the strata											
27	11.4	Yellowish brown clayey sandy silt with gravel	10	31	43	16	29	19					

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Job No. G(D)4539

Sheet No. : 1

SOIL PROFILE

Project : Proposed Warehouse at NH-919, Silani, Haryana - 12210

B.H. Location : | Water Table : 1.1m | Term. Depth : 24m | B.H. No.: 1

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 (°)
	12.0								2.04	22.3			
28	12.9	Yellowish brown clayey sandy silt with gravel	2	21	66	11	28	20					
	13.5								2.07	22.7			
25	14.4	Yellowish clayey sandy silt with gravel	7	18	57	18	32	21					
	15.0								2.07	24.4			
34	15.9	Yellowish brown clayey sandy silt with gravel	6	32	50	12	29	19					
	16.5								2.03	19.1	CD	0.14	27
38	17.4	Yellowish brown clayey sandy silt with gravel	2	39	36	23	32	22					
	18.0								2.06	18.0			
	18.4	Change of the strata											
52	20.4	Yellowish brown sand with silt	0	86	14	0	Non	Plastic					
	21.0	Change of the strata							Sample	slip			
50	23.4	Yellowish brown clayey sandy silt with gravel	3	30	55	12	31	21					
	24.0								2.09	22.4			
		Observed 'N' Values											

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Job No. : G(D)4539

Sheet No. : 2

SOIL PROFILE

Project : Proposed Warehouse at NH-919, Silani, Haryana - 12210

B.H. Location : | Water Table : 1.3m | Term. Depth : 24m | 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)	Φ (°)
	0.0												
	0.9								1.86	19.5			
4	1.5	Yellowish brown sand with silt	0	83	17	0	Non	Plastic					
	2.4								2.00	22.0			
13	3.0	Yellowish brown sand with silt	0	82	18	0	Non	Plastic					
	3.9	Change of the strata							2.09	22.8	CD	0.10	26
15	4.5	Yellowish brown clayey sandy silt	0	21	70	9	30	20					
	5.4								2.02	21.7			
16	6.0	Yellowish brown clayey sandy silt with gravel	10	21	54	15	31	21					
	6.9								2.06	23.4			
14	7.5	Yellowish brown clayey sandy silt	0	41	51	8	28	18					
	8.4	Change of the strata							2.03	23.9			
19	9.0	Yellowish brown silty sand	0	70	30	0	Non	Plastic					
	9.9	Change of the strata							1.96	22.2	CD	0.12	25
20	10.5	Yellowish brown clayey sandy silt with gravel	2	34	53	11	28	19					
	11.4								2.08	19.9			

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Job No. G(D)4539

Sheet No. : 3

SOIL PROFILE

Project : Proposed Warehouse at NH-919, Silani, Haryana - 12210

B.H. Location : | Water Table : 1.3m | Term. Depth : 24m | 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)	Φ (°)
19	12.0	Yellowish brown clayey sandy silt with gravel	2	31	53	14	30	20					
	12.9								2.09	22.3			
20	13.5	Yellowish brown clayey sandy silt with gravel	2	28	56	14	30	21					
	14.4								2.11	20.0			
24	15.0	Yellowish brown clayey sandy silt	0	27	61	12	29	20					
	15.9								2.07	22.0			
25	16.5	Yellowish brown clayey sandy silt with gravel	4	25	62	9	29	19					
	17.4	Change of the strata							2.06	19.8			
42	18.0	Yellowish brown clayey silty sand with gravel	2	55	33	10	Low	Plastic					
	20.4	Change of the strata							2.09	21.3	CD	0.12	27
41	21.0	Yellowish brown clayey sandy silt with gravel	11	25	52	12	30	20					
	23.4								2.08	19.9			
42	24.0	Yellowish brown clayey sandy silt with gravel	12	24	54	10	29	20					
		Observed 'N' Values											

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Job No. : G(D)4539

Sheet No. : 4

SOIL PROFILE

Project : Proposed Warehouse at NH-919, Silani, Haryana - 12210

B.H. Location : | Water Table : 0.9m | Term. Depth : 24m | B.H. No.: 3

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 (°)
	0.0												
2	0.9	Yellowish brown clayey silty sand with gravel	2	47	35	16	Low	Plastic					
	1.5								Sample	slip			
4	2.4	Yellowish brown silty sand with gravel	2	74	24	0	Non	Plastic					
	3.0								1.87	20.4			
	3.7	Change of the strata											
9	3.9	Yellowish brown clayey sandy silt with gravel	21	17	48	14	31	20					
	4.5								1.96	24.6			
12	5.4	Yellowish brown clayey sandy silt with gravel	3	23	65	9	28	19					
	6.0								1.97	21.4	CD	0.15	24
14	6.9	Yellowish brown sandy clayey silt with gravel	3	7	63	27	40	24					
	7.5								2.08	24.6			
15	8.4	Yellowish brown clayey sandy silt	0	31	59	10	28	18					
	9.0								2.07	24.1			
21	9.9	Yellowish brown clayey sandy silt with gravel	7	26	52	15	31	20					
	10.5								2.03	22.0			
24	11.4	Yellowish brown clayey sandy silt with gravel	5	25	60	10	27	18					

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Job No. : G(D)4539

Sheet No. : 5

SOIL PROFILE

Project : Proposed Warehouse at NH-919, Silani, Haryana - 12210

B.H. Location : | Water Table : 0.9m | Term. Depth : 24m | B.H. No.: 3

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 (°)
	12.0								2.08	20.4	CD	0.10	27
28	12.9	Yellowish brown clayey sandy silt with gravel	4	22	65	9	30	20					
	13.5								2.02	18.9			
31	14.4	Yellowish brown sandy clayey silt with gravel	2	14	59	25	35	22					
	15.0								2.04	20.3			
28	15.9	Yellowish brown sandy clayey silt with gravel	3	15	61	21	33	21					
	16.5								2.03	20.1			
	16.8	Change of the strata											
40	17.4	Yellowish brown silty sand with gravel	2	66	32	0	Non	Plastic					
	18.0	Change of the strata							2.10	19.6			
46	20.4	Yellowish brown sand with silt and gravel	5	81	14	0	Non	Plastic					
	21.0	Change of the strata							2.12	21.7	CD	0.06	28
50	23.4	Yellowish brown silty sand with gravel	2	64	34	0	Non	Plastic					
	24.0								2.09	21.3			
		Observed 'N' values											

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Job No. : G(D)4539

Sheet No. : 6

SOIL PROFILE

Project : Proposed Warehouse at NH-919, Silani, Haryana - 12210

B.H. Location : | Water Table : 0.8m | Term. Depth : 24m | 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	c (kg/cm^2)	Φ (°)
	0.0												
	0.9												
4	1.5	Yellowish brown silty sand	0	73	27	0	Non	Plastic					
	2.0	Change of the strata											
	2.4								1.90	20.4			
8	3.0	Yellowish brown sand with silt	0	81	19	0	Non	Plastic					
	3.9								1.97	22.7			
	4.3	Change of the strata											
7	4.5	Yellowish brown sandy clayey silt with gravel	6	12	66	16	31	21					
	5.4								1.99	28.6	CD	0.13	22
	5.8	Change of the strata											
17	6.0	Yellowish brown silty sand	0	78	22	0	Non	Plastic					
	6.9	Change of the strata							2.04	24.6			
9	7.5	Yellowish brown sandy clayey silt	0	3	57	40	42	25					
	8.4								2.05	22.2			
8	9.0	Yellowish brown clayey sandy silt with gravel	2	34	54	10	26	17					
	9.9								2.09	17.9			
	10.2	Change of the strata											
11	10.5	Yellowish brown silty sand with gravel	3	60	37	0	Non	Plastic					
	11.4	Change of the strata							2.06	21.0			

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Job No. : G(D)4539

Sheet No. : 7

SOIL PROFILE

Project : Proposed Warehouse at NH-919, Silani, Haryana - 12210

B.H. Location : | Water Table : 0.8m | Term. Depth : 24m | 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	c (kg/cm^2)	Φ (°)
22	12.0	Yellowish brown clayey sandy silt with gravel	6	27	55	12	27	18					
	12.9								2.03	21.0	CD	0.12	25
	13.3	Change of the strata											
23	13.5	Yellowish brown silty sand	0	79	21	0	Non	Plastic					
	14.4	Change of the strata							2.04	21.3			
24	15.0	Yellowish brown sandy clayey silt with gravel	2	3	63	32	41	24					
	15.9								2.07	22.6			
25	16.5	Yellowish brown clayey sandy silt with gravel	3	20	58	19	34	22					
	17.0	Change of the strata											
	17.4								2.05	20.1			
32	18.0	Yellowish brown silty sand with gravel	2	77	21	0	Non	Plastic					
	20.4								2.03	21.9	CD	0.08	27
31	21.0	Yellowish brown silty sand with gravel	4	59	37	0	Non	Plastic					
	23.4								2.08	21.2			
35	24.0	Yellowish brown silty sand with gravel	2	77	21	0	Non	Plastic					
		Observed 'N' Values											

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Job No. : G(D)4539

Sheet No. : 8

SOIL PROFILE

Project : Proposed Warehouse at NH-919, Silani, Haryana - 12210

B.H. Location : | Water Table : 0.9m | Term. Depth : 24m | B.H. No.: 5

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 (°)
	0.0												
2	0.9	Yellowish brown clayey sandy silt	0	31	51	18	33	22					
	1.5								1.92	23.1			
	2.0	Change of the strata											
9	2.4	Yellowish brown silty sand with gravel	3	66	31	0	Non	Plastic					
	3.0								1.96	23.4	CD	0.05	23
	3.7	Change of the strata											
8	3.9	Yellowish brown sandy clayey silt with gravel	2	6	75	17	36	26					
	4.5								2.00	25.8			
16	5.4	Yellowish brown clayey sandy silt	0	29	63	8	28	18					
	6.0								1.95	21.9			
9	6.9	Yellowish brown sandy clayey silt	0	3	65	32	41	26					
	7.5								2.09	25.4			
	8.2	Change of the strata											
7	8.4	Yellowish brown clayey silty sand	0	51	44	5	Low	Plastic					
	9.0	Change of the strata							2.02	20.2			
8	9.9	Yellowish brown clayey sandy silt with gravel	10	26	52	12	28	19					
	10.5								2.06	18.2			
19	11.4	Yellowish brown clayey sandy silt with gravel	9	28	51	12	28	18					
	12.0								2.04	21.2	CD	0.12	25

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Job No. G(D)4539

Sheet No. : 9

SOIL PROFILE

Project : Proposed Warehouse at NH-919, Silani, Haryana - 12210

B.H. Location : | Water Table : 0.9m | Term. Depth : 24m | B.H. No.: 5

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 (°)
29	12.9	Yellowish brown clayey sandy silt with gravel	2	24	62	12	29	19					
	13.5								2.14	22.2			
26	14.4	Yellowish brown clayey sandy silt with gravel	2	16	63	19	33	21					
	15.0								2.10	18.7			
30	15.9	Yellowish brown sandy clayey silt with gravel	2	18	53	27	37	24					
	16.5								2.06	19.7			
	17.0	Change of the strata											
31	17.4	Yellowish brown silty sand with gravel	11	61	28	0	Non	Plastic					
	18.0								2.14	22.3	CD	0.04	28
38	20.4	Yellowish brown silty sand with gravel	2	68	30	0	Non	Plastic					
	21.0	Change of the strata							2.11	21.6			
37	23.4	Yellowish brown clayey sandy silt with gravel	3	33	52	12	29	18					
	24.0								2.14	17.9			
		Observed 'N' values											

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Job No. G(D)4539

Sheet No. : 10

SOIL PROFILE

Project : Proposed Warehouse at NH-919, Silani, Haryana - 12210

B.H. Location : | Water Table : 0.6m | Term. Depth : 24m | B.H. No.: 6

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 (°)
	0.0												
	0.9								1.93	27.0			
2	1.5	Yellowish brown silty sand with gravel	20	56	24	0	Non	Plastic					
	2.4	Change of the strata							1.91	20.8			
9	3.0	Yellowish brown sand with silt and gravel	8	77	15	0	Non	Plastic					
	3.9	Change of the strata							2.03	17.4			
10	4.5	Yellowish brown clayey sandy silt	0	41	47	12	28	18					
	5.4								1.95	21.1	CD	0.13	23
11	6.0	Yellowish brown clayey sandy silt with gravel	2	17	71	10	31	21					
	6.9								2.08	23.5			
16	7.5	Yellowish brown sandy clayey silt	0	10	60	30	37	23					
	8.4								Sample	slip			
2	9.0	Yellowish brown clayey sandy silt	0	41	51	8	28	18					
	9.9								2.01	17.6			
9	10.5	Yellowish brown clayey sandy silt with gravel	9	34	47	10	29	18					
	11.4								2.04	21.3			

