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DIVISION OF SOIL MECHANICS AND FOUNDATION ENGINEERING
DEPARTMENT OF CIVIL ENGINEERING
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SOIL INVESTIGATION REPORT

NAME OF WORK : **RECOMMENDATION OF FOUNDATION FOR THE RE-CONSTRUCTION OF MULTI STORIED TENEMENTS (G+3 FLOORS) AT POWERKUPPAM SCHEME IN GREATER CHENNAI CORPORATION, DIVISION 43, ZONE IV.**

CLIENT : **The Executive Engineer**
Division – II,
Tamil Nadu Urban Habitat Development Board,
Vyasarpadi,
Chennai – 600 039.

Reference : The Executive Engineer, TNUHDB, Chennai, Lr. No. 152/JE(P)/Dn-II/2022, Dated 27.03.2023

JOB No : SM&FE 215 / Consultancy / 2023

DATE : 18th April 2023

DIVISION OF SOIL MECHANICS AND FOUNDATION ENGINEERING
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RECOMMENDATION OF FOUNDATION FOR THE RE-CONSTRUCTION OF MULTI STORIED TENEMENTS (G+3 FLOORS) AT POWERKUPPAM SCHEME IN GREATER CHENNAI CORPORATION, DIVISION 43, ZONE IV.

Job. No. SM&FE 215 / Consultancy / 2023 Date:18.04.2023

CLIENT:

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Tamil Nadu Urban Habitat Development Board,
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Chennai – 600 039.

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1. INTRODUCTION

The Tamil Nadu Urban Habitat Development Board (TNUHDB), Division – II, Vyasarpadi, Chennai – 600 039 has proposed to reconstruct dilapidated slum Tenements (G+3 Floors) of Block 15 & 16 at Powerkuppam Scheme in Greater Chennai Corporation, Division 43, Zone IV. The officials of TNUHDB, Division – II, Vyasarpadi, Chennai – 600 039 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 dilapidated slum Tenements (G+3 Floors) at Powerkuppam Scheme in Greater Chennai Corporation, Division 43, Zone IV. Accordingly, the work was taken up and field investigation was carried out during 31st March 2023 to 7th April 2023 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 – II, Vyasarpadi, Chennai – 600 039. This

report comprises the details of soil investigation, analysis of field and laboratory test results on soil and recommendation of suitable foundation system.

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2. SITE CONDITION AND EXPERIMENTAL PROGRAMME

The proposed site is located at Powerkuppam in Greater Chennai Corporation, Division 43, Zone IV. 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 – II, Vyasarpadi, 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 Appendix – D).

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.

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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 2 & 3 of Appendix – D).

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

1. Debris was found in top 2.0 m depth in both BH 1 and BH 2 bore-hole location.
2. Greyish Sand / Silty Sand was observed from top 3.0 m to 19.5 m depth in BH 1 location and 3.0 m to 21.0 m depth in BH 2 location with SPT 'N' value varying from 8 to 57.
3. In between these layers, Sandy Clay with Intermediate plasticity was encountered in 18.0 m with SPT 'N' value 9.
4. Greyish Silty / Clayey Sand was found in 19.5 m to 36.0 m in BH 1 location and 21.0 m to 36.0 m in BH 2 location with SPT 'N' value varying from 19 to >100.
5. The ground water table was observed from 2.2 m to 3.2 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).

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 A-1 and table A-2. The 'E_s' values are computed based on Bowles 1997 correlation.

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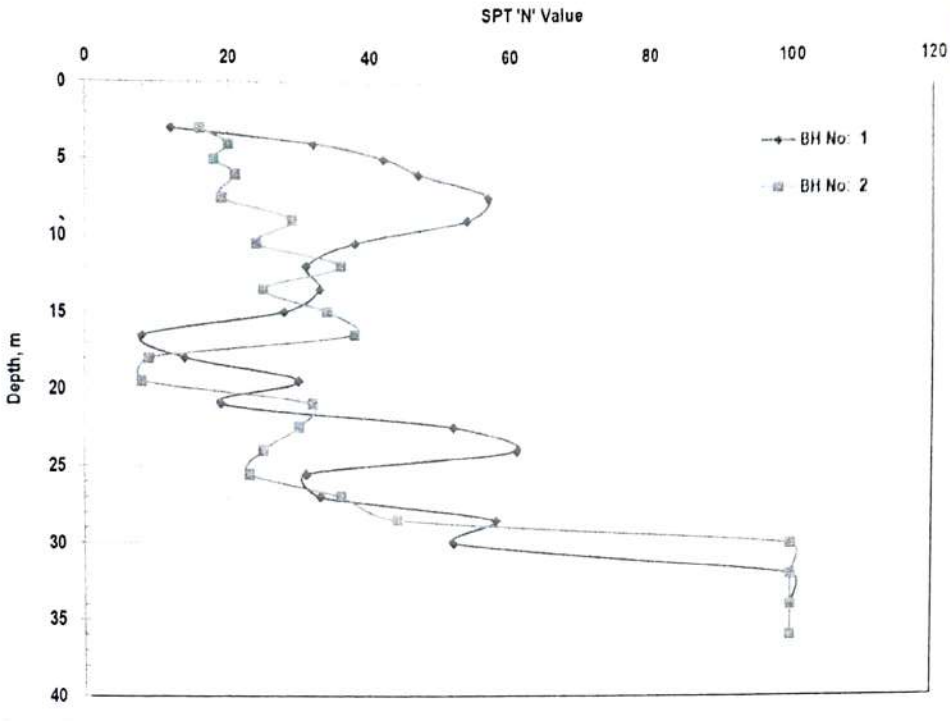


