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கோட்டம்-IV
05 JAN 2023
சென்னை-12

SOIL INVESTIGATION REPORT

NAME OF WORK : **REVISED RECOMMENDATION OF FOUNDATION FOR THE PROPOSED RECONSTRUCTION OF SLUM TENEMENTS (S+4 FLOORS) AT APPASAMY STREET TENEMENTAL SCHEME IN CORPORATION DIVISION 110, ZONE IX OF GREATER CHENNAI CORPORATION.**

CLIENT : **The Executive Engineer,**
Division – IV,
Tamil Nadu Urban Habitat Development Board,
No. 2/124, Sir Thiyagaraya Salai, Teynampet,
Chennai – 600 018.

Reference : The Executive Engineer, TNUHDB, Chennai, Lr. No. 120/AE(P)/Dn-IV/2021.

JOB No : SM&FE 216 / Consultancy / 2021

DATE : 30th December 2022

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REVISED RECOMMENDATION OF FOUNDATION FOR THE PROPOSED RECONSTRUCTION OF SLUM TENEMENTS (S+4 FLOORS) AT APPASAMY STREET TENEMENTAL SCHEME IN CORPORATION DIVISION 110, ZONE IX OF GREATER CHENNAI CORPORATION.

Job. No. SM&FE 216 / Consultancy / 2021 Date:30.12.2022

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Division – IV,
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1. INTRODUCTION

The Tamil Nadu Urban Habitat Development Board (TNUHDB), Division – IV, No. 2/124, Sir Thiyagaraya Salai, Teynampet, Chennai – 600 018 has proposed to reconstruct Slum Tenements (S+4 Floors) at Appasamy Street Tenemental Scheme in Corporation Division 110, Zone IX of Greater Chennai Corporation. The officials of TNUHDB, Division – IV, No. 2/124, Sir Thiyagaraya Salai, Teynampet, Chennai – 600 018 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 reconstruction of Slum Tenements (S+4 Floors) at Appasamy Street Tenemental Scheme in Corporation Division 110, Zone IX of Greater Chennai Corporation. Accordingly, the work was taken up and field investigation was carried out during

13th November 2021 to 22nd November 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 TNSCB, Division – IV, No. 2/124, Sir Thiyagaraya Salai, Teynampet, Chennai – 600 018. 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 Appasamy Street Tenemental Scheme in Corporation Division 110, Zone IX of Greater Chennai Corporation. The site is a plain terrain. The total number of borehole locations has been decided as '2', as agreed by the Officials of Executive Engineer of TNUHDB, Division – IV, Teynampet, Chennai 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 and A-2. 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 and table A-2 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 and BH 2 of the proposed site. It could be seen from figure 1 that the variations of SPT 'N' values are almost uniform in all the two bore holes, indicating the homogeneity of soil layer (Plate 1 and 2 of Annexure – 2).

3.1 Summary of Soil Profile in BH 1 and BH 2 Locations

1. Greyish Brown Silty Sand was found from top 1.0 m depth to 15.0 m depth in two bore-hole locations with SPT 'N' value varying from 4 to 24.

2. Silty / Clayey Sand was encountered from 16.5 m to 22.5 m depth in two bore-hole locations with SPT 'N' value varying from 9 to 60.

3. Greyish Brown Sand Stone interbedded with Shale was found from 25.5 m to 28.5 m in BH 1 location and from 24.0 m to 27.0 m depth in BH 2 location.

4. The ground water table was observed from 2.1 m to 2.2 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 and BH 2 locations (Figure 1).

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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 and table - 2. The 'E_s' values are computed based on Bowles 1997 correlation.

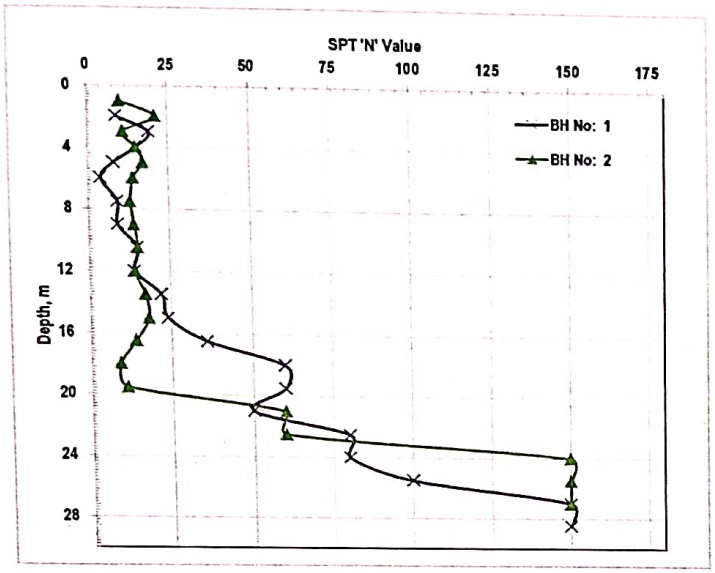


Figure (1) Variation of SPT 'N' value of different soil layers with respect to depth in Different Borehole Locations of the Site

5.0 COMPUTATION OF BEARING CAPACITY AND SETTLEMENT

Based on the observation made in the boreholes 1 and 2, an attempt is made to arrive the safe bearing capacity and allowable settlement of the foundation soil. The depth of foundation is taken as 3.0 m and size of foundation as 8.05 m x 50.85 m and 9.50 m x 54.82 m to compute safe bearing capacity. The SPT 'N' value, Correlated Elastic Modulus 'E_s' value (Bowles 1997) and shear strength parameters and engineering properties of soil layers which are required to determine bearing capacity and settlement were taken from Table 1 and Table 2. Safe bearing capacity and settlement computations were made for the two bore-hole data. The least value of safe bearing capacity is recommended for the proposed site. The Safe Bearing Capacity is computed using Bureau of Indian Standard IS 6403-1981 equation. The elastic settlement of foundation is arrived based on IS 8009 (Part I) 1976 Method using the Elastic Modulus values of soil layers for the proposed site. The ground water table depth is taken as ground surface to compute safe bearing capacity and settlement of foundation.

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5.1 Safe Bearing Capacity

For the determination of Safe Bearing Capacity using IS 6403-1981 equation, the average 'N' value and shear strength parameters below foundation level upto the influence depth of 1B is considered (Varghese 2005) for a depth of foundation 3.0 m and size of foundation as 8.05 m x 50.85 m and 9.50 m x 54.82 m. The safe bearing capacity thus computed is shown in Table 1. In general, the bearing capacity is a function of size of foundation for a given in-situ shear strength values. Accordingly, higher the width of foundation higher would be the bearing capacity. However, it is very important that bearing capacity should also satisfy the allowable settlement criteria. As seen from table 1, the safe bearing capacity keeps varying from 162 kN/m^2 to 177 kN/m^2 for BH 1 and BH 2 locations at 3.0 m depth for 8.05 x 50.85 m foundation size. The computed safe bearing capacity for 9.50 x 54.82 m size foundation is varying from 187 kN/m^2 to 210 kN/m^2.

TABLE 1 Net Safe Bearing Capacity of the proposed Site (Depth of Foundation is 3.0 m)

Borehole Locations	Size of Foundation	Design Shear Strength Parameters		Net Safe Bearing Capacity (kN/m^2) IS 6403-1981 Equation
		'c' (kN/m^2)	Φ in Degrees	
BH 1	8.05 m x 50.85 m	2.60	25.50	162.00
BH 2		0.00	26.90	177.00
BH 1	9.50 m x 54.82 m	2.30	25.90	187.00
BH 2		0.00	27.20	210.00

5.2 Settlement Calculations for Foundation Soil

One of the important aspects of any foundation systems is to satisfy the settlement criteria apart from bearing capacity criteria. The total settlement of foundation is becoming very critical, especially if the foundation is located on clays, because the clay layer is expected to undergo excessive consolidation settlement over a period of time under sustained loadings which of-course depends on the state of clay (initial water content / void ratio), whereas in the case of loose sand layer, elastic or immediate settlement plays a crucial role. In the proposed site, the soil profile below foundation depth is predominantly Silty Sand layer. Hence, elastic settlement was computed for 8.05 m x 50.85 m and 9.50 m x 54.82 m foundation upto the influence depth of "2B" below the foundation depth. The computed settlements are varying

between 56.45 mm to 65.89 mm for 8.05 m x 50.85 m size foundation. For 9.50 m x 54.82 m size foundation, the computed settlement is varying from 64.39 mm to 66.48 mm (Table 2). ***The allowable settlement as per IS 1904 Table I 1986 is limited to 50 mm for individual footing and 75 mm for raft foundation.***

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TABLE 2 Settlement calculations for the proposed Site (Depth of Foundation is 3.0 m)

Borehole Locations	Size of Foundation (m)	Pressure (kN/m^2)	Load (kN)	Elastic Settlement (mm)
BH 1	8.05 m x 50.85 m	160	65494.8	65.89
BH 2				56.45
BH 1	9.50 m x 54.82 m	160	83326.4	66.48
BH 2				64.39

6.0 COMPUTATION OF SAFE PILE CARRYING CAPACITY

Attempts are also 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 25.0 m to 27.0 m. Safe pile carrying capacity computations were made for two-borehole data. The Indian Standard IS 2911 (2010) specifies that the base resistance should not exceed 1000 to 1100 t/m^2 for bored cast-in-situ piles and 1500 t/m^2 for precast driven piles.

For calculating the skin friction along the pile length of 25.0 m to 27.0 m, the design 'N' values and shear strength parameters for the respective depths were used. The soil layers in top 3.0 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 3 Safe Load carrying capacity of Bored Cast-In-Situ Pile of 25.0 m to 27.0 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	1195	1406	1876	2408	3662	1030	1223	1656	2151	3332
BH 2	1205	1418	1890	2425	3683	934	1116	1527	2002	3139

TABLE 4 Safe Uplift Capacity of 25.0 m to 27.0 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	561	637	796	966	1338
BH 2	571	647	805	974	1341

7. CONCLUSIONS AND RECOMMENDATIONS

Based on the discussions made in sections 3, 4, and 5 the following recommendations are furnished for the reconstruction of Slum Tenements (S+4 Floors) at Appasamy Street Tenemental Scheme in Corporation Division 110, Zone IX of Greater Chennai Corporation.

Option – 1 (Shallow Foundation – Raft)

1) It is recommended to provide **RAFT FOUNDATION.**

2) The recommended depth of Raft Foundation is 3.0 m from the lowest borehole level of the site.

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3) The recommended safe bearing capacity at 3.0 m from the existing borehole level of the site is 160 kN/m^2. The permissible settlement for Raft Foundation is 75 mm.

4) The computed Settlement of sub-soil for are varying between 56.45 mm to 65.89 mm for 8.05 m x 50.85 m size foundation. For 9.50 m x 54.82 m size foundation, the computed settlement is varying from 64.39 mm to 66.48 mm. The computed settlement value at 3.0 depth is lower than the permissible settlement values of 75 mm as per Table I of IS 1904.

5) In order to minimize the settlement of Raft, it is recommended to excavate 3.5 m depth and provide 0.50 m thick compacted quarry sand with gravel bed (1:1 ratio). The Raft foundation may be placed over the 0.50 m thick compacted quarry sand - gravel bed.

6) The depth of foundation is 3.0 m from the existing ground level over the compacted quarry sand - gravel bed at Site (0.50 m thickness).

7) It is recommended to provide suitable supporting system to excavate soil up to 3.5 m depth to avoid collapse of soil mass.

8) Dewatering shall be adopted if water seepage encountered while excavating 3.5 m depth soil mass.

9) The TDS and chemical content of ground water may be checked and ensured that they are not exceeding the permissible limits prior to the use of same for construction activities.

Option – 2 (Pile Foundation)

1) If any difficulties are encountered while excavating 3.5 m depth in the sandy soil, even though dewatering & supporting system are adopted at site, because of high seepage of water, constrains encountered while excavating huge area at site, it is recommended to provide pile foundation for the proposed site.

2) The recommended type of pile foundation is ***"Bored Cast-In-Situ Pile"***

3) The recommended safe vertical and lateral pile carrying capacity of the 25.0 m to 27.0 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.

TABLE 5 Safe Load carrying capacity and Lateral Load Capacity of Bored Cast-In-Situ Pile for varying diameter and for a length of 25.0 to 27.0 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	900	38.00	4.43
500	1100	45.00	4.82
600	1500	60.20	5.58
700	2000	77.10	6.31
900	3000	115.50	7.71

4) The bored cast in-situ pile shall be terminated at 25.0 m to 27.0 m in Greyish Brown Sand Stone Interbedded with Shale stratum.

5) 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.

6) 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.

30/12/22

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IN-SITU GEOTECHNICAL BORE LOG

BORE-HOLE No. BH-1
SHEET No. (1/2)

Division of Soil Mech. & Found. Engg. CEGC Anna University Chennai-25

Project:	Reconstruction of Slum Tenements (S+4 Floors) at Appasamy Street Tenemental Scheme in Corporation Division 110, Zone IX of Greater Chennai Corporation.		
Co-ordinates:	-	Started:	13-11-2021
Location:	Appasamy Street	Completed:	16-11-2021
Elevation (RL):	-	Ground Water Level:	2.2 m
Dia of Boring:	150 mm	Type of Core Barrel:	Nx Size Core Barrel
Casing Depth:	-	Water Loss Depths :	-
Type of Boring:	Rotary	Total Drill Depth:	28.5 m (24.0 m - Soil & 4.5 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: 0-15 cm	15-30 cm	30-45 cm	SPT-N	TCR (%)	RQD (%)	Relative Density / Consistency of Soil / Strength of Rock
								0 30 60 90 120 150 180		
1.0	1.0		Debris	-	-	-	-			-
2.0	2.0		Brown Silty Sand (SM-SP)	5	5	4	9			Loose
3.0	3.0		Brown Sand (SP)	6	8	11	19			Medium Dense
4.0	4.0		Brown Sand (SP)	7	7	8	15			Medium Dense
5.0	5.0		Brownish Grey Silty Sand (SM-SP)	3	4	4	8			Loose
6.0	6.0		Greyish Sand (SP)	3	2	2	4			Loose
7.5	7.0		Greyish Silty / Clayey Sand (SC-SM)	7	4	5	9			Loose
9.0	8.0 9.0		Greyish Silty Sand (SM-SP)	4	4	5	9			Loose
10.5	10.0		Greyish Silty Sand (SM-SP)	5	6	9	15			Medium Dense
12.0	11.0 12.0		Greyish Silty Sand (SM-SP)	8	7	7	14			Medium Dense
13.5	13.0		Yellowish Grey Silty Sand (SM-SP)	5	9	13	22			Medium Dense
15.0	14.0 15.0		Yellowish Grey Silty Sand (SM-SP)	9	11	13	24			Medium Dense
16.5	16.0		Brownish Grey Silty / Clayey Sand (SC-Cl)	10	15	21	36			Dense

IN-SITU GEOTECHNICAL BORE LOG

BORE-HOLE No. BH-1
SHEET No. (2/2)

