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SOIL INVESTIGATION REPORT

NAME OF WORK : RECOMMENDATION OF FOUNDATION FOR THE
RECONSTRUCTION OF TENEMENTS (S+9
FLOORS) IN WARD NO. 52, ZONE V, CHETTY
THOTTAM, CHENNAI - 600 013.

CLIENT : The Executive Engineer
Division – I,
Tamil Nadu Urban Habitat Development Board,
HLL Nagar, Tondairpet,
Chennai – 600 081.

Reference : The Executive Engineer, TNUHDB, Chennai, Lr. No.
522/HD/Dn-I/TNUHDB/2021, Dated 27.10.2021

JOB No : SM&FE 209 / Consultancy / 2022

DATE : 17th January 2022



DIVISION OF SOIL MECHANICS AND FOUNDATION ENGINEERING
DEPARTMENT OF CIVIL ENGINEERING
College of Engineering Guindy Campus
Anna University, Chennai 600 025



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Professor & Head

Dr. V.K. STALIN, M.E., Ph.D.
Professor

**RECOMMENDATION OF FOUNDATION FOR THE RECONSTRUCTION OF TENEMENTS
 (S+9) FLOORS IN WARD NO. 52, ZONE V, CHETTY THOTTAM, CHENNAI - 600 013.**

Job. No. SM&FE / 209 / Consultancy / 2022

Date: 17.01.2022

CLIENT:

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 Tamil Nadu Urban Habitat Development Board,
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1. INTRODUCTION

The Tamil Nadu Urban Habitat Development Board (TNUHDB), Division – I, HLL Nagar, Tondairpet, Chennai – 600 081 has proposed to reconstruct Tenements (S+9 Floors) in Ward No. 52, zone V, Chetty Thottam, Chennai – 600 013. The officials of TNUHDB, Division – I, Tondairpet, Chennai – 600 081 have approached the Head, Division of Soil Mechanics and Foundation Engineering, Department of Civil Engineering, College of Engineering, Guindy (CEG), Anna University, Chennai - 25 to carryout soil investigation in the proposed site and to recommend the most suitable foundation system for the proposed reconstruction of Tenements (S+9 Floors) in Ward No. 52, zone V, Chetty Thottam, Chennai – 600 013. Accordingly, the work was taken up and field investigation was carried out during 25th November 2021 to 13th December 2021 by M/s VRR Engineering Consultancy, Chennai under the supervision of Faculty members of Division of Soil Mechanics and Foundation Engineering, Department of Civil Engineering, Anna University, Chennai, Executive Engineer, Asst. Executive Engineer and Assistant Engineer of TNUHDB, Division – I, Tondairpet, Chennai – 600 081. This report comprises the details of soil investigation, analysis of field and laboratory test results on soil and recommendation of suitable foundation system.

2. SITE CONDITION AND EXPERIMENTAL PROGRAMME

The proposed site is located at Ward No. 52, zone V, Chetty Thottam, Chennai 600 013. The site is a plain terrain. The total number of borehole locations has been decided as '4', as agreed by the Officials of Executive Engineer of TNUHDB, Division – I, Tondairpet, Chennai – 600 081 and the Professor cum Project Co-ordinator, Division of Soil Mechanics and Foundation Engineering, Department of Civil Engineering, Anna University, Chennai, such that these locations are coming well within the proposed construction area. The nature of field tests includes standard penetration tests, disturbed soil sampling through split spoon sampler, identification of different soil layers, retrieving of rock core samples, location of ground water table, complete logging of the borehole etc,. Laboratory investigation consists of classification tests such as grain size distribution, Atterberg limits, specific gravity and free swell index of soil samples.

The boreholes were advanced from the existing ground level using rotary boring technique supplemented by bentonite mud circulation. Mud circulation was used to stabilize the sides and bottom of the boreholes and then to bring the soil cuts to the surface. Bentonite slurry would also help to minimize the disturbance of the soil at the bottom of the borehole while drilling operation is in progress. In general, rotary boring technique with bentonite mud circulation is found most suitable to make exploratory boreholes of diameter 150 mm (IS 1892 : 1979). During boring operation, borehole was always kept full with the drilling mud so as to prevent any disturbance to the soil within the test zone (Plate 1 of Annexure – 1).

Standard penetration tests were conducted at every 1.0 m interval up to 6.0 m depth and thereafter 1.5 m interval in all the borehole locations. These SPT tests were carried out using Winch and Auto-trip free fall device for which the expected energy level is approximately 60% to 70%. The 'N' value resulting from this procedure may be considered as N_{60} . Disturbed soil samples collected through the split spoon sampler were preserved and transported to the soil testing laboratory for detailed identification tests. During the progress of soil investigation at the proposed site, the site was monitored by the Professor of Division of Soil Mechanics and Foundation Engineering, Department of Civil Engineering, CEG Campus, Anna University, Chennai – 25.

All field and laboratory tests were conducted as per the Indian Standard Testing procedure (SP 36 Part I: 1987 & Part II: 1988). All the field test results recorded in the bore logs are illustrated in figures A-1 to A-4. The field 'N' values at different depths and samples collected at these depths are mentioned in the bore logs. Laboratory test results (index and engineering properties) of soil samples collected through split spoon sampler are summarized in table A-1 to table A-4 of this report.

3. REVIEW OF FIELD AND LABORATORY TEST RESULTS OF SOIL PROFILE

Figures 1 show the variation of SPT 'N' value of different soil layers with respect to depth in BH 1 to BH 4 of the proposed site. It could be seen from figure 1 that the variations of SPT 'N' values are almost uniform in all the four bore holes, indicating the homogeneity of soil layer (Plate 2 of Annexure – 2).

3.1 Summary of Soil Profile in BH 1 to BH 4 Locations

1. The top 3.0 m was filled with cemented debris with made-up soil in all four bore-hole locations.
2. Brown / Greyish Brown Silty Sand was found from top 4.0 m depth to 27.0 m depth in all four bore-hole locations with SPT 'N' value varying from 8 to 82.
3. Greyish Brown weathered Residual Soil was encountered in BH 1 & BH 2 locations and Weathered Charnockite layer was observed in BH 3 and BH 4 locations in 28.5 m depth with SPT 'N' values of >100.
4. Greyish Weathered Charnockite layer are found from 28.5 m to 34.0 m in all four Bore-hole locations.
5. The ground water table was observed from 3.3 m to 4.1 m depth at the time of In-situ Soil Investigation work.

Thus, it is evident that the soil profile is homogeneous with reference to relative density / consistency in the proposed site as reflected from BH 1 to BH 4 locations (Figure 1).

4.0 SHEAR STRENGTH PROPERTIES AND ELASTICITY MODULUS VALUES 'E_s' OF SOIL SAMPLES

The Geotechnical design parameters required to determine the bearing capacity and settlement of foundation system are arrived by analyzing the Field Bore-Log profile and Laboratory test results and listed in table – 1 to table - 4. The 'E_s' values are computed based on Bowles 1997 correlation.

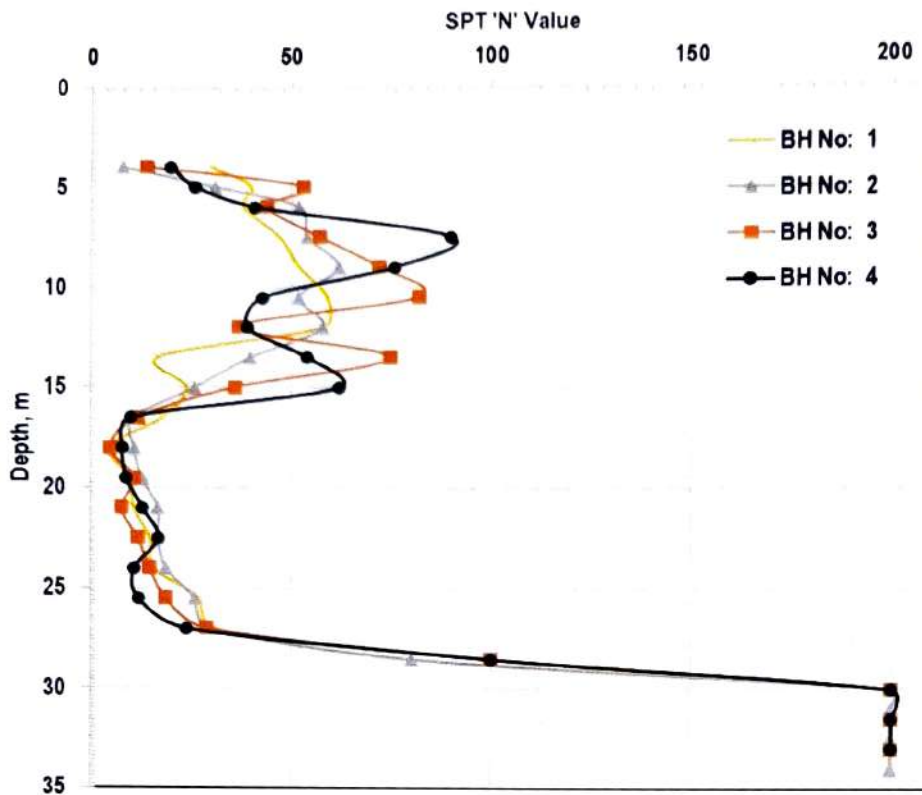


Figure (1) Variation of SPT 'N' value of different soil layers with respect to depth in Different Borehole Locations of the Site

5.0 COMPUTATION OF SAFE PILE CARRYING CAPACITY

The top 4.0 m depth layer is consisting of construction Debris. Provision of shallow foundation (i.e., Raft) at 5.0 m depth is cumbersome for (S + 13) floors structure. Huge excavation may be required with proper supporting system to place raft foundation. By considering the difficulties involved in Raft Foundation at 5.0 m depth for (S + 13) floors structure, attempts are made to suggest pile foundation for varying pile diameter. For computing the load carrying capacity of pile, Indian Standard IS 2911 (Part 1/Sec. 2) 2010 method and Meyerhof 1959 formula (Based on SPT 'N' Value) are used. The diameters of piles are assumed as 450 mm, 500 mm, 600 mm, 700 mm and 900 mm and the length of the pile is taken as 31.0 m. Safe pile carrying capacity computations were made for all four-borehole data. The Indian Standard IS 2911 (2010) specifies that the base resistance should not exceed 1000 to 1100 t/m² for bored cast-in-situ piles and 1500 t/m² for precast driven piles.

For calculating the skin friction along the pile length of 31.0 m, the design values and shear strength parameters for the respective depths were used. The soil layers in top 2 m depth may induce settlement of surrounding soil while pile driving which in turn may cause negative skin friction. Hence, the safe frictional resistance is computed by neglecting these layer's frictional capacity and the negative skin friction value was suitably deducted in the computation of safe bearing capacity of piles. The safe end bearing resistance and safe skin frictional resistance are together added for different pile diameter and the total safe load carrying capacity of pile thus computed is shown in Table 1. The calculations of pile carrying capacity by static formula (IS 2911: 2010) and Meyerhof formula (1959) are presented in Annexure 2. The factor of safety of 2.5 has been used for determining safe end bearing and also frictional capacity of bored cast-in-situ piles.

The uplift capacity of a pile is given by sum of the frictional resistance and the weight of the pile (buoyant or total as relevant) as per Section 6.3.2 of IS 2911 (Part 1/Sec. 2) 2010. As per codal provisions, the recommended factor of safety is 3.0 in the absence of any pull-out test results and 2.0 with pullout test results. Uplift capacity can be obtained from static formula by ignoring end-bearing, but adding weight of the pile (buoyant or total as relevant). The safe uplift capacities of pile for varying diameter are given in Table 2.

TABLE 1 Safe Load carrying capacity of Bored Cast-In-Situ Pile of 31.0 m Length for varying Diameter

Borehole Location	Pile capacity for Bored Cast-In-Situ Piles, (kN) IS 2911 Part-I 2010 Static Formula									
Diameter of Pile (mm)	Based on Shear Strength Parameters ('c' and ' Φ ')					Based on SPT 'N' Values				
	450	500	600	700	900	450	500	600	700	900
BH 1	1430	1675	2218	2829	4260	1070	1275	1738	2269	3540
BH 2	1529	1786	2350	2984	4458	1318	1551	2068	2655	4036
BH 3	1505	1758	2317	2945	4409	1234	1457	1956	2524	3867
BH 4	1470	1720	2272	2892	4340	1158	1373	1855	2406	3715

TABLE 2 Safe Uplift Capacity of 31.0 m Length Pile for varying Diameter (IS 2911 (Part 1/Sec. 2) 2010

Borehole Location	Safe Uplift Capacity (kN) IS 2911 (Part 1/Sec. 2) 2010				
Diameter of Pile (mm)	450	500	600	700	900
BH 1	701	794	989	1197	1648
BH 2	804	908	1126	1357	1854
BH 3	777	878	1090	1314	1800
BH 4	743	840	1045	1262	1732

6. CONCLUSIONS AND RECOMMENDATIONS

Based on the discussions made in sections 3, 4, 5 and 6, the following recommendations are furnished for the reconstruction of Tenements (S+13 Floors) in Ward No. 52, Zone V, Chetty Thottam, Chennai – 600 013.

- 1) The recommended type of pile foundation is **"Bored Cast-In-Situ Pile"**
- 2) The recommended safe vertical and lateral pile carrying capacity of the 31.0 m length of 'bored cast in-situ pile' for varying diameter is shown in Table 3. The required number of piles may be varied with respect to the varying column loads.
- 3) The bored cast in-situ pile shall be terminated at 31.0 m in Greyish Weathered Charnockite stratum.
- 4) With regard to execution of bored cast-in-situ pile, procedure outlined in IS 2911 Part 1 Section 2: 2010 may be referred and scrupulously followed.
- 5) Pile load test shall be conducted to ensure the designed pile carrying capacity. The minimum grade of concrete for pile foundation shall be M 30 to M 40.