Figure (1) Variation of SPT 'N' value of different soil layers with respect to depth in Different Borehole Locations of the Site

5.0 COMPUTATION OF BEARING CAPACITY AND SETTLEMENT

Based on the observation made in the boreholes 1 & 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 8.5 m x 35.0 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 three 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 8.5 m x 35.0 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 382 kN/m^2 to 972 kN/m^2 for BH 1 and BH 2 locations at 3.0 m depth for 8.5 m x 35.0 m foundation size.

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	8.5 m x 35.0 m	0.0	36.7	972.0
BH 2		0.0	31.9	382.0

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 8.5 m x 35.0 m foundation upto the influence depth of "2B" below the foundation depth. The computed settlements are varying between 30.73 mm to 43.85 mm for 8.5 m x 35.0 m size foundation (Table 2). ***The allowable settlement as per IS 1904 Table I 1986 is limited to 50 mm for individual footing and 100 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)	Elastic Settlement (mm)
BH 1	8.5 m x 35.0 m	160	30.73
BH 2			43.85

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 34.0 m. Safe pile carrying capacity computations were made for all three-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 34.0 m, the design 'N' values and shear strength parameters for the respective depths were used. The soil layers in top 3 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 3. The calculations of pile carrying capacity by static formula (IS 2911: 2010) and Meyerhof formula (1959) are presented in Appendix - C. 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.

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TABLE 3 Safe Load carrying capacity of Bored Cast-In-Situ Pile of 34.0 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	1240	1456	1935	2478	3751	1353	1582	2087	2655	3979
BH 2	1225	1447	1925	2466	3736	1186	1396	1864	2394	3644

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 4.

TABLE 4 Safe Uplift Capacity of 34.0 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	593	675	850	1039	1455
BH 2	593	676	851	1040	1457

7. CONCLUSIONS AND RECOMMENDATIONS

Based on the discussions made in sections 3, 4, 5 and 6, the following recommendations are furnished for the reconstruction of Multi Storied Tenements (G+3 Floors) at Powerkuppam Scheme in Greater Chennai Corporation, Division 43, Zone IV.

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 100 mm.

4) The computed Settlement of sub-soil for are varying between 30.73 mm to 43.85 mm for 8.5 m x 35.0 m size foundation. The computed settlement value at 3.0 m depth is lower than the permissible settlement values of 100 mm for Raft Foundation as per Table I of IS 1904.

5) It is recommended to provide suitable supporting system to excavate soil up to 3.0 m depth to avoid collapse of soil mass.

6) Dewatering shall be adopted if water seepage encountered while excavating 3.0 m depth soil mass.

7) 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 3.0 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 34.0 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.

4) The bored cast in-situ pile shall be terminated at 34.0 m in Greyish Clayey Sand layer.

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 35.

TABLE 5 Safe Load carrying capacity and Lateral Load Capacity of Bored Cast-In-Situ Pile for varying diameter and for a length of 34.0 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	1000	55.00	4.02
500	1300	64.80	4.38
600	1800	87.20	5.06
700	2300	111.20	5.73
900	3500	166.60	7.00

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IN-SITU GEOTECHNICAL BORE LOG

BORE-HOLE No.	BH 01
SHEET No.	(1/3)

Project:	Geotechnical Investigation for the Re-construction of Multi Storied Tenements (G+3 Floors) at Powerkuppam Scheme in Greater Chennai Corporation, Division 43, Zone IV
Co-ordinates:	N - 1451170 ; E - 423637
Location	Powerkuppam
Elevation (RL):	-
Dia of Boring:	Px Size in Soil & Nx Size in Rock
Casing Depth:	-
Type of Boring:	Rotary - Auto Trip SPT
Started:	31-03-2023
Completed:	03-04-2023
Ground Water Level:	2.20 m
Type of Core Barrel:	Nx Size Core Barrel
Water Loss Depths :	-
Total Drill Depth:	36.0 m - Soil