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Job No. G(D)4539

Sheet No. : 11

SOIL PROFILE

Project : Proposed Warehouse at NH-919, Silani, Haryana - 12210

B.H. Location : | Water Table : 0.9m | Term. Depth : 24m | B.H. No.: 6

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 (°)
11	12.0	Yellowish brown clayey sandy silt with gravel	8	25	55	12	29	20					
	12.9								2.05	18.5	CD	0.12	26
19	13.5	Yellowish brown clayey sandy silt with gravel	8	21	59	12	29	19					
	14.4								2.10	21.4			
26	15.0	Yellowish brown sandy clayey silt	0	17	55	28	35	22					
	15.9								2.06	22.0			
28	16.5	Yellowish brown sandy clayey silt with gravel	3	20	55	22	33	21					
	17.2	Change of the strata											
	17.4								2.04	20.2			
32	18.0	Yellowish brown silty sand with gravel	5	63	32	0	Non	Plastic					
	20.4	Change of the strata							2.10	22.4	CD	0.11	28
35	21.0	Yellowish brown clayey sandy silt with gravel	3	30	54	13	29	20					
	23.4								2.16	25.7			
36	24.0	Yellowish brown clayey sandy silt with gravel	11	38	39	12	28	18					
		Observed 'N' Values											

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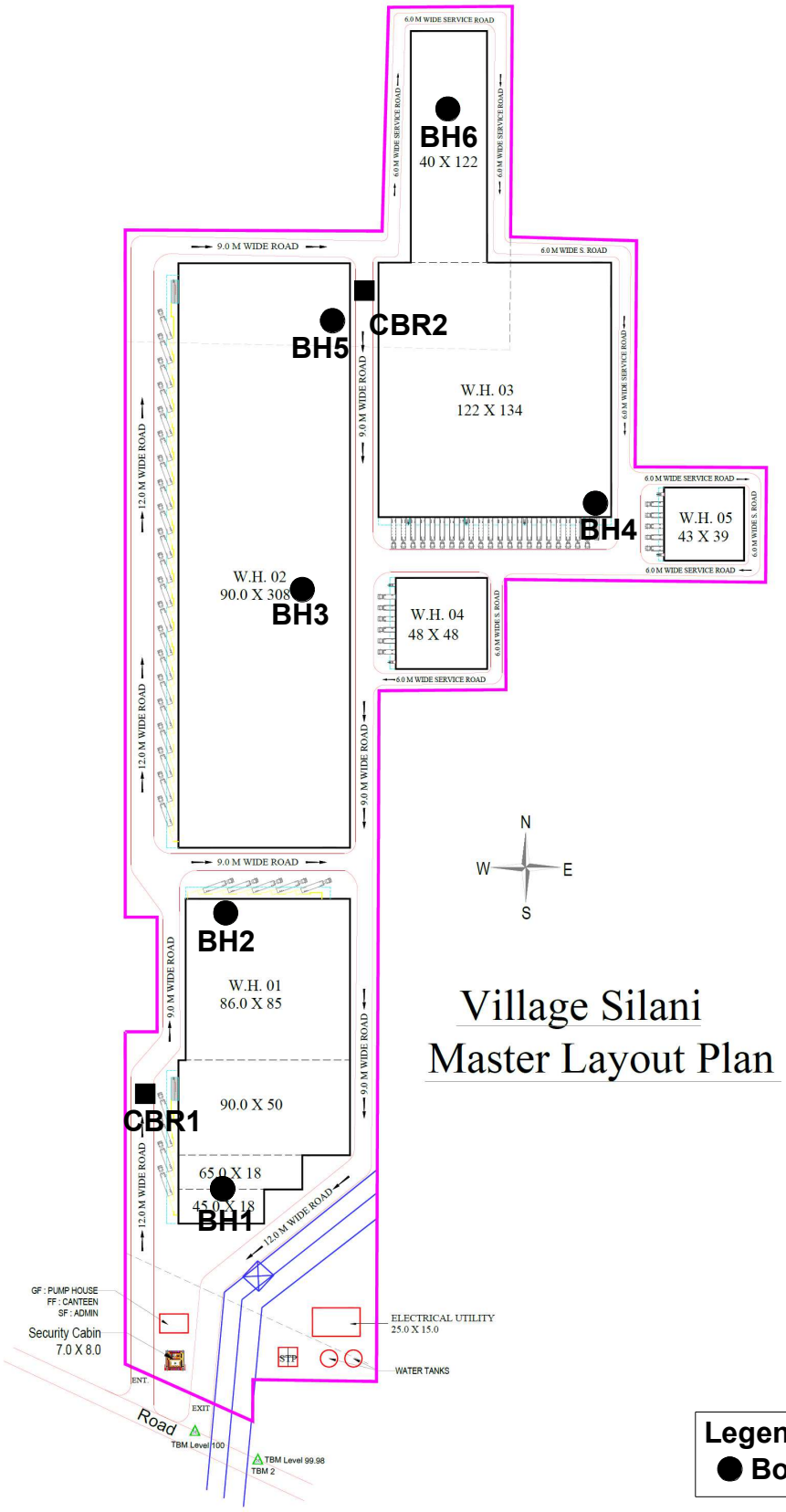
Job No. G(D)4539

Sheet No. : 12



Village Silani
Master Layout Plan

Legend
● **Borehole (BH)**

SCHEMATIC SITE PLAN SHOWING TESTING LOCATIONS

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Job No. : G(D)4539

Sheet No. : 1a

PHOTOGRAPH SHOWING
VIEW OF THE SITE & BOREHOLE UNDER PROGRESS

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Sheet No. : 1b

PHOTOGRAPH SHOWING
VIEW OF THE SITE & BOREHOLE UNDER PROGRESS

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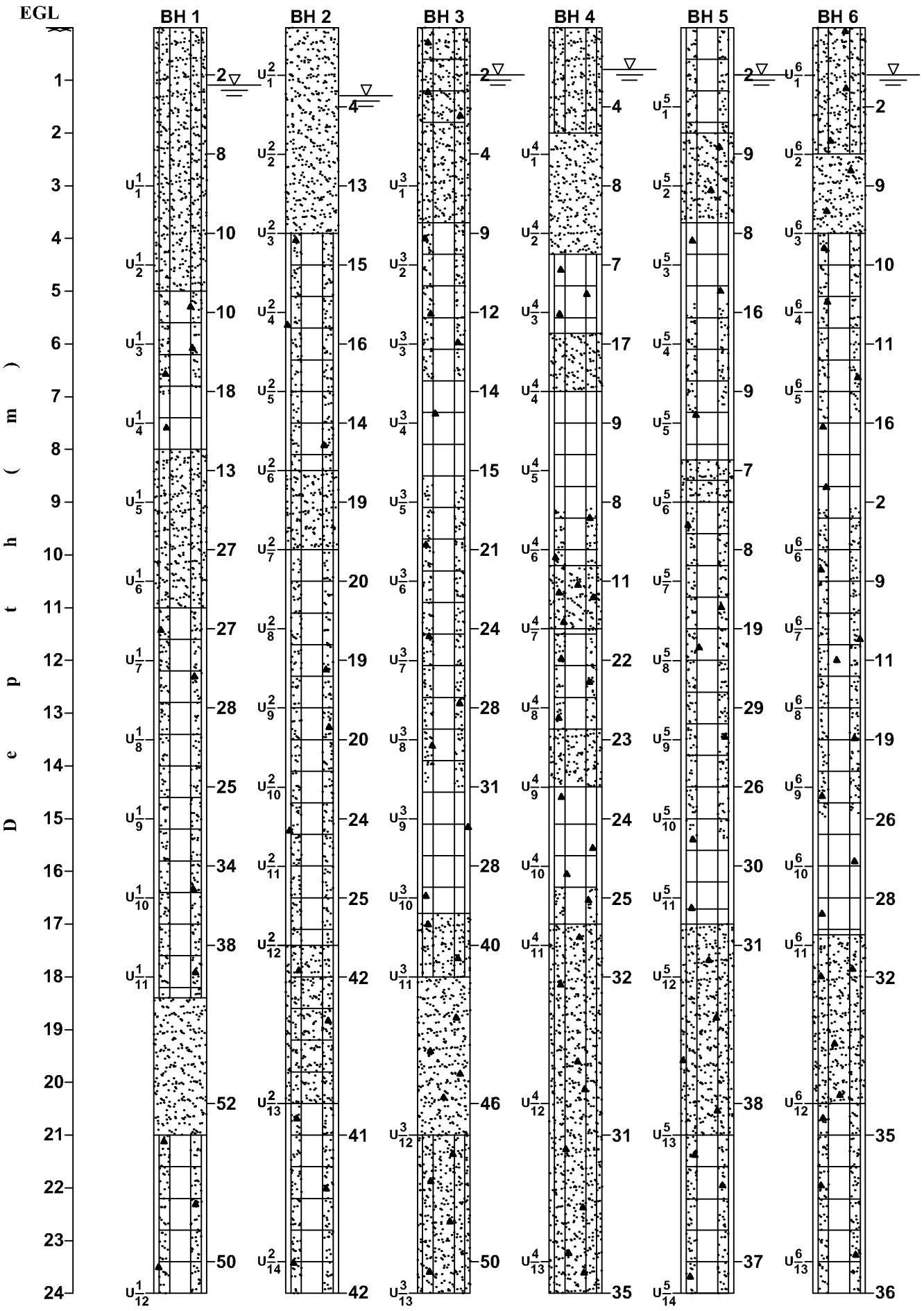

LEGEND

Yellowish brown silty sand with occasional clay and gravel
(21-44)% (25-79)% (0-16)% (0-20)%

Yellowish brown clayey sandy silt with occasional gravel /
(8-40)% (3-41)% (42-75)% (0-21)%
sandy clayey silt

Yellowish brown sand with silt and occasional gravel
(77-86)% (14-19)% (0-5)%

24 Observed ' N ' Values

U_2^1 2nd undisturbed soil sample of BH 1

Ground Water table has been encountered as on March 2023

COMPILED SOIL PROFILE

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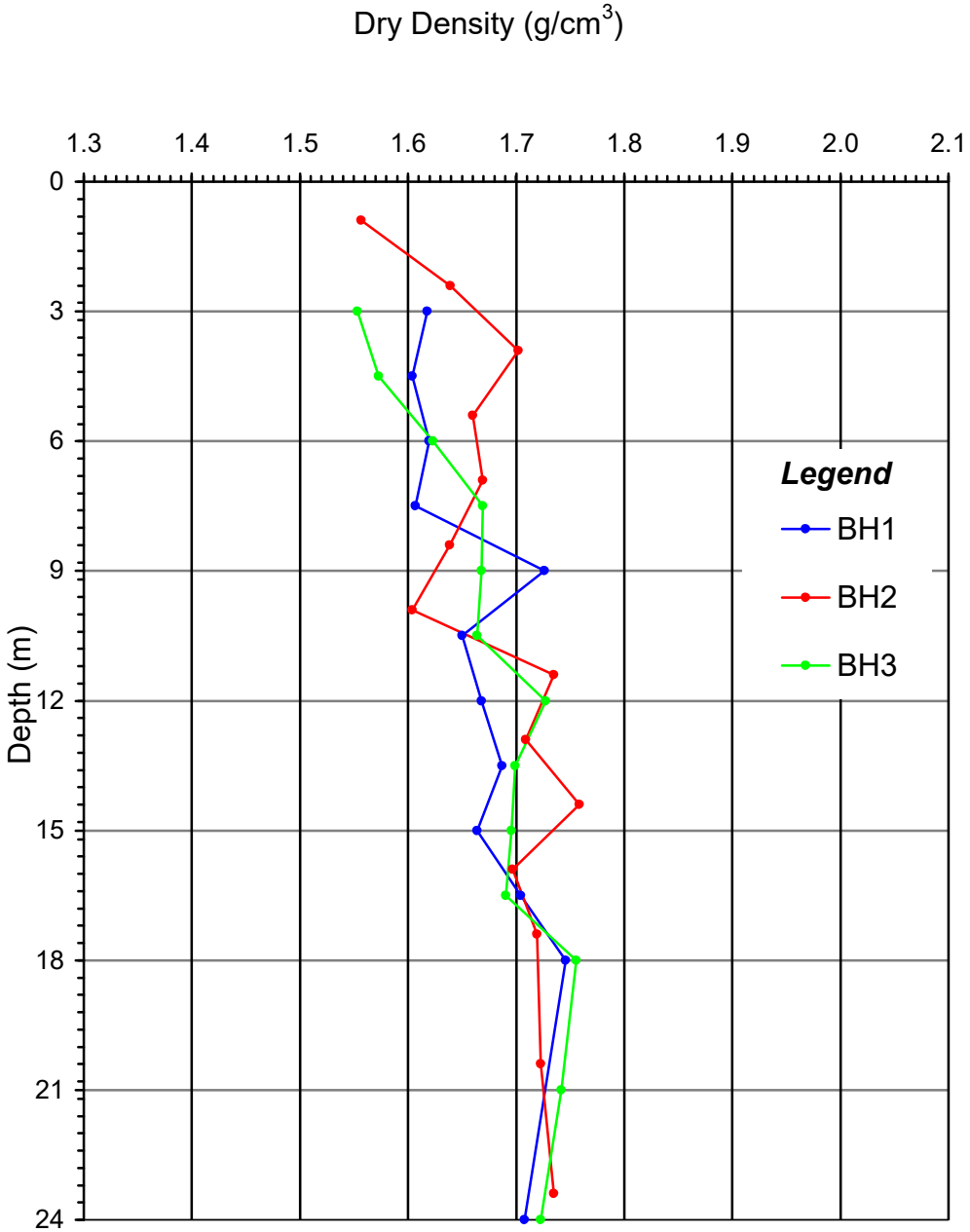
GEOTECHNICAL INVESTIGATION FOR THE PROPOSED WAREHOUSE AT VILLAGE SILANI, SOHNA