TABLE 8 Safe Load carrying capacity and Lateral Load Capacity of Bored Cast-In-Situ Pile for varying diameter and for a length of 31.0 m from the existing ground level (Borehole level)

Diameter of Pile (mm)	Recommended Safe Load carrying capacity of Bored Cast-In-Situ Piles, (kN)	Recommended Lateral Load Capacity for 5 mm deflection, (kN)	Depth of fixity from bore-hole level (m)
450	1100	87.20	3.36
500	1250	103.70	3.65
600	1750	138.10	4.23
700	2200	177.30	4.78
900	3300	264.30	5.85

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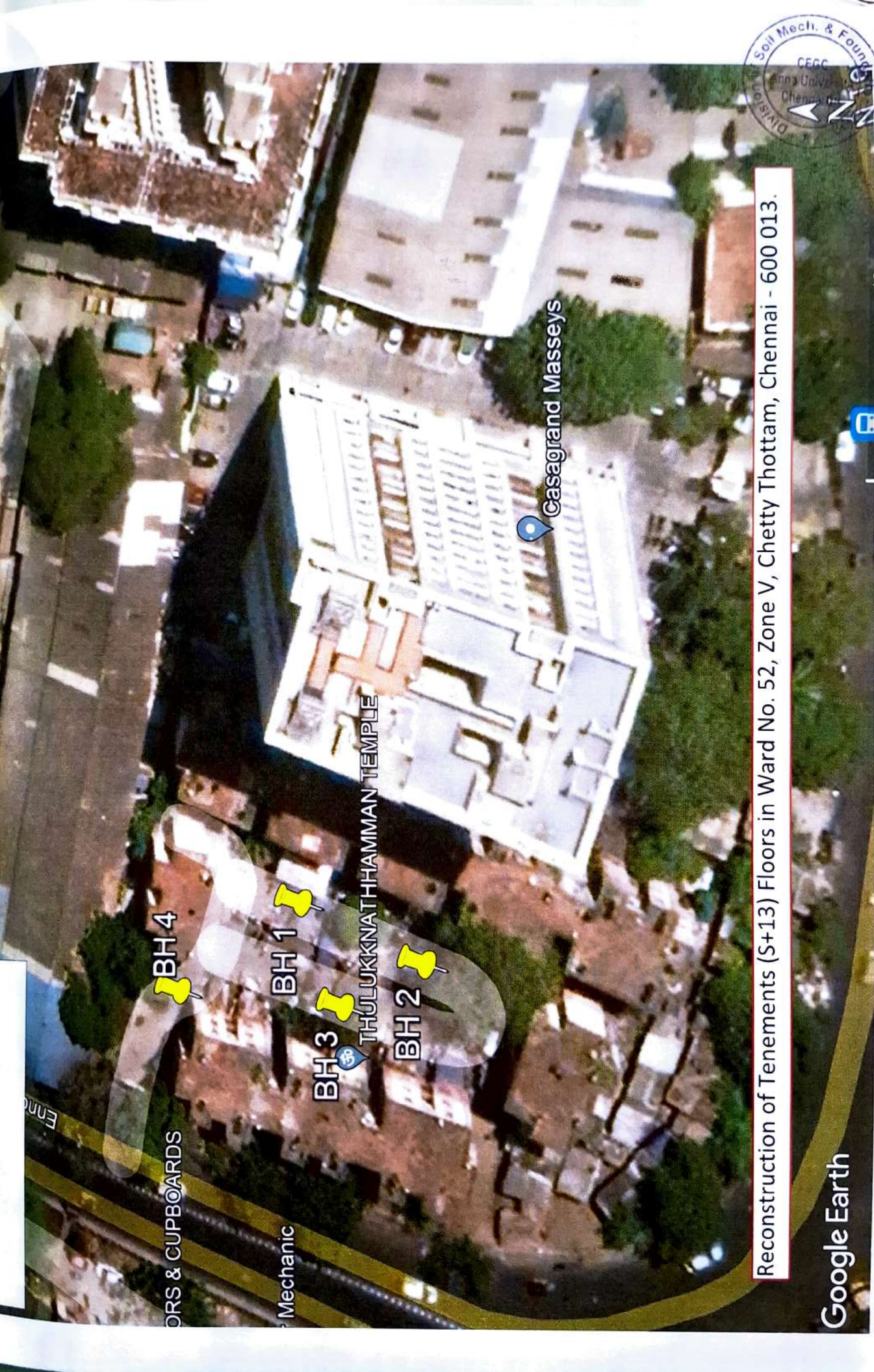
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Anna University, Chennai-25

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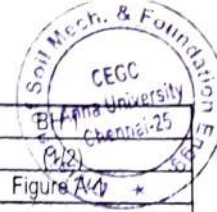
Reconstruction of Tenements (S+13) Floors in Ward No. 52, Zone V, Chetty Thottam, Chennai - 600 013.



IN-SITU GEOTECHNICAL BORE LOG

BORE-HOLE No.

SHEET No.



Project: Reconstruction of Tenements (S+13) Floors in Ward No. 52, Zone V, Chetty Thottam, Chennai - 600 013.

Co-ordinates: N - 1449031 ; E - 423210

Started: 25-11-2021

Location: Chettithottam

Completed: 28-11-2021

Elevation (RL): -

Ground Water Level: 4.1 m

Dia of Boring: Px Size in Soil & Nx Size in Rock

Type of Core Barrel: Nx Size Core Barrel

Casing Depth: 4.5 m

Water Loss Depths : 4.0 m - Grouted

Type of Boring: Rotary - Auto Trip SPT

Total Drill Depth: 34.0 m (28.5 m - Soil & 5.5 m Rock)

Depth from EGL (m)	Log	Lithology	Description / Classification of Soil and Rock / Weathering Grade of Rock as per IS 4464 / Special Observations and Interpretations	Standard Penetration Test (SPT) / UDS / Core Drilling						Relative Density / Consistency of Soil / Strength of Rock
				0-15 cm	15-30 cm	30-45 cm	SPT-N	TCR (%)	RQD (%)	
0 30 60 90 120 150 180										
1.0	1.0		Concrete Debris with made-up Soil	-	-	-	-			Loose
2.0	2.0		-	-	-	-				
3.0	3.0		-	-	-	-				
4.0	4.0		Brown Sand (SP)	13	13	17	30			Medium Dense
5.0	5.0		Greyish Brown Sand (SP)	7	19	21	40			Dense
6.0	6.0		Greyish Brown Sand (SP)	14	18	20	38			Dense
7.5	7.0		Greyish Brown Sand (SP)	6	18	29	47			Dense
9.0	8.0		Greyish Brown Sand (SP)	30	25	27	52			Very Dense
10.5	10.0		Greyish Brown Sand (SP)	8	25	34	59			Very Dense
12.0	11.0		Greyish Brown Silty Sand (SM-SP)	22	26	32	58			Very Dense
13.5	13.0		Greyish Silty Sand (SM-SP)	7	8	9	17			Medium Dense
15.0	14.0		Greyish Silty Sand (SM-SP)	9	11	13	24			Medium Dense
16.5	15.0		Greyish Silty Sand (SM-SP)	6	8	10	18			Medium Dense



SHEET No.

Total Drill Depth:	34.0 m (28.5 m - Soil & 5.5 m Rock)
--------------------	-------------------------------------

Depth from E.G.L. (m)		Log	Lithology	Description / Classification of Soil and Rock / Weathering Grade of Rock as per IS 4464 / Special Observations and Interpretations	Standard Penetration Test (SPT) / UDS / Core Drilling						Relative Density / Consistency of Soil / Strength of Rock
					0-15 cm	15-30 cm	30-45 cm	SPT-N	TCR (%)	RQD (%)	
0 30 60 90 120 150 180											
17.0											
18.0				Greyish Brown Silty Sand (SM-SP)	5	2	3	5			Loose
19.5				Greyish Silty Sand (SM-SP)	3	3	7	10			Loose
21.0				Greyish Silty Sand (SM-SP)	3	3	8	11			Medium Dense
22.5				Greyish Silty Sand (SM-SP)	5	5	10	15			Medium Dense
24.0				Greyish Sand (SM-SP)	7	7	9	16			Medium Dense
25.5				Greyish Silty Sand (SM-SP)	10	14	13	27			Medium Dense
27.0				Greyish Silty Sand (SM-SP)	14	14	17	31			Dense
28.5				Greyish Brown Residual Soil	55 (6 cm) Rebound			> 100			Hard
30.0				Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)					14.6	14.6	Weak
31.5				Charnockite, Grey, Medium Grained, Completely Weathered (Grade V)					16.0	0.0	Very Weak
33.0				Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)					25.3	21.3	Weak
34.0									32.0	13.0	



IN-SITU GEOTECHNICAL BORE LOG

BORE-HOLE No.
SHEET No.



Project:		Reconstruction of Tenements (S+13) Floors in Ward No. 52, Zone V, Chetty Thottam, Chennai - 600 013.									
Co-ordinates:		N - 1449015 ; E - 423205				Started:		01-12-2021			
Location:		Chettithottam				Completed:		03-12-2021			
Elevation (RL):		-				Ground Water Level:		3.9 m			
Dia of Boring:		Px Size in Soil & Nx Size in Rock				Type of Core Barrel:		Nx Size Core Barrel			
Casing Depth:		4.5 m				Water Loss Depths :		3.5 m - Grouted			
Type of Boring:		Rotary – Auto Trip SPT				Total Drill Depth:		34.0 m (28.5 m - Soil & 5.5 m Rock)			
Depth from EGL (m)	Log	Lithology	Description / Classification of Soil and Rock / Weathering Grade of Rock as per IS 4464 / Special Observations and Interpretations	Standard Penetration Test (SPT) / UDS / Core Drilling						Relative Density / Consistency of Soil / Strength of Rock	
				0-15 cm	15-30 cm	30-45 cm	SPT-N	TCR (%)	RQD (%)		
0 30 60 90 120 150 180											
18.0	17.0		Greyish Brown Sand (SP)	5	5	6	11				Medium Dense
19.5	19.0		Greyish Silty Sand (SM-SP)	4	4	9	13				Medium Dense
21.0	20.0		Greyish Silty Sand (SM-SP)	4	6	11	17				Medium Dense
22.5	22.0		Brownish Grey Sand (SP)	6	7	10	17				Medium Dense
24.0	23.0		Greyish Sand (SP)	5	8	11	19				Medium Dense
25.5	24.0		Greyish Sand (SP)	9	12	14	26				Medium Dense
27.0	26.0		Greyish Sand (SP)	10	12	18	30				Medium Dense
28.5	27.0		Greyish Residual Soil	50 (3 cm) Rebound			> 100				Hard
30.0	28.0		Charnockite, Grey, Medium Grained, Completely Weathered (Grade V)					10.6	0.0		Very Weak
31.0	29.0		Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)					25.0	10.0		Weak
32.5	30.0							20.0	14.0		
34.0	31.0							19.0	19.0		



IN-SITU GEOTECHNICAL BORE LOG

BORE-HOLE No.

SHEET No.

Figure No. 3

Project: Reconstruction of Tenements (S+13) Floors in Ward No. 52, Zone V, Chetty Thottam, Chennai - 600 013.

Co-ordinates: N - 1449025 ; E - 423199

Started: 05-12-2021

Location: Chettithottam

Completed: 08-12-2021

Elevation (RL): -

Ground Water Level: 3.5 m

Dia of Boring: Px Size in Soil & Nx Size in Rock

Type of Core Barrel: Nx Size Core Barrel

Casing Depth: 4.5 m

Water Loss Depths : -

Type of Boring: Rotary - Auto Trip SPT

Total Drill Depth: 33.0 m (28.5 m - Soil & 4.5 m Rock)

Depth from EGL (m)	Log	Lithology	Standard Penetration Test (SPT) / UDS / Core Drilling						Relative Density / Consistency of Soil / Strength of Rock
			0-15 cm	15-30 cm	30-45 cm	SPT-N	TCR (%)	RQD (%)	
1.0	1.0	Concrete Debris with made-up Soil	-	-	-	-			Loose
2.0	2.0		-	-	-	-			
3.0	3.0		-	-	-	-			
4.0	4.0	Brownish Sand (SP)	3	6	8	14			Medium Dense
5.0	5.0	Greyish Brown Sand (SP)	17	24	29	53			Very Dense
6.0	6.0	Brownish Sand (SP)	15	19	25	44			Dense
7.5	7.0	Greyish Brown Silty Sand (SM-SP)	16	24	33	57			Very Dense
9.0	8.0	Greyish Brown Sand (SP)	17	24	48	72			Very Dense
10.5	9.0	Greyish Brown Sand (SP)	20	35	47	82			Very Dense
12.0	10.0	Greyish Brown Sand (SP)	10	22	25	47			Dense
13.5	11.0	Greyish Brown Silty Sand (SM-SP)	21	31	44	75			Very Dense
15.0	12.0	Greyish Brown Sand (SP)	10	12	14	26			Medium Dense
16.5	13.0	Greyish Silty Sand (SM-SP)	3	4	8	12			Medium Dense



IN-SITU GEOTECHNICAL BORE LOG

BORE-HOLE No.

SHEET No.



Project: Reconstruction of Tenements (S+13) Floors in Ward No. 52, Zone V, Chetty Thottam, Chennai - 600 013.

Co-ordinates: N - 1449047 ; E - 423198

Started: 11-12-2021

Location: Chettithottam

Completed: 13-12-2021

Elevation (RL): -

Ground Water Level: 3.3 m

Dia of Boring: Px Size in Soil & Nx Size in Rock

Type of Core Barrel: Nx Size Core Barrel

Casing Depth: 4.5 m

Water Loss Depths : -

Type of Boring: Rotary - Auto Trip SPT

Total Drill Depth: 33.0 m (28.5 m - Soil & 4.5 m Rock)

Depth from EGL (m)	Log	Lithology	Standard Penetration Test (SPT) / UDS / Core Drilling						Relative Density / Consistency of Soil / Strength of Rock
			0-15 cm	15-30 cm	30-45 cm	SPT-N	TCR (%)	RQD (%)	
1.0	1.0	Concrete Debris with made-up Soil	-	-	-	-			Loose
2.0	2.0		-	-	-	-			
3.0	3.0		-	-	-	-			
4.0	4.0	Brownish Sand (SP)	8	10	10	20			Medium Dense
5.0	5.0	Greyish Brown Sand (SP)	9	11	15	26			Medium Dense
6.0	6.0	Brownish Sand (SP)	14	18	23	41			Dense
7.5	7.0	Brownish Sand (SP)	23	35	55	90			Very Dense
9.0	8.0	Greyish Brown Silty Sand (SM-SP)	20	30	46	76			Very Dense
10.5	9.0	Greyish Brown Silty Sand (SM-SP)	15	19	24	43			Dense
12.0	10.0	Greyish Brown Silty Sand (SM-SP)	14	18	21	39			Dense
13.5	11.0	Greyish Brown Silty Sand (SM-SP)	17	26	28	54			Very Dense
15.0	12.0	Greyish Brown Sand (SP)	19	31	31	62			Very Dense
16.5	13.0	Brownish Grey Silty Sand (SM-SP)	3	4	6	10			Loose

IN-SITU GEOTECHNICAL BORE LOG

BORE-HOLE No.

SHEET No.

Figure A-4 Chennai-25

Project: Reconstruction of Tenements (S+13) Floors in Ward No. 52, Zone V, Chetty Thottam, Chennai - 600 013.