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 50 100 150 200		
1.5	1.0		Top Soil	-	-	-	-			Very Loose
3.0	2.0 3.0		Greyish Sand (SP)	5	6	6	12			Medium Dense
4.0	4.0		Brownish Sand (SP)	9	15	17	32			Dense
5.0	5.0		Brownish Silty Sand (SP-SM)	5	18	24	42			Dense
6.0	6.0		Brownish Silty Sand (SM)	16	21	26	47			Dense
7.5	7.0		Brownish Grey Silty Sand (SP-SM)	21	27	30	57			Very Dense
9.0	8.0 9.0		Greyish Silty Sand (SP-SM)	15	24	30	54			Very Dense
10.5	10.0		Greyish Silty Sand (SM)	16	18	20	38			Dense
12.0	11.0 12.0		Greyish Silty Sand (SM)	12	14	17	31			Dense
13.5	13.0		Greyish Silty Sand (SM)	11	14	19	33			Dense
15.0	14.0 15.0		Greyish Silty Sand (SM)	10	13	15	28			Medium Dense
16.5	16.0		Greyish Silty Sand (SM)	3	4	4	8			Loose

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IN-SITU GEOTECHNICAL BORE LOG

BORE-HOLE No.	BH 01
SHEET No.	(2/3)

Project:	Geotechnical Investigation for the Re-construction of Multi Storied Tenements (G+3 Floors) at Powerkuppam Scheme in Greater Chennai Corporation, Division 43, Zone IV
Co-ordinates:	N - 1451170 ; E - 423637
Location	Powerkuppam
Elevation (RL):	-
Dia of Boring:	Px Size in Soil & Nx Size in Rock
Casing Depth:	-
Type of Boring:	Rotary - Auto Trip SPT
Started:	31-03-2023
Completed:	03-04-2023
Ground Water Level:	2.20 m
Type of Core Barrel:	Nx Size Core Barrel
Water Loss Depths :	-
Total Drill Depth:	36.0 m - Soil

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 50 100 150 200		
18.0	17.0 – 18.0		Greyish Silty Sand (SM)	5	6	8	14			Medium Dense
19.5	19.0		Greyish Silty Sand (SM)	11	13	17	30			Medium Dense
21.0	20.0 – 21.0		Greyish Silty / Clayey Sand (SC)	4	6	13	19			Medium Dense
22.5	22.0		Greyish Silty / Clayey Sand (SC)	16	21	31	52			Very Dense
24.00	23.0 – 24.0		Greyish Silty / Clayey Sand (SC)	19	26	35	61			Very Dense
25.5	25.0		Greyish Silty / Clayey Sand (SC)	11	13	18	31			Dense
27.0	26.0 – 27.0		Greyish Silty Sand (SM)	11	14	19	33			Dense
28.5	28.0		Greyish Silty Sand (SM)	11	21	37	58			Very Dense
30.0	29.0 – 30.0		Greyish Silty / Clayey Sand (SC)	21	20	32	52			Very Dense
32.0	31.0 – 32.0		Greyish Silty / Clayey Sand (SC)	28	57 (7 cm) Rebound		>100			Very Dense
34.00	33.0 –		Greyish Silty / Clayey Sand (SC)	22	53 (13 cm) Rebound		>100			Very Dense

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

IN-SITU GEOTECHNICAL BORE LOG

BORE-HOLE No.	BH 03
SHEET No.	(3/3)

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

Project:	Geotechnical Investigation for the Re-construction of Multi Storied Tenements (G+3 Floors) at Powerkuppam Scheme in Greater Chennai Corporation, Division 43, Zone IV		
Co-ordinates:	N - 1451170 ; E - 423637	Started:	31-03-2023
Location	Powerkuppam	Completed:	03-04-2023
Elevation (RL):	-	Ground Water Level:	2.20 m
Dia of Boring:	Px Size in Soil & Nx Size in Rock	Type of Core Barrel:	Nx Size Core Barrel
Casing Depth:	-	Water Loss Depths :	-
Type of Boring:	Rotary - Auto Trip SPT	Total Drill Depth:	36.0 m - Soil

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 50 100 150 200		
35.0										
36.00			Greyish Silty / Clayey Sand (SC)	29	65 (7 cm) Rebound		>100			Very Dense
36.0										

IN-SITU GEOTECHNICAL BORE LOG

BORE-HOLE No.	BH 02
SHEET No.	(1/3)

Project:	Geotechnical Investigation for the Re-construction of Multi Storied Tenements (G+3 Floors) at Powerkuppam Scheme in Greater Chennai Corporation, Division 43, Zone IV
Co-ordinates:	N - 1451072 ; E - 413626
Location	Powerkuppam
Elevation (RL):	-
Dia of Boring:	Px Size in Soil & Nx Size in Rock
Casing Depth:	-
Type of Boring:	Rotary - Auto Trip SPT
Started:	04-04-2023
Completed:	07-04-2023
Ground Water Level:	3.20 m
Type of Core Barrel:	Nx Size Core Barrel
Water Loss Depths :	-
Total Drill Depth:	36.0 m - Soil