Soil Mech. & Found. Engg. CEOC Anna University Chennai-25

Project:	Reconstruction of Slum Tenements (S+4 Floors) at Appasamy Street Tenemental Scheme in Corporation Division 110, Zone IX of Greater Chennai Corporation.		
Co-ordinates:	-	Started:	13-11-2021
Location:	Appasamy Street	Completed:	16-11-2021
Elevation (RL):	-	Ground Water Level:	2.2 m
Dia of Boring:	150 mm	Type of Core Barrel:	Nx Size Core Barrel
Casing Depth:	-	Water Loss Depths :	-
Type of Boring:	Rotary	Total Drill Depth:	28.5 m (24.0 m - Soil & 4.5 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 – 18.0		Brownish Grey Silty / Clayey Sand (SC)	10	$50_{(21\ cm)}$ Rebound		>100			Very Dense
19.5	19.0		Greyish Brown Silty / Clayey Sand with Lime Particles (SC)	22	$55_{(12\ cm)}$ Rebound		>100			Very Dense
21.0	20.0 – 21.0		Greyish Brown Silty / Clayey Sand with Lime Particles (SC)	14	22	28	50			Very Dense
22.5	22.0		Greyish Brown Silty Sand (SM-SP)	$55_{(12\ cm)}$ Rebound			>100			Very Dense
24.0	23.0 – 24.0		Brown Silty Sand (SM-SP)	$60_{(9\ cm)}$ Rebound			>100			Very Dense
25.5	25.0		Brown Weathered Sand Stone / Shale (Grade VI)	$55_{(2\ cm)}$ Rebound			>100			Hard / Very Weak
27.0	26.0 – 27.0		Greyish Brown Sand Stone Interbedded with Shale (Grade IV)	$55_{(0\ cm)}$ Rebound			>100	32.0	22.0	Moderately Weak
28.5	28.0		Greyish Brown Sand Stone Interbedded with Shale (Grade II)	$55_{(0\ cm)}$ Rebound			>100	82.0	73.0	Strong

IN-SITU GEOTECHNICAL BORE LOG

BORE-HOLE No. BH-2
SHEET No. (1/2)

Division of Soil Mech. & Foundation Engg. CEGC Anna University Chennai-25

Project:	Reconstruction of Slum Tenements (S+4 Floors) at Appasamy Street Tenemental Scheme in Corporation Division 110, Zone IX of Greater Chennai Corporation.		
Co-ordinates:	-	Started:	19-11-2021
Location:	Appasamy Street	Completed:	22-11-2021
Elevation (RL):	-	Ground Water Level:	2.1 m
Dia of Boring:	150 mm	Type of Core Barrel:	Nx Size Core Barrel
Casing Depth:	-	Water Loss Depths :	-
Type of Boring:	Rotary	Total Drill Depth:	27.0 m (22.5 m - Soil & 4.5 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		Brown Silty Sand with Gravel (GM-SP)	0	1	1	2			Loose
2.0	2.0		Blackish Grey Silty Sand (SM-SP)	2	2	2	4			Loose
3.0	3.0		Brown Silty Sand (SM-SP)	4	6	8	14			Medium Dense
4.0	4.0		Brown Silty Sand (SM-SP)	6	8	9	17			Medium Dense
5.0	5.0		Brown Sand (SP)	7	8	7	15			Medium Dense
6.0	6.0		Greyish Silty Sand (SM-SP)	3	4	4	8			Loose
7.5	7.0		Greyish Silty Sand (SM-SP)	4	3	4	7			Loose
9.0	8.0 9.0		Brownish Grey Silty Sand (SM-SP)	5	4	5	9			Loose
10.5	10.0		Brown Silty Sand (SM-SP)	6	8	8	16			Medium Dense
12.0	11.0 12.0		Greyish Brown Silty Sand (SM-SP)	6	8	9	17			Medium Dense
13.5	13.0		Greyish Brown Silty Sand (SM-SP)	5	5	8	13			Medium Dense
15.0	14.0 15.0		Greyish Brown Silty Sand (SM-SP)	8	12	16	28			Medium Dense
16.5	16.0		Greyish Brown Silty Sand (SM-SP)	10	14	20	34			Dense

IN-SITU GEOTECHNICAL BORE LOG

BORE-HOLE No. BH-2
SHEET No. (2/2)

Division of Soil Mech. & Foundation Engg. CEGC Anna University Chennai-25

Project:	Reconstruction of Slum Tenements (S+4 Floors) at Appasamy Street Tenemental Scheme in Corporation Division 110, Zone IX of Greater Chennai Corporation.		
Co-ordinates:	-	Started:	19-11-2021
Location:	Appasamy Street	Completed:	22-11-2021
Elevation (RL):	-	Ground Water Level:	2.1 m
Dia of Boring:	150 mm	Type of Core Barrel:	Nx Size Core Barrel
Casing Depth:	-	Water Loss Depths :	-
Type of Boring:	Rotary	Total Drill Depth:	27.0 m (22.5 m - Soil & 4.5 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 – 18.0		Greyish Brown Silty / Clayey Sand with Lime Particles (SC)	10	30	37	67			Very Dense
19.5	19.0		Brownish Grey Silty / Clayey Sand with Lime Particles (SC)	13	22	40	62			Very Dense
21.0	20.0 – 21.0		Brown Silty Clay (CH)	$55_{(8\ cm)}$ Rebound			>100			Hard
22.5	22.0		Greyish Brown Silty / Clayey Sand (SC)	$60_{(5\ cm)}$ Rebound			>100			Very Dense
24.0	23.0 – 24.0		Greyish Brown Sand Stone Interbedded with Shale (Grade V)	$55_{(0\ cm)}$ Rebound			>100	22.0	0.0	Weak
25.5	25.0		Greyish Brown Sand Stone Interbedded with Shale (Grade IV)	$55_{(0\ cm)}$ Rebound			>100	23.3	19.0	Moderately Weak
27.0	26.0 – 27.0		Greyish Brown Sand Stone Interbedded with Shale (Grade III)	$55_{(0\ cm)}$ Rebound			>100	55.3	44.6	Moderately Strong

Table A-1

Project : Proposed Reconstruction of Slum Tenements (S+4 Floors) at Appasamy Street Tenemental Scheme in Corporation Division 110, Zone IX of Greater Chennai Corporation.

BH No: 1 | Ground Water Table Depth (m): 2.2

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: Silt & Clay	Cohesion (c), kN/m^2	Angle of Friction (Φ) in Degrees
2.0	9	Brown Silty Sand (SM-SP)	15	16.5	NP	NP	NP	NP	2.63	0	9	52	25	14	0	25
3.0	19	Brown Sand (SP)	16	19.1	NP	NP	NP	NP	2.64	0	15	61	17	7	0	32
4.0	15	Brown Sand (SP)	18	18.2	NP	NP	NP	NP	2.63	0	1	66	26	7	0	30
5.0	8	Brownish Grey Silty Sand (SM-SP)	18	16.1	NP	NP	NP	NP	2.64	0	1	48	40	11	0	25
6.0	4	Greyish Sand (SP)	20	14.1	NP	NP	NP	NP	2.64	0	2	48	40	10	0	21
7.5	9	Greyish Silty / Clayey Sand (SC-SM)	14	16.5	31	15	16	40	2.62	0	9	60	18	13	14	22
9.0	9	Greyish Silty Sand (SM-SP)	14	16.5	NP	NP	NP	NP	2.64	0	0	50	36	14	0	25
10.5	15	Greyish Silty Sand (SM-SP)	16	18.2	NP	NP	NP	NP	2.63	0	5	24	58	13	0	29
12.0	14	Greyish Silty Sand (SM-SP)	16	18.0	NP	NP	NP	NP	2.61	0	4	28	55	13	0	29
13.5	22	Yellowish Grey Silty Sand (SM-SP)	19	19.6	NP	NP	NP	NP	2.62	0	0	13	66	21	0	33
15.0	24	Yellowish Grey Silty Sand (SM-SP)	17	20.0	NP	NP	NP	NP	2.65	0	8	17	49	26	0	34
16.5	36	Brownish Grey Silty / Clayey Sand (SC-Cl)	22	21.6	44	24	20	65	2.65	0	5	17	29	49	108	30
18.0	>100	Brownish Grey Silty / Clayey Sand (SC)	12	22.0	37	16	21	20	2.66	0	2	35	27	36	90	40
19.5	>100	Greyish Brown Silty / Clayey Sand with Lime Particles (SC)	14	22.0	52	25	27	70	2.65	0	6	39	23	32	90	40
21.0	50	Greyish Brown Silty / Clayey Sand with Lime Particles (SC)	14	22.0	65	28	37	80	2.65	0	10	52	16	22	75	38
22.5	>100	Greyish Brown Silty Sand (SM-SP)	15	22.0	NP	NP	NP	NP	2.66	0	5	20	53	22	0	42
24.0	>100	Brown Silty Sand (SM-SP)	16	22.0	NP	NP	NP	NP	2.65	0	1	31	46	22	0	42
					Porosity of Rock (%)					Strength of Rock: UCS, kN/m^2		Strength of Rock: I_s, kN/m^2			Shear Strength Parameters (IS 2911 Part 1 Sec 2:2010 : Fig 3)	
25.5	>100	Brown Weathered Sand Stone / Shale (Grade VI)	-	22.0	-				2.67	-		-			1000	0
27.0	>100	Greyish Brown Sand Stone Interbedded with Shale (Grade IV)	3.52	24.6	9.22				2.68	9883		2006			2000	0
28.5	>100	Greyish Brown Sand Stone Interbedded with Shale (Grade II)	3.23	24.7	8.76				2.68	15741		6019			2000	0

Foundation Engg. Division, Dept. of Civil Engg., CEGC, Anna University, Chennai-25

Table A-2

Project : Proposed Reconstruction of Slum Tenements (S+4 Floors) at Appasamy Street Tenemental Scheme in Corporation Division 110, Zone IX of Greater Chennai Corporation.

BH No: 2 | Ground Water Table Depth (m): 2.1

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: Silt & Clay	Cohesion (c), kN/m^2	Angle of Friction (Φ) in Degrees
1.0	2	Brown Silty Sand with Gravel (GM-SP)	10	12.3	NP	NP	NP	NP	2.65	35	14	22	13	16	0	19
2.0	4	Blackish Grey Silty Sand (SM-SP)	21	14.1	NP	NP	NP	NP	2.63	0	20	20	31	29	0	21
3.0	14	Brown Silty Sand (SM-SP)	11	18.0	NP	NP	NP	NP	2.64	0	2	59	28	11	0	29
4.0	17	Brown Silty Sand (SM-SP)	15	18.7	NP	NP	NP	NP	2.54	0	2	55	33	10	0	30
5.0	15	Brown Sand (SP)	17	18.2	NP	NP	NP	NP	2.56	0	4	67	23	6	0	30
6.0	8	Greyish Silty Sand (SM-SP)	14	22.0	NP	NP	NP	NP	2.63	0	1	57	31	11	0	25
7.5	7	Greyish Silty Sand (SM-SP)	13	15.7	NP	NP	NP	NP	2.64	0	6	67	15	12	0	24
9.0	9	Brownish Grey Silty Sand (SM-SP)	14	16.5	NP	NP	NP	NP	2.53	0	3	44	39	14	0	25
10.5	16	Brown Silty Sand (SM-SP)	15	18.5	NP	NP	NP	NP	2.64	0	2	38	50	10	0	30
12.0	17	Greyish Brown Silty Sand (SM-SP)	14	18.7	NP	NP	NP	NP	2.63	0	3	39	47	11	0	30
13.5	13	Greyish Brown Silty Sand (SM-SP)	17	17.7	NP	NP	NP	NP	2.62	0	1	18	56	25	0	28
15.0	28	Greyish Brown Silty Sand (SM-SP)	18	20.6	NP	NP	NP	NP	2.65	0	2	13	59	26	0	36
16.5	34	Greyish Brown Silty Sand (SM-SP)	14	22.0	NP	NP	NP	NP	2.65	0	3	29	44	24	0	38
18.0	67	Greyish Brown Silty / Clayey Sand with Lime Particles (SC)	9	22.0	52	21	31	46	2.58	0	7	37	23	33	90	40
19.5	62	Brownish Grey Silty / Clayey Sand with Lime Particles (SC)	11	22.0	55	23	32	83	2.65	0	3	38	32	27	90	40
21.0	>100	Brown Silty Clay (CH)	12	22.0	60	26	34	20	2.66	0	0	3	26	71	500	0
22.5	>100	Greyish Brown Silty / Clayey Sand (SC)	14	22.0	43	25	18	12	2.67	0	0	9	50	41	90	40

Depth (m)	SPT 'N' Value	Description / Classification of Soil and Rock / Weathering Grade of Rock as per IS 4464	Natural Moisture Content, %	Bulk Density (kN/m^3)	Porosity of Rock (%)	Specific Gravity	Strength of Rock: UCS, kN/m^2	Strength of Rock: I_s, kN/m^2	Shear Strength Parameters (IS 2911 Part 1 Sec 2:2010 : Fig 3): Cohesion (c), kN/m^2	Shear Strength Parameters (IS 2911 Part 1 Sec 2:2010 : Fig 3): Angle of Friction (Φ) in Degrees
24.00	>100	Greyish Brown Sand Stone Interbedded with Shale (Grade V)	4.12	26.1	10.12	2.67	-	334	2000	0
25.50	>100	Greyish Brown Sand Stone Interbedded with Shale (Grade IV)	3.74	27.4	9.68	2.68	12246	1551	2000	0
27.00	>100	Greyish Brown Sand Stone Interbedded with Shale (Grade III)	3.41	26.8	8.45	2.68	12803	736	2000	0