Co-ordinates: N - 1449047 ; E - 423198

Started: 11-12-2021

Location: Chettithottam

Completed: 13-12-2021

Elevation (RL): -

Ground Water Level: 3.3 m

Dia of Boring: Px Size in Soil & Nx Size in Rock

Type of Core Barrel: Nx Size Core Barrel

Casing Depth: 4.5 m

Water Loss Depths : -

Type of Boring: Rotary - Auto Trip SPT

Total Drill Depth: 33.0 m (28.5 m - Soil & 4.5 m Rock)

Depth from EGL (m)	Log	Lithology	Standard Penetration Test (SPT) / UDS / Core Drilling						Relative Density / Consistency of Soil / Strength of Rock
			0-15 cm	15-30 cm	30-45 cm	SPT-N	TCR (%)	RQD (%)	
			0 30 60 90 120 150 180						
17.0									
18.0		Greyish Silty Sand (SM-SP)	3	3	5	8			Loose
19.0									
19.5		Greyish Silty Sand (SM-SP)	2	4	5	9			Loose
20.0									
21.0		Greyish Brown Silty Sand (SM-SP)	2	5	8	13			Medium Dense
22.0									
22.5		Greyish Silty Sand (SM-SP)	3	6	11	17			Medium Dense
23.0									
24.0		Brownish Grey Silty Sand (SM-SP)	6	5	6	11			Medium Dense
25.0									
25.5		Greyish Brown Silty Sand (SM-SP)	7	6	6	12			Medium Dense
26.0									
27.0		Greyish Silty Sand (SM-SP)	10	10	14	24			Medium Dense
28.0									
28.5		Brown Weathered Charnockite	55 (3 cm) Rebound			> 100			Hard
29.0									
30.0		Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)					20.0	8.0	Weak
31.0									
31.5		Charnockite, Grey, Medium Grained, Moderately Weathered (Grade III)					36.6	25.3	Moderately Weak
32.0									
33.0							46.0	39.3	

Project : Reconstruction of Tenements (S+13) Floors in Ward No. 52, Zone V, Chetty Thottam, Chennai - 600 013.																			
BH No: 1		Ground Water Table Depth (m): 4.1																	
LABORATORY TEST RESULTS																			
Depth (m)	SPT 'N' Value	Description / Classification of Soil and Rock / Weathering Grade of Rock as per IS 4464	Index Properties						Specific Gravity	Grain Size Analysis (%)					Direct Shear / Terzaghi and Peck (1974) - Shear Strength Parameters				
			Natural Moisture Content, %	Bulk Density (kN/m ³)	Liquid Limit, %	Plastic Limit, %	Plasticity Index, %	Free Swell Index		Gravel	Coarse Sand	Medium Sand	Fine Sand	Fines	Cohesion (c), kN/m ²	Angle of Friction (φ) in Degrees			
4.0	30	Brown Sand (SP)	15	20.9	NP	NP	NP	NP	NP	2.63	0	4	52	35	9	0	37		
5.0	40	Greyish Brown Sand (SP)	14	22.0	NP	NP	NP	NP	NP	2.63	0	6	63	23	8	0	41		
6.0	38	Greyish Brown Sand (SP)	18	21.8	NP	NP	NP	NP	NP	2.64	0	3	54	36	7	0	40		
7.5	47	Greyish Brown Sand (SP)	19	22.0	NP	NP	NP	NP	NP	2.63	0	4	24	64	8	0	42		
9.0	52	Greyish Brown Sand (SP)	13	22.0	NP	NP	NP	NP	NP	2.64	0	5	52	40	3	0	42		
10.5	59	Greyish Brown Sand (SP)	18	22.0	NP	NP	NP	NP	NP	2.64	0	6	43	43	8	0	42		
12.0	58	Greyish Brown Silty Sand (SM-SP)	20	22.0	NP	NP	NP	NP	NP	2.65	0	2	15	72	11	0	41		
13.5	17	Greyish Silty Sand (SM-SP)	21	18.7	NP	NP	NP	NP	NP	2.62	0	0	11	73	16	0	30		
15.0	24	Greyish Silty Sand (SM-SP)	22	20.0	NP	NP	NP	NP	NP	2.63	0	2	12	73	13	0	34		
16.5	18	Greyish Silty Sand (SM-SP)	24	18.9	NP	NP	NP	NP	NP	2.64	0	0	9	73	18	0	31		
18.0	5	Greyish Brown Silty Sand (SM-SP)	21	14.7	NP	NP	NP	NP	NP	2.64	0	2	36	45	17	0	21		
19.5	10	Greyish Silty Sand (SM-SP)	17	16.9	NP	NP	NP	NP	NP	2.63	0	2	39	46	13	0	26		
21.0	11	Greyish Silty Sand (SM-SP)	16	17.2	NP	NP	NP	NP	NP	2.62	0	3	41	44	12	0	27		
22.5	15	Greyish Silty Sand (SM-SP)	17	18.2	NP	NP	NP	NP	NP	2.63	0	2	52	33	13	0	29		
24.0	16	Greyish Sand (SM-SP)	15	18.5	NP	NP	NP	NP	NP	2.62	0	4	56	31	9	0	31		
25.5	27	Greyish Silty Sand (SM-SP)	15	20.4	NP	NP	NP	NP	NP	2.63	0	5	56	28	11	0	35		
27.0	31	Greyish Silty Sand (SM-SP)	16	21.0	NP	NP	NP	NP	NP	2.62	0	4	45	29	22	0	37		
28.5	>100	Greyish Brown Residual Soil	13	22.0	NP	NP	NP	NP	NP	2.64	16	15	33	16	20	0	42		
											</								

BH No: 2

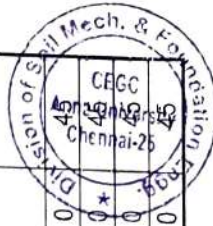
LABORATORY TEST RESULTS

LABORATORY TEST RESULTS																		
Depth (m)	SPT 'N' Value	Description / Classification of Soil and Rock / Weathering Grade of Rock as per IS 4464	Index Properties						Specific Gravity	Grain Size Analysis (%)					Cohesion (c), KN/m^2	Angle of Friction (Φ) in Degrees	Direct Shear / Terzaghi and Peck (1974) - Shear Strength Parameters	
			Natural Moisture Content / Water Absorption, %	Bulk Density (KN/m^3)	Liquid Limit, %	Plastic Limit, %	Plasticity Index, %	Free Swell Index		Gravel	Coarse Sand	Medium Sand	Fine Sand	Fines				
														Silt & Clay				
4.0	8	Brownish Silty Sand (SM-SP)	19	16.1	NP	NP	NP	NP	2.62	0	5	28	56	11	0	25		
5.0	31	Brownish Sand (SP)	18	21.0	NP	NP	NP	NP	2.63	0	2	66	28	4	0	38		
6.0	52	Brownish Sand (SP)	18	22.0	NP	NP	NP	NP	2.63	0	3	52	42	3	0	42		
7.5	54	Brownish Silty Sand (SM-SP)	20	22.0	NP	NP	NP	NP	2.64	0	1	23	63	13	0	41		
9.0	62	Brownish Sand (SP)	19	22.0	NP	NP	NP	NP	2.64	0	2	37	56	5	0	42		
10.5	52	Greyish Brown Sand (SP)	19	22.0	NP	NP	NP	NP	2.63	0	1	31	61	7	0	42		
12.0	58	Brownish Sand (SP)	19	22.0	NP	NP	NP	NP	2.64	0	0	35	57	8	0	42		
13.5	40	Greyish Brown Silty Sand (SM-SP)	22	22.0	NP	NP	NP	NP	2.63	0	0	10	76	14	0	40		
15.0	26	Brownish Sand (SP)	22	20.3	NP	NP	NP	NP	2.63	0	1	37	57	5	0	36		
16.5	11	Greyish Brown Sand (SP)	21	17.2	NP	NP	NP	NP	2.64	0	0	38	58	4	0	27		
18.0	11	Greyish Brown Sand (SP)	21	17.2	NP	NP	NP	NP	2.63	0	0	30	60	10	0	28		
19.5	13	Greyish Silty Sand (SM-SP)	16	17.7	NP	NP	NP	NP	2.63	0	2	41	46	11	0	28		
21.0	17	Greyish Silty Sand (SM-SP)	17	18.7	NP	NP	NP	NP	2.64	0	4	41	43	12	0	30		
22.5	17	Brownish Grey Sand (SP)	18	18.7	NP	NP	NP	NP	2.63	0	2	47	42	9	0	31		
24.0	19	Greyish Sand (SP)	18	19.1	NP	NP	NP	NP	2.62	0	5	43	43	9	0	32		
25.5	26	Greyish Sand (SP)	15	20.3	NP	NP	NP	NP	2.63	0	10	53	31	6	0	36		
27.0	30	Greyish Sand (SP)	16	20.9	NP	NP	NP	NP	2.64	0	6	47	39	8	0	37		
28.5	>100	Greyish Residual Soil	14	22.0	NP	NP	NP	NP	2.65	0	13	40	16	31	0	41		
					Porosity of Rock (%)					Strength of Rock								
										UCS, KN/m^2		I_s , KN/m^2						
30.00	>100	Charnockite, Grey, Medium Grained, Completely Weathered (Grade V)	0.61	27.12	0.73				2.68	-		6545				0	45	
31.00	>100	Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)	0.57	27.86	0.69				2.67	48335		8641				0	45	
32.50	>100	Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)	0.55	28.45	0.64				2.69	52634		9634				0	45	
34.00	>100	Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)	0.42	28.64	0.59				2.68	56763		10459				0	45	

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Project : Reconstruction of Tenements (S+13) Floors in Ward No. 52, Zone V, Chetty Thottam, Chennai - 600 013.																
Ground Water Table Depth (m): 3.5																
LABORATORY TEST RESULTS																
BH No:	3															
Depth (m)	SPT 'N' Value	Description / Classification of Soil and Rock / Weathering Grade of Rock as per IS 4464	Index Properties					Specific Gravity	Grain Size Analysis (%)				Direct Shear I Terzaghi and Peck (1974) - Shear Strength Parameters			
			Natural Moisture Content / Water Absorption, %	Bulk Density (kN/m ³)	Liquid Limit, %	Plastic Limit, %	Plasticity Index, %		Free Swell Index	Fines				Cohesion (c), kN/m ²	Angle of Friction (φ) in Degrees	
										Gravel	Coarse Sand	Medium Sand	Fine Sand			
4.0	14	Brownish Sand (SP)	15	18.0	NP	NP	NP	NP	2.63	0	0	70	26	4	0	30
5.0	53	Greyish Brown Sand (SP)	14	22.0	NP	NP	NP	NP	2.63	0	6	31	56	7	0	42
6.0	44	Brownish Sand (SP)	17	22.0	NP	NP	NP	NP	2.64	0	3	36	53	8	0	42
7.5	57	Greyish Brown Silty Sand (SM-SP)	18	22.0	NP	NP	NP	NP	2.63	0	0	17	70	13	0	41
9.0	72	Greyish Brown Sand (SP)	20	22.0	NP	NP	NP	NP	2.64	0	0	30	64	6	0	42
10.5	82	Greyish Brown Sand (SP)	16	22.0	NP	NP	NP	NP	2.65	0	5	39	51	5	0	42
12.0	47	Greyish Brown Sand (SP)	18	22.0	NP	NP	NP	NP	2.64	0	0	37	54	9	0	40
13.5	75	Greyish Brown Silty Sand (SM-SP)	16	22.0	NP	NP	NP	NP	2.63	0	5	25	59	11	0	41
15.0	26	Greyish Brown Sand (SP)	20	20.3	NP	NP	NP	NP	2.64	0	0	32	59	9	0	39
16.5	12	Greyish Silty Sand (SM-SP)	21	17.5	NP	NP	NP	NP	2.63	0	0	17	67	16	0	27
18.0	5	Greyish Silty Sand (SM-SP)	15	14.7	NP	NP	NP	NP	2.64	0	2	47	39	12	0	22
19.5	11	Greyish Sand (SP)	17	17.2	NP	NP	NP	NP	2.63	0	3	45	45	7	0	28
21.0	8	Greyish Silty Sand (SM-SP)	17	16.1	NP	NP	NP	NP	2.63	0	4	47	38	11	0	25
22.5	12	Greyish Sand (SP)	17	17.5	NP	NP	NP	NP	2.64	0	3	42	47	8	0	28
24.0	15	Greyish Silty Sand (SM-SP)	16	18.2	NP	NP	NP	NP	2.64	0	4	38	45	13	0	29
25.5	19	Greyish Silty Sand (SM-SP)	16	19.1	NP	NP	NP	NP	2.63	0	14	42	30	14	0	31
27.0	29	Greyish Sand (SP)	16	20.7	NP	NP	NP	NP	2.63	0	4	45	43	8	0	37

Project : Reconstruction of Tenements (S+13) Floors in Ward No. 52, Zone V, Chetty Thottam, Chennai - 600 043.																	
Ground Water Table Depth (m): 3.3																	
LABORATORY TEST RESULTS																	
Depth (m)	SPT 'N' Value	Description / Classification of Soil and Rock / Weathering Grade of Rock as per IS 4464	Index Properties						Specific Gravity	Grain Size Analysis (%)				Direct Shear / Terzaghi and Peck (1974) - Shear Strength Parameters			
			Natural Moisture Content / Water Absorption, %	Bulk Density (kN/m ³)	Liquid Limit, %	Plastic Limit, %	Plasticity Index, %	Free Swell Index		Fines				Cohesion (c), kN/m ²	Angle of Friction (φ) in Degrees		
										Gravel	Coarse Sand	Medium Sand	Fine Sand			Silt & Clay	
4.0	20	Brownish Sand (SP)	18	19.3	NP	NP	NP	NP	NP	2.62	0	8	43	43	6	0	33
5.0	26	Greyish Brown Sand (SP)	16	20.3	NP	NP	NP	NP	NP	2.63	0	1	55	38	6	0	36
6.0	41	Brownish Sand (SP)	17	22.0	NP	NP	NP	NP	NP	2.63	0	7	42	45	6	0	42
7.5	90	Brownish Sand (SP)	17	22.0	NP	NP	NP	NP	NP	2.64	0	2	37	55	6	0	42
9.0	76	Greyish Brown Silty Sand (SM-SP)	24	22.0	NP	NP	NP	NP	NP	2.63	0	0	3	86	11	0	41
10.5	43	Greyish Brown Silty Sand (SM-SP)	22	22.0	NP	NP	NP	NP	NP	2.64	0	0	11	78	11	0	41
12.0	39	Greyish Brown Silty Sand (SM-SP)	21	21.9	NP	NP	NP	NP	NP	2.64	0	2	15	72	11	0	40
13.5	54	Greyish Brown Silty Sand (SM-SP)	22	22.0	NP	NP	NP	NP	NP	2.63	0	0	9	78	13	0	41
15.0	62	Greyish Brown Sand (SP)	20	22.0	NP	NP	NP	NP	NP	2.63	0	0	29	63	8	0	42
16.5	10	Brownish Grey Silty Sand (SM-SP)	18	16.9	NP	NP	NP	NP	NP	2.64	0	0	20	65	15	0	26
18.0	8	Greyish Silty Sand (SM-SP)	22	16.1	NP	NP	NP	NP	NP	2.63	0	0	8	72	20	0	25
19.5	9	Greyish Silty Sand (SM-SP)	18	16.5	NP	NP	NP	NP	NP	2.64	0	2	40	45	13	0	25
21.0	13	Greyish Brown Silty Sand (SM-SP)	16	17.7	NP	NP	NP	NP	NP	2.63	0	4	44	41	11	0	28
22.5	17	Greyish Silty Sand (SM-SP)	17	18.7	NP	NP	NP	NP	NP	2.64	0	2	40	43	15	0	30
24.0	11	Brownish Grey Silty Sand (SM-SP)	15	17.2	NP	NP	NP	NP	NP	2.63	0	5	41	40	14	0	27
25.5	12	Greyish Brown Silty Sand (SM-SP)	18	17.5	NP	NP	NP	NP	NP	2.64	0	7	34	48	11	0	27
27.0	24	Greyish Silty Sand (SM-SP)	16	20.0	NP	NP	NP	NP	NP	2.63	0	8	29	43	20	0	34
			Porosity of Rock (%)						Strength of Rock				Direct Shear / Terzaghi and Peck (1974) - Shear Strength Parameters				
									UCS, kN/m ²	I _s , kN/m ²					L _s , kN/m ²		
28.5	>100	Brown Weathered Charnockite	-	22.00	-	-	-	-	2.66	-	-	-	-	-	-	0	44
30.0	>100	Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)	0.59	28.64	0.63	0.63	0.63	0.63	2.67	48145	10554	10554	10554	10554	10554	0	45
31.5	>100	Charnockite, Grey, Medium Grained, Moderately Weathered (Grade III)	0.47	28.67	0.59	0.59	0.59	0.59	2.68	54675	12547	12547	12547	12547	12547	0	45
33.0	>100	Charnockite, Grey, Medium Grained, Moderately Weathered (Grade III)	0.42	28.94	0.55	0.55	0.55	0.55	2.68	55898	13546	13546	13546	13546	13546	0	45