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 50 100 150 200		
1.0	1.0		Top Soil	-	-	-	-			Very Loose
2.0	2.0		Top Soil	-	-	-	-			Very Loose
3.0	3.0		Greyish Silty Sand (SP-SM)	7	7	9	16			Medium Dense
4.0	4.0		Brownish Silty Sand (SP-SM)	5	11	9	20			Medium Dense
5.0	5.0		Brownish Silty Sand (SM)	8	12	6	18			Medium Dense
6.0	6.0		Brownish Silty Sand (SP-SM)	6	9	12	21			Medium Dense
7.5	7.0		Brownish Greyish Silty Sand (SP-SM)	9	8	11	19			Medium Dense
9.0	8.0 9.0		Greyish Silty Sand (SM)	11	16	13	29			Medium Dense
10.5	10.0		Greyish Sand (SP)	8	10	14	24			Medium Dense
12.0	11.0 12.0		Greyish Silty Sand (SM)	18	24	12	36			Dense
13.5	13.0		Greyish Silty Sand (SM)	7	11	14	25			Medium Dense
15.0	14.0 15.0		Greyish Silty Sand (SM)	12	20	14	34			Dense
16.5	16.0		Greyish Silty Sand (SP-SM)	14	17	21	38			Dense

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IN-SITU GEOTECHNICAL BORE LOG

BORE-HOLE No. BH 02
SHEET No. (2/3)

Project:	Geotechnical Investigation for the Re-construction of Multi Storied Tenements (G+3 Floors) at Powerkuppam Scheme in Greater Chennai Corporation, Division 43, Zone IV		
Co-ordinates:	N - 1451072 ; E - 413626	Started:	04-04-2023
Location	Powerkuppam	Completed:	07-04-2023
Elevation (RL):	-	Ground Water Level:	3.20 m
Dia of Boring:	Px Size in Soil & Nx Size in Rock	Type of Core Barrel:	Nx Size Core Barrel
Casing Depth:	-	Water Loss Depths :	-
Type of Boring:	Rotary - Auto Trip SPT	Total Drill Depth:	36.0 m - Soil

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 50 100 150 200		
18.0	17.0		Greyish Silty / Clayey Sand (Cl)	4	4	5	9			Loose
19.5	19.0		Greyish Silty Sand (SM)	3	5	3	8			Loose
21.0	20.0		Greyish Silty Sand (SP)	16	13	19	32			Dense
22.50	22.0		Greyish Silty / Clayey Sand (SC)	6	12	18	30			Dense
24.0	23.0		Greyish Silty / Clayey Sand (SC)	5	11	14	25			Medium Dense
25.5	25.0		Greyish Silty / Clayey Sand (SC)	11	14	9	23			Medium Dense
27.0	26.0		Greyish Silty Sand (SM)	12	19	17	36			Dense
28.5	28.0		Greyish Silty Sand (SM)	11	19	25	44			Dense
30.0	29.0		Greyish Silty / Clayey Sand (SC)	17	56 (4 cm) Rebound		>100			Very Dense
32.00	31.0		Greyish Silty / Clayey Sand (SC)	24	57 (2 cm) Rebound		>100			Very Dense
34.00	33.0		Greyish Silty / Clayey Sand (SC)	59 (7 cm) Rebound			>100			Very Dense

IN-SITU GEOTECHNICAL BORE LOG

BORE-HOLE No. BH 02
SHEET No. (3/3)

Project: Geotechnical Investigation for the Re-construction of Multi Storied Tenements (G+3 Floors) at Powerkuppam Scheme in Greater Chennai Corporation, Division 43, Zone IV

Co-ordinates:	N - 1451072 ; E - 413626	Started:	04-04-2023
Location	Powerkuppam	Completed:	07-04-2023
Elevation (RL):	-	Ground Water Level:	3.20 m
Dia of Boring:	Px Size in Soil & Nx Size in Rock	Type of Core Barrel:	Nx Size Core Barrel
Casing Depth:	-	Water Loss Depths :	-
Type of Boring:	Rotary - Auto Trip SPT	Total Drill Depth:	36.0 m - Soil

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 50 100 150 200		
36.00	35.0 36.0		Greyish Silty / Clayey Sand (SC)	65 (9 cm) Rebound			>100			Very Dense

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Annexure - A-2

Laboratory Test Results

PROJECT: Geotechnical Investigation for the Re-construction of Multi Storied Tenements (G+3 Floors) at Powerkuppam Scheme in Greater Chennai Corporation, Division 43, Zone IV.