Job No: G(D) 4539

Sheet No: 2



Dry Density vs Depth Curves

(Refer paragraph no. 7.4.2)

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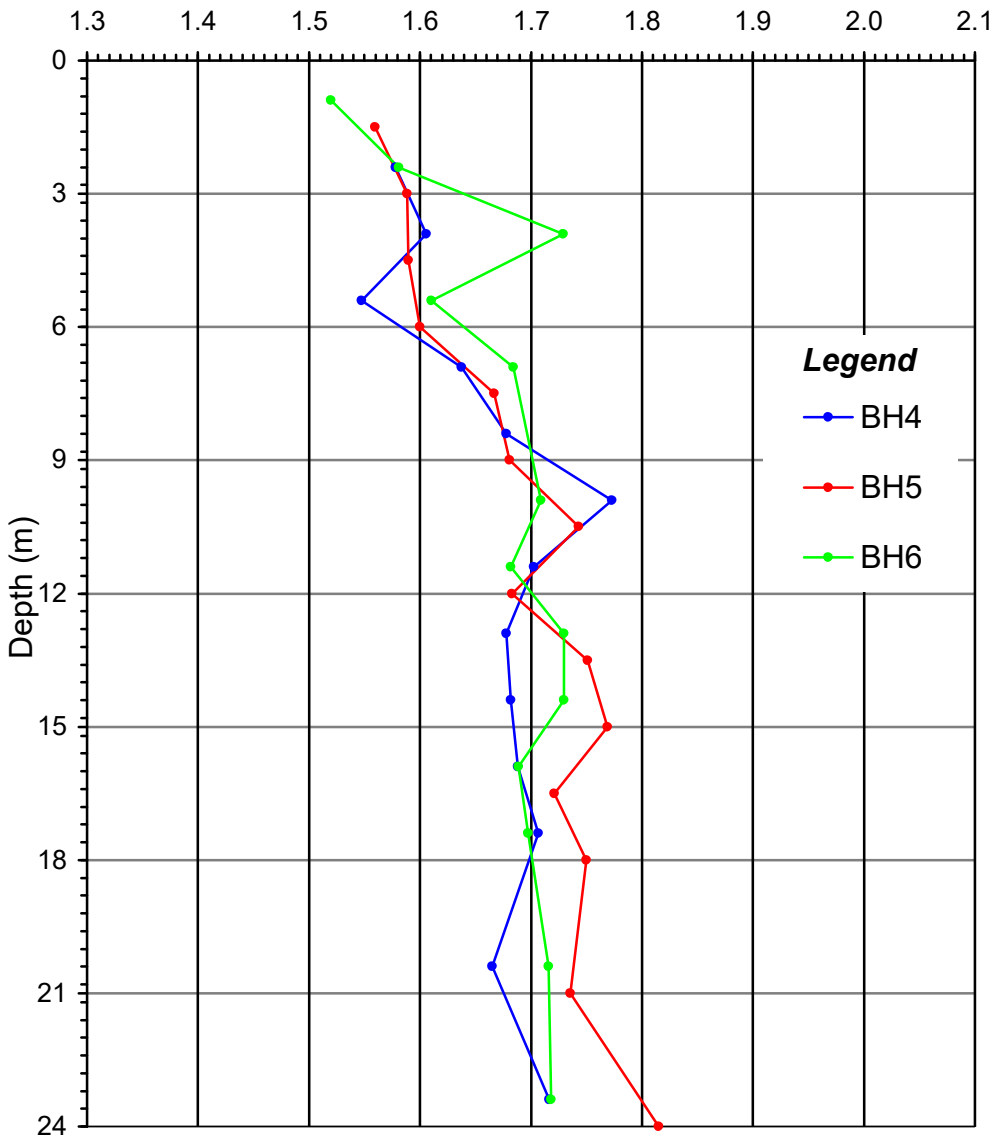

Dry Density vs Depth Curves

(Refer paragraph no. 7.4.2)

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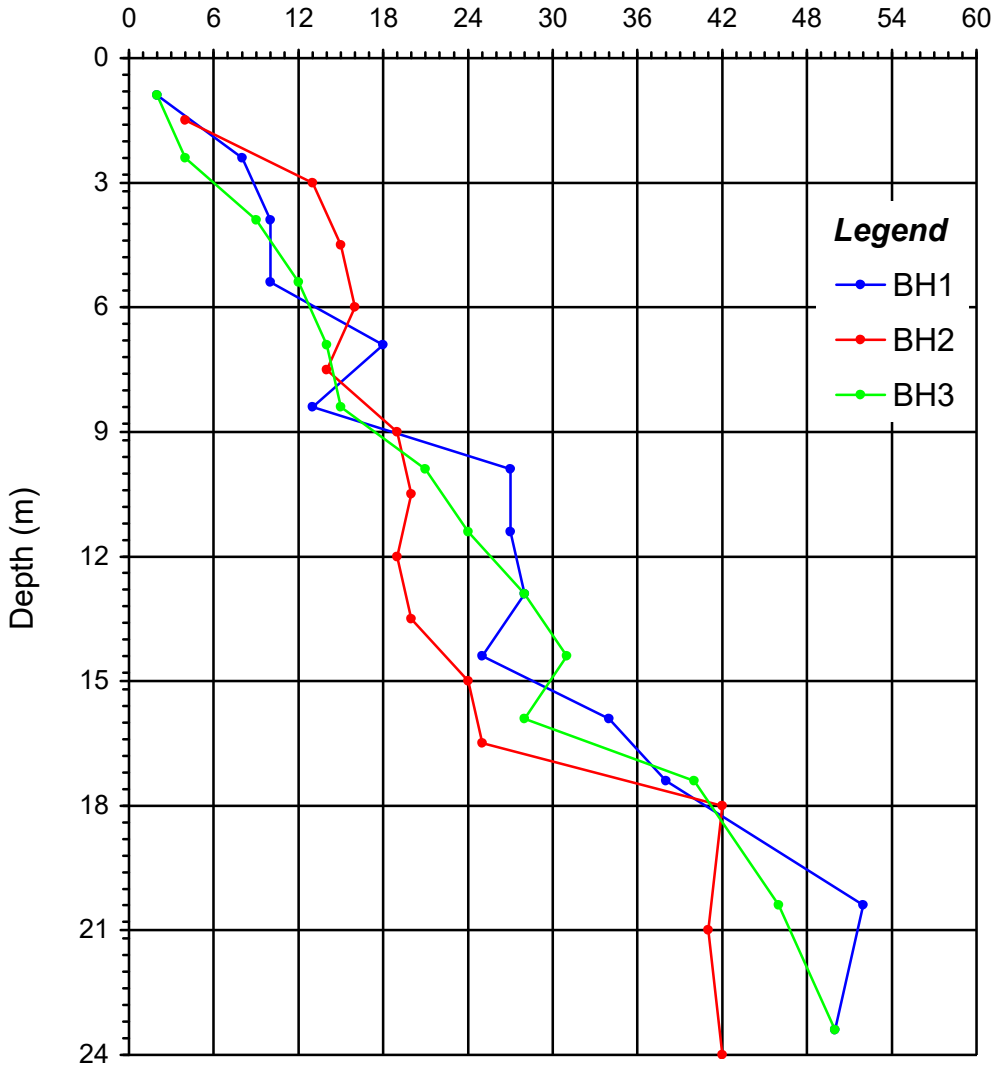
Job No. G(D)4539

Sheet No. : 3b

N - Values (Observed)



N - Values vs Depth Curves

(Refer paragraph no. 7.6.1)

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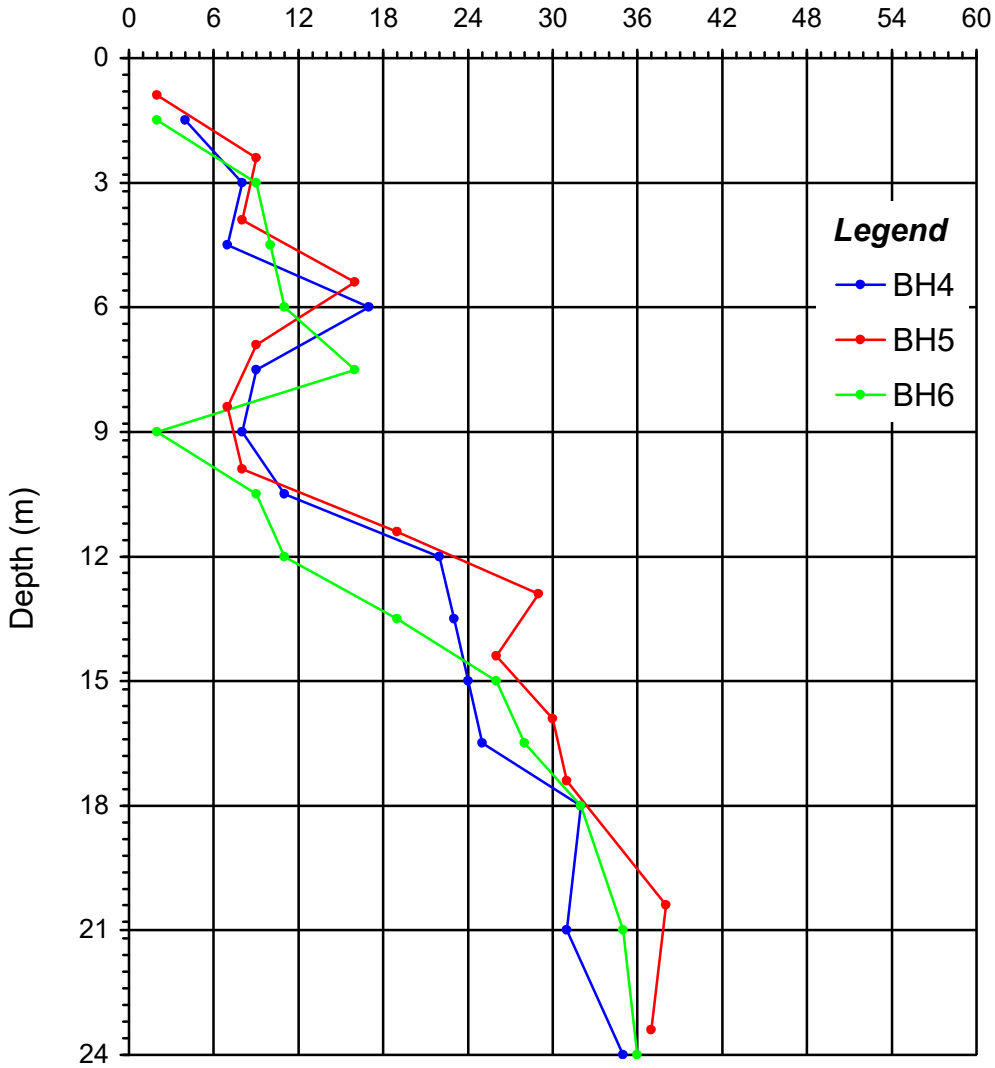
Job No. : G(D)4539

Sheet No. : 4a

N - Values (Observed)