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04-05-2019

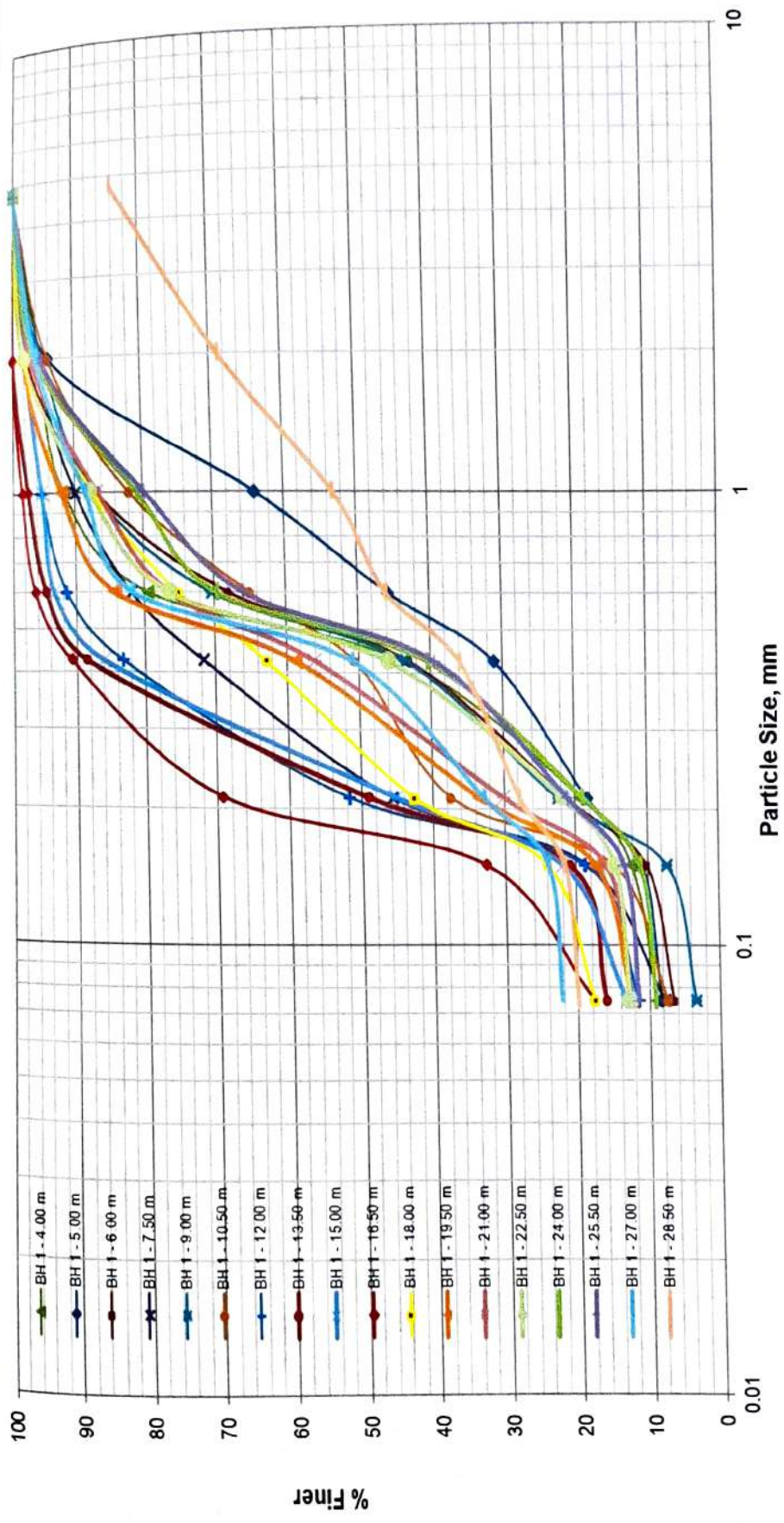


Figure C- 1 Grain Size Distribution of Soil Samples collected in BH 1 Location

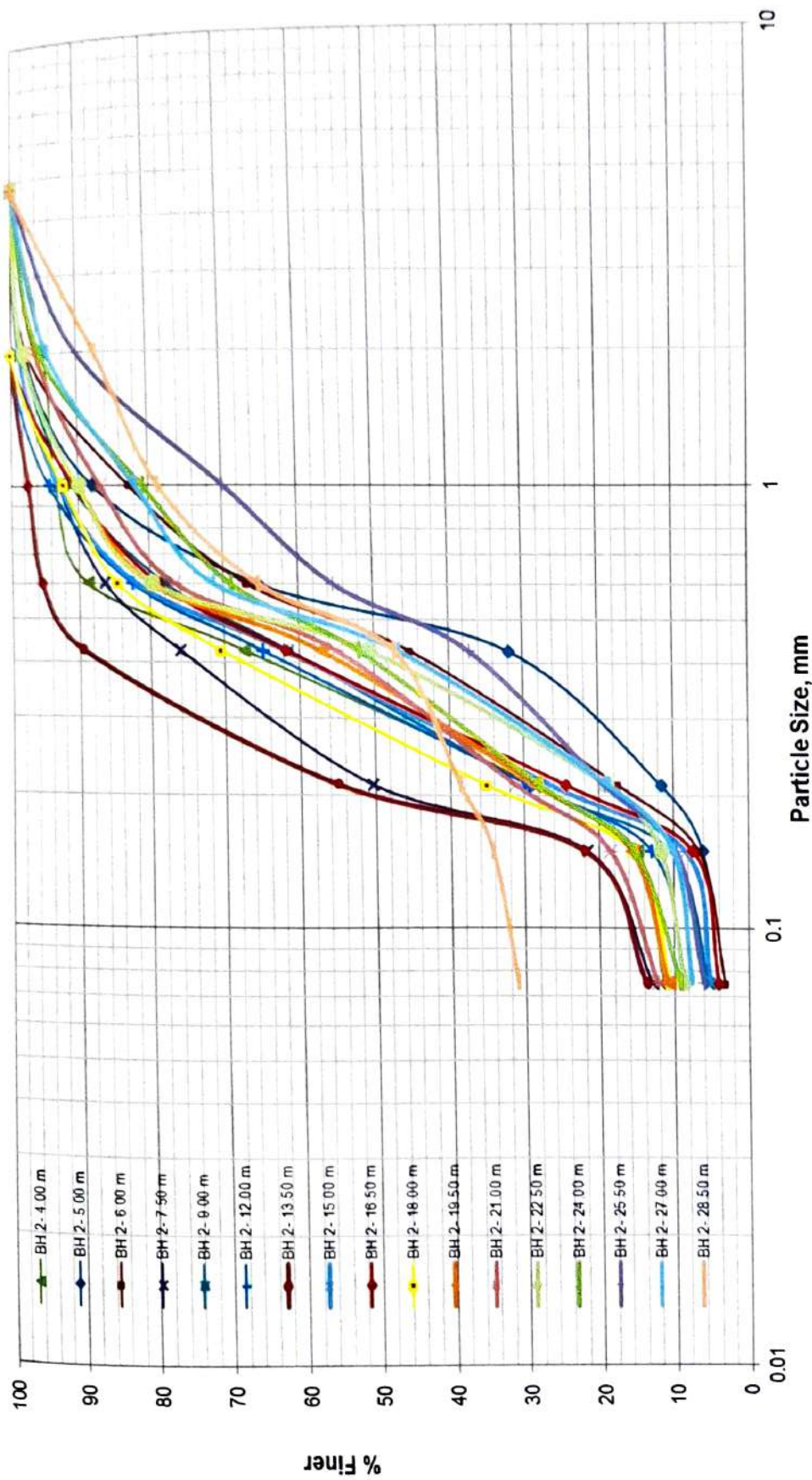


Figure C-2 Grain Size Distribution of Soil Samples collected in BH 2 Location

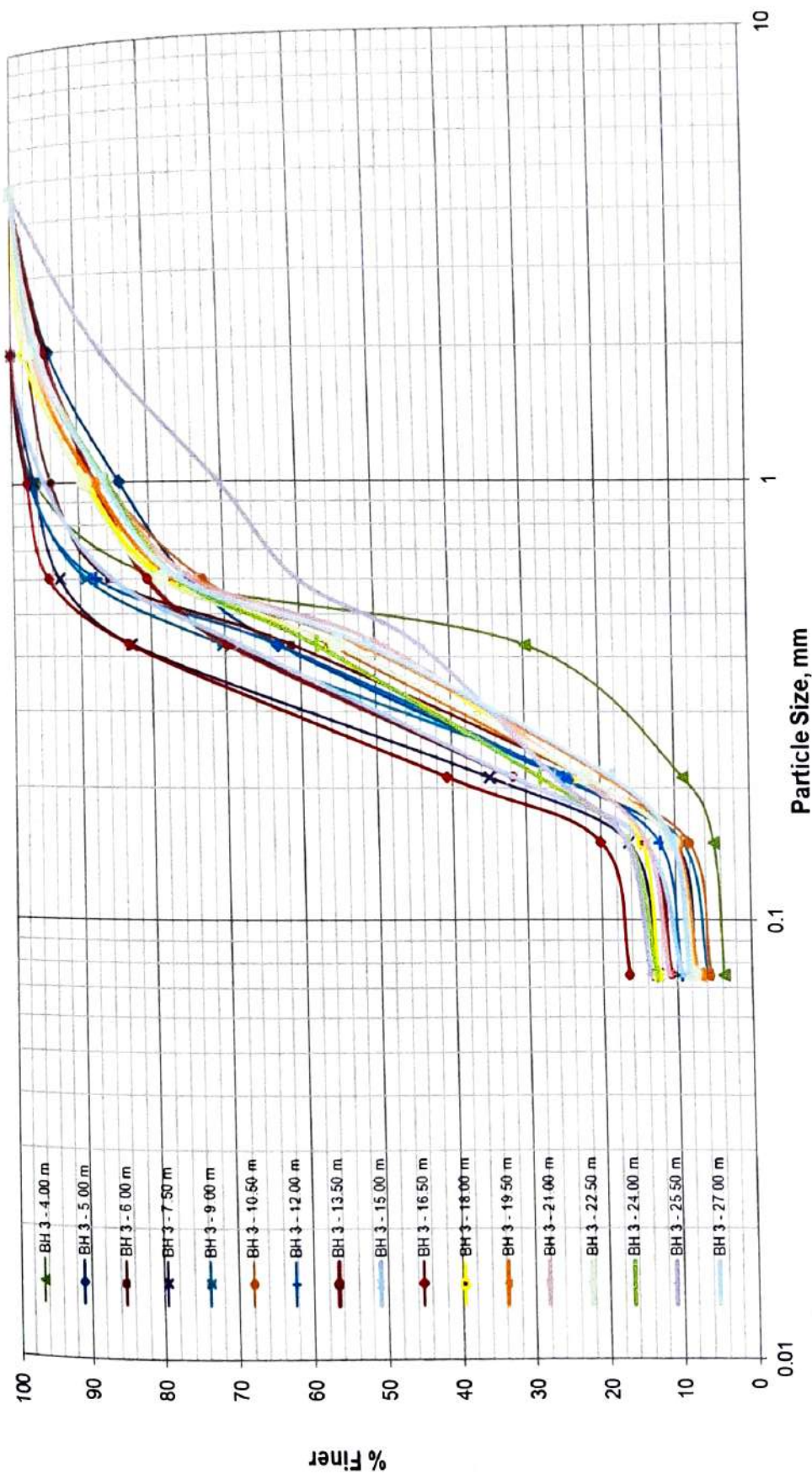


Figure C-3 Grain Size Distribution of Soil Samples collected in BH 3 Location

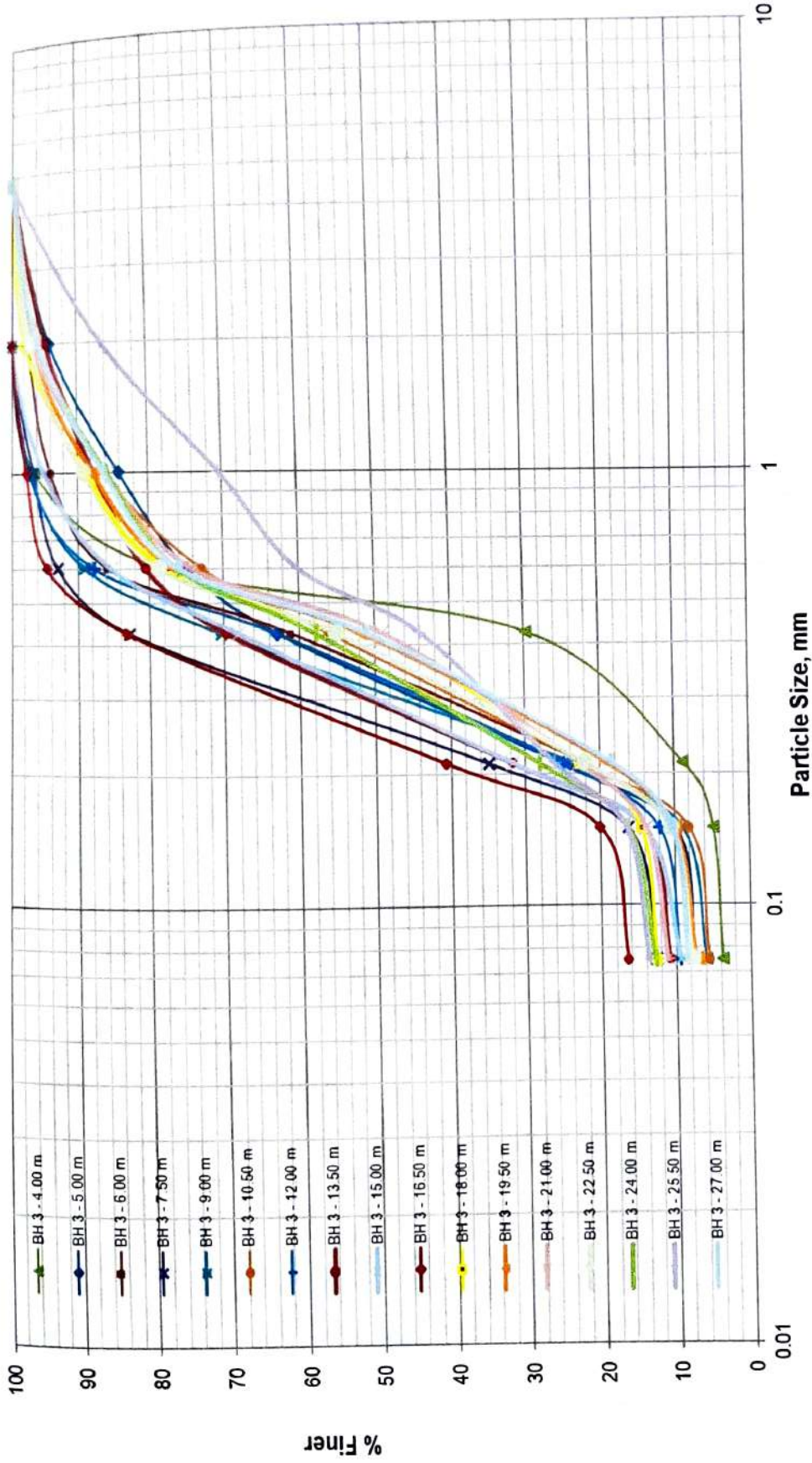


Figure C-3 Grain Size Distribution of Soil Samples collected in BH 3 Location

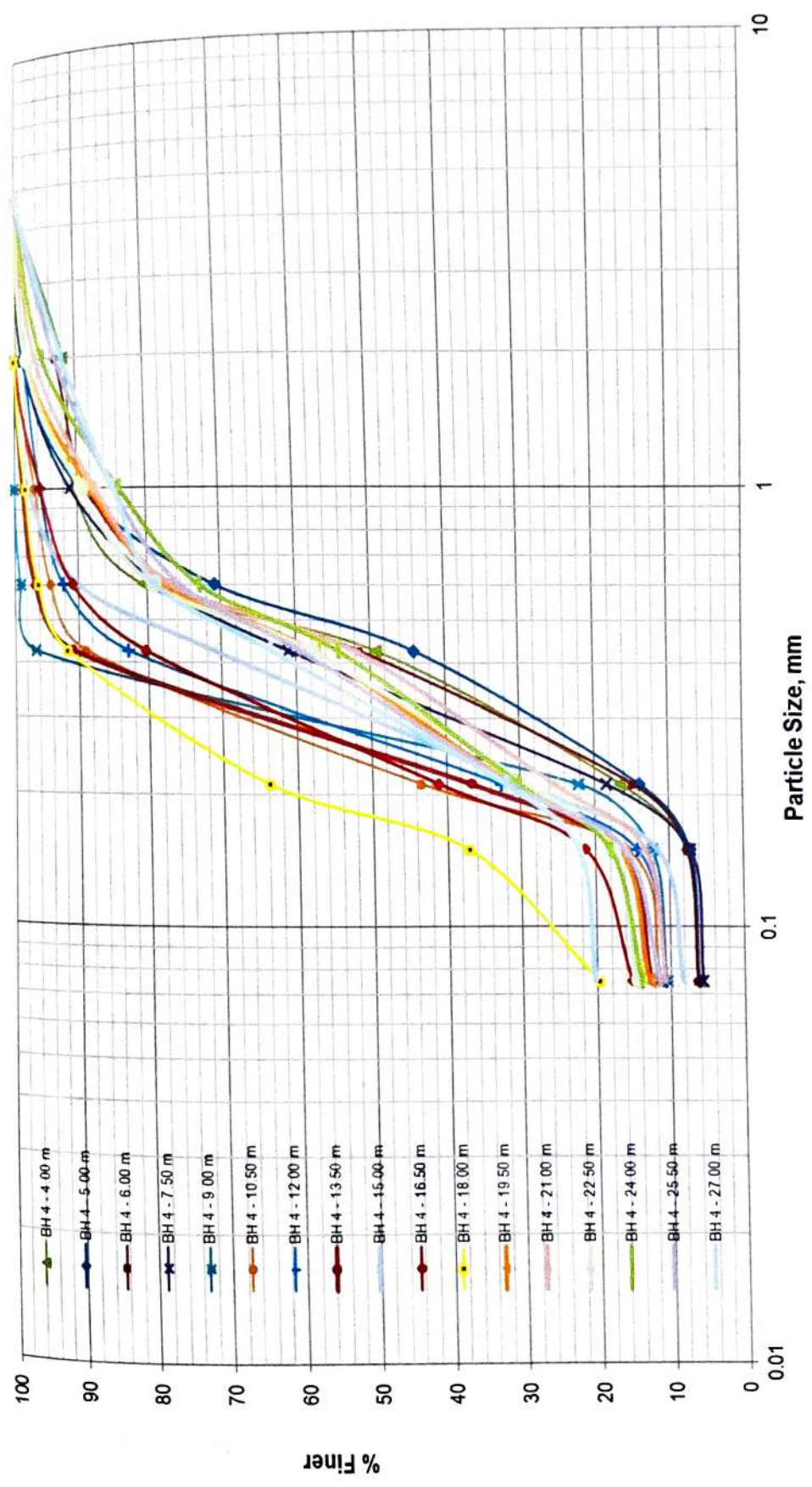


Figure C-4 Grain Size Distribution of Soil Samples collected in BH 4 Location

Appendix – 1 View of Soil Samples collected in BH 1 to BH 4 Locations of the Reconstruction of Tenements (S+13) Floors in Ward No. 52, Zone V, Chetty Thottam, Chennai - 600 013.



Plate – 1 Soil Sample Collected by conducting SPT in BH-01 Location



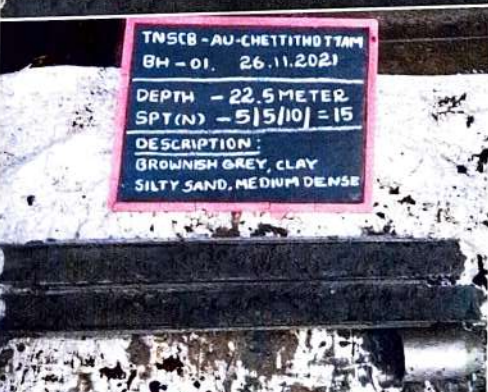
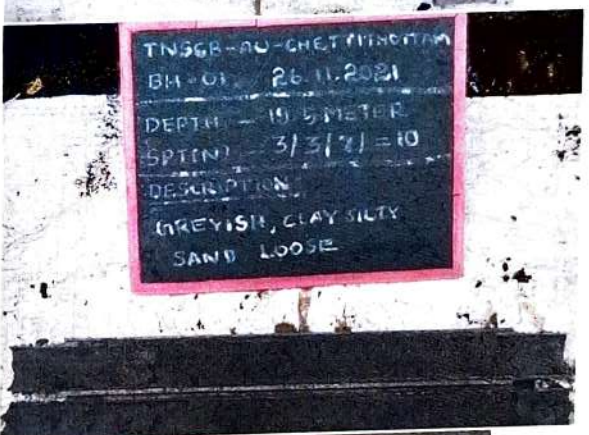
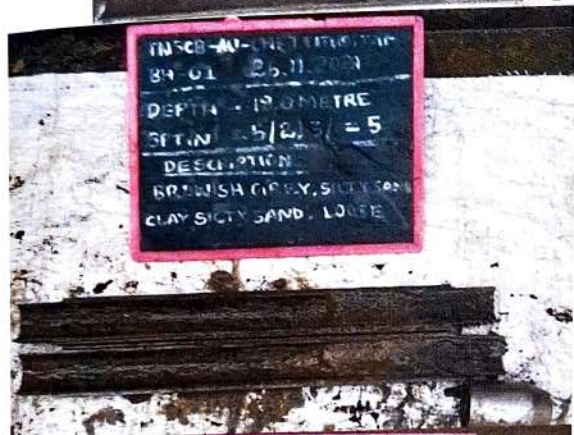
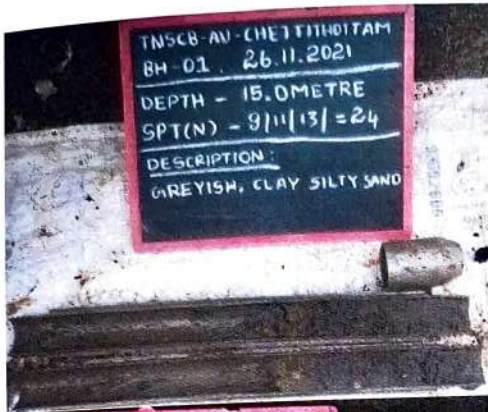




Plate – 2 Soil Sample Collected by conducting SPT in BH-02 Location



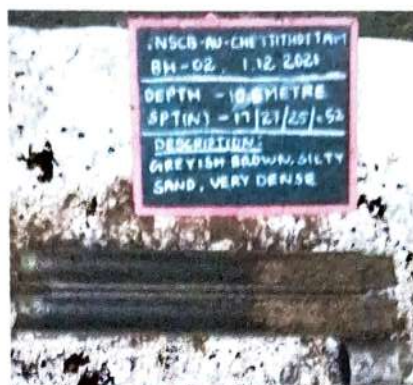




Plate – 3 Soil Sample Collected by conducting SPT in BH-03 Location



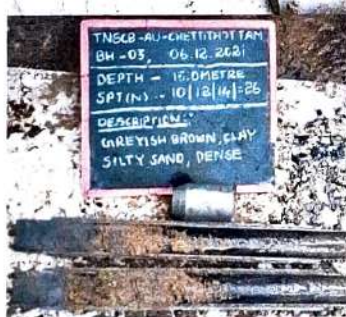




Plate – 4 Soil Sample Collected by conducting SPT in BH-04 Location



INSCB-AU-CHEITTHOITAM
BH-04 11.12.2021
DEPTH - 6.0METRE
SPT(N) - 14/23/27 = 41
DESCRIPTION:
BROWNISH, SILTY SAND,
DENSE

INSCB-AU-CHEITTHOITAM
BH-04 11.12.2021
DEPTH - 9.0METRE
SPT(N) - 20/30/46 = 76
DESCRIPTION:
GREYISH BROWN, SILTY
SAND, VERY DENSE

INSCB-AU-CHEITTHOITAM
BH-04 11.12.2021
DEPTH - 12.0METRE
SPT(N) - 14/18/21 = 33
DESCRIPTION:
GREYISH BROWN, SILTY
SAND, DENSE

INSCB-AU-CHEITTHOITAM
BH-04 11.12.2021
DEPTH - 15.0METRE
SPT(N) - 19/31/31 = 62
DESCRIPTION:
GREYISH BROWN, SILTY
SAND, VERY DENSE

INSCB-AU-CHEITTHOITAM
BH-04 11.12.2021
DEPTH - 18.0METRE
SPT(N) - 3/3/5 = 8
DESCRIPTION:
GREYISH, CLAY, CLAY
SILTY SAND, LOOSE

INSCB-AU-CHEITTHOITAM
BH-04 11.12.2021
DEPTH - 7.5METRE
SPT(N) - 23/30/39 = 40
DESCRIPTION:
BROWNISH, SILTY SAND,
VERY DENSE

INSCB-AU-CHEITTHOITAM
BH-04 11.12.2021
DEPTH - 10.5METRE
SPT(N) - 15/19/24 = 43
DESCRIPTION:
GREYISH BROWN, SILTY
SAND, DENSE

INSCB-AU-CHEITTHOITAM
BH-04 11.12.2021
DEPTH - 13.5METRE
SPT(N) - 17/26/28 = 54
DESCRIPTION:
GREYISH BROWN, SILTY
SAND, VERY DENSE

INSCB-AU-CHEITTHOITAM