BH No: 01 | Ground Water Table Depth (m): 2.20

LABORATORY TEST RESULTS

Depth (m)	SPT 'N' Value	Soil Description / Classification	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		Gravel	Coarse Sand	Medium Sand	Fine Sand	Fines: Silt & Clay	Cohesion (c), kN/m^2	Angle of Friction (Φ) in Degrees
3.00	12	Greyish Sand (SP)	11	15.70	NP	NP	NP	NP	2.63	0	6	44	45	5	0	27
4.00	32	Brownish Sand (SP)	14	19.00	NP	NP	NP	NP	2.64	0	5	38	53	4	0	33
5.00	42	Brownish Silty Sand (SP-SM)	13	20.00	NP	NP	NP	NP	2.64	0	2	45	43	10	0	38
6.00	47	Brownish Silty Sand (SM)	12	20.40	NP	NP	NP	NP	2.65	0	1	19	59	21	0	38
7.50	57	Brownish Grey Silty Sand (SP-SM)	14	21.20	NP	NP	NP	NP	2.65	0	2	33	59	6	0	40
9.00	54	Greyish Silty Sand (SP-SM)	17	21.00	NP	NP	NP	NP	2.64	0	0	25	65	10	0	40
10.50	38	Greyish Silty Sand (SM)	21	19.60	NP	NP	NP	NP	2.65	0	1	10	69	20	0	37
12.00	31	Greyish Silty Sand (SM)	18	18.80	NP	NP	NP	NP	2.65	0	2	17	68	13	0	33
13.50	33	Greyish Silty Sand (SM)	19	19.10	NP	NP	NP	NP	2.65	0	0	11	73	16	0	34
15.00	28	Greyish Silty Sand (SM)	13	18.50	NP	NP	NP	NP	2.64	0	8	26	51	15	0	31
16.50	8	Greyish Silty Sand (SM)	18	14.50	NP	NP	NP	NP	2.63	0	13	21	43	23	0	25
18.00	14	Greyish Silty Sand (SM)	20	16.20	NP	NP	NP	NP	2.64	0	5	11	63	21	0	29
19.50	30	Greyish Silty Sand (SM)	18	18.70	NP	NP	NP	NP	2.63	0	0	16	70	14	0	32
21.00	19	Greyish Silty / Clayey Sand (SC)	19	17.10	26	12	14	14	2.65	0	4	16	58	22	30	25
22.50	52	Greyish Silty / Clayey Sand (SC)	11	20.80	29	12	17	33	2.65	0	0	36	37	27	50	40
24.00	61	Greyish Silty / Clayey Sand (SC)	14	21.50	30	11	19	25	2.65	0	8	26	43	23	60	40
25.50	31	Greyish Silty / Clayey Sand (SC)	14	18.80	31	13	18	43	2.65	0	2	25	41	32	45	32
27.00	33	Greyish Silty Sand (SM)	14	19.10	NP	NP	NP	NP	2.65	0	0	38	48	14	0	35
28.50	58	Greyish Silty Sand (SM)	16	21.30	NP	NP	NP	NP	2.64	0	1	20	64	15	0	40



Table A-1

PROJECT: Geotechnical Investigation for the Re-construction of Multi Storied Tenements (G+3 Floors) at Powerkuppam Scheme in Greater Chennai Corporation, Division 43, Zone IV.

BH No: 01 | Ground Water Table Depth (m): 2.20

LABORATORY TEST RESULTS

Depth (m)	SPT 'N' Value	Soil Description / Classification	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		Gravel	Coarse Sand	Medium Sand	Fine Sand	Fines (Silt & Clay)	Cohesion (c), kN/m^2	Angle of Friction (Φ) in Degrees
30.00	52	Greyish Silty / Clayey Sand (SC)	16	20.80	39	12	27	25	2.65	0	15	8	40	37	50	40
32.00	>100	Greyish Silty / Clayey Sand (SC)	15	21.20	36	11	25	22	2.65	20	2	9	34	35	90	40
34.00	>100	Greyish Silty / Clayey Sand (SC)	19	21.60	34	10	24	24	2.65	0	1	8	59	32	90	40
36.00	>100	Greyish Silty / Clayey Sand (SC)	16	21.90	42	13	29	33	2.65	0	3	10	41	46	90	40

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PROJECT: Geotechnical Investigation for the Re-construction of Multi Storied Tenements (G+3 Floors) at Powerkuppam Scheme in Greater Chennai Corporation, Division 43, Zone IV.