N - Values vs Depth Curves

(Refer paragraph no. 7.6.1)

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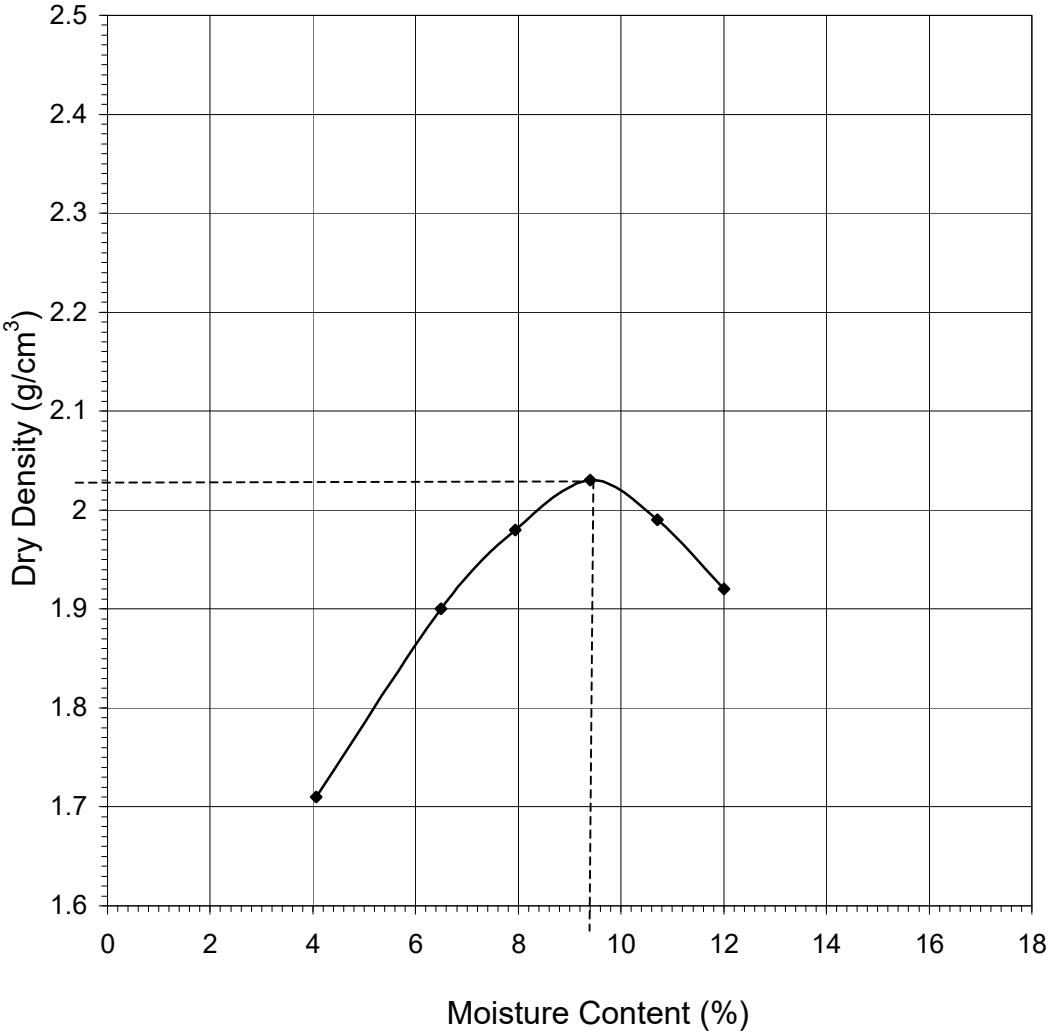
Job No. : G(D)4539

Sheet No. : 4b



Maximum Dry Density = 2.03 g/cm^3
Optimum Moisture Content = 9.4 %

Modified Proctor Density Test - 1

(Refer paragraph no. 7.10.1)

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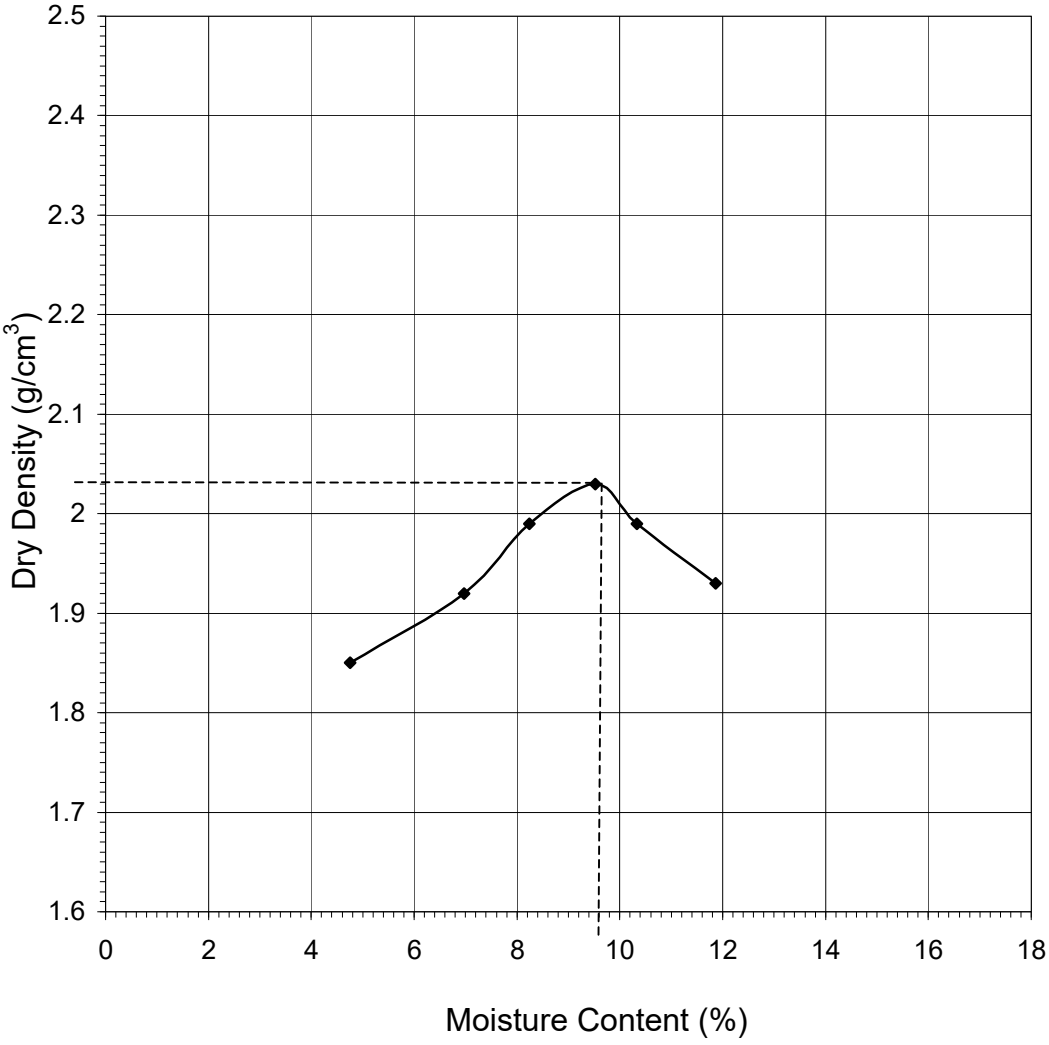
Job No. : G(D)4539

Sheet No. : 5a



Maximum Dry Density = 2.03 g/cm^3
Optimum Moisture Content = 9.6 %

Modified Proctor Density Test - 2

(Refer paragraph no. 7.10.1)

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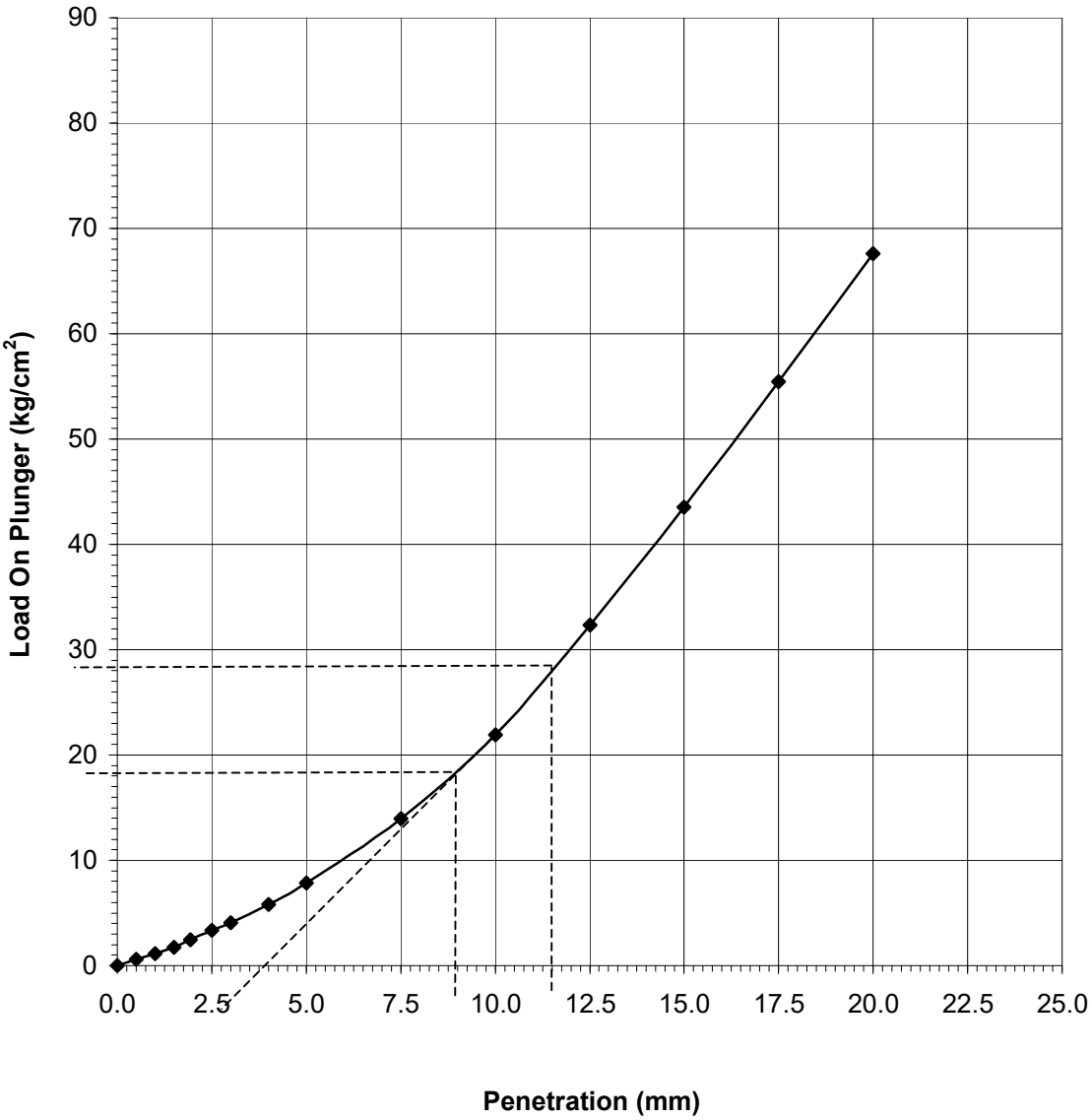
Job No. : G(D)4539

Sheet No. : 5b



PENETRATION	2.5 mm	5.0 mm
CBR VALUE	25.7	26.7

Laboratory CBR Curve - 1

(Refer paragraph no. 7.10.1)