BH-04 11.12.2021
DEPTH - 16.0METRE
SPT(N) - 3/4/6 = 10
DESCRIPTION:
BROWNISH GREY, SILTY
SAND, CLAY SILTY SAND,
LOOSE

INSCB-AU-CHEITTHOITAM
BH-04 11.12.2021
DEPTH - 19.5METRE
SPT(N) - 12/14/15 = 9
DESCRIPTION:
GREYISH, CLAY, CLAY
SILTY SAND, LOOSE

Appendix – 2
Site Photographs



Plate 1 SPT test is in progress at Reconstruction of Tenements (S+13 Floors) in Ward No. 52, Zone V, Chetty Thottam, Chennai - 600 013.



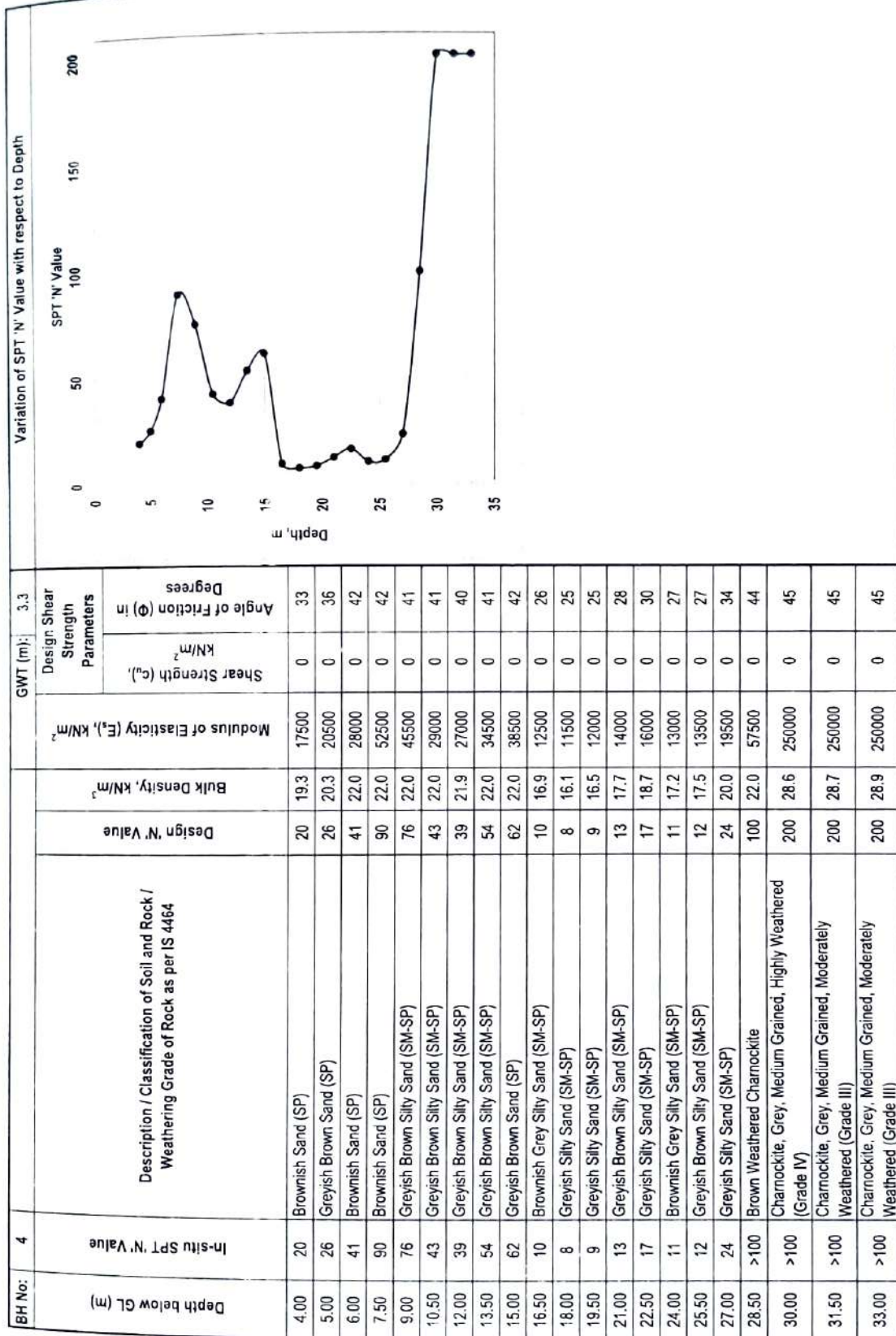
Plate 2 View of Soil / Rock Samples collected in 4 borehole locations of the proposed site

PROJECT: Reconstruction of Tenements (S+13) Floors in Ward No. 52, Zone V, Chetty Thottam, Chennai - 600 013.



GEOTECHNICAL DESIGN PARAMETERS OF DIFFERENT LAYERS BELOW GROUND LEVEL

PROJECT: Reconstruction of Tenements (S+13) Floors in Ward No. 52, Zone V, Chetty Thottam, Chennai - 600 013.



PILES IN GRANULAR SOILS

The ultimate load capacity (Q_u) of piles, in kN, in granular soils is given by the following formula:

$$Q_u = A_p \left(\frac{1}{2} DY N_f + P_D N_q \right) + \sum_{i=1}^n K_i P_{Di} \tan \delta_i A_{si}$$

The first term gives end-bearing resistance and the second term gives skin friction resistance.

where

A_p = cross-sectional area of pile tip, in m^2 ;

D = diameter of pile shaft, in m;

γ = effective unit weight of the soil at pile tip, in kN/m^3 ;

N_f = bearing capacity factors depending upon the angle of internal friction, ϕ at pile tip;

P_D = effective overburden pressure at pile tip, in kN/m^2 (see Note 5);

$\sum_{i=1}^n$ = summation for layers 1 to n in which pile is installed and which contribute to positive skin friction;

K_i = coefficient of earth pressure applicable for the i th layer (see Note 3);

P_{Di} = effective overburden pressure for the i th layer, in kN/m^2 ;

δ_i = angle of wall friction between pile and soil for the i th layer; and

A_{si} = surface area of pile shaft in the i th layer, in m^2 .

NOTES

1 N_f factor can be taken for general shear failure according to IS 6405.

2 N_q factor will depend on the nature of soil, type of pile, the L/B ratio and its method of construction. The values applicable for bored piles are given in Fig. 1 of IS 2911 : 2010 Part I

3 K_i , the earth pressure coefficient depends on the nature of soil strata, type of pile, spacing of pile and its method of construction. For driven piles in loose to dense sand with ϕ varying between 30° and 40° , K_i values in the range of 1 to 1.5 may be used.