BH No: 02 | Ground Water Table Depth (m): 3.20

LABORATORY TEST RESULTS

Depth (m)	SPT 'N' Value	Soil Description / Classification	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		Gravel	Coarse Sand	Medium Sand	Fine Sand	Fines: Silt & Clay	Cohesion (c), kN/m^2	Angle of Friction (Φ) in Degrees
3.00	16	Greyish Silty Sand (SP-SM)	11	16.60	NP	NP	NP	NP	2.64	0	3	13	75	9	0	30
4.00	20	Brownish Silty Sand (SP-SM)	15	17.30	NP	NP	NP	NP	2.63	0	0	39	54	7	0	32
5.00	18	Brownish Silty Sand (SM)	18	17.00	NP	NP	NP	NP	2.64	0	0	12	73	15	0	31
6.00	21	Brownish Silty Sand (SP-SM)	16	17.50	NP	NP	NP	NP	2.64	0	2	44	48	6	0	32
7.50	19	Brownish Greyish Silty Sand (SP-SM)	13	17.10	NP	NP	NP	NP	2.64	0	8	40	38	14	0	31
9.00	29	Greyish Silty Sand (SM)	17	18.60	NP	NP	NP	NP	2.65	0	2	22	52	24	0	34
10.50	24	Greyish Sand (SP)	11	17.90	NP	NP	NP	NP	2.65	0	4	63	29	4	0	33
12.00	36	Greyish Silty Sand (SM)	20	19.40	NP	NP	NP	NP	2.63	0	0	10	56	34	0	37
13.50	25	Greyish Silty Sand (SM)	19	18.10	NP	NP	NP	NP	2.64	0	5	27	43	25	0	34
15.00	34	Greyish Silty Sand (SM)	15	19.20	NP	NP	NP	NP	2.63	0	5	27	43	25	0	37
16.50	38	Greyish Silty Sand (SP-SM)	15	19.60	NP	NP	NP	NP	2.63	0	3	28	58	11	0	38
18.00	9	Greyish Sandy Clay (CI)	37	14.80	38	15	23	50	2.62	0	0	13	25	62	56	0
19.50	8	Greyish Silty Sand (SM)	27	14.50	NP	NP	NP	NP	2.63	0	7	16	39	38	0	25
21.00	32	Greyish Silty Sand (SP)	13	19.00	NP	NP	NP	NP	2.64	0	11	64	19	6	0	35
22.50	30	Greyish Silty / Clayey Sand (SC)	40	18.70	29	14	15	33	2.65	0	0	28	34	38	45	30
24.00	25	Greyish Silty / Clayey Sand (SC)	16	18.10	27	13	14	30	2.65	0	0	28	38	34	37	28
25.50	23	Greyish Silty / Clayey Sand (SC)	15	17.80	31	16	15	50	2.65	0	0	30	36	34	34	27
27.00	36	Greyish Silty Sand (SM)	13	19.40	NP	NP	NP	NP	2.64	0	0	37	43	20	0	37
28.50	44	Greyish Silty Sand (SM)	17	20.20	NP	NP	NP	NP	2.63	0	0	14	56	30	0	38

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PROJECT: Geotechnical Investigation for the Re-construction of Multi Storied Tenements (G+3 Floors) at Powerkuppam Scheme in Greater Chennai Corporation, Division 43, Zone IV.

BH No: 02

Ground Water Table Depth (m): 3.20

LABORATORY TEST RESULTS

Depth (m)	SPT 'N' Value	Soil Description / Classification	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		Gravel	Coarse Sand	Medium Sand	Fine Sand	Fines: Silt & Clay	Cohesion (c), kN/m^2	Angle of Friction (Φ) in Degrees
30.00	>100	Greyish Silty / Clayey Sand (SC)	17	20.70	44	16	28	44	2.65	0	11	16	25	48	90	40
32.00	>100	Greyish Silty / Clayey Sand (SC)	13	20.90	38	14	24	20	2.65	0	6	15	32	47	90	40
34.00	>100	Greyish Silty / Clayey Sand (SC)	20	21.30	46	15	31	33	2.65	0	4	19	29	48	90	40
36.00	>100	Greyish Silty / Clayey Sand (SC)	18	21.50	53	14	39	20	2.65	0	0	18	34	48	90	40

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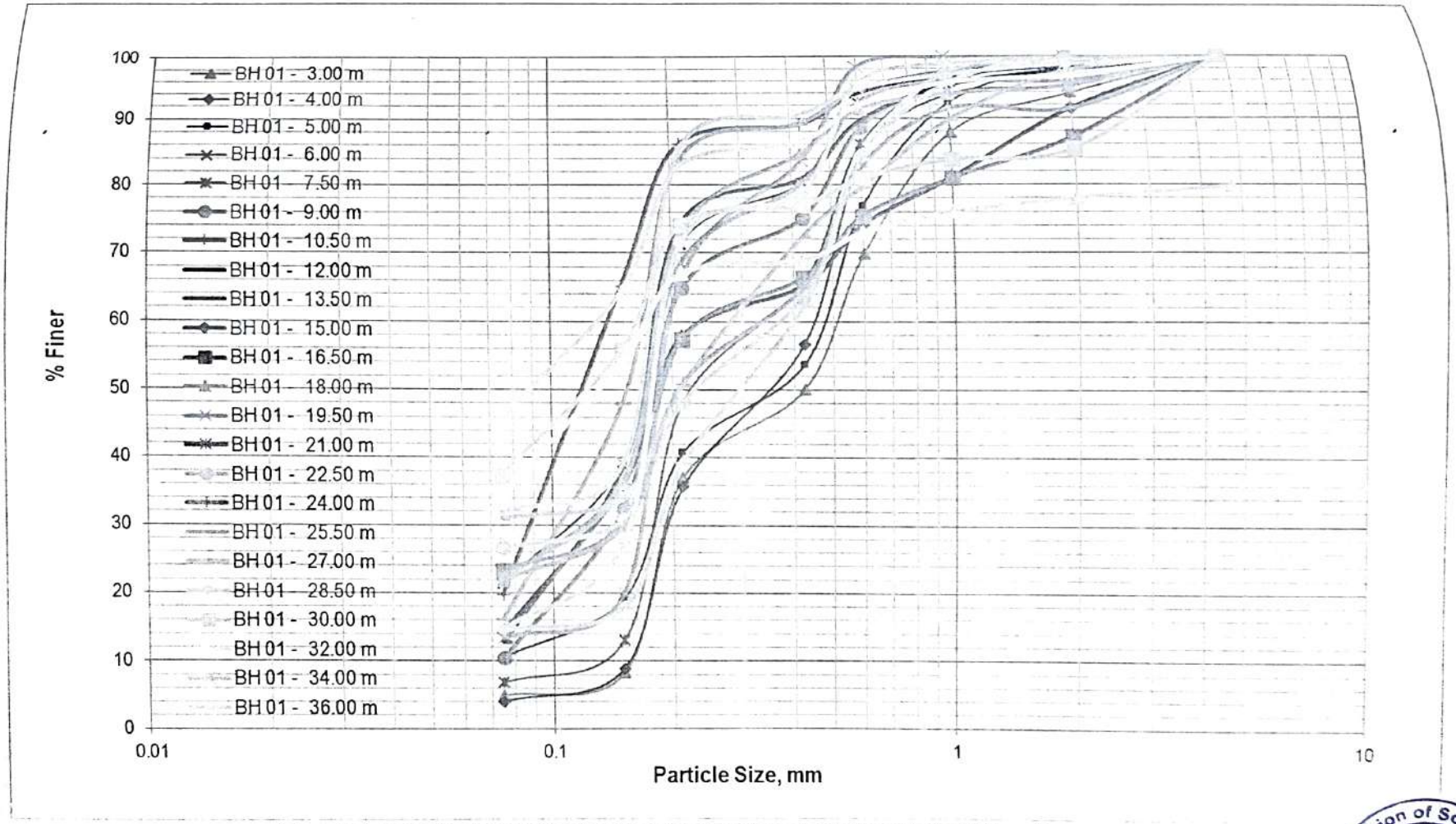