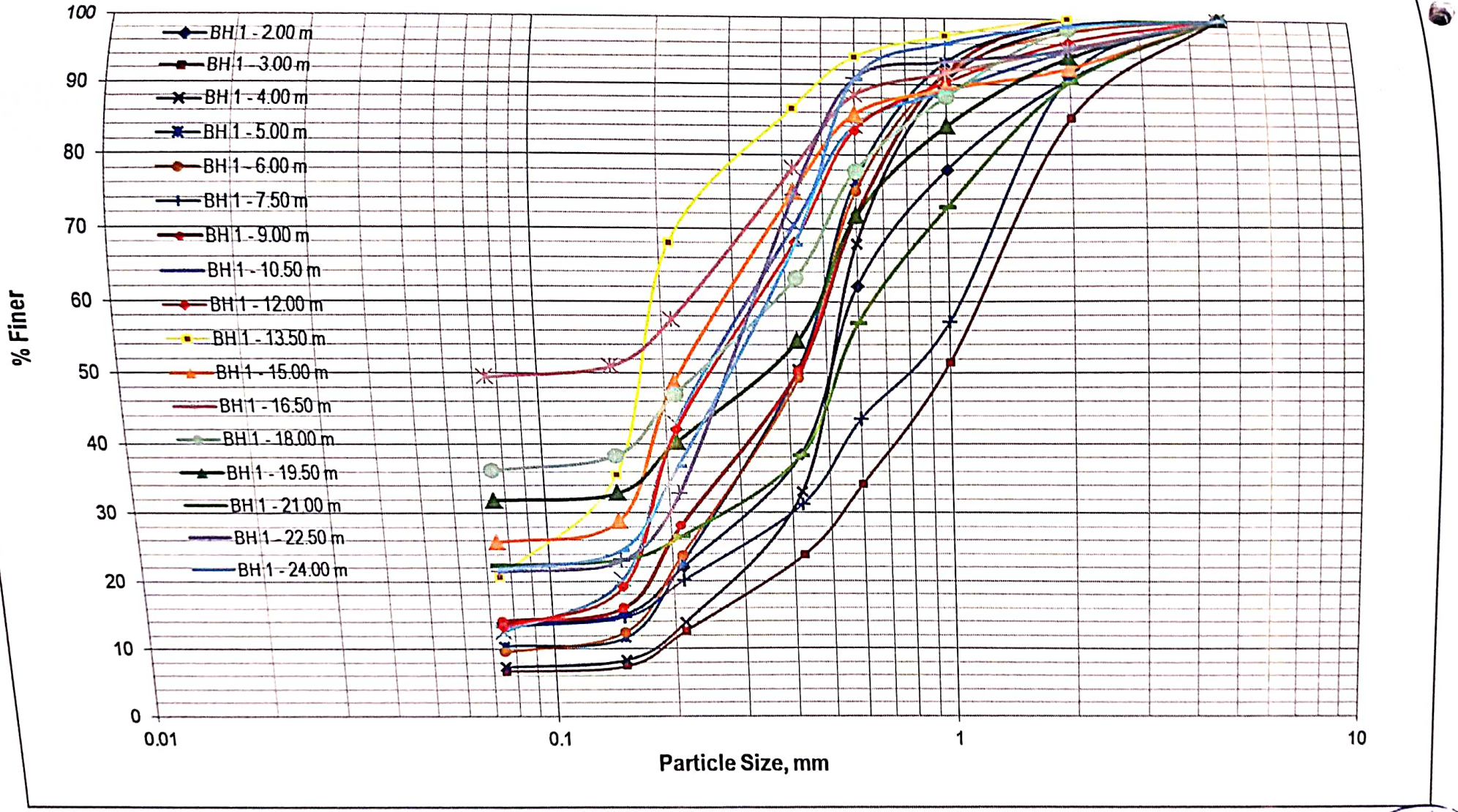


Figure C- 1 Grain Size Distribution of Soil Samples collected in BH 1 Location

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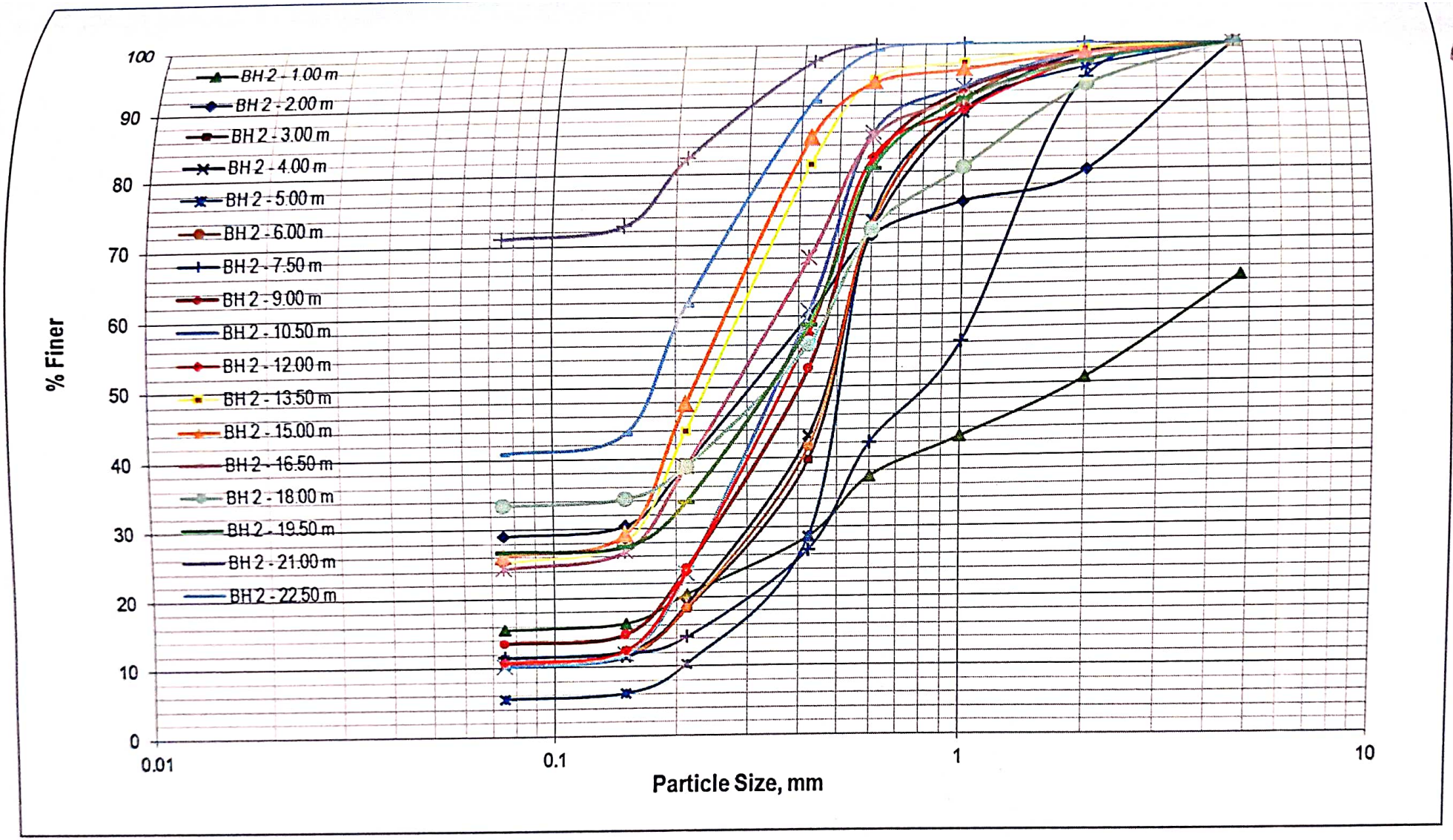


Figure C-2 Grain Size Distribution of Soil Samples collected in BH 2 Location



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Appendix - A

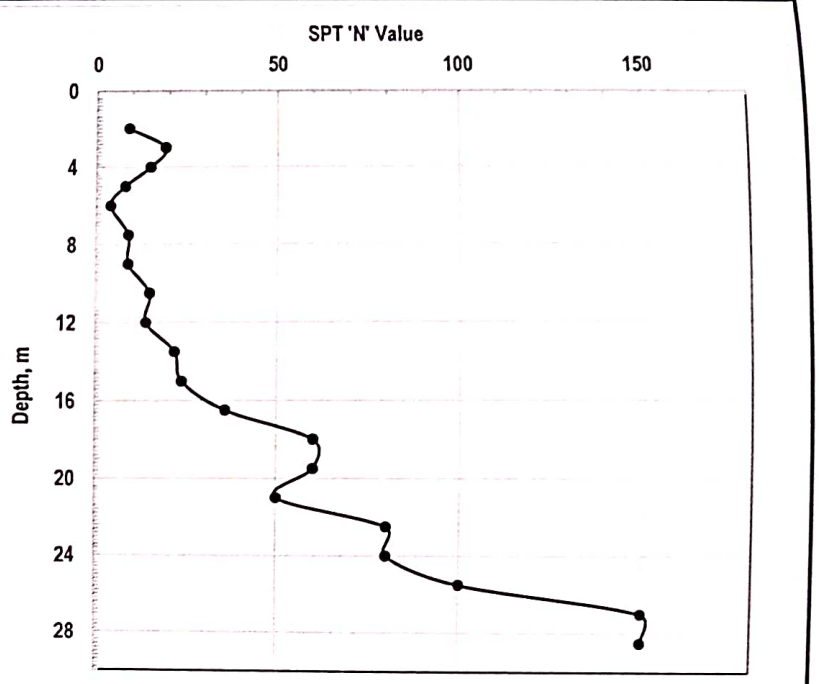
GEOTECHNICAL DESIGN PARAMETERS

GEOTECHNICAL DESIGN PARAMETERS OF DIFFERENT LAYERS BELOW GROUND LEVEL

PROJECT: Proposed Reconstruction of Slum Tenements (S+4 Floors) at Appasamy Street Tenemental Scheme in Corporation Division 110, Zone IX of Greater Chennai Corporation.

BH No:	1					GWT (m):	2.2
Depth below GL (m)	In-situ SPT 'N' Value	Description / Classification of Soil and Rock / Weathering Grade of Rock as per IS 4464	Design 'N' Value	Bulk Density, kN/m^3	Modulus of Elasticity (E_s), kN/m^2	Design Shear Strength Parameters	
						Shear Strength (c_u), kN/m^2	Angle of Friction (Φ) in Degrees
2.00	9	Brown Silty Sand (SM-SP)	9	16.5	23400	0	25
3.00	19	Brown Sand (SP)	19	19.1	49400	0	32
4.00	15	Brown Sand (SP)	15	18.2	39000	0	30
5.00	8	Brownish Grey Silty Sand (SM-SP)	8	16.1	20800	0	25
6.00	4	Greyish Sand (SP)	4	14.1	10400	0	21
7.50	9	Greyish Silty / Clayey Sand (SC-SM)	9	16.5	23400	14	22
9.00	9	Greyish Silty Sand (SM-SP)	9	16.5	23400	0	25
10.50	15	Greyish Silty Sand (SM-SP)	15	18.2	39000	0	29
12.00	14	Greyish Silty Sand (SM-SP)	14	18.0	36400	0	29
13.50	22	Yellowish Grey Silty Sand (SM-SP)	22	19.6	57200	0	33
15.00	24	Yellowish Grey Silty Sand (SM-SP)	24	20.0	62400	0	34
16.50	36	Brownish Grey Silty / Clayey Sand (SC-Cl)	36	21.6	93600	108	30
18.00	>100	Brownish Grey Silty / Clayey Sand (SC)	60	22.0	156000	90	40
19.50	>100	Greyish Brown Silty / Clayey Sand with Lime Particles (SC)	60	22.0	156000	90	40
21.00	50	Greyish Brown Silty / Clayey Sand with Lime Particles (SC)	50	22.0	130000	75	38
22.50	>100	Greyish Brown Silty Sand (SM-SP)	80	22.0	208000	0	42
24.00	>100	Brown Silty Sand (SM-SP)	80	22.0	208000	0	42
25.50	>100	Brown Weathered Sand Stone / Shale (Grade VI)	100	22.0	145000	1000	0
27.00	>100	Greyish Brown Sand Stone Interbedded with Shale (Grade IV)	150	24.6	197500	2000	0
28.50	>100	Greyish Brown Sand Stone Interbedded with Shale (Grade II)	150	24.7	197500	2000	0

Variation of SPT 'N' Value with respect to Depth



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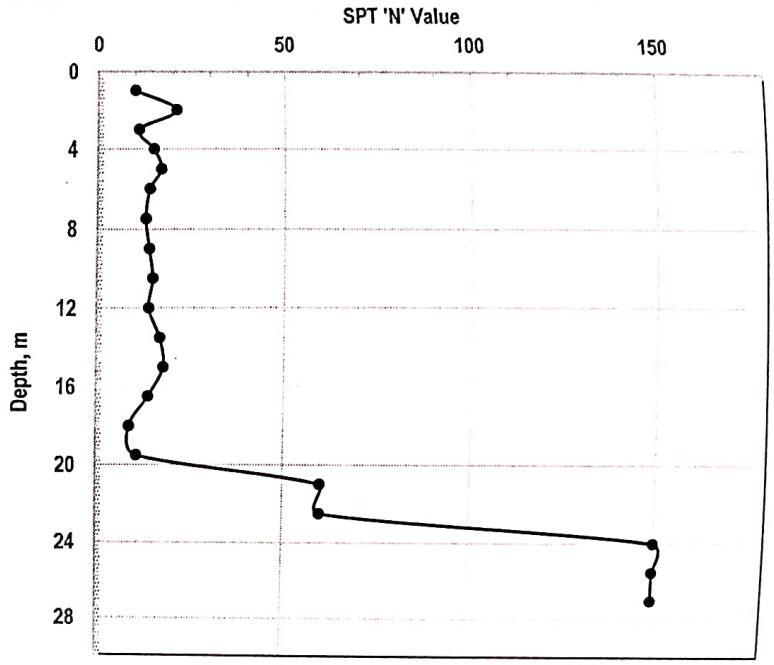
GEOTECHNICAL DESIGN PARAMETERS OF DIFFERENT LAYERS BELOW GROUND LEVEL

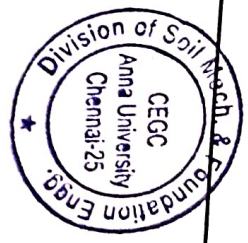
PROJECT: Proposed Reconstruction of Slum Tenements (S+4 Floors) at Appasamy Street Tenemental Scheme in Corporation Division 110, Zone IX of Greater Chennai Corporation.

BH No: 2 | **GWT (m): 2.1**

Depth below GL (m)	In-situ SPT 'N' Value	Description / Classification of Soil and Rock / Weathering Grade of Rock as per IS 4464	Design 'N' Value	Bulk Density, kN/m^3	Modulus of Elasticity (E_s), kN/m^2	Design Shear Strength Parameters	
						Shear Strength (c_u), kN/m^2	Angle of Friction (Φ) in Degrees
1.00	2	Brown Silty Sand with Gravel (GM-SP)	10	12.3	26000	0	19
2.00	4	Blackish Grey Silty Sand (SM-SP)	21	14.1	54600	0	21
3.00	14	Brown Silty Sand (SM-SP)	11	18.0	28600	0	29
4.00	17	Brown Silty Sand (SM-SP)	15	18.7	39000	0	30
5.00	15	Brown Sand (SP)	17	18.2	44200	0	30
6.00	8	Greyish Silty Sand (SM-SP)	14	22.0	36400	0	25
7.50	7	Greyish Silty Sand (SM-SP)	13	15.7	33800	0	24
9.00	9	Brownish Grey Silty Sand (SM-SP)	14	16.5	36400	0	25
10.50	16	Brown Silty Sand (SM-SP)	15	18.5	39000	0	30
12.00	17	Greyish Brown Silty Sand (SM-SP)	14	18.7	36400	0	30
13.50	13	Greyish Brown Silty Sand (SM-SP)	17	17.7	44200	0	28
15.00	28	Greyish Brown Silty Sand (SM-SP)	18	20.6	46800	0	36
16.50	34	Greyish Brown Silty Sand (SM-SP)	14	22.0	36400	0	38
18.00	67	Greyish Brown Silty / Clayey Sand with Lime Particles (SC)	9	22.0	23400	90	40
19.50	62	Brownish Grey Silty / Clayey Sand with Lime Particles (SC)	11	22.0	28600	90	40
21.00	>100	Brown Silty Clay (CH)	60	22.0	100000	500	0
22.50	>100	Greyish Brown Silty / Clayey Sand (SC)	60	22.0	156000	90	40
24.00	>100	Greyish Brown Sand Stone Interbedded with Shale (Grade V)	150	26.1	197500	2000	0
25.50	>100	Greyish Brown Sand Stone Interbedded with Shale (Grade IV)	150	27.4	197500	2000	0
27.00	>100	Greyish Brown Sand Stone Interbedded with Shale (Grade III)	150	26.8	197500	2000	0

Variation of SPT 'N' Value with respect to Depth





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Appendix - B

SBC AND SETTLEMENT CALCULATIONS

APPENDIX - B - SBC and Settlement Calculations

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DETERMINATION OF BEARING CAPACITY USING IS 6403 – 1981 EQUATION

$$q_u = c\,N_c\,s_c\,d_c\,i_c + q_0\,N_q\,s_q\,d_q\,i_q + 0.5\,B\,\gamma_1\,N_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

Where,

q_u - Ultimate Bearing Capacity, kN/m²

B - Width of foundation, m

c - Undraind cohesion value below foundation, kN/m²

q_0 - Effective overburden pressure at foundation level (γ_0 D), kN/m²

γ_0 - Effective unit weight of soil above foundation level

γ_1 - Effective unit weight of soil below foundation level

N_c, N_q, N_γ - Bearing Capacity Factors

s_c, s_q, s_γ - Shape factors

d_c, d_q, d_γ - Depth factors

i_c, i_q, i_γ - Inclination factors

W' - Water table correction factor

Computation of Average Shear Strength Parameters 1 B below Foundation Level

$$c_{av} = (c_1H_1 + c_2H_2 + c_3H_3 + c_4H_4)/(H_1 + H_2 + H_3 + H_4)$$

$$\tan\varphi_{av} = (\tan\varphi_1H_1 + \tan\varphi_2H_2 + \tan\varphi_3H_3 + \tan\varphi_4H_4)/(H_1 + H_2 + H_3 + H_4)$$

Elastic / Immediate Settlement computation as per IS 8009 (Part I)

9.2.3.2 The immediate settlement beneath the centre or corner of a flexible loaded area is given by:

$$S_i = pB\,\frac{(1-\mu^2)}{E}\,I \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (11)$$

where

μ = Poisson's ratio = 0·5 for clay, and

I = Influence factor [depends on length (L) to breadth (B) ratio of the footing].