4 δ , the angle of wall friction may be taken equal to the friction angle of the soil around the pile stem.

5 In working out pile capacity by static formula, the maximum effective overburden at the pile tip should correspond to the critical depth, which may be taken as 15 times the diameter of the pile shaft for $\phi \leq 30^\circ$ and increasing to 20 times for $\phi \geq 40^\circ$.

6 For piles passing through cohesive strata and terminating in a granular stratum, a penetration of at least twice the diameter of the pile shaft should be given into the granular stratum.



The ultimate load capacity (Q_u) of piles, in kN, in cohesive soils is given by the following formula:

$$Q_u = A_p N_c C_p + \sum_{i=1}^n \alpha_i C_i A_{si}$$

The first term gives the end-bearing resistance and the second term gives the skin friction resistance.

where

A_p = cross-sectional area of pile tip, in m^2 ;
 N_c = bearing capacity factor, may be taken as 9;

C_p = average cohesion at pile tip, in kN/m^2 ;

$\sum_{i=1}^n$ = summation for layers 1 to n in which the pile is installed and which contribute to positive skin friction;

α_i = adhesion factor for the i th layer depending on the consistency of soil. (see Note);

C_i = average cohesion for the i th layer, in kN/m^2 ; and

A_{si} = surface area of pile shaft in the i th layer, in m^2 .

B-3.3 Ultimate skin friction resistance can be approximated to local side friction (f_s), in kN/m^2 , obtained from static cone resistance as given in Table 1.

Table 1 Side Friction for Different Types of Soil

Sl No. (1)	Type of Soil (2)	Local Side Friction, f_s kN/m^2 (3)
i)	q_c less than 1 000 kN/m^2	$q_c/30 < f_s < q_c/10$
ii)	Clay	$q_c/25 < f_s < 2q_c/25$
iii)	Silty clay and silty sand	$q_c/100 < f_s < q_c/25$
iv)	Sand	$q_c/100 < f_s < q_c/50$
v)	Coarse sand and gravel	$q_c/100 < f_s < q_c/150$
q_c = cone resistance, in kN/m^2 .		

When full static cone penetration data are available for the entire depth, the following correlation may be used as a guide for the determination of ultimate load capacity of a pile.

Ultimate end bearing resistance (q_u), in kN/m^2 , may be obtained as:

$$q_u = \frac{q_{c0} + q_{c1} + q_{c2}}{2}$$

where

q_{c0} = average static cone resistance over a depth of $2D$ below the pile tip, in kN/m^2 ;

q_{c1} = minimum static cone resistance over the same $2D$ below the pile tip, in kN/m^2 ;

q_{c2} = average of the envelope of minimum static cone resistance values over the length of pile of $8D$ above the pile tip, in kN/m^2 ; and

D = diameter of pile shaft.

NOTE — The value of adhesion factor, α_i depends on the undrained shear strength of the clay and may be obtained from Fig. 2 of IS 2911 : 2010 Part 1

Table 2 Co-relation Between N and q_c for Different Types of Soil

Sl No. (1)	Type of Soil (2)	q_c/N (3)
i)	Clay	150-200
ii)	Silts, sandy silts and slightly cohesive silt-sand mixtures	200-250
iii)	Clean fine to medium sand and slightly silty sand	300-400
iv)	Coarse sand and sands with little gravel	500-600
v)	Sandy gravel and gravel	800-1 000



PILE CARRYING CAPACITY BASED ON SHEAR STRENGTH PARAMETERS ('c' and 'Φ') (IS 2911: 2010)

$$Q_u = A_p (c N_c + P_D N_q + 0.5 \gamma D N_\gamma) + \Sigma A_{si} (\alpha_i c_i + K P_{Di} \tan \Phi)$$

Where,

Q_u	-	Ultimate Pile Capacity, kN	A_{Si}	-	Surface Area of Pile at respective soil layers, m^2
A_p	-	Cross Sectional Area of Pile, m^2	α_i	-	Adhesion factor
c_i	-	Cohesion value of soil at pile base, kN/m^2	c	-	Cohesion value of soil at respective soil layers, kN/m^2
P_D	-	Effective overburden pressure at pile base, kN/m^2	K_i	-	Co-efficient of earth pressure at respective soil layers
γ	-	Unit weight of soil, kN/m^3	P_{Di}	-	Effective overburden pressure at respective soil layers, kN/m^2
D	-	Diameter of pile, m	Φ	-	Friction angle, degrees
			N_c	-	Bearing capacity factors based on IS 2911: 2010 and IS 6403 -1981
			N_q, N_γ		

PILE CARRYING CAPACITY OF SOCKETED PILES BY COLE AND STROUD APPROACH (1977) - IS 2911 : 2010

$$Q_a = c_{u1} N_c \frac{\pi B^2}{4 F_s} + \alpha c_{u2} \frac{\pi B L}{F_s}$$

where

c_{u1} = shear strength of rock below the base of the pile, in kN/m^2 (see Fig. 3);

N_c = bearing capacity factor taken as 9;

F_s = factor of safety usually taken as 3;

α = 0.9 (recommended value);

c_{u2} = average shear strength of rock in the socketed length of pile, in kN/m^2 (see Fig 3);

B = minimum width of pile shaft (diameter in case of circular piles), in m; and

L = socket length of pile, in m.

Type of Soil	Limiting Frictional Resistance (t/m ²)
Sand	6
Silt	6
Clay	7

Limiting End Bearing Resistance (t/m ²) as per IS 2911	
Bored Piles	Driven Piles
1000 - 1100	1500



DETERMINATION OF PILE CARRYING CAPACITY AS PER IS 2911 : 2010

BH 1

Borehole Location

	31.00 m	From Existing Borehole Level
Length of Pile (L), m	45.00	
Angle of Internal Friction (ϕ) in Degrees	0.00	
Undrained cohesion value at Pile Tip (c_p), kN/m ²	17.84	
Submerged Unit Weight at Pile Tip (γ_p), kN/m ³	0.00 m	
Ground Water Table Depth (GWT), m	9.00	
Bearing Capacity Factor (N_c)	350.00	
Bearing Capacity Factor (N_c)	271.75	
Bearing Capacity Factor (N_c)	2.50	
Factor of Safety (FS)	450	500
Diameter of Pile (D), mm	9	10
Critical Depth of Pile (20 x D), m	116.20	134.20
Effective overburden pressure at Pile Tip (P_o), kN/m ²	41760.80	54724.39
End Bearing Resistncoe of Pile (q_p), kN/m ² using 'c' and ' ϕ '	80000.00	80000.00
End Bearing Resistncoe of Pile (q_p), kN/m ² using 'N' values	11000.00	11000.00
Limiting End Bearing Resistncoe of Pile (q_p), kN/m ²	1749.47	2159.84
Ultimate End Bearing Capacity of Pile (Q_p), kN using 'c' and ' ϕ ' values	1749.47	2159.84
Ultimate End Bearing Capacity of Pile (Q_p), kN using 'N' values	699.79	863.94
Safe End Bearing Capacity of Pile (Q_p), kN using 'c' and ' ϕ ' values	699.79	863.94
Safe End Bearing Capacity of Pile (Q_p), kN using 'N' values	2290.22	2544.69
Ultimate Frictional Capacity of Pile (Q_{pf}), kN using 'c' and ' ϕ ' values	1632.84	1814.27
Ultimate Frictional Capacity of Pile (Q_{pf}), kN using 'N' values	185.79	206.43
Negative Skin Friction of Pile (Q_{nf}), kN using 'c' and ' ϕ ' values	282.74	314.16
Negative Skin Friction of Pile (Q_{nf}), kN using 'N' values	730.30	811.44
Safe Frictional Capacity of Pile (Q_{pf}), kN using 'c' and ' ϕ ' values	370.39	411.55
Safe Frictional Capacity of Pile (Q_{pf}), kN using 'N' values	123.26	152.17
Self Weight of Pile (W), kN	1430	1675
Safe Pile Carrying Capacity of Pile (Q_{safe}), kN ('c' and ' ϕ ')	1070	1275
Safe Pile Carrying Capacity of Pile (Q_{safe}), kN ('N' values)	1250	1475
Recommended Safe Pile Carrying Capacity of Pile (Q_{safe}), kN	701	794
Safe Uplift Capacity of Pile (Q_{up}), kN using 'c' and ' ϕ ' values		989



Depth (m)	Soil Description	H _i (m)	'c' kN/m ²	'φ'	'γ' kN/m ³	'γ _{sub} ' kN/m ³	P ₀ (kN/m ²)	'α'	'K _v '	N' Value
4.00	Brown Sand (SP)	4.00	0	37	20.90	10.90	43.60	0.00	1.00	30
5.00	Greyish Brown Sand (SP)	1.00	0	41	22.00	12.00	71.40	0.00	1.00	40
6.00	Greyish Brown Sand (SP)	1.00	0	40	21.80	11.80	83.30	0.00	1.00	38
7.50	Greyish Brown Sand (SP)	1.50	0	42	22.00	12.00	98.20	0.00	1.00	47
9.00	Greyish Brown Sand (SP)	1.50	0	42	22.00	12.00	116.20	0.00	1.00	52
10.50	Greyish Brown Sand (SP)	1.50	0	42	22.00	12.00	134.20	0.00	1.00	59
12.00	Greyish Brown Silty Sand (SM-SP)	1.50	0	41	22.00	12.00	152.20	0.00	1.00	58
13.50	Greyish Silty Sand (SM-SP)	1.50	0	30	18.70	8.70	167.73	0.00	1.00	17
15.00	Greyish Silty Sand (SM-SP)	1.50	0	34	20.00	10.00	181.75	0.00	1.00	24
16.50	Greyish Silty Sand (SM-SP)	1.50	0	31	18.90	8.90	195.93	0.00	1.00	18
18.00	Greyish Brown Silty Sand (SM-SP)	1.50	0	21	14.70	4.70	206.13	0.00	1.00	5
19.50	Greyish Silty Sand (SM-SP)	1.50	0	26	16.90	6.90	214.83	0.00	1.00	10
21.00	Greyish Silty Sand (SM-SP)	1.50	0	27	17.20	7.20	225.40	0.00	1.00	11
22.50	Greyish Silty Sand (SM-SP)	1.50	0	29	18.20	8.20	236.95	0.00	1.00	15
24.00	Greyish Sand (SM-SP)	1.50	0	31	18.50	8.50	249.48	0.00	1.00	16
25.50	Greyish Silty Sand (SM-SP)	1.50	0	35	20.40	10.40	263.65	0.00	1.00	27
27.00	Greyish Silty Sand (SM-SP)	1.50	0	37	21.00	11.00	279.70	0.00	1.00	31
28.50	Greyish Brown Residual Soil	1.50	0	42	22.00	12.00	296.95	0.00	1.00	80
30.00	Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)	1.50	0	45	26.57	16.57	318.38	0.00	1.00	200
31.50	Charnockite, Grey, Medium Grained, Completely Weathered (Grade V)	1.00	0	45	27.08	17.08	339.35	0.00	1.00	200
33.00	Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)	1.50	0	45	27.56	17.56	361.06	0.00	1.00	200
34.00	Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)	1.00	0	45	27.84	17.84	383.15	0.00	1.00	200



Depth (m)	Soil Description	Ultimate Frictional Capacity, kN using 'c' and 'φ' values					Ultimate Frictional Capacity, kN using 'N' values						
		q _s (kN/m ²)	450 mm	500 mm	600 mm	700 mm	900 mm	q _s (kN/m ²)	450 mm	500 mm	600 mm	700 mm	900 mm
4.00	Brown Sand (SP)	32.85	185.79	206.43	247.72	289.01	371.58	50.00	282.74	314.16	376.99	439.82	565.49
5.00	Greyish Brown Sand (SP)	62.07	84.82	94.25	113.10	131.95	169.65	66.67	84.82	94.25	113.10	131.95	169.65
6.00	Greyish Brown Sand (SP)	69.90	84.82	94.25	113.10	131.95	169.65	63.33	84.82	94.25	113.10	131.95	169.65
7.50	Greyish Brown Sand (SP)	88.42	127.23	141.37	169.65	197.92	254.47	78.33	127.23	141.37	169.65	197.92	254.47
9.00	Greyish Brown Sand (SP)	104.63	127.23	141.37	169.65	197.92	254.47	86.67	127.23	141.37	169.65	197.92	254.47
10.50	Greyish Brown Sand (SP)	120.83	127.23	141.37	169.65	197.92	254.47	98.33	127.23	141.37	169.65	197.92	254.47
12.00	Greyish Brown Silty Sand (SM-SP)	132.31	127.23	141.37	169.65	197.92	254.47	96.67	127.23	141.37	169.65	197.92	254.47
13.50	Greyish Silty Sand (SM-SP)	96.84	127.23	141.37	169.65	197.92	254.47	28.33	60.08	66.76	80.11	93.46	120.17
15.00	Greyish Silty Sand (SM-SP)	122.59	127.23	141.37	169.65	197.92	254.47	40.00	84.82	94.25	113.10	131.95	169.65
16.50	Greyish Silty Sand (SM-SP)	117.72	127.23	141.37	169.65	197.92	254.47	30.00	63.62	70.69	84.82	98.96	127.23
18.00	Greyish Brown Silty Sand (SM-SP)	79.12	127.23	141.37	169.65	197.92	254.47	8.33	17.67	19.63	23.56	27.49	35.34
19.50	Greyish Silty Sand (SM-SP)	104.78	127.23	141.37	169.65	197.92	254.47	16.67	35.34	39.27	47.12	54.98	70.69
21.00	Greyish Silty Sand (SM-SP)	114.85	127.23	141.37	169.65	197.92	254.47	18.33	38.88	43.20	51.84	60.48	77.75
22.50	Greyish Silty Sand (SM-SP)	131.34	127.23	141.37	169.65	197.92	254.47	25.00	53.01	58.90	70.69	82.47	106.03
24.00	Greyish Sand (SM-SP)	149.90	127.23	141.37	169.65	197.92	254.47	26.67	56.55	62.83	75.40	87.96	113.10
25.50	Greyish Silty Sand (SM-SP)	184.61	127.23	141.37	169.65	197.92	254.47	45.00	95.43	106.03	127.23	148.44	190.85
27.00	Greyish Silty Sand (SM-SP)	210.77	127.23	141.37	169.65	197.92	254.47	51.67	109.56	121.74	146.08	170.43	219.13
28.50	Greyish Brown Residual Soil	267.37	127.23	141.37	169.65	197.92	254.47	133.33	127.23	141.37	169.65	197.92	254.47
30.00	Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)	318.38	127.23	141.37	169.65	197.92	254.47	333.33	127.23	141.37	169.65	197.92	254.47
31.50	Charnockite, Grey, Medium Grained, Completely Weathered (Grade V)	339.35	84.82	94.25	113.10	131.95	169.65	333.33	84.82	94.25	113.10	131.95	169.65
33.00	Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)	361.06	127.23	141.37	169.65	197.92	254.47	333.33	127.23	141.37	169.65	197.92	254.47
34.00	Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)	383.15	84.82	94.25	113.10	131.95	169.65	333.33	84.82	94.25	113.10	131.95	169.65