Figure B-1 Grain Size Distribution Curves of Soil Samples encountered in BH-01 Location

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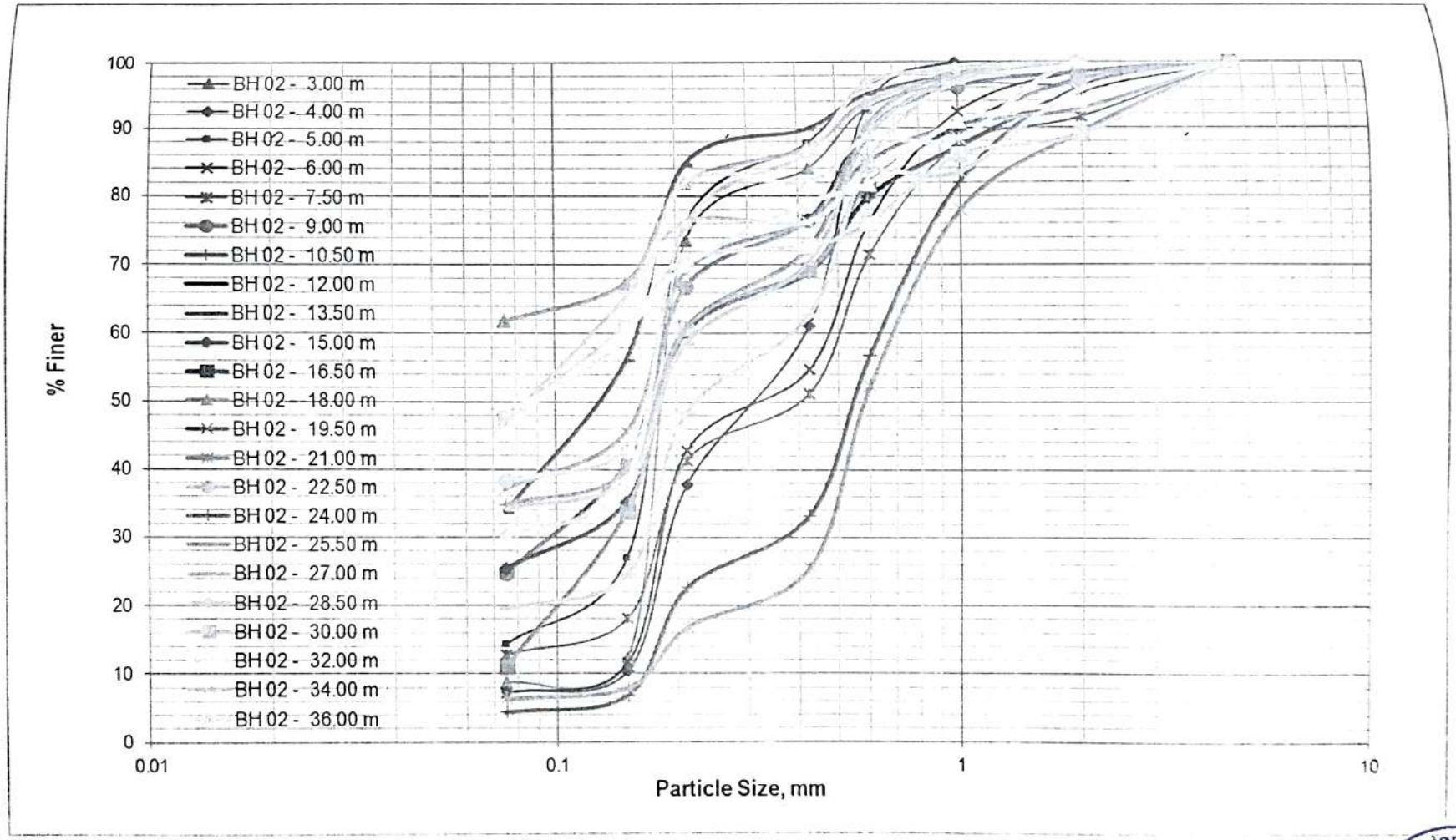