Values of E shall be determined from the stress strain curve obtained from triaxial consolidated undrained test. The consolidation pressure adopted in triaxial consolidation test should be equal to the effective pressure at the depth from which the sample has been taken. The values of I may be determined from Fig. 11 for clay layers with various H_t/B ratio and from Table 2 for clay layers of semi-infinite extent.

TABLE 2 VALUES OF I FOR CLAY LAYERS OF SEMI-INFINITE EXTENT

Shape	Influence Factor (I)		
	Centre	Corner	Average
(1)	(2)	(3)	(4)
Circle	1·00	0·64 (edge)	0·85
Square	1·12	0·56	0·95
Rectangle:			
L/B = 1·5	1·36	0·68	1·20
2	1·53	0·77	1·31
5	2·10	1·05	1·83
10	2·52	1·26	2·25
100	3·38	1·69	2·96

APPENDIX - B - SBC and Settlement Calculations

Div. of Soil Mech. & Foundation Engg. CEGC Anna University Chennai

Bowles, J. (1997). Foundation Analysis and Design. 5th Ed., The McGraw-Hill Companies, Inc., New York, 8825

TABLE 5-6

Equations for stress-strain modulus E_s by several test methods

E_s in kPa for SPT and units of q_c for CPT; divide kPa by 50 to obtain ksf. The N values should be estimated as N_{55} and not N_{70}. Refer also to Tables 2-7 and 2-8.

Soil	SPT	CPT
Sand (normally consolidated)	$E_s = 500(N + 15)$	$E_s = (2 \text{ to } 4)q_u$
	$= 7000\sqrt{N}$	$= 8000\sqrt{q_c}$
	$= 6000N$	— — —
	— — —	$E_s = 1.2(3D_r^2 + 2)q_c$
	‡$E_s = (15\,000 \text{ to } 22\,000) \cdot \ln N$	*$E_s = (1 + D_r^2)q_c$
Sand (saturated)	$E_s = 250(N + 15)$	$E_s = Fq_c$
		$e = 1.0 \quad F = 3.5$
		$e = 0.6 \quad F = 7.0$
Sands, all (norm. consol.)	¶$E_s = (2600 \text{ to } 2900)N$	
Sand (overconsolidated)	†$E_s = 40\,000 + 1050N$	$E_s = (6 \text{ to } 30)q_c$
	$E_{s(OCR)} \approx E_{s,nc}\sqrt{OCR}$	
Gravelly sand	$E_s = 1200(N + 6)$	
	$= 600(N + 6) \quad N \le 15$	
	$= 600(N + 6) + 2000 \quad N > 15$	
Clayey sand	$E_s = 320(N + 15)$	$E_s = (3 \text{ to } 6)q_c$
Silts, sandy silt, or clayey silt	$E_s = 300(N + 6)$	$E_s = (1 \text{ to } 2)q_c$
	If $q_c < 2500$ kPa use $\quad$ §$E'_s = 2.5q_c$	
	$2500 < q_c < 5000$ use $\quad E'_s = 4q_c + 5000$	
	where	
	E'_s = constrained modulus $= \dfrac{E_s(1-\mu)}{(1+\mu)(1-2\mu)} = \dfrac{1}{m_v}$	
Soft clay or clayey silt		$E_s = (3 \text{ to } 8)q_c$

*Vesić (1970).

†Author's equation from plot of D'Appolonia et al. (1970).

‡USSR (may not be standard blow count N).

¶Japanese Design Standards (lower value for structures).

§Senneset et al. (1988)

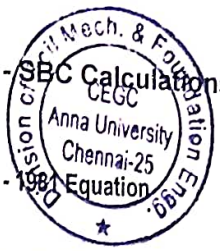
General sources: First European Conference on Standard Penetration Testing (1974), vol. 2.1, pp. 150–151; *CGJ*, November 1983, pp. 726–737; *Use of In Situ Tests in Geotechnical Engineering*, ASCE (1986), p. 1173; Mitchell and Gardner (1975); *Penetration Testing (Second European Conference)* (1982), vol. 1, p. 160; 11th ICSMFE (1985), vol. 2, pp. 462, 765; vol. 4, p. 2185; *International Symposium on Penetration Testing* (1988), 2 vols.

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SBC at 3.0 m Depth for 8.05 m x 50.85 m size in Different Borehole Locations **IS 6403 - 1981 Equation**

Borehole Location	=	BH 1	BH 2
Length of foundation (L), m	=	50.85	50.85
Width of foundation (B), m	=	8.05	8.05
Depth of foundation (D), m	=	3.00	3.00
Angle of Internal Friction (φ) in Degrees	=	25.50	26.90
Undraind cohesion value below foundation (c), kN/m^2	=	2.60	0.00
Ground Water Table Depth (GWT), m	=	0.00	0.00
Effective unit weight of soil above foundation level (γ_0), kN/m^3	=	6.50	3.20
Effective overburden pressure at foundation level (q_0), (γ_0 x D), kN/m^2	=	19.50	9.60
Effective unit weight of soil below foundation level (γ_1), kN/m^3	=	6.70	8.20
Bearing Capacity Factor (N_c)	=	21.47	23.77
Bearing Capacity Factor (N_q)	=	11.24	13.06
Bearing Capacity Factor (N_γ)	=	11.68	14.27
Shape factor (s_c)	=	1.03	1.03
Shape factor (s_q)	=	1.03	1.03
Shape factor (s_γ)	=	0.94	0.94
Depth factor (d_c)	=	1.12	1.12
Depth factor (d_q)	=	1.06	1.06
Depth factor (d_γ)	=	1.06	1.06
Inclination factor (i_c)	=	1.00	1.00
Inclination factor (i_q)	=	1.00	1.00
Inclination factor (i_γ)	=	1.00	1.00
Water table correction factor (W')	=	0.50	0.50
Net Ulitmate Bearing Capacity (q_{nu}), kN/m^2	=	487	532
Factor of Safety	=	3.00	3.00
Net Safe Bearing Capacity ($q_{n.safe}$), kN/m^2	=	162	177

APPENDIX - B 1 - SBC Calculations



SBC at 3.0 m Depth for 9.50 m x 54.82 m size in Different Borehole Locations — IS 6403 - 1981 Equation

Borehole Location	=	BH 1	BH 2
Length of foundation (L), m	=	54.82	54.82
Width of foundation (B), m	=	9.50	9.50
Depth of foundation (D), m	=	3.00	3.00
Angle of Internal Friction (φ) in Degrees	=	25.90	27.20
Undraind cohesion value below foundation (c), kN/m^2	=	2.30	0.00
Ground Water Table Depth (GWT), m	=	0.00	0.00
Effective unit weight of soil above foundation level (γ_0), kN/m^3	=	6.50	3.20
Effective overburden pressure at foundation level (q_0), (γ_0 x D), kN/m^2	=	19.50	9.60
Effective unit weight of soil below foundation level (γ_1), kN/m^3	=	6.80	8.20
Bearing Capacity Factor (N_c)	=	22.10	24.30
Bearing Capacity Factor (N_q)	=	11.73	13.49
Bearing Capacity Factor (N_γ)	=	12.36	14.89
Shape factor (s_c)	=	1.03	1.03
Shape factor (s_q)	=	1.03	1.03
Shape factor (s_γ)	=	0.93	0.93
Depth factor (d_c)	=	1.10	1.10
Depth factor (d_q)	=	1.05	1.05
Depth factor (d_γ)	=	1.05	1.05
Inclination factor (i_c)	=	1.00	1.00
Inclination factor (i_q)	=	1.00	1.00
Inclination factor (i_γ)	=	1.00	1.00
Water table correction factor (W')	=	0.50	0.50
Net Ulitmate Bearing Capacity (q_{nu}), kN/m^2	=	561	631
Factor of Safety	=	3.00	3.00
Net Safe Bearing Capacity ($q_{n.safe}$), kN/m^2	=	187	210

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Settlement Analysis of Foundation for 8.05 m x 50.85 m Foundation at 3.0 m Depth in BH 1 Location

Length of foundation (L), m	=	50.85
Width of foundation (B), m	=	8.05
Depth of foundation (D), m	=	3.00
L/B Ratio	=	6.32
Average Influence Factor as per Table 2 of 8009 (Part-I)	=	1.941
Stress at the Level of Foundation, (q), kN/m^2	=	160.00
Depth correction factor as per Fig. 12 of 8009 (Part-I)	=	0.96
Rigidity factor as per Sec.9.5.2 of 8009 (Part-I)	=	0.80
$\sum q \times B \times ((1-\mu^2) / E_s) \times I_f$ at corner of footing in 'm'	=	0.01104972
Average Settlement of Foundation (mm)	=	65.89

Depth (m)	Soil / Rock Type	'μ' Value	'E_s' Value (kN/m^2)	Depth Below Footing 'z' (m)	H_t (m)	H_t/B	'I_f' (Fig. 11 IS 8009-Part I) at Corner	$q \times B \times ((1-\mu^2) / E_s) \times I_f$
2.00	Brown Silty Sand (SM-SP)	0.35000	23400	-	-	-	-	-
3.00	Brown Sand (SP)	0.35000	49400	0.50	1.00	0.11696	0.01800	0.00043740
4.00	Brown Sand (SP)	0.35000	39000	1.50	1.00	0.10471	0.01600	0.00055008
5.00	Brownish Grey Silty Sand (SM-SP)	0.35000	20800	2.50	1.00	0.09479	0.01400	0.00099698
6.00	Greyish Sand (SP)	0.35000	10400	3.75	1.50	0.12712	0.01900	0.00302670
7.50	Greyish Silty / Clayey Sand (SC-SM)	0.30000	23400	5.25	1.50	0.11278	0.01700	0.00140684
9.00	Greyish Silty Sand (SM-SP)	0.35000	23400	6.75	1.50	0.10135	0.01500	0.00133200
10.50	Greyish Silty Sand (SM-SP)	0.35000	39000	8.25	1.50	0.09202	0.01400	0.00082152
12.00	Greyish Silty Sand (SM-SP)	0.35000	36400	9.75	1.50	0.08427	0.01300	0.00089254
13.50	Yellowish Grey Silty Sand (SM-SP)	0.35000	57200	11.25	1.50	0.07772	0.01200	0.00056847
15.00	Yellowish Grey Silty Sand (SM-SP)	0.35000	62400	12.75	1.50	0.07212	0.01100	0.00051480
16.50	Brownish Grey Silty / Clayey Sand (SC-Cl)	0.30000	93600	14.25	1.50	0.06726	0.01000	0.00034689
18.00	Brownish Grey Silty / Clayey Sand (SC)	0.30000	156000	15.75	1.10	0.04622	0.00700	0.00015549
19.50	Greyish Brown Silty / Clayey Sand with Lime Particles (SC)	0.30000	156000	17.25	1.50	0.05929	0.00900	0.00021252
21.00	Greyish Brown Silty / Clayey Sand with Lime Particles (SC)	0.30000	130000	18.75	1.50	0.05597	0.00800	0.00024013
22.50	Greyish Brown Silty Sand (SM-SP)	0.35000	208000	20.25	1.50	0.05300	0.00800	0.00015282
24.00	Brown Silty Sand (SM-SP)	0.35000	208000	21.75	1.50	0.05034	0.00800	0.00016092
25.50	Brown Weathered Sand Stone / Shale (Grade VI)	0.35000	145000	23.25	1.50	0.04792	0.00700	0.00021215
27.00	Greyish Brown Sand Stone Interbedded with Shale (Grade IV)	0.35000	197500	24.75	1.50	0.04573	0.00700	0.00016322
28.50	Greyish Brown Sand Stone Interbedded with Shale (Grade II)	0.35000	197500	27.75	4.50	0.12570	0.01900	0.00048354
			Total (2B)=		16.10			0.01104972

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Settlement Analysis of Foundation for 8.05 m x 50.85 m Foundation at 3.0 m Depth in BH 2 Location

Length of foundation (L), m	=	50.85
Width of foundation (B), m	=	8.05
Depth of foundation (D), m	=	3.00
L/B Ratio	=	6.32
Average Influence Factor as per Table 2 of 8009 (Part-I)	=	1.941
Stress at the Level of Foundation, (q), kN/m^2	=	160.00
Depth correction factor as per Fig. 12 of 8009 (Part-I)	=	0.96
Rigidity factor as per Sec.9.5.2 of 8009 (Part-I)	=	0.80
$\sum q \times B \times ((1-\mu^2) / E_s) \times I_f$ at corner of footing in 'm'	=	0.00946789
Average Settlement of Foundation (mm)	=	**56.45**

Depth (m)	Soil / Rock Type	'μ' Value	'E_s' Value (kN/m^2)	Depth Below Footing 'z' (m)	H_t (m)	H_t/B	'I_f' (Fig. 11-IS 8009-Part I) at Corner	$q \times B \times ((1-\mu^2) / E_s) \times I_f$
1.00	Brown Silty Sand with Gravel (GM-SP)	0.35000	26000	-	-	-	-	-
2.00	Blackish Grey Silty Sand (SM-SP)	0.35000	54600	-	-	-	-	-
3.00	Brown Silty Sand (SM-SP)	0.35000	28600	0.50	1.00	0.11696	0.01800	0.00075551
4.00	Brown Silty Sand (SM-SP)	0.35000	39000	1.50	1.00	0.10471	0.01600	0.00055008
5.00	Brown Sand (SP)	0.35000	44200	2.50	1.00	0.09479	0.01400	0.00046916
6.00	Greyish Silty Sand (SM-SP)	0.35000	36400	3.75	1.50	0.12712	0.01900	0.00086477
7.50	Greyish Silty Sand (SM-SP)	0.35000	33800	5.25	1.50	0.11278	0.01700	0.00093918
9.00	Brownish Grey Silty Sand (SM-SP)	0.35000	36400	6.75	1.50	0.10135	0.01500	0.00085629
10.50	Brown Silty Sand (SM-SP)	0.35000	39000	8.25	1.50	0.09202	0.01400	0.00082152
12.00	Greyish Brown Silty Sand (SM-SP)	0.35000	36400	9.75	1.50	0.08427	0.01300	0.00089254
13.50	Greyish Brown Silty Sand (SM-SP)	0.35000	44200	11.25	1.50	0.07772	0.01200	0.00073567
15.00	Greyish Brown Silty Sand (SM-SP)	0.35000	46800	12.75	1.50	0.07212	0.01100	0.00068640
16.50	Greyish Brown Silty Sand (SM-SP)	0.35000	36400	14.25	1.50	0.06726	0.01000	0.00086014
18.00	Greyish Brown Silty / Clayey Sand with Lime Particles (SC)	0.30000	23400	15.75	1.10	0.04622	0.00700	0.00103662
19.50	Brownish Grey Silty / Clayey Sand with Lime Particles (SC)	0.30000	28600	17.25	1.50	0.05929	0.00900	0.00115920
21.00	Brown Silty Clay (CH)	0.30000	100000	18.75	1.50	0.05597	0.00800	0.00031217
22.50	Greyish Brown Silty / Clayey Sand (SC)	0.30000	156000	20.25	1.50	0.05300	0.00800	0.00021131
24.00	Greyish Brown Sand Stone Interbedded with Shale (Grade V)	0.35000	197500	21.75	1.50	0.05034	0.00800	0.00016948
25.50	Greyish Brown Sand Stone Interbedded with Shale (Grade IV)	0.35000	197500	23.25	1.50	0.04792	0.00700	0.00015576
27.00	Greyish Brown Sand Stone Interbedded with Shale (Grade III)	0.35000	197500	27.00	6.00	0.17118	0.02600	0.00064783
			Total (2B)=		16.10			0.00946789