Borehole Location

BH 2

Length of Pile (L), m	31.00 m	From Existing Borehole Level
Angle of Internal Friction (ϕ) in Degrees	45.00	
Undraind cohesion value at Pile Tip (c_p), kN/m ²	0.00 kN/m ²	
Submerged Unit Weight at Pile Tip (γ_p), kN/m ³	17.86 kN/m ³	
Ground Water Table Depth (GWT), m	0.00 m	Submerged Condition
Bearing Capacity Factor (N_c)	9.00	
Bearing Capacity Factor (N_q)	350.00	
Bearing Capacity Factor (N_{γ})	271.75	
Factor of Safety (FS)	2.50	
Diameter of Pile (D), mm	450	500
Critical Depth of Pile (20 x D), m	9	10
Effective overburden pressure at Pile Tip (P_0), kN/m ²	86.60	104.60
End Bearing Resistnace of Pile (q_p), kN/m ² using 'c' and 'φ'	31402.02	37823.35
End Bearing Resistnace of Pile (q_p), kN/m ² using 'N' values	80000.00	80000.00
Limiting End Bearing Resistnace of Pile (q_p), kN/m ²	11000.00	11000.00
Ultimate End Bearing Capacity of Pile (Q_p), kN using 'c' and 'φ' values	1749.47	2159.84
Ultimate End Bearing Capacity of Pile (Q_p), kN using 'N' values	1749.47	2159.84
Safe End Bearing Capacity of Pile (Q_p), kN using 'c' and 'φ' values	699.79	863.94
Safe End Bearing Capacity of Pile (Q_p), kN using 'N' values	699.79	863.94
Ultimate Frictional Capacity of Pile (Q_{fp}), kN using 'c' and 'φ' values	2234.53	2482.81
Ultimate Frictional Capacity of Pile (Q_{fp}), kN using 'N' values	1734.16	1926.84
Negative Skin Friction of Pile (Q_{mf}), kN using 'c' and 'φ' values	64.34	71.49
Negative Skin Friction of Pile (Q_{mf}), kN using 'N' values	75.40	83.78
Safe Frictional Capacity of Pile (Q_{fp}), kN using 'c' and 'φ' values	829.47	921.63
Safe Frictional Capacity of Pile (Q_{fp}), kN using 'N' values	618.27	686.96
Self Weight of Pile (W), kN	123.26	152.17
Safe Pile Carrying Capacity of Pile (Q_{safe}), kN ('c' and 'φ')	1529	1786
Safe Pile Carrying Capacity of Pile (Q_{safe}), kN ('N' values)	1318	1551
Recommended Safe Pile Carrying Capacity of Pile (Q_{safe}), kN	1424	1668
Safe Uplift Capacity of Pile (Q_{up}), kN using 'c' and 'φ' values	804	908
		1126
		1357
		1854

Taken from Figure 1 of IS 2911:2010 Part 1 Sec.2



Depth (m)	Soil Description	H _i (m)	'c' kN/m ²	'φ'	'γ' kN/m ³	'γ _{sub} ' kN/m ³	P _{Di} (kN/m ²)	'α _i '	'K _i '	N' Value
4.00	Brownish Silty Sand (SM-SP)	4.00	0	25	16.10	6.10	24.40	0.00	1.00	8
5.00	Brownish Sand (SP)	1.00	0	38	21.00	11.00	42.10	0.00	1.00	31
6.00	Brownish Sand (SP)	1.00	0	42	22.00	12.00	53.60	0.00	1.00	52
7.50	Brownish Silty Sand (SM-SP)	1.50	0	41	22.00	12.00	68.60	0.00	1.00	54
9.00	Brownish Sand (SP)	1.50	0	42	22.00	12.00	86.60	0.00	1.00	62
10.50	Greyish Brown Sand (SP)	1.50	0	42	22.00	12.00	104.60	0.00	1.00	52
12.00	Brownish Sand (SP)	1.50	0	42	22.00	12.00	122.60	0.00	1.00	58
13.50	Greyish Brown Silty Sand (SM-SP)	1.50	0	40	22.00	12.00	140.60	0.00	1.00	40
15.00	Brownish Sand (SP)	1.50	0	36	20.30	10.30	157.33	0.00	1.00	26
16.50	Greyish Brown Sand (SP)	1.50	0	27	17.20	7.20	170.45	0.00	1.00	11
18.00	Greyish Brown Sand (SP)	1.50	0	28	17.20	7.20	181.25	0.00	1.00	11
19.50	Greyish Silty Sand (SM-SP)	1.50	0	28	17.70	7.70	192.43	0.00	1.00	13
21.00	Greyish Silty Sand (SM-SP)	1.50	0	30	18.70	8.70	204.73	0.00	1.00	17
22.50	Brownish Grey Sand (SP)	1.50	0	31	18.70	8.70	217.78	0.00	1.00	17
24.00	Greyish Sand (SP)	1.50	0	32	19.10	9.10	231.13	0.00	1.00	19
25.50	Greyish Sand (SP)	1.50	0	36	20.30	10.30	245.68	0.00	1.00	26
27.00	Greyish Sand (SP)	1.50	0	37	20.90	10.90	261.58	0.00	1.00	30
28.50	Greyish Residual Soil	1.50	0	41	22.00	12.00	278.75	0.00	1.00	80
30.00	Charnockite, Grey, Medium Grained, Completely Weathered (Grade V)	1.50	0	45	27.12	17.12	300.59	0.00	1.00	200
31.00	Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)	1.00	0	45	27.86	17.86	322.37	0.00	1.00	200
32.50	Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)	1.50	0	45	28.45	18.45	345.13	0.00	1.00	200
34.00	Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)	1.50	0	45	28.64	18.64	372.95	0.00	1.00	200

Depth (m)	Soil Description	Ultimate Frictional Capacity, kN using C and ϕ values											
		q_s (kN/m ²)	450 mm	500 mm	600 mm	700 mm	900 mm	q_s (kN/m ²)	450 mm	500 mm	600 mm	700 mm	900 mm
4.00	Brownish Silty Sand (SM-SP)	11.38	64.34	71.49	85.79	100.09	128.68	13.33	75.40	83.78	100.53	117.29	150.80
5.00	Brownish Sand (SP)	32.89	46.50	51.67	62.00	72.33	93.00	51.67	73.04	81.16	97.39	113.62	146.08
6.00	Brownish Sand (SP)	48.26	68.23	75.81	90.97	106.13	136.46	86.67	84.82	94.25	113.10	131.95	169.65
7.50	Brownish Silty Sand (SM-SP)	59.63	126.46	140.51	168.61	196.71	252.91	90.00	127.23	141.37	169.65	197.92	254.47
9.00	Brownish Sand (SP)	77.97	127.23	141.37	169.65	197.92	254.47	103.33	127.23	141.37	169.65	197.92	254.47
10.50	Greyish Brown Sand (SP)	94.18	127.23	141.37	169.65	197.92	254.47	86.67	127.23	141.37	169.65	197.92	254.47
12.00	Brownish Sand (SP)	110.39	127.23	141.37	169.65	197.92	254.47	96.67	127.23	141.37	169.65	197.92	254.47
13.50	Greyish Brown Silty Sand (SM-SP)	117.98	127.23	141.37	169.65	197.92	254.47	66.67	127.23	141.37	169.65	197.92	254.47
15.00	Brownish Sand (SP)	114.30	127.23	141.37	169.65	197.92	254.47	43.33	91.89	102.10	122.52	142.94	183.78
16.50	Greyish Brown Sand (SP)	86.85	127.23	141.37	169.65	197.92	254.47	18.33	38.88	43.20	51.84	60.48	77.75
18.00	Greyish Brown Sand (SP)	96.37	127.23	141.37	169.65	197.92	254.47	18.33	38.88	43.20	51.84	60.48	77.75
19.50	Greyish Silty Sand (SM-SP)	102.31	127.23	141.37	169.65	197.92	254.47	21.67	45.95	51.05	61.26	71.47	91.89
21.00	Greyish Silty Sand (SM-SP)	118.20	127.23	141.37	169.65	197.92	254.47	28.33	60.08	66.76	80.11	93.46	120.17
22.50	Brownish Grey Sand (SP)	130.85	127.23	141.37	169.65	197.92	254.47	28.33	60.08	66.76	80.11	93.46	120.17
24.00	Greyish Sand (SP)	144.42	127.23	141.37	169.65	197.92	254.47	31.67	67.15	74.61	89.54	104.46	134.30
25.50	Greyish Sand (SP)	178.49	127.23	141.37	169.65	197.92	254.47	43.33	91.89	102.10	122.52	142.94	183.78
27.00	Greyish Sand (SP)	197.11	127.23	141.37	169.65	197.92	254.47	50.00	106.03	117.81	141.37	164.93	212.06
28.50	Greyish Residual Soil	242.31	127.23	141.37	169.65	197.92	254.47	133.33	127.23	141.37	169.65	197.92	254.47
30.00	Charnockite, Grey, Medium Grained, Completely Weathered (Grade V)	300.59	127.23	141.37	169.65	197.92	254.47	333.33	127.23	141.37	169.65	197.92	254.47
31.00	Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)	322.37	84.82	94.25	113.10	131.95	169.65	333.33	84.82	94.25	113.10	131.95	169.65
32.50	Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)	345.13	127.23	141.37	169.65	197.92	254.47	333.33	127.23	141.37	169.65	197.92	254.47
34.00	Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)	372.95	127.23	141.37	169.65	197.92	254.47	333.33	127.23	141.37	169.65	197.92	254.47



Length of Pile (L), m	=	31.00 m	From Existing Borehole Level				
Angle of Internal Friction (φ) in Degrees	=	45.00					
Undrained cohesion value at Pile Tip (c _p), kN/m ²	=	0.00 kN/m ²					
Submerged Unit Weight at Pile Tip (γ _a), kN/m ²	=	18.45 kN/m ²					
Ground Water Table Depth (GWT), m	=	0.00 m	Submerged Condition				
Bearing Capacity Factor (N _c)	=	9.00					
Bearing Capacity Factor (N _q)	=	350.00					
Bearing Capacity Factor (N _γ)	=	271.75					
Factor of Safety (FS)	=	2.50					
Diameter of Pile (D), mm	=	450	500	600	700	900	
Critical Depth of Pile (20 x D), m	=	9	10	12	14	18	
Effective overburden pressure at Pile Tip (P ₀), kN/m ²	=	99.00	117.00	135.00	153.00	192.23	
End Bearing Resistnre of Pile (q _p), kN/m ² using 'c' and 'φ'	=	35778.09	42203.44	48754.12	55304.81	69534.94	
End Bearing Resistnre of Pile (q _p), kN/m ² using 'N' values	=	80000.00	80000.00	80000.00	80000.00	80000.00	
Limiting End Bearing Resistnre of Pile (q _p), kN/m ²	=	11000.00	11000.00	11000.00	11000.00	11000.00	
Ultimate End Bearing Capacity of Pile (Q _p), kN using 'c' and 'φ' values	=	1749.47	2159.84	3110.18	4233.30	6997.90	
Ultimate End Bearing Capacity of Pile (Q _p), kN using 'N' values	=	1749.47	2159.84	3110.18	4233.30	6997.90	
Safe End Bearing Capacity of Pile (Q _p), kN using 'c' and 'φ' values	=	699.79	863.94	1244.07	1693.32	2799.16	
Safe End Bearing Capacity of Pile (Q _p), kN using 'N' values	=	699.79	863.94	1244.07	1693.32	2799.16	
Ultimate Frictional Capacity of Pile (Q _p), kN using 'c' and 'φ' values	=	2273.32	2525.92	3031.10	3536.28	4546.65	
Ultimate Frictional Capacity of Pile (Q _p), kN using 'N' values	=	1664.65	1849.61	2219.54	2589.46	3329.30	
Negative Skin Fricton of Pile (Q _{nf}), kN using 'c' and 'φ' values	=	104.47	116.08	139.30	162.52	208.95	
Negative Skin Friction of Pile (Q _{nf}), kN using 'N' values	=	131.95	146.61	175.93	205.25	263.89	
Safe Frictional Capacity of Pile (Q _p), kN using 'c' and 'φ' values	=	804.86	894.28	1073.14	1252.00	1609.71	
Safe Frictional Capacity of Pile (Q _p), kN using 'N' values	=	533.91	593.24	711.88	830.53	1067.83	
Self Weight of Pile (W), kN	=	123.26	152.17	219.13	298.25	493.03	
Safe Pile Carrying Capacity of Pile (Q _{safe}), kN ('c' and 'φ')	=	1505	1758	2317	2945	4409	
Safe Pile Carrying Capacity of Pile (Q _{safe}), kN ('N' values)	=	1234	1457	1956	2524	3867	
Recommended Safe Pile Carrying Capacity of Pile (Q _{safe}), kN	=	1369	1608	2137	2735	4138	
Safe Uplift Capacity of Pile (Q _{up}), kN using 'c' and 'φ' values	=	777	878	1090	1314	1800	

Depth (m)	Soil Description	H _i (m)	'c' kN/m ²	'φ'	'γ' kN/m ³	'γ _{sub} ' kN/m ³	P _{bi} (kN/m ²)	'α _i '	'K _i '	N' Value
4.00	Brownish Sand (SP)	4.00	0	30	18.00	8.00	32.00	0.00	1.00	14
5.00	Greyish Brown Sand (SP)	1.00	0	42	22.00	12.00	54.00	0.00	1.00	53
6.00	Brownish Sand (SP)	1.00	0	42	22.00	12.00	66.00	0.00	1.00	44
7.50	Greyish Brown Silty Sand (SM-SP)	1.50	0	41	22.00	12.00	81.00	0.00	1.00	57
9.00	Greyish Brown Sand (SP)	1.50	0	42	22.00	12.00	99.00	0.00	1.00	72
10.50	Greyish Brown Sand (SP)	1.50	0	42	22.00	12.00	117.00	0.00	1.00	82
12.00	Greyish Brown Sand (SP)	1.50	0	40	22.00	12.00	135.00	0.00	1.00	37
13.50	Greyish Brown Silty Sand (SM-SP)	1.50	0	41	22.00	12.00	153.00	0.00	1.00	75
15.00	Greyish Brown Sand (SP)	1.50	0	39	20.30	10.30	169.73	0.00	1.00	36
16.50	Greyish Silty Sand (SM-SP)	1.50	0	27	17.50	7.50	183.08	0.00	1.00	12
18.00	Greyish Silty Sand (SM-SP)	1.50	0	22	14.70	4.70	192.23	0.00	1.00	5
19.50	Greyish Sand (SP)	1.50	0	28	17.20	7.20	201.15	0.00	1.00	11
21.00	Greyish Silty Sand (SM-SP)	1.50	0	25	16.10	6.10	211.13	0.00	1.00	8
22.50	Greyish Sand (SP)	1.50	0	28	17.50	7.50	221.33	0.00	1.00	12
24.00	Greyish Silty Sand (SM-SP)	1.50	0	29	18.20	8.20	233.10	0.00	1.00	15
25.50	Greyish Silty Sand (SM-SP)	1.50	0	31	19.10	9.10	246.08	0.00	1.00	19
27.00	Greyish Sand (SP)	1.50	0	37	20.70	10.70	260.93	0.00	1.00	29
28.50	Brown Weathered Charnockite	1.50	0	44	22.00	12.00	277.95	0.00	1.00	100
30.00	Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)	1.50	0	45	27.46	17.46	300.05	0.00	1.00	200
31.50	Charnockite, Grey, Medium Grained, Moderately Weathered (Grade III)	1.00	0	45	28.45	18.45	322.37	0.00	1.00	200
33.00	Charnockite, Grey, Medium Grained, Moderately Weathered (Grade III)	1.50	0	45	28.65	18.65	345.58	0.00	1.00	200