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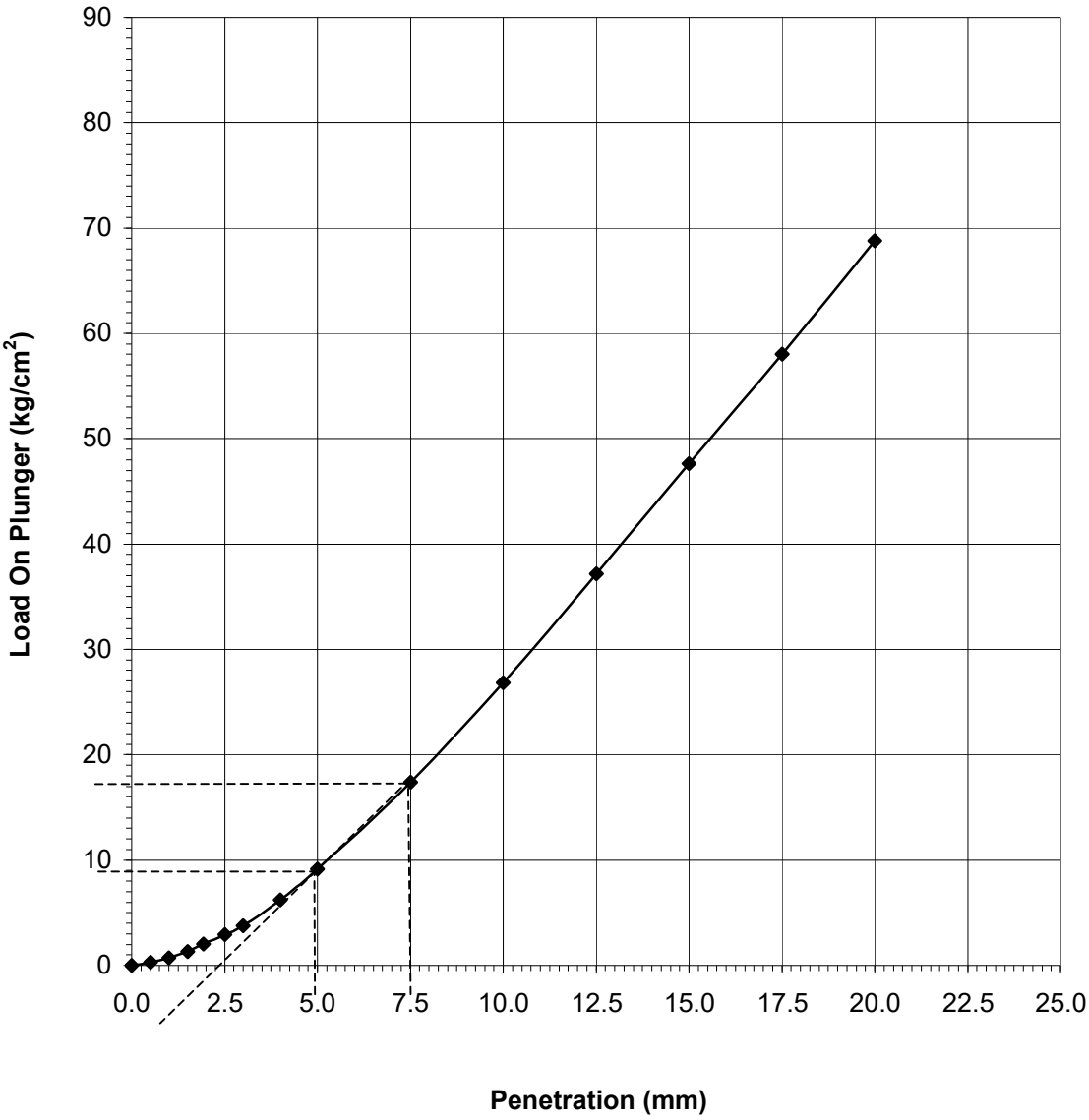
Sheet No. : 6a



PENETRATION	2.5 mm	5.0 mm
CBR VALUE	12.9	16.2

Laboratory CBR Curve - 2

(Refer paragraph no. 7.10.1)

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Job No. G(D) 4539

Sheet No. : 6b

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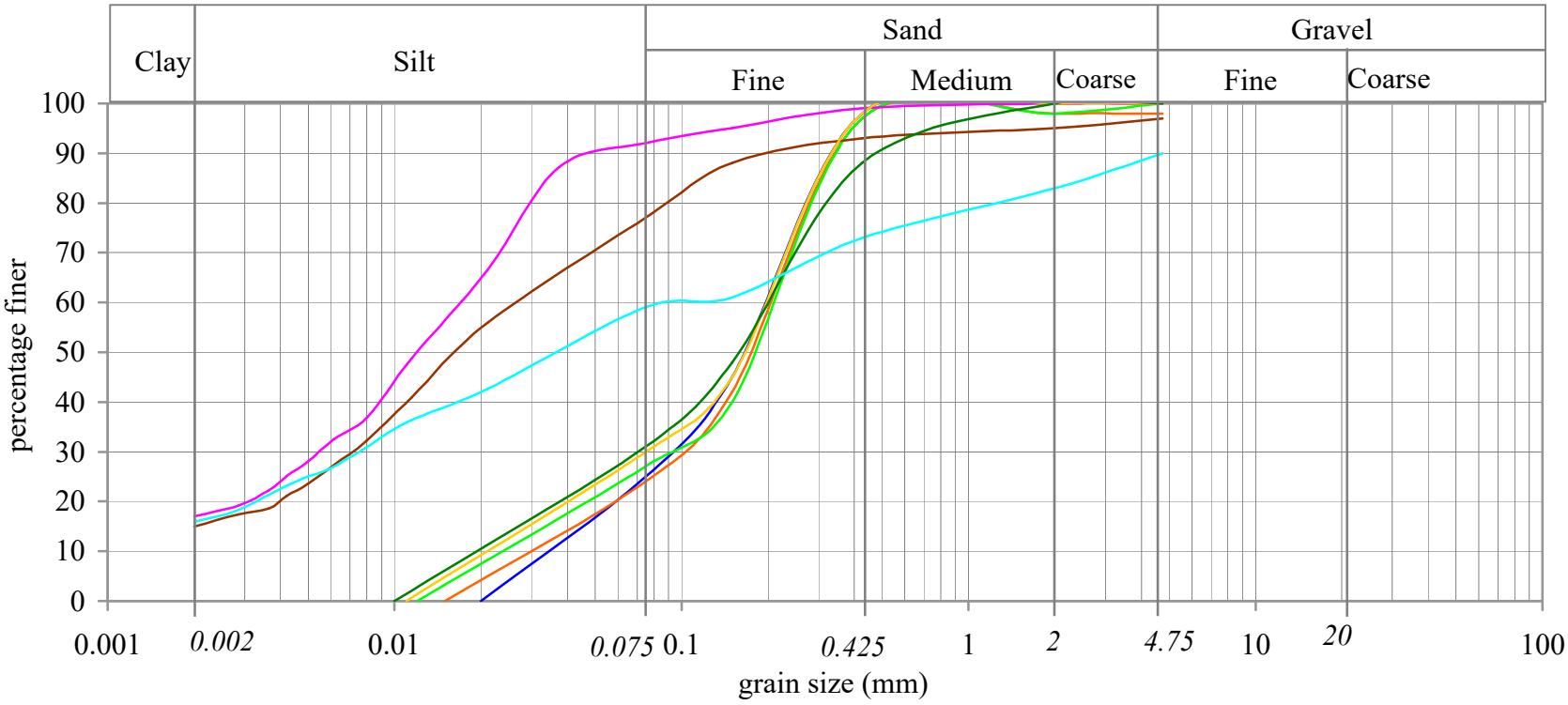
Job No. : G(D)4539

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	Silty sand	0	75	25	0	0.19	0.032	5.9
	1	2.4	Silty sand with gravel	2	74	24	0	0.21	0.029	7.2
	1	3.9	Silty sand	0	73	27	0	0.21	0.023	9.1
	1	5.4	Clayey sandy silt with gravel	3	20	62	15	0.026	-	-
	1	6.9	Sandy clayey silt	0	8	75	17	0.017	-	-
	1	8.4	Silty sand	0	70	30	0	0.21	0.021	10.0
	1	9.9	Silty sand	0	69	31	0	0.21	0.019	11.1
	1	11.4	Clayey sandy silt with gravel	10	31	43	16	0.089	-	-

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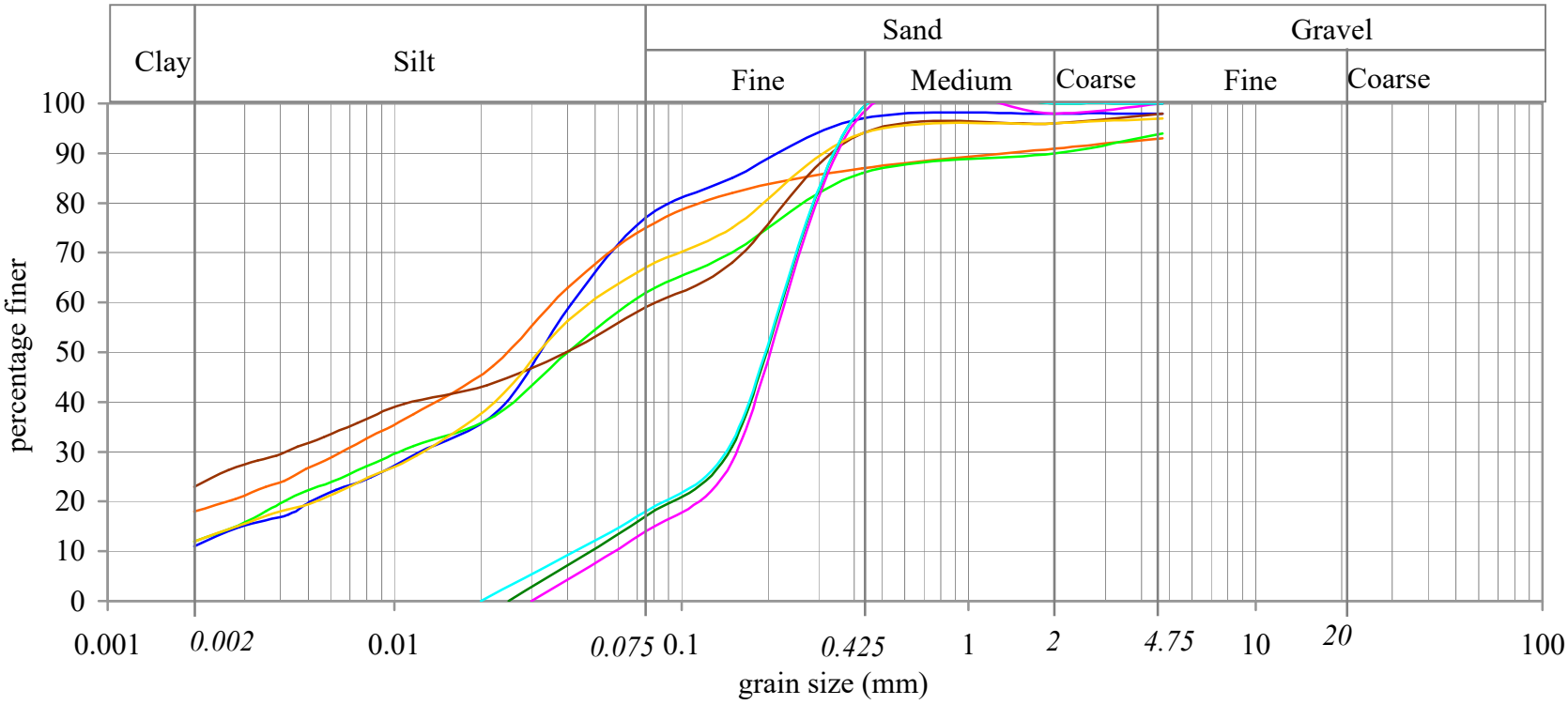
Job No. : G(D)4539

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	12.9	Clayey sandy silt with gravel	2	21	66	11	0.041	-	-
	1	14.4	Clayey sandy silt with gravel	7	18	57	18	0.035	-	-
	1	15.9	Clayey sandy silt with gravel	6	32	50	12	0.065	-	-
	1	17.4	Clayey sandy silt with gravel	2	39	36	23	0.081	-	-
	1	20.4	Sand with silt	0	86	14	0	0.23	0.059	3.9
	1	23.4	Clayey sandy silt with gravel	3	30	55	12	0.049	-	-
	2	1.5	Sand with silt	0	83	17	0	0.23	0.046	5.0
	2	3	Sand with silt	0	82	18	0	0.23	0.042	5.5