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Settlement Analysis of Foundation for 9.50 m x 54.82 m Foundation at 3.0 m Depth in BH 1 Location

Length of foundation (L), m	=	54.82
Width of foundation (B), m	=	9.50
Depth of foundation (D), m	=	3.00
L/B Ratio	=	5.77
Average Influence Factor as per Table 2 of 8009 (Part-I)	=	1.895
Stress at the Level of Foundation, (q), kN/m^2	=	160.00
Depth correction factor as per Fig. 12 of 8009 (Part-I)	=	0.96
Rigidity factor as per Sec.9.5.2 of 8009 (Part-I)	=	0.80
$\sum q \times B \times ((1-\mu^2) / E_s) \times I_f$ at corner of footing in 'm'	=	0.01142037
Average Settlement of Foundation (mm)	=	66.48

Depth (m)	Soil / Rock Type	'μ' Value	'E_s' Value (kN/m^2)	Depth Below Footing 'z' (m)	H_t (m)	H_t/B	'I_f' (Fig. 11 IS 8009-Part I) at Corner	$q \times B \times ((1-\mu^2) / E_s) \times I_f$
2.00	Brown Silty Sand (SM-SP)	0.35000	23400	-	-	-	-	-
3.00	Brown Sand (SP)	0.35000	49400	0.50	1.00	0.10000	0.01500	0.00042632
4.00	Brown Sand (SP)	0.35000	39000	1.50	1.00	0.09091	0.01400	0.00055440
5.00	Brownish Grey Silty Sand (SM-SP)	0.35000	20800	2.50	1.00	0.08333	0.01200	0.00097200
6.00	Greyish Sand (SP)	0.35000	10400	3.75	1.50	0.11321	0.01700	0.00304088
7.50	Greyish Silty / Clayey Sand (SC-SM)	0.30000	23400	5.25	1.50	0.10169	0.01500	0.00137667
9.00	Greyish Silty Sand (SM-SP)	0.35000	23400	6.75	1.50	0.09231	0.01400	0.00136500
10.50	Greyish Silty Sand (SM-SP)	0.35000	39000	8.25	1.50	0.08451	0.01300	0.00083070
12.00	Greyish Silty Sand (SM-SP)	0.35000	36400	9.75	1.50	0.07792	0.01200	0.00089100
13.50	Yellowish Grey Silty Sand (SM-SP)	0.35000	57200	11.25	1.50	0.07229	0.01100	0.00056025
15.00	Yellowish Grey Silty Sand (SM-SP)	0.35000	62400	12.75	1.50	0.06742	0.01000	0.00050063
16.50	Brownish Grey Silty / Clayey Sand (SC-Cl)	0.30000	93600	14.25	1.50	0.06316	0.00900	0.00033250
18.00	Brownish Grey Silty / Clayey Sand (SC)	0.30000	156000	15.75	1.50	0.05941	0.00900	0.00021210
19.50	Greyish Brown Silty / Clayey Sand with Lime Particles (SC)	0.30000	156000	17.25	1.50	0.05607	0.00800	0.00019973
21.00	Greyish Brown Silty / Clayey Sand with Lime Particles (SC)	0.30000	130000	18.75	1.00	0.03540	0.00500	0.00015820
22.50	Greyish Brown Silty Sand (SM-SP)	0.35000	208000	20.25	1.50	0.05042	0.00800	0.00016065
24.00	Brown Silty Sand (SM-SP)	0.35000	208000	21.75	1.50	0.04800	0.00700	0.00014766
25.50	Brown Weathered Sand Stone / Shale (Grade VI)	0.35000	145000	23.25	1.50	0.04580	0.00700	0.00022198
27.00	Greyish Brown Sand Stone Interbedded with Shale (Grade IV)	0.35000	197500	24.75	1.50	0.04380	0.00700	0.00017043
28.50	Greyish Brown Sand Stone Interbedded with Shale (Grade II)	0.35000	197500	27.75	4.50	0.12081	0.01800	0.00047665
				Total (2B)=	19.00			0.01142037

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Settlement Analysis of Foundation for 9.50 m x 54.82 m Foundation at 3.0 m Depth in BH 2 Location

Length of foundation (L), m	=	54.82
Width of foundation (B), m	=	9.50
Depth of foundation (D), m	=	3.00
L/B Ratio	=	5.77
Average Influence Factor as per Table 2 of 8009 (Part-I)	=	1.895
Stress at the Level of Foundation, (q), kN/m^2	=	160.00
Depth correction factor as per Fig. 12 of 8009 (Part-I)	=	0.96
Rigidity factor as per Sec.9.5.2 of 8009 (Part-I)	=	0.80
$\sum q \times B \times ((1-\mu^2) / E_s) \times I_f$ at corner of footing in 'm'	=	0.01106134
Average Settlement of Foundation (mm)	=	64.39

Depth (m)	Soil / Rock Type	'μ' Value	'E$_s$' Value (kN/m^2)	Depth Below Footing 'z' (m)	H$_t$ (m)	H$_t$/B	'I$_f$' (Fig. 11-IS 8009-Part I) at Corner	q x B x ((1-μ^2) / E$_s$) x I$_f$
1.00	Brown Silty Sand with Gravel (GM-SP)	0.35000	26000	-	-	-	-	-
2.00	Blackish Grey Silty Sand (SM-SP)	0.35000	54600	-	-	-	-	-
3.00	Brown Silty Sand (SM-SP)	0.35000	28600	0.50	1.00	0.10000	0.01500	0.00073636
4.00	Brown Silty Sand (SM-SP)	0.35000	39000	1.50	1.00	0.09091	0.01400	0.00055440
5.00	Brown Sand (SP)	0.35000	44200	2.50	1.00	0.08333	0.01200	0.00045741
6.00	Greyish Silty Sand (SM-SP)	0.35000	36400	3.75	1.50	0.11321	0.01700	0.00086882
7.50	Greyish Silty Sand (SM-SP)	0.35000	33800	5.25	1.50	0.10169	0.01500	0.00091904
9.00	Brownish Grey Silty Sand (SM-SP)	0.35000	36400	6.75	1.50	0.09231	0.01400	0.00087750
10.50	Brown Silty Sand (SM-SP)	0.35000	39000	8.25	1.50	0.08451	0.01300	0.00083070
12.00	Greyish Brown Silty Sand (SM-SP)	0.35000	36400	9.75	1.50	0.07792	0.01200	0.00089100
13.50	Greyish Brown Silty Sand (SM-SP)	0.35000	44200	11.25	1.50	0.07229	0.01100	0.00072503
15.00	Greyish Brown Silty Sand (SM-SP)	0.35000	46800	12.75	1.50	0.06742	0.01000	0.00066750
16.50	Greyish Brown Silty Sand (SM-SP)	0.35000	36400	14.25	1.50	0.06316	0.00900	0.00082446
18.00	Greyish Brown Silty / Clayey Sand with Lime Particles (SC)	0.30000	23400	15.75	1.50	0.05941	0.00900	0.00141400
19.50	Brownish Grey Silty / Clayey Sand with Lime Particles (SC)	0.30000	28600	17.25	1.50	0.05607	0.00800	0.00108945
21.00	Brown Silty Clay (CH)	0.30000	100000	18.75	1.00	0.03540	0.00500	0.00020566
22.50	Greyish Brown Silty / Clayey Sand (SC)	0.30000	156000	20.25	1.50	0.05042	0.00800	0.00022213
24.00	Greyish Brown Sand Stone Interbedded with Shale (Grade V)	0.35000	197500	21.75	1.50	0.04800	0.00700	0.00015551
25.50	Greyish Brown Sand Stone Interbedded with Shale (Grade IV)	0.35000	197500	23.25	1.50	0.04580	0.00700	0.00016297
27.00	Greyish Brown Sand Stone Interbedded with Shale (Grade III)	0.35000	197500	27.00	6.00	0.16438	0.02500	0.00064868
				Total (2B)=	19.00			0.01106134

LOAD-CARRYING CAPACITY OF PILES — STATIC ANALYSIS - IS 2911 : 2010

PILES IN GRANULAR SOILS

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

$$Q_u = A_p(\tfrac{1}{2} D\gamma N_\gamma + P_D N_q) + \sum_{i=1}^{n} K_i P_{Di} \tan\delta_i A_{si}$$

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_γ and N_q = 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 ith layer (*see* Note 3);

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

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

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

NOTES

1 N_γ factor can be taken for general shear failure according to IS 6403.

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 $\phi \leq 30°$ and increasing to 20 times for $\phi \geq 40°$.

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.



PILES IN COHESIVE SOILS

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 m²;

N_c – bearing capacity factor, may be taken as 9;

c_p = average cohesion at pile tip, in kN/m²;

$\sum_{i=1}^{n}$ = 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 ith layer depending on the consistency of soil, (*see* Note);

c_i = average cohesion for the ith layer, in kN/m²; and

A_{si} = surface area of pile shaft in the ith layer, in m².

B-3.3 Ultimate skin friction resistance can be approximated to local side friction (f_s), in kN/m², obtained from static cone resistance as given in Table 1.

Table 1 Side Friction for Different Types of Soil

Sl No.	Type of Soil	Local Side Friction, f_s kN/m²
(1)	(2)	(3)
i)	[illegible]	$q_c/30 < f_s < q_c/10$
ii)	[illegible]	$q_c/25 < f_s < 2q_c/25$
iii)	[illegible]	$q_c/100 < f_s < q_c/25$
iv)	[illegible]	$q_c/100 < f_s < q_c/50$
v)	[illegible]	$q_c/100 < f_s < q_c/150$

q_c = cone resistance, in kN/m²

0.6

USE OF STATIC CONE PENETRATION DATA

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/m², may be obtained as:

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

where

q_{c0} = average static cone resistance over a depth of 2D below the pile tip, in kN/m²;

q_{c1} = minimum static cone resistance over the same 2D below the pile tip, in kN/m²;

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/m²; 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 I

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

Sl No.	Type of Soil	q_c/N
(1)	(2)	(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

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

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

Where,

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

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

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

where

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

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

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.

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

Borehole Location BH 1

Length of Pile (L), m	=	27.00 m					From Existing Borehole Level
Angle of Internal Friction (φ) in Degrees	=	0.00					
Undraind cohesion value at PileTip (c_p), kN/m^2	=	2000.00 kN/m^2					
Submerged Unit Weight at PileTip (Υ_p), kN/m^2	=	14.60 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)	=	0.00					Taken from Figure 1 of IS 2911:2010 Part 1 Sec.2
Bearing Capacity Factor (N_γ)	=	0.00					
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_D), kN/m^2	=	57.18	68.20	80.35	93.55	142.15	
End Bearing Resisrtnce of Pile (q_p), kN/m^2 using 'c' and 'φ'	=	18000.00	18000.00	18000.00	18000.00	18000.00	
End Bearing Resisrtnce of Pile (q_p), kN/m^2 using 'N' values	=	60000.00	60000.00	60000.00	60000.00	60000.00	
Limiting End Bearing Resisrtnce of Pile (q_p), kN/m^2	=	10000.00	10000.00	10000.00	10000.00	10000.00	
Ultimate End Bearing Capacity of Pile ($Q_{p\text{-}ult}$), kN using 'c' and 'φ' values	=	1590.43	1963.50	2827.43	3848.45	6361.73	
Ultimate End Bearing Capacity of Pile ($Q_{p\text{-}ult}$), kN using 'N' values	=	1590.43	1963.50	2827.43	3848.45	6361.73	
Safe End Bearing Capacity of Pile ($Q_{p\text{-}safe}$), kN using 'c' and 'φ' values	=	636.17	785.40	1130.97	1539.38	2544.69	
Safe End Bearing Capacity of Pile ($Q_{p\text{-}safe}$), kN using 'N' values	=	636.17	785.40	1130.97	1539.38	2544.69	
Ultimate Frictional Capacity of Pile ($Q_{f\text{-}ult}$), kN using 'c' and 'φ' values	=	1564.74	1738.60	2086.32	2434.04	3129.48	
Ultimate Frictional Capacity of Pile ($Q_{f\text{-}ult}$), kN using 'N' values	=	1337.14	1485.71	1782.85	2080.00	2674.28	
Negetive Skin Fricton of Pile (Q_{nf}), kN using 'c' and 'φ' values	=	67.44	74.94	89.92	104.91	134.89	
Negetive Skin Friction of Pile (Q_{nf}), kN using 'N' values	=	141.37	157.08	188.50	219.91	282.74	
Safe Frictional Capacity of Pile ($Q_{f\text{-}safe}$), kN using 'c' and 'φ' values	=	558.45	620.50	744.60	868.70	1116.91	
Safe Frictional Capacity of Pile ($Q_{f\text{-}safe}$), kN using 'N' values	=	393.48	437.20	524.65	612.09	786.97	
Self Weight of Pile (W), kN	=	107.35	132.54	190.85	259.77	429.42	
Safe Pile Carrying Capacity of Pile (Q_{safe}), kN ('c' and 'φ')	=	1195	1406	1876	2408	3662	
Safe Pile Carrying Capacity of Pile (Q_{safe}), kN ('N' values)	=	1030	1223	1656	2151	3332	
Recommended Safe Pile Carrying Capacity of Pile (Q_{safe}), kN	=	**1112**	**1314**	**1766**	**2280**	**3497**	
Safe Uplift Capacity of Pile (Q_{up}), kN using 'c' and 'φ' values	=	**561**	**637**	**796**	**966**	**1338**	

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Appendix - C (Determination of Pile Carrying Capacity as Per IS 2911:2010)