Depth (m)	Soil Description	Ultimate Frictional Capacity, kN using 'c' and 'φ' values						Ultimate Frictional Capacity, kN using 'N' values					
		q _s (kN/m ²)	450 mm	500 mm	600 mm	700 mm	900 mm	q _s (kN/m ²)	450 mm	500 mm	600 mm	700 mm	900 mm
4.00	Brownish Sand (SP)	18.48	104.47	116.08	139.30	162.52	208.95	23.33	131.95	146.61	175.93	205.25	263.89
5.00	Greyish Brown Sand (SP)	48.62	68.74	76.37	91.65	106.92	137.47	88.33	84.82	94.25	113.10	131.95	169.65
6.00	Brownish Sand (SP)	59.43	84.01	93.35	112.02	130.69	168.02	73.33	84.82	94.25	113.10	131.95	169.65
7.50	Greyish Brown Silty Sand (SM-SP)	70.41	127.23	141.37	169.65	197.92	254.47	95.00	127.23	141.37	169.65	197.92	254.47
9.00	Greyish Brown Sand (SP)	89.14	127.23	141.37	169.65	197.92	254.47	120.00	127.23	141.37	169.65	197.92	254.47
10.50	Greyish Brown Sand (SP)	105.35	127.23	141.37	169.65	197.92	254.47	136.67	127.23	141.37	169.65	197.92	254.47
12.00	Greyish Brown Sand (SP)	113.28	127.23	141.37	169.65	197.92	254.47	61.67	127.23	141.37	169.65	197.92	254.47
13.50	Greyish Brown Silty Sand (SM-SP)	133.00	127.23	141.37	169.65	197.92	254.47	125.00	127.23	141.37	169.65	197.92	254.47
15.00	Greyish Brown Sand (SP)	137.44	127.23	141.37	169.65	197.92	254.47	60.00	127.23	141.37	169.65	197.92	254.47
16.50	Greyish Silty Sand (SM-SP)	93.28	127.23	141.37	169.65	197.92	254.47	20.00	42.41	47.12	56.55	65.97	84.82
18.00	Greyish Silty Sand (SM-SP)	77.66	127.23	141.37	169.65	197.92	254.47	8.33	17.67	19.63	23.56	27.49	35.34
19.50	Greyish Sand (SP)	106.95	127.23	141.37	169.65	197.92	254.47	18.33	38.88	43.20	51.84	60.48	77.75
21.00	Greyish Silty Sand (SM-SP)	98.45	127.23	141.37	169.65	197.92	254.47	13.33	28.27	31.42	37.70	43.98	56.55
22.50	Greyish Sand (SP)	117.68	127.23	141.37	169.65	197.92	254.47	20.00	42.41	47.12	56.55	65.97	84.82
24.00	Greyish Silty Sand (SM-SP)	129.21	127.23	141.37	169.65	197.92	254.47	25.00	53.01	58.90	70.69	82.47	106.03
25.50	Greyish Silty Sand (SM-SP)	147.86	127.23	141.37	169.65	197.92	254.47	31.67	67.15	74.61	89.54	104.46	134.30
27.00	Greyish Sand (SP)	196.62	127.23	141.37	169.65	197.92	254.47	48.33	102.49	113.88	136.66	159.44	204.99
28.50	Brown Weathered Charnockite	268.41	127.23	141.37	169.65	197.92	254.47	166.67	127.23	141.37	169.65	197.92	254.47
30.00	Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)	300.05	127.23	141.37	169.65	197.92	254.47	333.33	127.23	141.37	169.65	197.92	254.47
31.50	Charnockite, Grey, Medium Grained, Moderately Weathered (Grade III)	322.37	84.82	94.25	113.10	131.95	169.65	333.33	84.82	94.25	113.10	131.95	169.65
33.00	Charnockite, Grey, Medium Grained, Moderately Weathered (Grade III)	345.58	127.23	141.37	169.65	197.92	254.47	333.33	127.23	141.37	169.65	197.92	254.47

Length of Pile (L), m	=	31.00	m	From Existing Borehole Level		
Angle of Internal Friction (φ) in Degrees	=	45.00				
Undrained cohesion value at PileTip (c _p), kN/m ²	=	0.00	kN/m ²			
Submerged Unit Weight at PileTip (γ _p), kN/m ²	=	18.67	kN/m ²	Submerged Condition		
Ground Water Table Depth (GWT), m	=	0.00	m			
Bearing Capacity Factor (N _c)	=	9.00				
Bearing Capacity Factor (N _q)	=	350.00				
Bearing Capacity Factor (N _γ)	=	271.75				
Factor of Safety (FS)	=	2.50				
Diameter of Pile (D), mm	=	450	500	600	700	900
Critical Depth of Pile (20 x D), m	=	9	10	12	14	18
Effective overburden pressure at Pile Tip (P ₀), kN/m ²	=	105.10	123.10	141.03	158.95	200.88
End Bearing Resistnace of Pile (q _p), kN/m ² using 'c' and 'φ'	=	37926.54	44353.38	50880.81	57408.24	72589.34
End Bearing Resistnace of Pile (q _p), kN/m ² using 'N' values	=	80000.00	80000.00	80000.00	80000.00	80000.00
Limiting End Bearing Resistnace of Pile (q _p), kN/m ²	=	11000.00	11000.00	11000.00	11000.00	11000.00
Ultimate End Bearing Capacity of Pile (Q _p), kN using 'c' and 'φ' values	=	1749.47	2159.84	3110.18	4233.30	5997.90
Ultimate End Bearing Capacity of Pile (Q _p), kN using 'N' values	=	1749.47	2159.84	3110.18	4233.30	5997.90
Safe End Bearing Capacity of Pile (Q _p), kN using 'c' and 'φ' values	=	699.79	863.94	1244.07	1693.32	2799.16
Safe End Bearing Capacity of Pile (Q _p), kN using 'N' values	=	699.79	863.94	1244.07	1693.32	2799.16
Ultimate Frictional Capacity of Pile (Q _p), kN using 'c' and 'φ' values	=	2268.00	2520.00	3024.00	3528.00	4536.00
Ultimate Frictional Capacity of Pile (Q _p), kN using 'N' values	=	1616.35	1795.94	2155.13	2514.32	3232.70
Negative Skin Friction of Pile (Q _{nf}), kN using 'c' and 'φ' values	=	136.61	151.79	182.15	212.50	273.22
Negative Skin Friction of Pile (Q _{nf}), kN using 'N' values	=	188.50	209.44	251.33	293.22	376.99
Safe Frictional Capacity of Pile (Q _p), kN using 'c' and 'φ' values	=	770.59	856.21	1027.45	1198.70	1541.18
Safe Frictional Capacity of Pile (Q _p), kN using 'N' values	=	458.04	508.94	610.73	712.51	916.09
Self Weight of Pile (W), kN	=	123.26	152.17	219.13	298.25	493.03
Safe Pile Carrying Capacity of Pile (Q _{safe}), kN ('c' and 'φ')	=	1470	1720	2272	2892	4340
Safe Pile Carrying Capacity of Pile (Q _{safe}), kN ('N' values)	=	1158	1373	1855	2406	3715
Recommended Safe Pile Carrying Capacity of Pile (Q _{safe}), kN	=	1314	1547	2063	2649	4028
Safe Uplift Capacity of Pile (Q _{up}), kN using 'c' and 'φ' values	=	743	840	1045	1262	1732

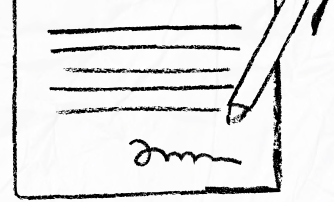
Taken from Figure 1 of IS 2911:2010 Part 1 Sec.2

Depth (m)	Soil Description	H _i (m)	'c' kN/m ²	'φ'	'γ' kN/m ³	'γ _{sub} ' kN/m ³	P _{0i} (kN/m ²)	'α _i '	'K _i '	N' Value
4.00	Brownish Sand (SP)	4.00	0	33	19.30	9.30	37.20	0.00	1.00	20
5.00	Greyish Brown Sand (SP)	1.00	0	36	20.30	10.30	60.95	0.00	1.00	26
6.00	Brownish Sand (SP)	1.00	0	42	22.00	12.00	72.10	0.00	1.00	41
7.50	Brownish Sand (SP)	1.50	0	42	22.00	12.00	87.10	0.00	1.00	90
9.00	Greyish Brown Silty Sand (SM-SP)	1.50	0	41	22.00	12.00	105.10	0.00	1.00	76
10.50	Greyish Brown Silty Sand (SM-SP)	1.50	0	41	22.00	12.00	123.10	0.00	1.00	43
12.00	Greyish Brown Silty Sand (SM-SP)	1.50	0	40	21.90	11.90	141.03	0.00	1.00	39
13.50	Greyish Brown Silty Sand (SM-SP)	1.50	0	41	22.00	12.00	158.95	0.00	1.00	54
15.00	Greyish Brown Sand (SP)	1.50	0	42	22.00	12.00	176.95	0.00	1.00	62
16.50	Brownish Grey Silty Sand (SM-SP)	1.50	0	26	16.90	6.90	191.13	0.00	1.00	10
18.00	Greyish Silty Sand (SM-SP)	1.50	0	25	16.10	6.10	200.88	0.00	1.00	8
19.50	Greyish Silty Sand (SM-SP)	1.50	0	25	16.50	6.50	210.33	0.00	1.00	9
21.00	Greyish Brown Silty Sand (SM-SP)	1.50	0	28	17.70	7.70	220.98	0.00	1.00	13
22.50	Greyish Silty Sand (SM-SP)	1.50	0	30	18.70	8.70	233.28	0.00	1.00	17
24.00	Brownish Grey Silty Sand (SM-SP)	1.50	0	27	17.20	7.20	245.20	0.00	1.00	11
25.50	Greyish Brown Silty Sand (SM-SP)	1.50	0	27	17.50	7.50	256.23	0.00	1.00	12
27.00	Greyish Silty Sand (SM-SP)	1.50	0	34	20.00	10.00	269.35	0.00	1.00	24
28.50	Brown Weathered Charnockite	1.50	0	44	22.00	12.00	285.85	0.00	1.00	100
30.00	Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)	1.50	0	45	28.64	18.64	308.83	0.00	1.00	200
31.50	Charnockite, Grey, Medium Grained, Moderately Weathered (Grade III)	1.00	0	45	28.67	18.67	332.15	0.00	1.00	200
33.00	Charnockite, Grey, Medium Grained, Moderately Weathered (Grade III)	1.50	0	45	28.94	18.94	355.69	0.00	1.00	200

Depth (m)	Soil Description	Ultimate Frictional Capacity, kN using 'c' and 'φ' values						Ultimate Frictional Capacity, kN using 'N' values					
		q _s (kN/m ²)	450 mm	500 mm	600 mm	700 mm	900 mm	q _s (kN/m ²)	450 mm	500 mm	600 mm	700 mm	900 mm
4.00	Brownish Sand (SP)	24.16	136.61	151.79	182.15	212.50	273.22	33.33	188.50	209.44	251.33	293.22	376.99
5.00	Greyish Brown Sand (SP)	44.28	62.60	69.56	83.47	97.38	125.21	43.33	61.26	68.07	81.68	95.29	122.52
6.00	Brownish Sand (SP)	64.92	84.82	94.25	113.10	131.95	169.65	68.33	84.82	94.25	113.10	131.95	169.65
7.50	Brownish Sand (SP)	78.43	127.23	141.37	169.65	197.92	254.47	150.00	127.23	141.37	169.65	197.92	254.47
9.00	Greyish Brown Silty Sand (SM-SP)	91.36	127.23	141.37	169.65	197.92	254.47	126.67	127.23	141.37	169.65	197.92	254.47
10.50	Greyish Brown Silty Sand (SM-SP)	107.01	127.23	141.37	169.65	197.92	254.47	71.67	127.23	141.37	169.65	197.92	254.47
12.00	Greyish Brown Silty Sand (SM-SP)	118.33	127.23	141.37	169.65	197.92	254.47	65.00	127.23	141.37	169.65	197.92	254.47
13.50	Greyish Brown Silty Sand (SM-SP)	138.17	127.23	141.37	169.65	197.92	254.47	90.00	127.23	141.37	169.65	197.92	254.47
15.00	Greyish Brown Sand (SP)	159.33	127.23	141.37	169.65	197.92	254.47	103.33	127.23	141.37	169.65	197.92	254.47
16.50	Brownish Grey Silty Sand (SM-SP)	93.22	127.23	141.37	169.65	197.92	254.47	16.67	35.34	39.27	47.12	54.98	70.69
18.00	Greyish Silty Sand (SM-SP)	93.67	127.23	141.37	169.65	197.92	254.47	13.33	28.27	31.42	37.70	43.98	56.55
19.50	Greyish Silty Sand (SM-SP)	98.08	127.23	141.37	169.65	197.92	254.47	15.00	31.81	35.34	42.41	49.48	63.62
21.00	Greyish Brown Silty Sand (SM-SP)	117.49	127.23	141.37	169.65	197.92	254.47	21.67	45.95	51.05	61.26	71.47	91.89
22.50	Greyish Silty Sand (SM-SP)	134.68	127.23	141.37	169.65	197.92	254.47	28.33	60.08	66.76	80.11	93.46	120.11
24.00	Brownish Grey Silty Sand (SM-SP)	124.94	127.23	141.37	169.65	197.92	254.47	18.33	38.88	43.20	51.84	60.48	77.75
25.50	Greyish Brown Silty Sand (SM-SP)	130.55	127.23	141.37	169.65	197.92	254.47	20.00	42.41	47.12	56.55	65.97	84.82
27.00	Greyish Silty Sand (SM-SP)	181.68	127.23	141.37	169.65	197.92	254.47	40.00	84.82	94.25	113.10	131.95	169.65
28.50	Brown Weathered Charnockite	276.04	127.23	141.37	169.65	197.92	254.47	166.67	127.23	141.37	169.65	197.92	254.47
30.00	Charnockite, Grey, Medium Grained, Highly Weathered (Grade IV)	308.83	127.23	141.37	169.65	197.92	254.47	333.33	127.23	141.37	169.65	197.92	254.47
31.50	Charnockite, Grey, Medium Grained, Moderately Weathered (Grade III)	332.15	84.82	94.25	113.10	131.95	169.65	333.33	84.82	94.25	113.10	131.95	169.65
33.00	Charnockite, Grey, Medium Grained, Moderately Weathered (Grade III)	355.69	127.23	141.37	169.65	197.92	254.47	333.33	127.23	141.37	169.65	197.92	254.47

Length of Pile (L), m	=	31.00 m	From Existing Borehole Level
Type of Fixity	=	Fixed Head by Pile Cap	
Cantilever Length above Ground Level (e), m	=	0.00 m	
Allowable Deflection as per IS 2911 Part 4 : 1985, Page No. 10 in mm	=	5.00 mm	Point of application of Lateral Load (Assumed)
Modulus of Subgrade Reaction of Soil (η_n)	=	3200.00 kN/m ³	From Table 3 of IS 2911 Part 1 Sec. 2
Grade of Concrete	=	30.00 N/mm ²	M 30
Young's Modulus of Pile Material (E), kN/m ²	=	27386127.88 kN/m ²	
Diameter of Pile (D), mm	=	450	500
Moment of Inertia of Pile Section (I), m ⁴	=	0.00201	0.00307
Stiffness Factor, (T)	=	1.77	1.92
Criteria for Behaviour of Pile as per Table 5 of IS 2911 Part I Sec. 2	=	Long Pile	Long Pile
(e/R)	=	0.00	0.00
(Z _r /T) from Fig.4 of IS 2911 Part 1 Sec.2	=	1.90	1.90
Depth of Fixity (Z _f), m	=	3.36	3.65
Allowable Deflection as per IS 2911 Part 4 : 1985, Page No. 10 in mm	=	5.00	5.00
Lateral Load Capacity of Pile (H), kN	=	87.20	103.70
		138.10	177.30
			264.30





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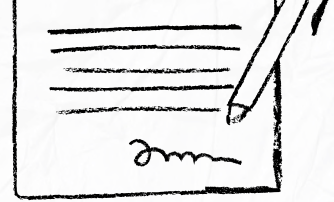
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