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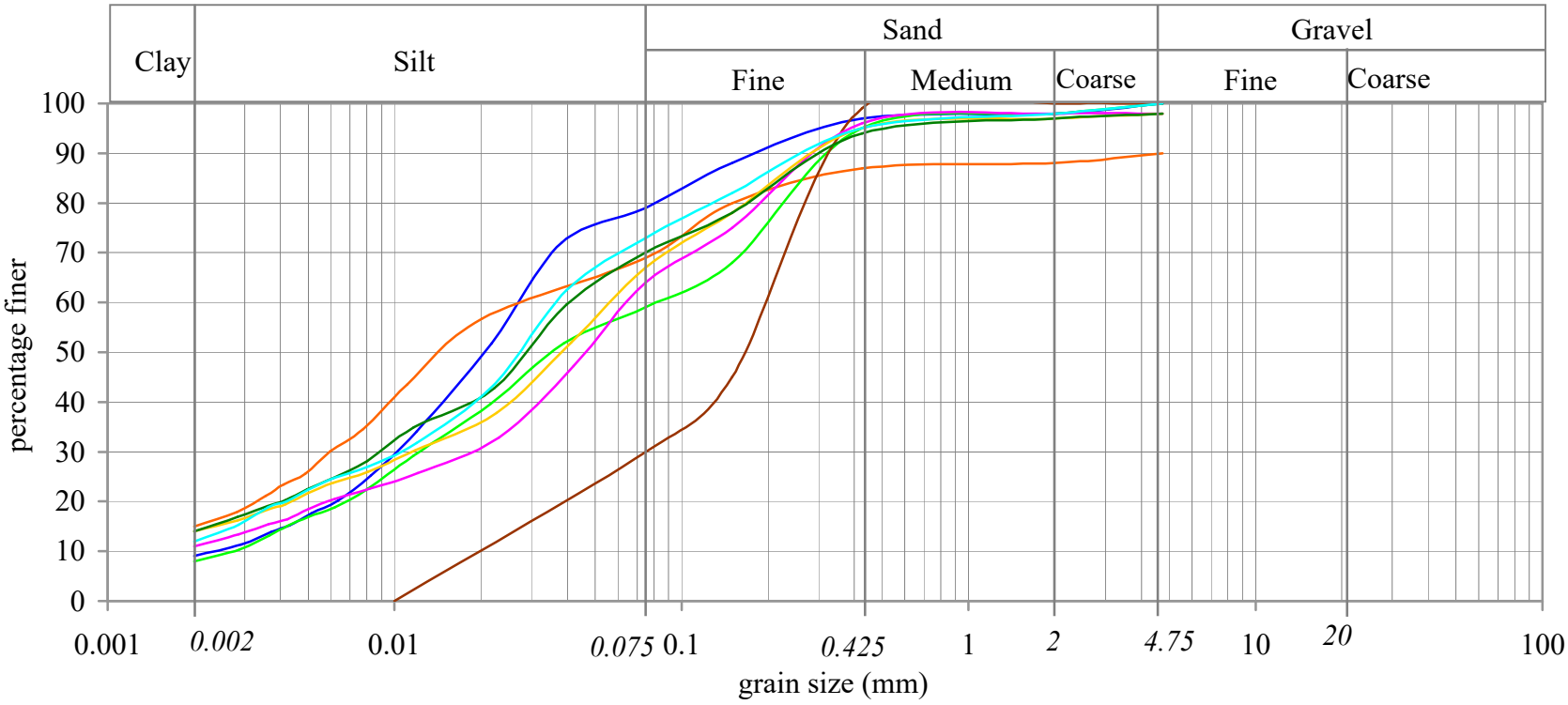
Job No. : G(D)4539

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	4.5	Clayey sandy silt	0	21	70	9	0.025	0.0025	10.0
	2	6	Clayey sandy silt with gravel	10	21	54	15	0.025	-	-
	2	7.5	Clayey sandy silt	0	41	51	8	0.08	0.0026	30.8
	2	9	Silty sand	0	70	30	0	0.19	0.019	10.0
	2	10.5	Clayey sandy silt with gravel	2	34	53	11	0.062	-	-
	2	12	Clayey sandy silt with gravel	2	31	53	14	0.055	-	-
	2	13.5	Clayey sandy silt with gravel	2	28	56	14	0.04	-	-
	2	15	Clayey sandy silt	0	27	61	12	0.035	-	-

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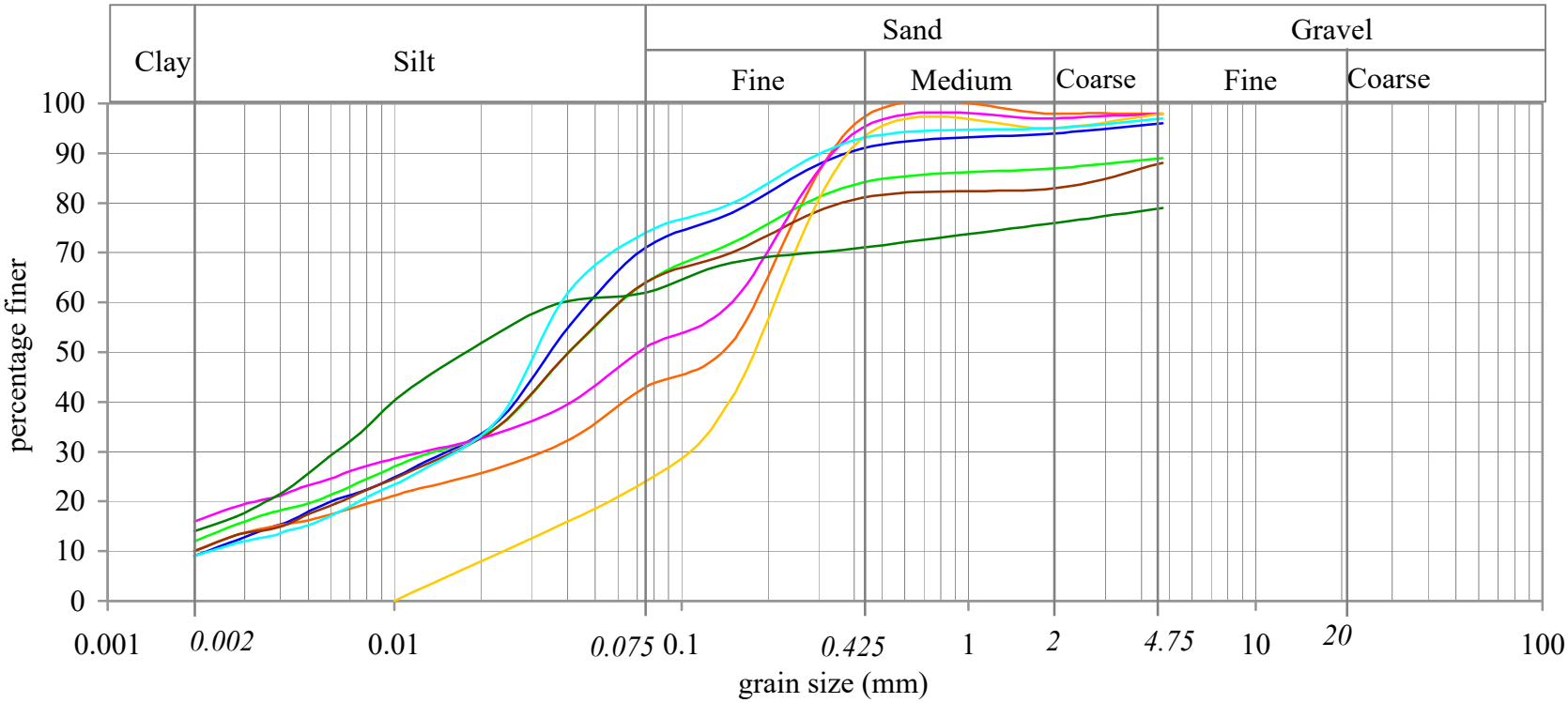
Job No. : G(D)4539

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
	2	16.5	Clayey sandy silt with gravel	4	25	62	9	0.045	0.0022	20.5
	2	18	Clayey sandy silt with gravel	2	55	33	10	0.19	0.002	95.0
	2	21	Clayey sandy silt with gravel	11	25	52	12	0.061	-	-
	2	24	Clayey sandy silt with gravel	12	24	54	10	0.061	0.002	30.5
	3	0.9	Clayey silty sand with gravel	2	47	35	16	0.16	-	-
	3	2.4	Silty sand with gravel	2	74	24	0	0.21	0.023	9.1
	3	3.9	Clayey sandy silt with gravel	21	17	48	14	0.039	-	-
	3	5.4	Clayey sandy silt with gravel	3	23	65	9	0.038	0.0022	17.3

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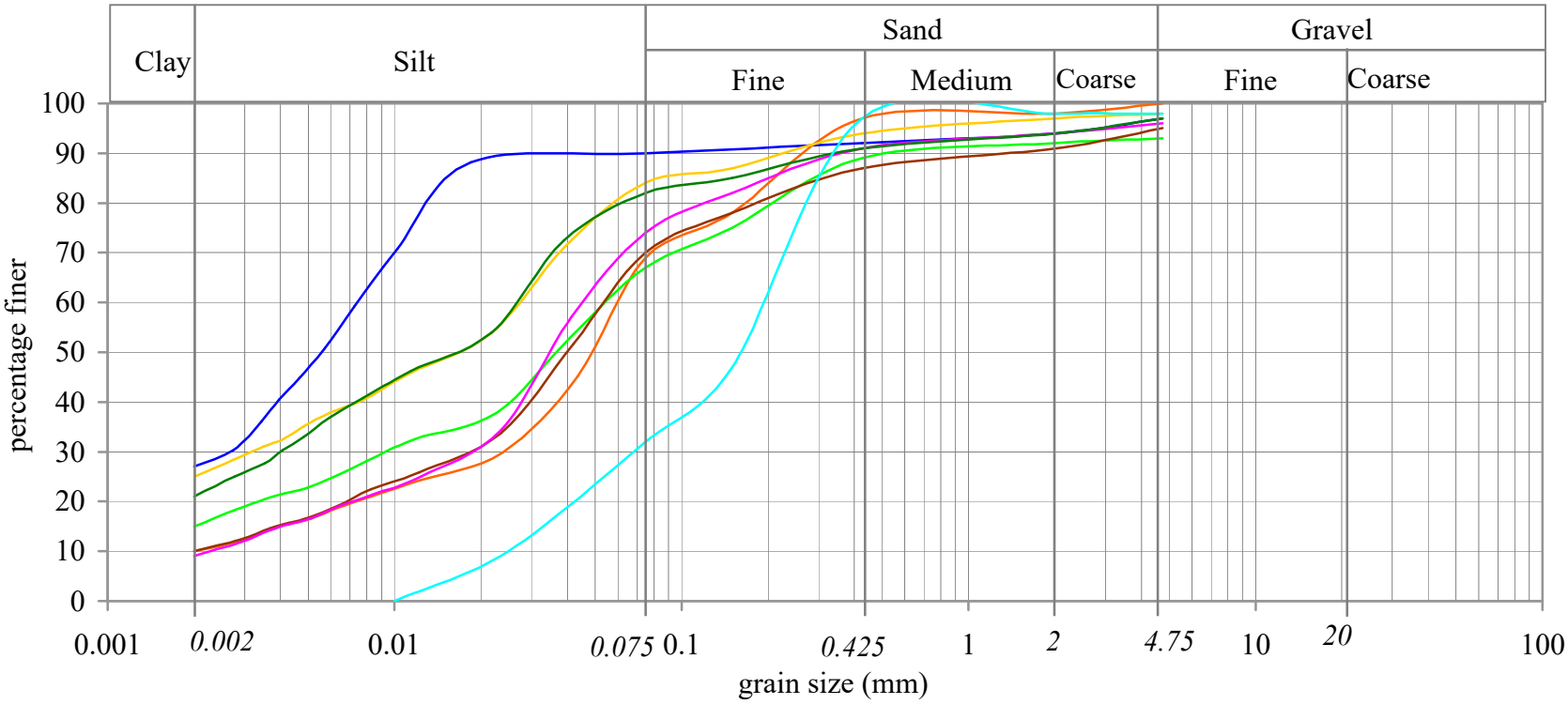
Sheet No. : 7e

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	6.9	Sandy clayey silt with gravel	3	7	63	27	0.0075	-	-
	3	8.4	Clayey sandy silt	0	31	59	10	0.06	0.002	30.0
	3	9.9	Clayey sandy silt with gravel	7	26	52	15	0.055	-	-
	3	11.4	Clayey sandy silt with gravel	5	25	60	10	0.052	0.002	26.0
	3	12.9	Clayey sandy silt with gravel	4	22	65	9	0.045	0.0022	20.5
	3	14.4	Sandy clayey silt with gravel	2	14	59	25	0.026	-	-
	3	15.9	Sandy clayey silt with gravel	3	15	61	21	0.026	-	-
	3	17.4	Silty sand with gravel	2	66	32	0	0.19	0.023	8.3