Depth (m)	Soil Description	H_i (m)	'c' kN/m^2	'φ'	'Y' kN/m^3	'Y_{sub}' kN/m^3	P_{Di} (kN/m^2)	'α_i'	'K_i'	N' Value
2.00	Brown Silty Sand (SM-SP)	2.00	0	25	16.50	6.50	6.50	0.00	1.00	9
3.00	Brown Sand (SP)	1.00	0	32	19.10	9.10	17.55	0.00	1.00	19
4.00	Brown Sand (SP)	1.00	0	30	18.20	8.20	26.20	0.00	1.00	15
5.00	Brownish Grey Silty Sand (SM-SP)	1.00	0	25	16.10	6.10	33.35	0.00	1.00	8
6.00	Greyish Sand (SP)	1.50	0	21	14.10	4.10	39.48	0.00	1.00	4
7.50	Greyish Silty / Clayey Sand (SC-SM)	1.50	14	22	16.50	6.50	47.43	0.30	1.00	9
9.00	Greyish Silty Sand (SM-SP)	1.50	0	25	16.50	6.50	57.18	0.00	1.00	9
10.50	Greyish Silty Sand (SM-SP)	1.50	0	29	18.20	8.20	68.20	0.00	1.00	15
12.00	Greyish Silty Sand (SM-SP)	1.50	0	29	18.00	8.00	80.35	0.00	1.00	14
13.50	Yellowish Grey Silty Sand (SM-SP)	1.50	0	33	19.60	9.60	93.55	0.00	1.00	22
15.00	Yellowish Grey Silty Sand (SM-SP)	1.50	0	34	20.00	10.00	108.25	0.00	1.00	24
16.50	Brownish Grey Silty / Clayey Sand (SC-Cl)	1.50	108	30	21.60	11.60	124.45	0.30	1.00	36
18.00	Brownish Grey Silty / Clayey Sand (SC)	1.50	90	40	22.00	12.00	142.15	0.30	1.00	60
19.50	Greyish Brown Silty / Clayey Sand with Lime Particles (SC)	1.50	90	40	22.00	12.00	160.15	0.30	1.00	60
21.00	Greyish Brown Silty / Clayey Sand with Lime Particles (SC)	1.50	75	38	22.00	12.00	178.15	0.30	1.00	50
22.50	Greyish Brown Silty Sand (SM-SP)	1.50	0	42	22.00	12.00	196.15	0.00	1.00	80
24.00	Brown Silty Sand (SM-SP)	1.50	0	42	22.00	12.00	214.15	0.00	1.00	80
25.50	Brown Weathered Sand Stone / Shale (Grade VI)	1.50	1000	0	22.00	12.00	232.15	0.30	1.00	100
27.00	Greyish Brown Sand Stone Interbedded with Shale (Grade IV)	1.00	2000	0	24.60	14.60	248.45	0.30	1.00	150
28.50	Greyish Brown Sand Stone Interbedded with Shale (Grade II)	1.50	2000	0	24.70	14.70	266.78	0.30	1.00	150



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
2.00	Brown Silty Sand (SM-SP)	3.03	8.57	9.52	11.43	13.33	17.14	15.00	42.41	47.12	56.55	65.97	84.82
3.00	Brown Sand (SP)	10.97	15.50	17.23	20.67	24.12	31.01	31.67	44.77	49.74	59.69	69.64	89.54
4.00	Brown Sand (SP)	15.13	21.38	23.76	28.51	33.27	42.77	25.00	35.34	39.27	47.12	54.98	70.69
5.00	Brownish Grey Silty Sand (SM-SP)	15.55	21.99	24.43	29.31	34.20	43.97	13.33	18.85	20.94	25.13	29.32	37.70
6.00	Greyish Sand (SP)	15.15	32.13	35.70	42.84	49.98	64.27	6.67	14.14	15.71	18.85	21.99	28.27
7.50	Greyish Silty / Clayey Sand (SC-SM)	23.36	49.54	55.04	66.05	77.06	99.08	15.00	31.81	35.34	42.41	49.48	63.62
9.00	Greyish Silty Sand (SM-SP)	26.66	56.54	62.82	75.38	87.95	113.07	15.00	31.81	35.34	42.41	49.48	63.62
10.50	Greyish Silty Sand (SM-SP)	37.80	80.17	89.07	106.89	124.70	160.33	25.00	53.01	58.90	70.69	82.47	106.03
12.00	Greyish Silty Sand (SM-SP)	44.54	94.45	104.94	125.93	146.92	188.90	23.33	49.48	54.98	65.97	76.97	98.96
13.50	Yellowish Grey Silty Sand (SM-SP)	60.75	127.23	141.37	169.65	197.92	254.47	36.67	77.75	86.39	103.67	120.95	155.51
15.00	Yellowish Grey Silty Sand (SM-SP)	73.02	127.23	141.37	169.65	197.92	254.47	40.00	84.82	94.25	113.10	131.95	169.65
16.50	Brownish Grey Silty / Clayey Sand (SC-Cl)	104.25	127.23	141.37	169.65	197.92	254.47	60.00	127.23	141.37	169.65	197.92	254.47
18.00	Brownish Grey Silty / Clayey Sand (SC)	146.28	127.23	141.37	169.65	197.92	254.47	100.00	127.23	141.37	169.65	197.92	254.47
19.50	Greyish Brown Silty / Clayey Sand with Lime Particles (SC)	161.38	127.23	141.37	169.65	197.92	254.47	100.00	127.23	141.37	169.65	197.92	254.47
21.00	Greyish Brown Silty / Clayey Sand with Lime Particles (SC)	161.69	127.23	141.37	169.65	197.92	254.47	83.33	127.23	141.37	169.65	197.92	254.47
22.50	Greyish Brown Silty Sand (SM-SP)	176.61	127.23	141.37	169.65	197.92	254.47	133.33	127.23	141.37	169.65	197.92	254.47
24.00	Brown Silty Sand (SM-SP)	192.82	127.23	141.37	169.65	197.92	254.47	133.33	127.23	141.37	169.65	197.92	254.47
25.50	Brown Weathered Sand Stone / Shale (Grade VI)	300.00	127.23	141.37	169.65	197.92	254.47	166.67	127.23	141.37	169.65	197.92	254.47
27.00	Greyish Brown Sand Stone Interbedded with Shale (Grade IV)	600.00	84.82	94.25	113.10	131.95	169.65	250.00	84.82	94.25	113.10	131.95	169.65
28.50	Greyish Brown Sand Stone Interbedded with Shale (Grade II)	600.00	127.23	141.37	169.65	197.92	254.47	250.00	127.23	141.37	169.65	197.92	254.47

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DETERMINATION OF PILE CARRYING CAPACITY AS PER IS 2911 : 2010

Borehole Location **BH 2**

Length of Pile (L), m	=	25.00 m					From Existing Borehole Level
Angle of Internal Friction (φ) in Degrees	=	0.00					
Undraind cohesion value at PileTip (c_p), kN/m^2	=	2000.00 kN/m^2					
Submerged Unit Weight at PileTip (Υ_p), kN/m^2	=	17.40 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)	=	0.00					Taken from Figure 1 of IS 2911:2010 Part 1 Sec.2
Bearing Capacity Factor (N_γ)	=	0.00					
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_D), kN/m^2	=	77.83	90.73	103.03	116.75	169.70	
End Bearing Resisrtnce of Pile (q_p), kN/m^2 using 'c' and 'φ'	=	18000.00	18000.00	18000.00	18000.00	18000.00	
End Bearing Resisrtnce of Pile (q_p), kN/m^2 using 'N' values	=	60000.00	60000.00	60000.00	60000.00	60000.00	
Limiting End Bearing Resisrtnce of Pile (q_p), kN/m^2	=	10000.00	10000.00	10000.00	10000.00	10000.00	
Ultimate End Bearing Capacity of Pile ($Q_{p\text{-}ult}$), kN using 'c' and 'φ' values	=	1590.43	1963.50	2827.43	3848.45	6361.73	
Ultimate End Bearing Capacity of Pile ($Q_{p\text{-}ult}$), kN using 'N' values	=	1590.43	1963.50	2827.43	3848.45	6361.73	
Safe End Bearing Capacity of Pile ($Q_{p\text{-}safe}$), kN using 'c' and 'φ' values	=	636.17	785.40	1130.97	1539.38	2544.69	
Safe End Bearing Capacity of Pile ($Q_{p\text{-}safe}$), kN using 'N' values	=	636.17	785.40	1130.97	1539.38	2544.69	
Ultimate Frictional Capacity of Pile ($Q_{f\text{-}ult}$), kN using 'c' and 'φ' values	=	1463.07	1625.63	1950.76	2275.89	2926.14	
Ultimate Frictional Capacity of Pile ($Q_{f\text{-}ult}$), kN using 'N' values	=	990.78	1100.87	1321.04	1541.21	1981.56	
Negetive Skin Fricton of Pile (Q_{nf}), kN using 'c' and 'φ' values	=	16.18	17.97	21.57	25.16	32.35	
Negetive Skin Friction of Pile (Q_{nf}), kN using 'N' values	=	98.96	109.96	131.95	153.94	197.92	
Safe Frictional Capacity of Pile ($Q_{f\text{-}safe}$), kN using 'c' and 'φ' values	=	569.05	632.28	758.74	885.19	1138.10	
Safe Frictional Capacity of Pile ($Q_{f\text{-}safe}$), kN using 'N' values	=	297.35	330.39	396.47	462.55	594.70	
Self Weight of Pile (W), kN	=	99.40	122.72	176.71	240.53	397.61	
Safe Pile Carrying Capacity of Pile (Q_{safe}), kN ('c' and 'φ')	=	1205	1418	1890	2425	3683	
Safe Pile Carrying Capacity of Pile (Q_{safe}), kN ('N' values)	=	934	1116	1527	2002	3139	
Recommended Safe Pile Carrying Capacity of Pile (Q_{safe}), kN	=	**1069**	**1267**	**1709**	**2213**	**3411**	
Safe Uplift Capacity of Pile (Q_{up}), kN using 'c' and 'φ' values	=	**571**	**647**	**805**	**974**	**1341**	

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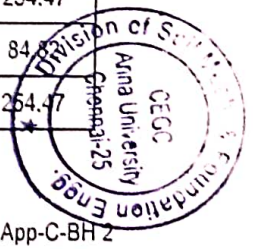
Appendix - C (Determination of Pile Carrying Capacity as Per IS 2911:2010)

Depth (m)	Soil Description	H_i (m)	'c' kN/m^2	'φ'	'Y' kN/m^3	'Y_{sub}' kN/m^3	P_{DI} (kN/m^2)	'α_i'	'K_i'	N' Value
1.00	Brown Silty Sand with Gravel (GM-SP)	1.00	0	19	12.30	2.30	1.15	0.00	1.00	10
2.00	Blackish Grey Silty Sand (SM-SP)	1.00	0	21	14.10	4.10	8.20	0.00	1.00	21
3.00	Brown Silty Sand (SM-SP)	1.00	0	29	18.00	8.00	14.25	0.00	1.00	11
4.00	Brown Silty Sand (SM-SP)	1.00	0	30	18.70	8.70	22.60	0.00	1.00	15
5.00	Brown Sand (SP)	1.00	0	30	18.20	8.20	31.05	0.00	1.00	17
6.00	Greyish Silty Sand (SM-SP)	1.50	0	25	22.00	12.00	44.15	0.00	1.00	14
7.50	Greyish Silty Sand (SM-SP)	1.50	0	24	15.70	5.70	57.43	0.00	1.00	13
9.00	Brownish Grey Silty Sand (SM-SP)	1.50	0	25	16.50	6.50	66.58	0.00	1.00	14
10.50	Brown Silty Sand (SM-SP)	1.50	0	30	18.50	8.50	77.83	0.00	1.00	15
12.00	Greyish Brown Silty Sand (SM-SP)	1.50	0	30	18.70	8.70	90.73	0.00	1.00	14
13.50	Greyish Brown Silty Sand (SM-SP)	1.50	0	28	17.70	7.70	103.03	0.00	1.00	17
15.00	Greyish Brown Silty Sand (SM-SP)	1.50	0	36	20.60	10.60	116.75	0.00	1.00	18
16.50	Greyish Brown Silty Sand (SM-SP)	1.50	0	38	22.00	12.00	133.70	0.00	1.00	14
18.00	Greyish Brown Silty / Clayey Sand with Lime Particles (SC)	1.50	90	40	22.00	12.00	151.70	0.00	1.00	9
19.50	Brownish Grey Silty / Clayey Sand with Lime Particles (SC)	1.50	90	40	22.00	12.00	169.70	0.30	1.00	11
21.00	Brown Silty Clay (CH)	1.50	500	0	22.00	12.00	187.70	0.30	1.00	60
22.50	Greyish Brown Silty / Clayey Sand (SC)	1.50	90	40	22.00	12.00	205.70	0.25	1.00	60
24.00	Greyish Brown Sand Stone Interbedded with Shale (Grade V)	1.50	2000	0	26.10	16.10	226.78	0.30	1.00	150
25.50	Greyish Brown Sand Stone Interbedded with Shale (Grade IV)	0.50	2000	0	27.40	17.40	243.20	0.30	1.00	150
27.00	Greyish Brown Sand Stone Interbedded with Shale (Grade III)	1.50	2000	0	26.80	16.80	260.15	0.30	1.00	150



Appendix - C (Determination of Pile Carrying Capacity as Per IS 2911:2010)

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
1.00	Brown Silty Sand with Gravel (GM-SP)	0.40	0.56	0.62	0.75	0.87	1.12	16.67	23.56	26.18	31.42	36.65	47.12
2.00	Blackish Grey Silty Sand (SM-SP)	3.15	4.45	4.94	5.93	6.92	8.90	35.00	49.48	54.98	65.97	76.97	98.96
3.00	Brown Silty Sand (SM-SP)	7.90	11.17	12.41	14.89	17.37	22.33	18.33	25.92	28.80	34.56	40.32	51.84
4.00	Brown Silty Sand (SM-SP)	13.05	18.45	20.50	24.60	28.69	36.89	25.00	35.34	39.27	47.12	54.98	70.69
5.00	Brown Sand (SP)	17.93	25.34	28.16	33.79	39.42	50.69	28.33	40.06	44.51	53.41	62.31	80.11
6.00	Greyish Silty Sand (SM-SP)	20.59	43.66	48.51	58.21	67.91	87.31	23.33	49.48	54.98	65.97	76.97	98.96
7.50	Greyish Silty Sand (SM-SP)	25.57	54.22	60.24	72.29	84.34	108.43	21.67	45.95	51.05	61.26	71.47	91.89
9.00	Brownish Grey Silty Sand (SM-SP)	31.04	65.83	73.15	87.78	102.41	131.66	23.33	49.48	54.98	65.97	76.97	98.96
10.50	Brown Silty Sand (SM-SP)	44.93	95.28	105.87	127.04	148.22	190.56	25.00	53.01	58.90	70.69	82.47	106.03
12.00	Greyish Brown Silty Sand (SM-SP)	52.38	111.08	123.42	148.10	172.78	222.15	23.33	49.48	54.98	65.97	76.97	98.96
13.50	Greyish Brown Silty Sand (SM-SP)	54.78	116.16	129.07	154.89	180.70	232.33	28.33	60.08	66.76	80.11	93.46	120.17
15.00	Greyish Brown Silty Sand (SM-SP)	84.82	127.23	141.37	169.65	197.92	254.47	30.00	63.62	70.69	84.82	98.96	127.23
16.50	Greyish Brown Silty Sand (SM-SP)	104.46	127.23	141.37	169.65	197.92	254.47	23.33	49.48	54.98	65.97	76.97	98.96
18.00	Greyish Brown Silty / Clayey Sand with Lime Particles (SC)	127.29	127.23	141.37	169.65	197.92	254.47	15.00	31.81	35.34	42.41	49.48	63.62
19.50	Brownish Grey Silty / Clayey Sand with Lime Particles (SC)	169.40	127.23	141.37	169.65	197.92	254.47	18.33	38.88	43.20	51.84	60.48	77.75
21.00	Brown Silty Clay (CH)	150.00	127.23	141.37	169.65	197.92	254.47	100.00	127.23	141.37	169.65	197.92	254.47
22.50	Greyish Brown Silty / Clayey Sand (SC)	195.10	127.23	141.37	169.65	197.92	254.47	100.00	127.23	141.37	169.65	197.92	254.47
24.00	Greyish Brown Sand Stone Interbedded with Shale (Grade V)	600.00	127.23	141.37	169.65	197.92	254.47	250.00	127.23	141.37	169.65	197.92	254.47
25.50	Greyish Brown Sand Stone Interbedded with Shale (Grade IV)	600.00	42.41	47.12	56.55	65.97	84.82	250.00	42.41	47.12	56.55	65.97	84.82
27.00	Greyish Brown Sand Stone Interbedded with Shale (Grade III)	600.00	127.23	141.37	169.65	197.92	254.47	250.00	127.23	141.37	169.65	197.92	254.47



DETERMINATION OF LATERAL PILE CARRYING CAPACITY AS PER IS 2911 : 2010

Length of Pile (L), m	=	**27.00**	**m**	**From Existing Borehole Level**			
Type of Fixity	=	**Fixed Head by Pile Cap**					
Cantilever Length above Ground Level (e), m	=	**0.00**	**m**	**Point of appilcation of Lateral Load (Assumed)**			
Allowable Deflection as per IS 2911 Part 4 : 1985, Page No. 10 in mm	=	**5.00**	**mm**				
Modulus of Subgrade Reaction of Soil (η_h)	=	800.00	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 Materia (E), kN/m^2	=	27386127.88	kN/m^2				
Diametr of Pile (D), mm	=	450	500	600	700	900	
Moment of Inertia of Pile Section (I), m^4	=	0.00201	0.00307	0.00636	0.01179	0.03221	
Stiffness Factor, (T)	=	2.33	2.54	2.93	3.32	4.06	
Criteria for Behaviour of Pile as per Table 5 of IS 2911 Part I Sec. 2	=	Long Pile	Long Pile	Long Pile	Long Pile	Long Pile	
(e/R)	=	0.00	0.00	0.00	0.00	0.00	
(Z_f/T) from Fig.4 of IS 2911 Part 1 Sec.2	=	1.90	1.90	1.90	1.90	1.90	
Depth of Fixity (Z_f), m	=	4.43	4.82	5.58	6.31	7.71	
Allowable Deflection as per IS 2911 Part 4 : 1985, Page No. 10 in mm	=	5.00	5.00	5.00	5.00	5.00	
Lateral Load Capacity of Pile (H), kN	=	**38.00**	**45.00**	**60.20**	**77.10**	**115.50**	



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Annexure – 1

Site Photographs



Plate 1 SPT test is in progress at the Proposed reconstruction of Slum Tenements (S+4 Floors) at Appasamy Street Tenemental Scheme in Corporation Division 110, Zone IX of Greater Chennai Corporation.

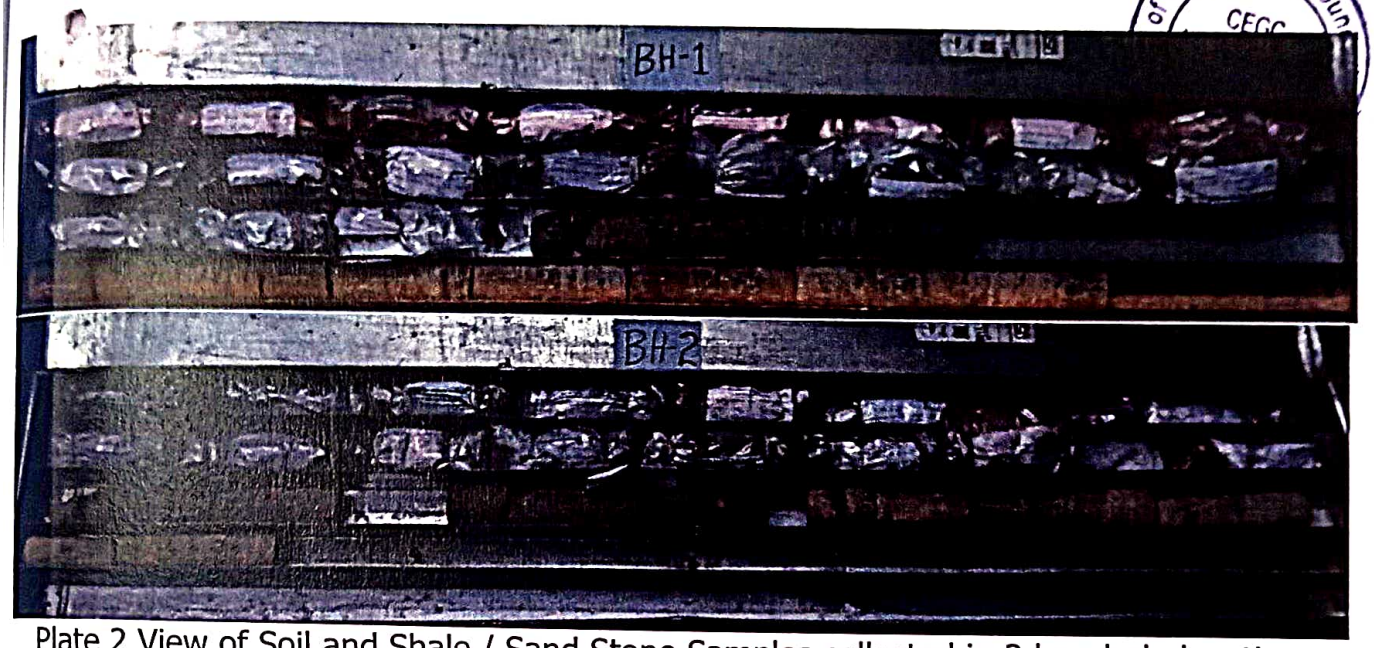


Plate 2 View of Soil and Shale / Sand Stone Samples collected in 2 borehole locations of the proposed site

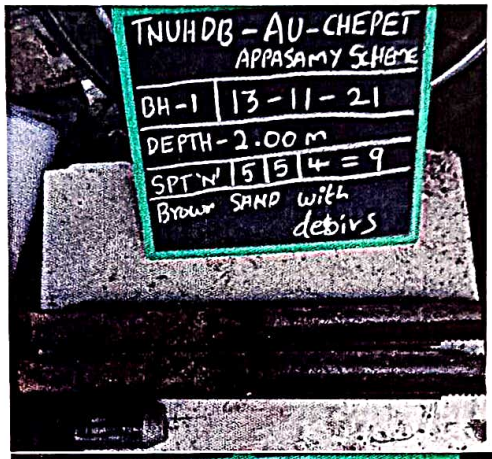
Annexure – 2

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View of Soil Samples collected in BH 1 and BH 2 Locations of the Proposed Reconstruction of Slum Tenements (S+4 Floors) at Appasamy Street Tenemental Scheme in Corporation Division 110, Zone IX of Greater Chennai Corporation.

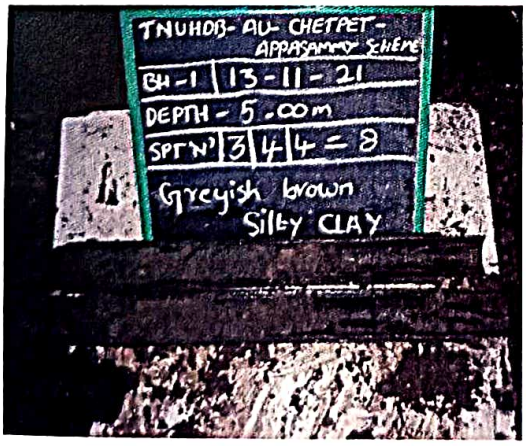
Plate – 1 Soil Sample Collected by conducting SPT in BH-01 Location

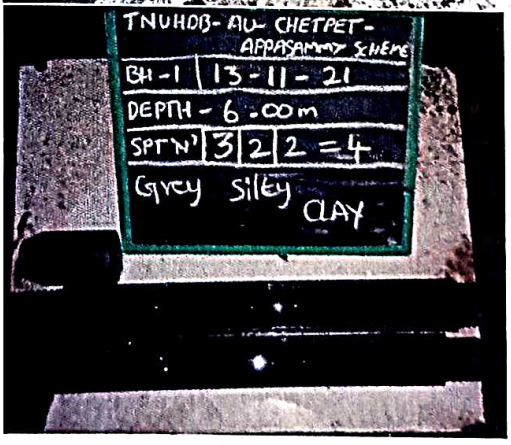




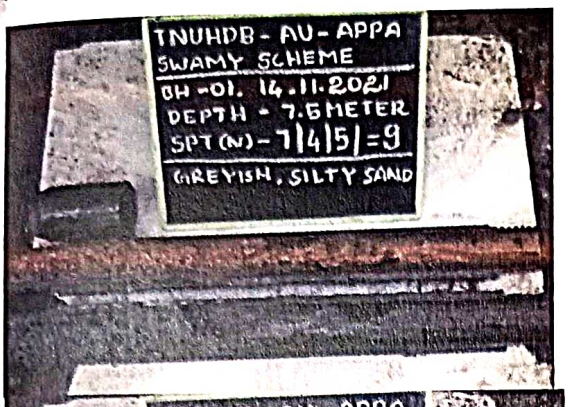


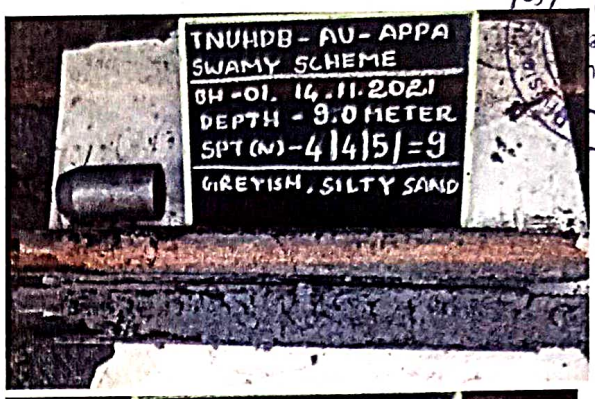


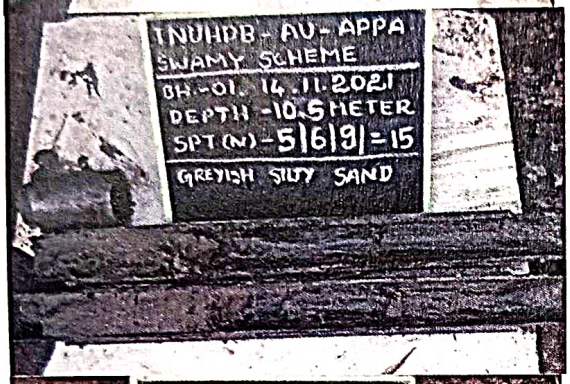


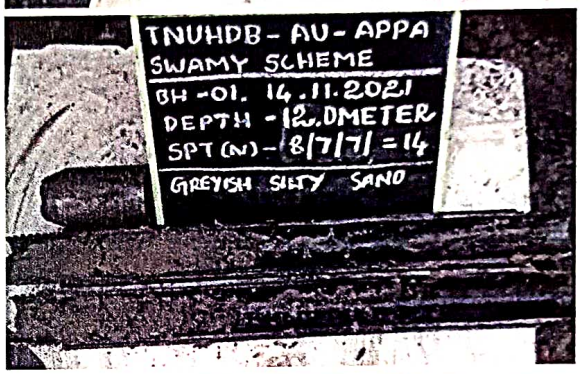


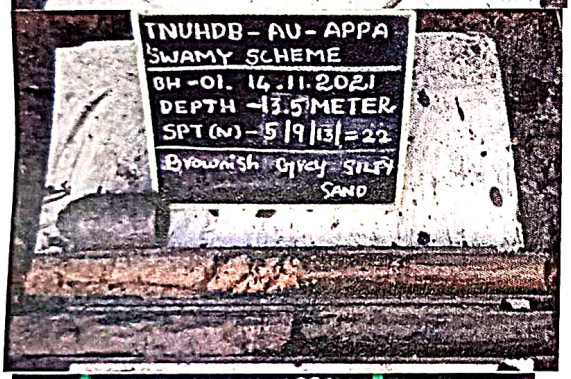
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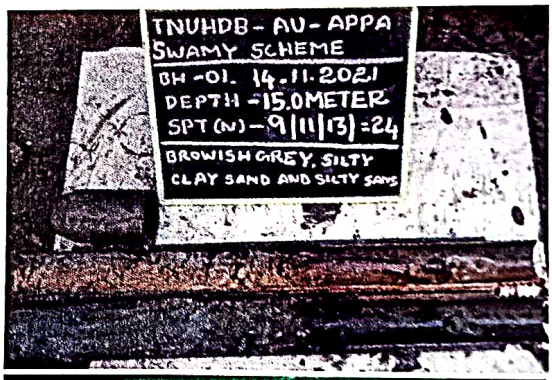