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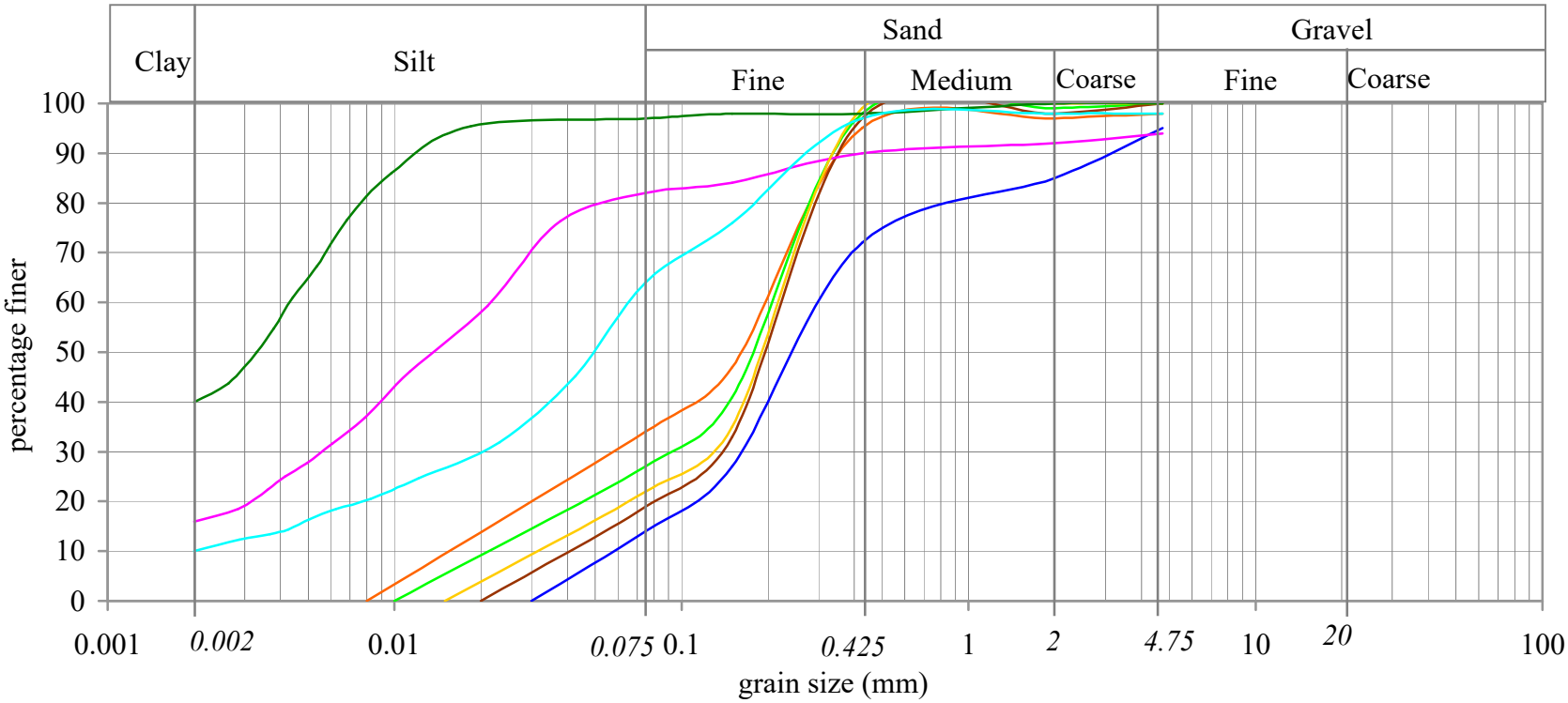
Sheet No. : 7f

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
	3	20.4	Sand with silt and gravel	5	81	14	0	0.29	0.059	4.9
	3	23.4	Silty sand with gravel	2	64	34	0	0.19	0.016	11.9
	4	1.5	Silty sand	0	73	27	0	0.21	0.021	10.0
	4	3	Sand with silt	0	81	19	0	0.22	0.04	5.5
	4	4.5	Sandy clayey silt with gravel	6	12	66	16	0.022	-	-
	4	6	Silty sand	0	78	22	0	0.23	0.03	7.7
	4	7.5	Sandy clayey silt	0	3	57	40	0.0042	-	-
	4	9	Clayey sandy silt with gravel	2	34	54	10	0.068	0.002	34.0

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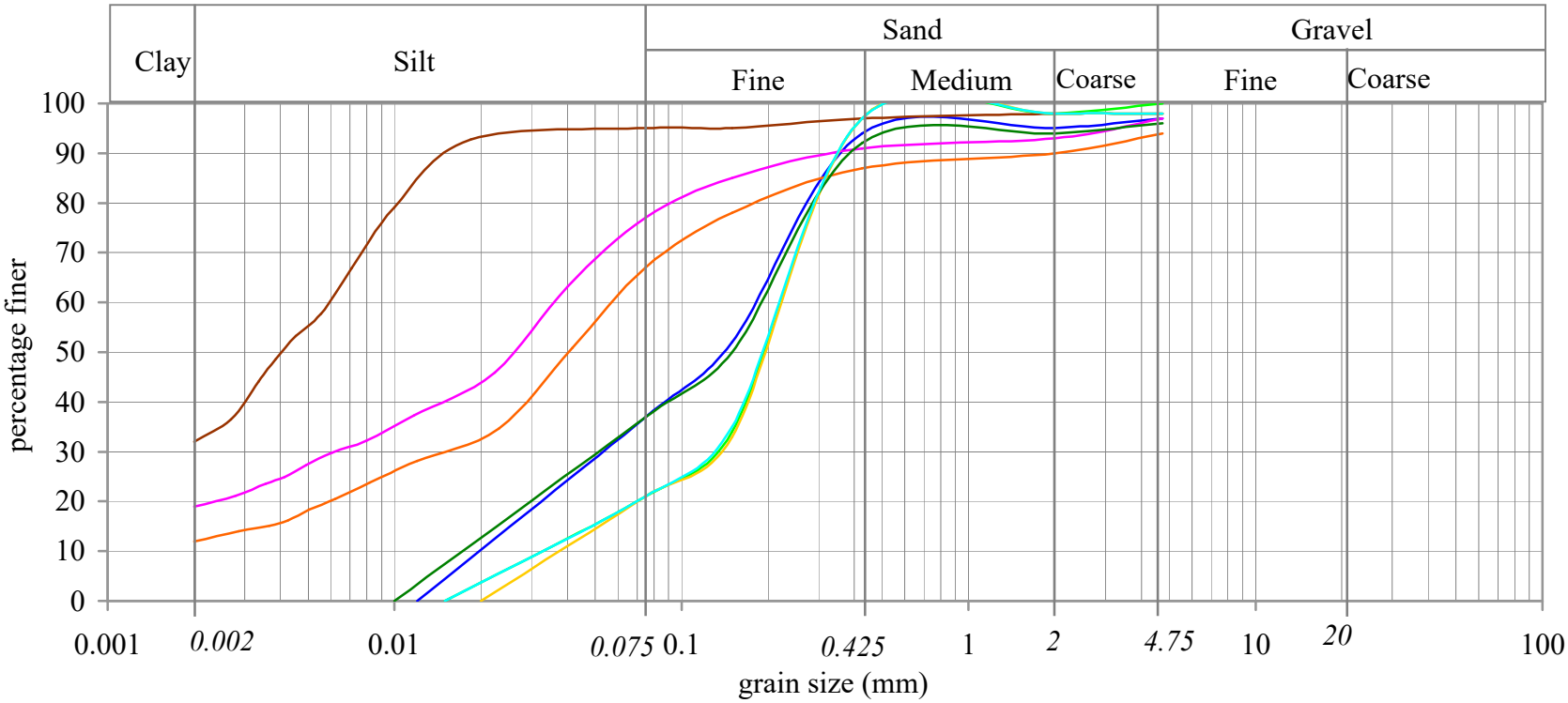
Sheet No. : 7g

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	10.5	Silty sand with gravel	3	60	37	0	0.18	0.019	9.5
	4	12	Clayey sandy silt with gravel	6	27	55	12	0.059	-	-
	4	13.5	Silty sand	0	79	21	0	0.22	0.032	6.9
	4	15	Sandy clayey silt with gravel	2	3	63	32	0.0059	-	-
	4	16.5	Clayey sandy silt with gravel	3	20	58	19	0.035	-	-
	4	18	Silty sand with gravel	2	77	21	0	0.23	0.038	6.1
	4	21	Silty sand with gravel	4	59	37	0	0.17	0.016	10.6
	4	24	Silty sand with gravel	2	77	21	0	0.23	0.031	7.4

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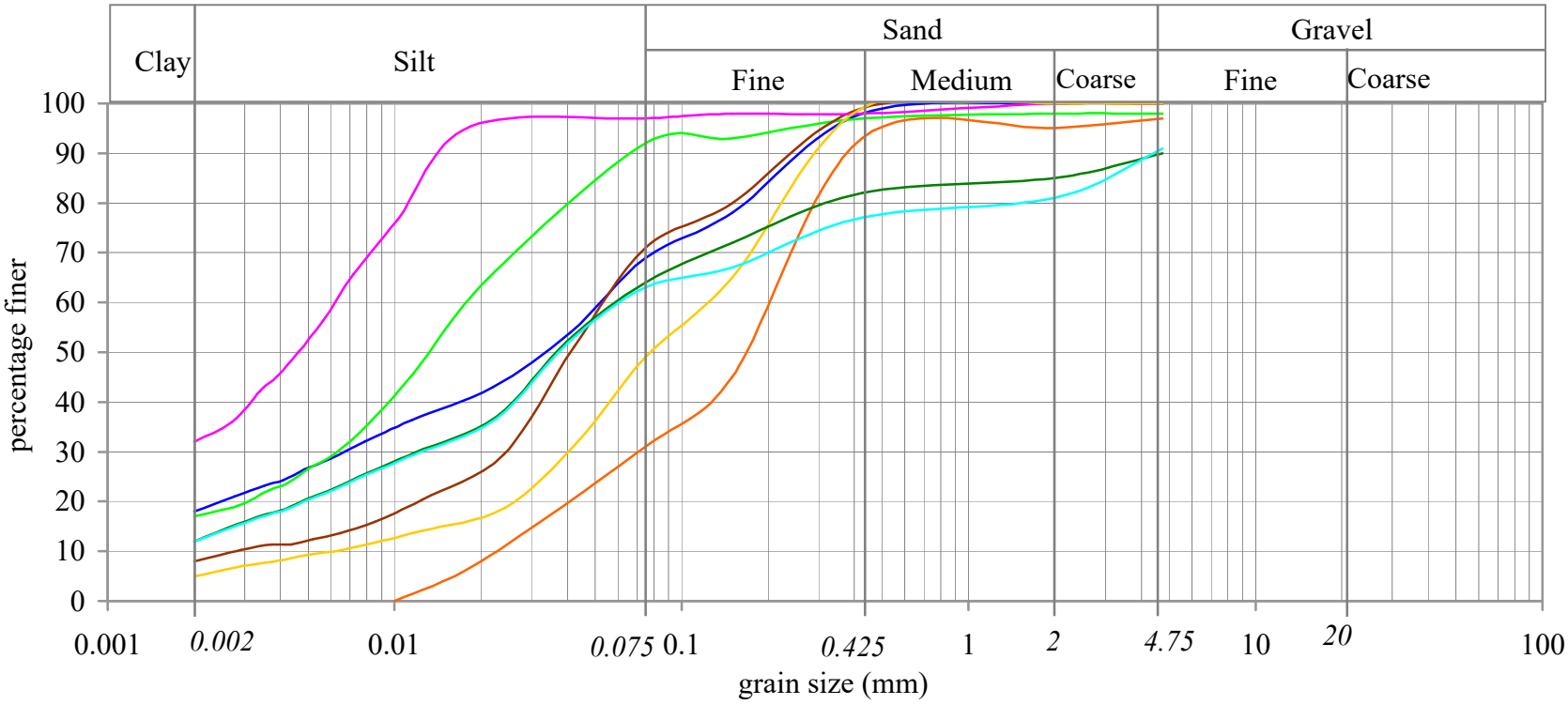
Sheet No. : 7h

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	0.9	Clayey sandy silt	0	31	51	18	0.051	-	-
	5	2.4	Silty sand with gravel	3	66	31	0	0.21	0.022	9.5
	5	3.9	Sandy clayey silt with gravel	2	6	75	17	0.018	-	-
	5	5.4	Clayey sandy silt	0	29	63	8	0.052	0.0026	20.0
	5	6.9	Sandy clayey silt	0	3	65	32	0.0061	-	-
	5	8.4	Clayey silty sand	0	51	44	5	0.12	0.0055	21.8
	5	9.9	Clayey sandy silt with gravel	10	26	52	12	0.052	-	-
	5	11.4	Clayey sandy silt with gravel	9	28	51	12	0.061	-	-