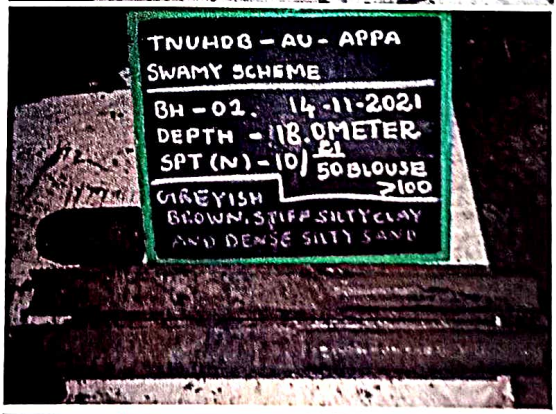


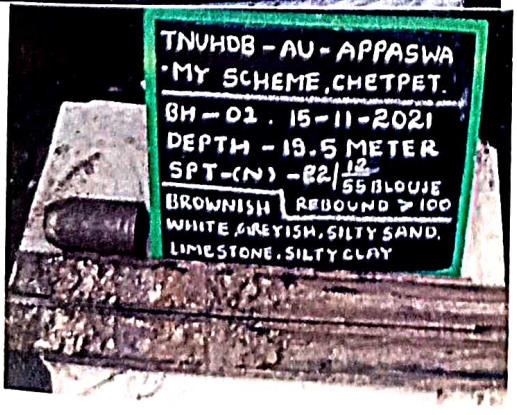












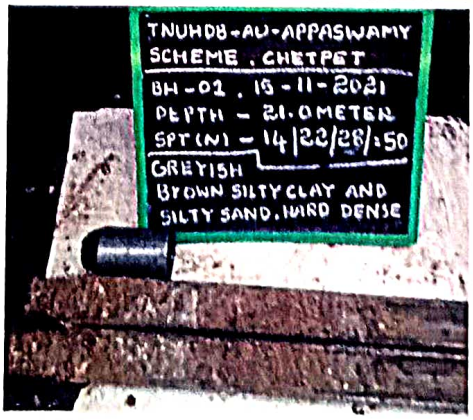
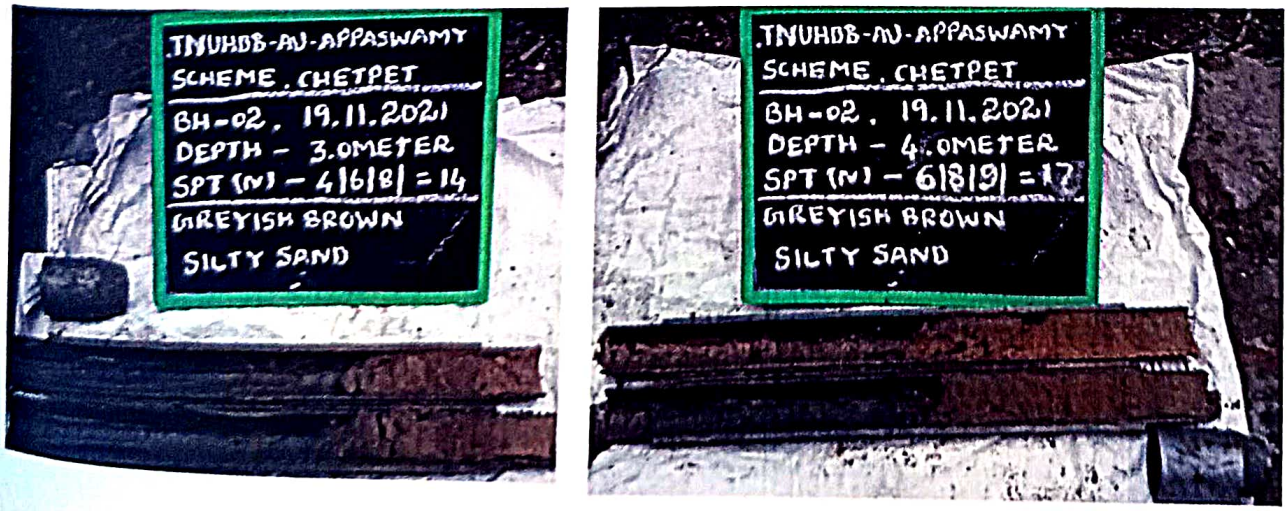
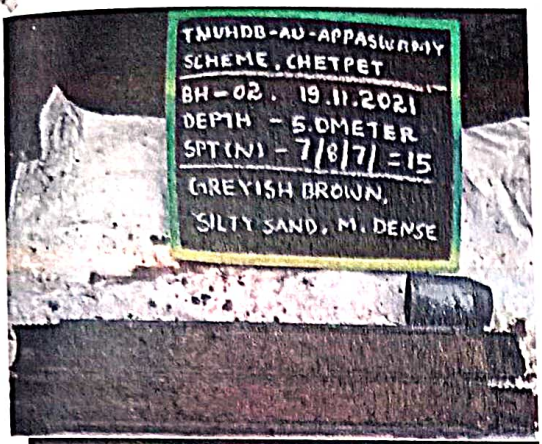




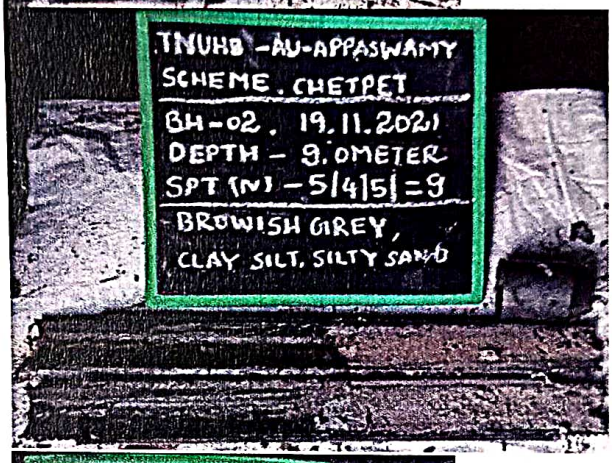
Plate – 2 Soil Sample Collected by conducting SPT in BH-02 Location



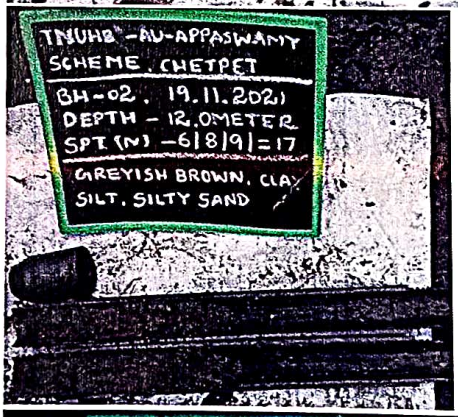


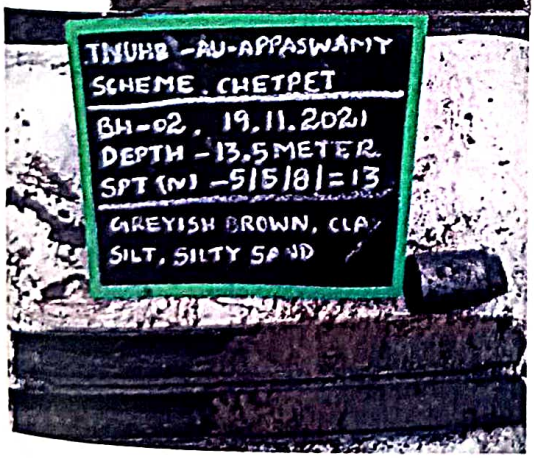








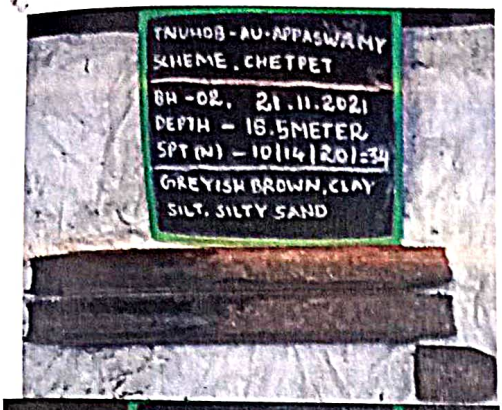


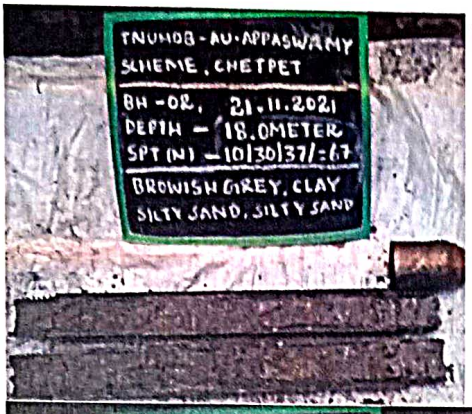


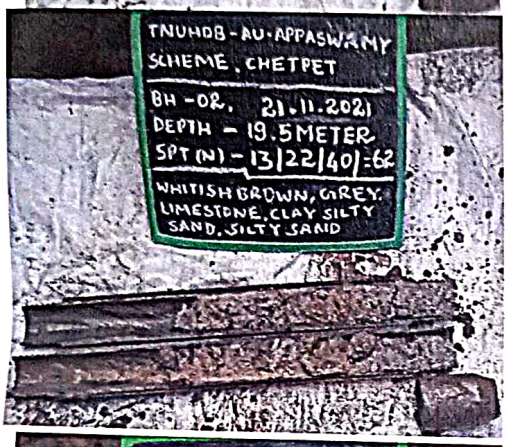


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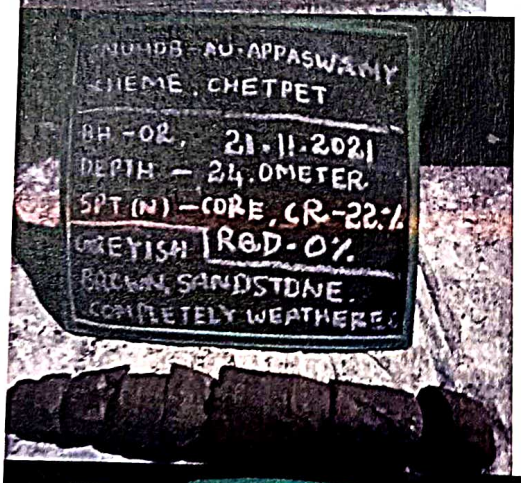


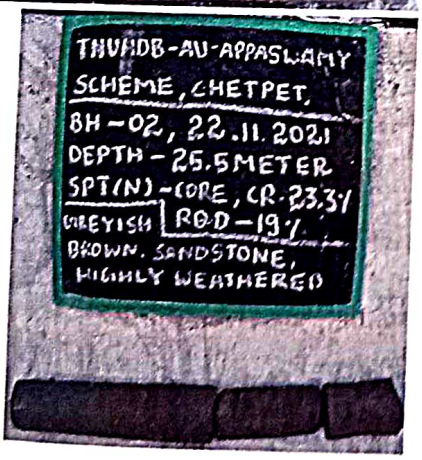


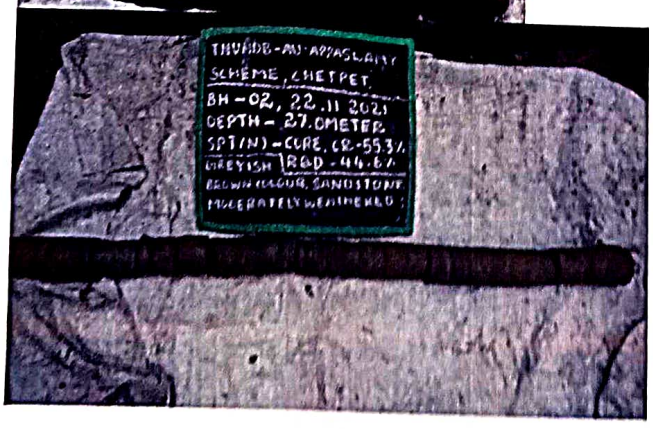


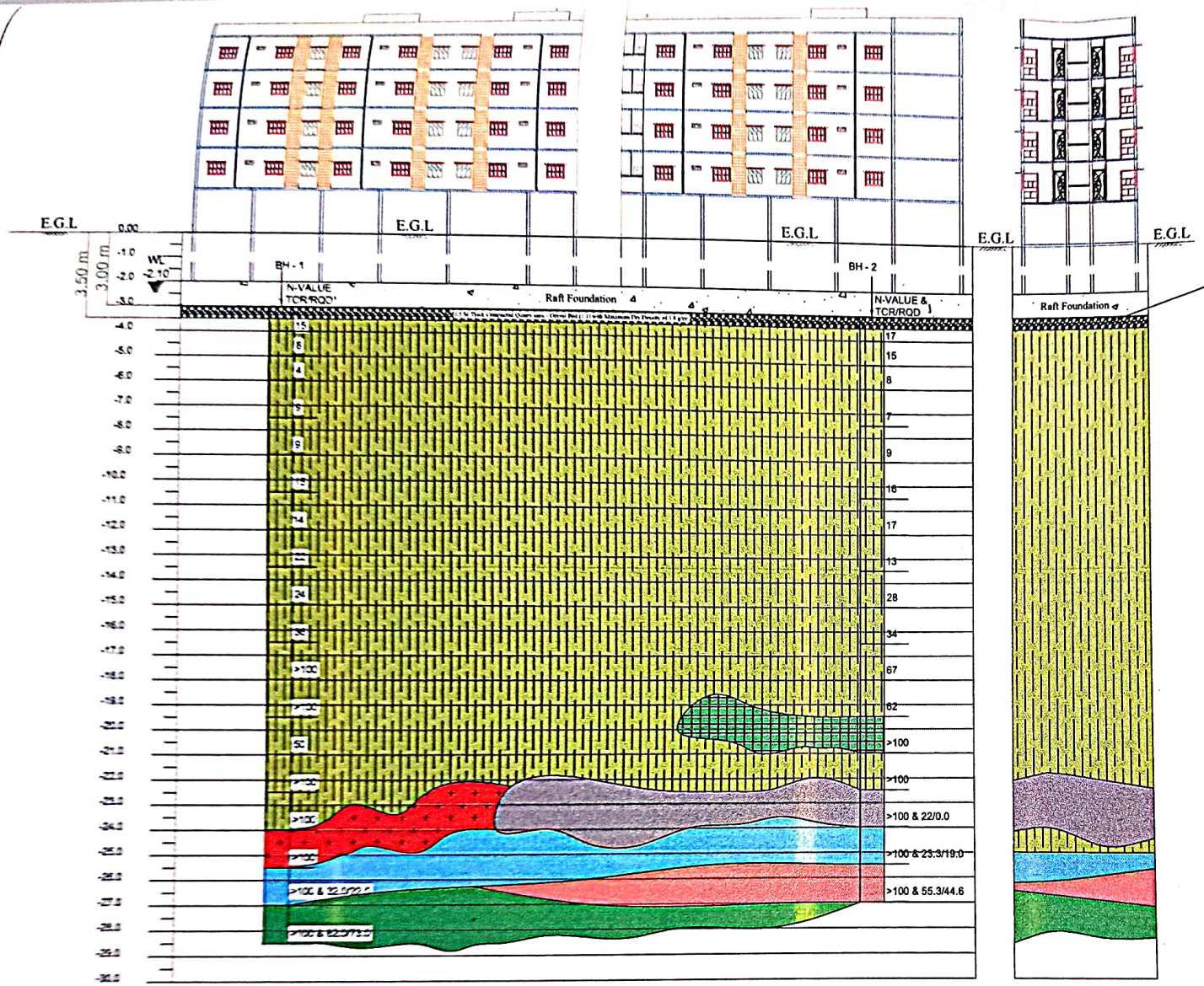












LEGEND:-

GL - GROUND LEVEL
WL - WATER LEVEL
TCR - TOTAL CORE RECOVERY
RQD - ROCK QUALITY DESIGNATION

CLAY (CI / CL / CH)
SAND (SC / SM / SP /SW)
SILT (MI / ML / MH)
GRAVEL
SILT STONE SAND STONE
GNIESS
CHARNOCKITE / GRANITE
Grade-VI
DIS-INTEGRATED & DE-COMPOSED ROCK
Grade-V/I
COMPLETELY WEATHERED ROCK
Grade-V
RQD = 0 to 10
HIGHLY WEATHERED ROCK
Grade-IV
RQD = 11 to 30
MODERATLY WEATHERED ROCK
Grade-III
RQD = 31 to 60
SLIGTLY WEATHERED ROCK
Grade-II
FRESH ROCK
Grade-I
RQD = 81 to 100
QUARRY SAND - GRAVEL BED (1:1)
RAFT FOUNDATION

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DIVISION OF SOIL MECHANICS AND FOUNDATION ENGINEERING
DEPARTMENT OF CIVIL ENGINEERING
COLLEGE OF ENGINEERING GUINDY CAMPUS
ANNA UNIVERSITY, CHENNAI 600 025

GEOTECHNICAL INVESTIGATION SUB-SOIL LS PROFILE FOR THE PROPOSED RECONSTRUCTION OF SLUM TENEMENTS (S+4 FLOORS) AT APPASAMY STREET TENEMENTAL SCHEME IN CORPORATION DIVISION 110,ZONE IX OF GREATER CHENNAI CORPORATION.

CLIENT : *GOVERNMENT OF TAMILNADU THE EXECUTIVE ENGINEER, TNUHDB, DIVISION-IV, CHENNAI-18.*

DATE :-

SCALE: 1:100

DRG. NO :-

SH. No. 1 OF 1

REVISION : 0



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