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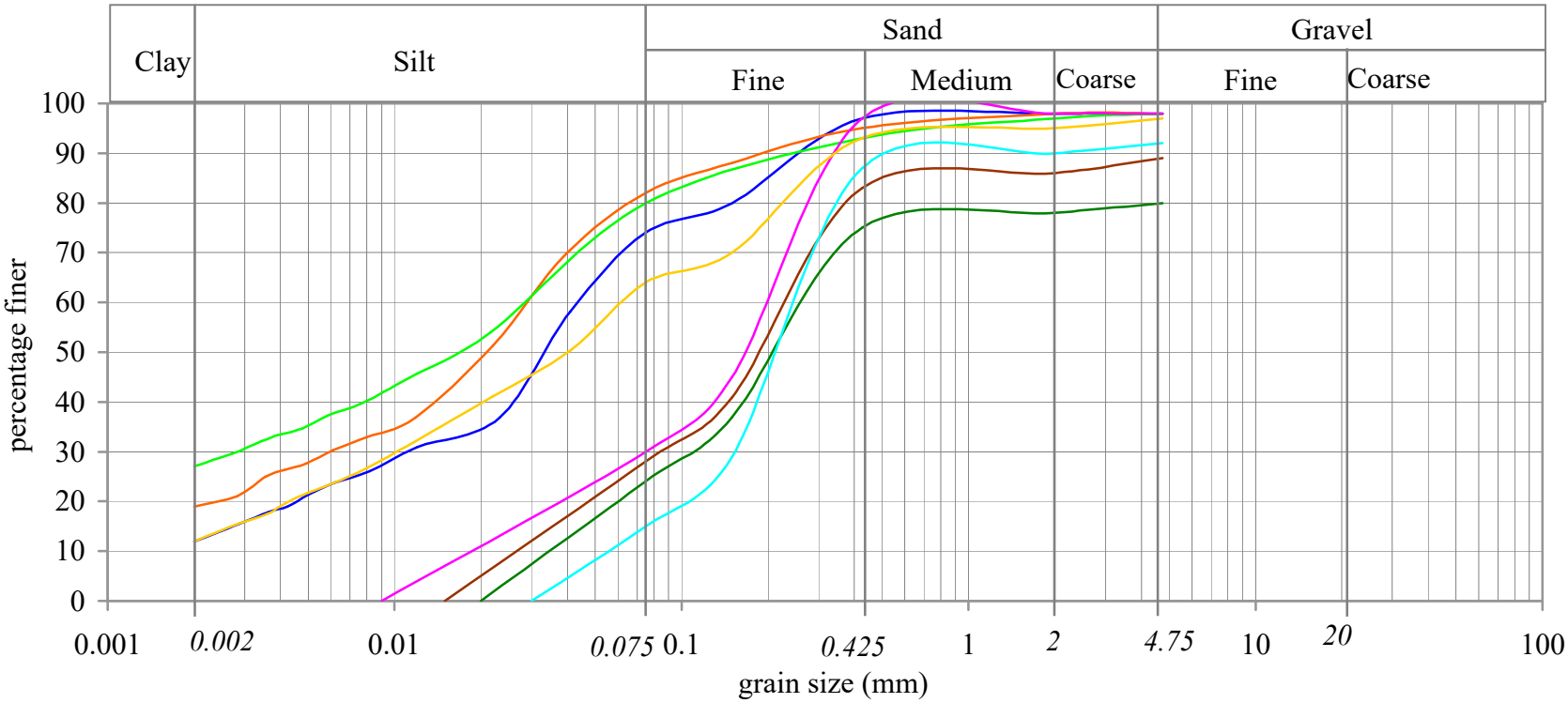
Sheet No. : 7i

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	12.9	Clayey sandy silt with gravel	2	24	62	12	0.041	-	-
	5	14.4	Sandy clayey silt with gravel	2	16	63	19	0.029	-	-
	5	15.9	Sandy clayey silt with gravel	2	18	53	27	0.028	-	-
	5	17.4	Silty sand with gravel	11	61	28	0	0.23	0.026	8.8
	5	20.4	Silty sand with gravel	2	68	30	0	0.2	0.018	11.1
	5	23.4	Clayey sandy silt with gravel	3	33	52	12	0.061	-	-
	6	1.5	Silty sand with gravel	20	56	24	0	0.26	0.032	8.1
	6	3	Sand with silt with gravel	8	77	15	0	0.25	0.055	4.5

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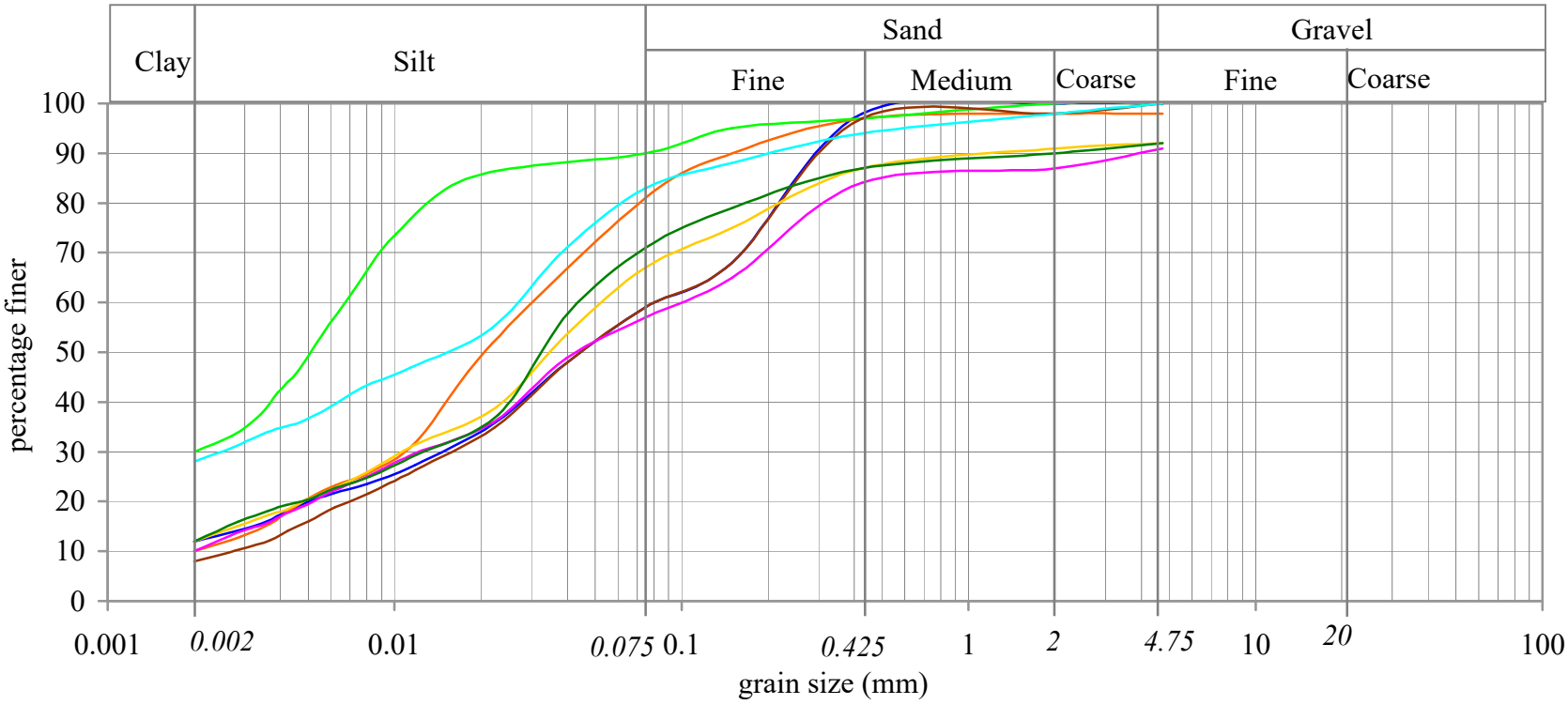
Sheet No. : 7j

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	Clayey sandy silt	0	41	47	12	0.08	-	-
	6	6	Clayey sandy silt with gravel	2	17	71	10	0.03	0.002	15.0
	6	7.5	Sandy clayey silt	0	10	60	30	0.0068	-	-
	6	9	Clayey sandy silt	0	41	51	8	0.081	0.0028	28.9
	6	10.5	Clayey sandy silt with gravel	9	34	47	10	0.095	0.002	47.5
	6	12	Clayey sandy silt with gravel	8	25	55	12	0.051	-	-
	6	13.5	Clayey sandy silt with gravel	8	21	59	12	0.042	-	-
	6	15	Sandy clayey silt	0	17	55	28	0.026	-	-

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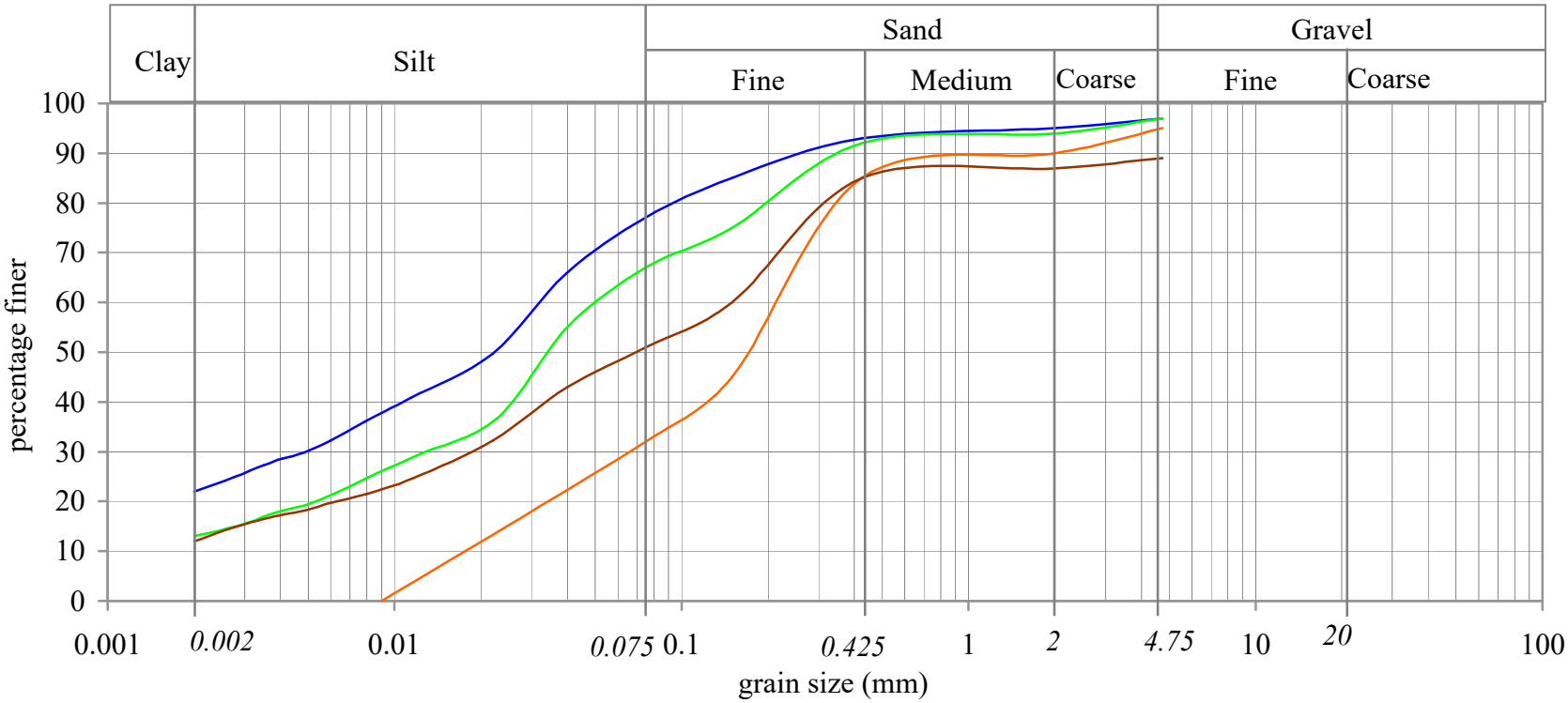
Sheet No. : 7k

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
	6	16.5	Sandy clayey silt with gravel	3	20	55	22	0.031	-	-
	6	18	Silty sand with gravel	5	63	32	0	0.22	0.018	12.2
	6	21	Clayey sandy silt with gravel	3	30	54	13	0.05	-	-
	6	24	Clayey sandy silt with gravel	11	38	39	12	0.15	-	-