Figure B-2 Grain Size Distribution Curves of Soil Samples encountered in BH-02 Location

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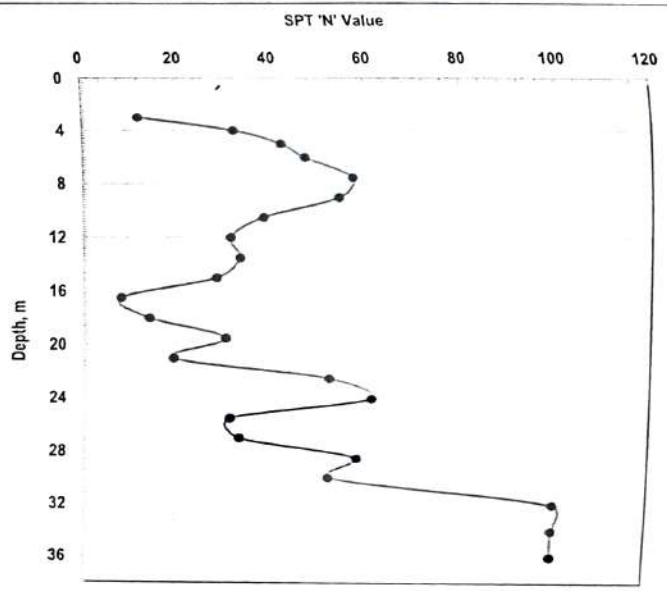
Appendix - A
GEOTECHNICAL DESIGN PARAMETERS

GEOTECHNICAL DESIGN PARAMETERS OF DIFFERENT LAYERS BELOW GROUND LEVEL

PROJECT: **Geotechnical Investigation for the Re-construction of Multi Storied Tenements (G+3 Floors) at Powerkuppam Scheme in Greater Chennai Corporation, Division 43, Zone IV.**

BH No:	1				GWT (m):	2.20	
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
3.00	12	Greyish Sand (SP)	12	15.7	31200	0	27.0
4.00	32	Brownish Sand (SP)	32	19.0	83200	0	33.0
5.00	42	Brownish Silty Sand (SP-SM)	42	20.0	109200	0	38.0
6.00	47	Brownish Silty Sand (SM)	47	20.4	122200	0	38.0
7.50	57	Brownish Grey Silty Sand (SP-SM)	57	21.2	148200	0	40.0
9.00	54	Greyish Silty Sand (SP-SM)	54	21.0	140400	0	40.0
10.50	38	Greyish Silty Sand (SM)	38	19.6	98800	0	37.0
12.00	31	Greyish Silty Sand (SM)	31	18.8	80600	0	33.0
13.50	33	Greyish Silty Sand (SM)	33	19.1	85800	0	34.0
15.00	28	Greyish Silty Sand (SM)	28	18.5	72800	0	31.0
16.50	8	Greyish Silty Sand (SM)	8	14.5	20800	0	25.0
18.00	14	Greyish Silty Sand (SM)	14	16.2	36400	0	29.0
19.50	30	Greyish Silty Sand (SM)	30	18.7	78000	0	32.0
21.00	19	Greyish Silty / Clayey Sand (SC)	19	17.1	49400	30	25.0
22.50	52	Greyish Silty / Clayey Sand (SC)	52	20.8	135200	50	40.0
24.00	61	Greyish Silty / Clayey Sand (SC)	61	21.5	158600	60	40.0
25.50	31	Greyish Silty / Clayey Sand (SC)	31	18.8	80600	45	32.0
27.00	33	Greyish Silty Sand (SM)	33	19.1	85800	0	35.0
28.50	58	Greyish Silty Sand (SM)	58	21.3	150800	0	40.0
30.00	52	Greyish Silty / Clayey Sand (SC)	52	20.8	135200	50	40.0
32.00	>100	Greyish Silty / Clayey Sand (SC)	100	21.2	260000	90	40.0
34.00	>100	Greyish Silty / Clayey Sand (SC)	100	21.6	260000	90	40.0
36.00	>100	Greyish Silty / Clayey Sand (SC)	100	21.9	260000	90	40.0

Variation of SPT 'N' Value with respect to Depth

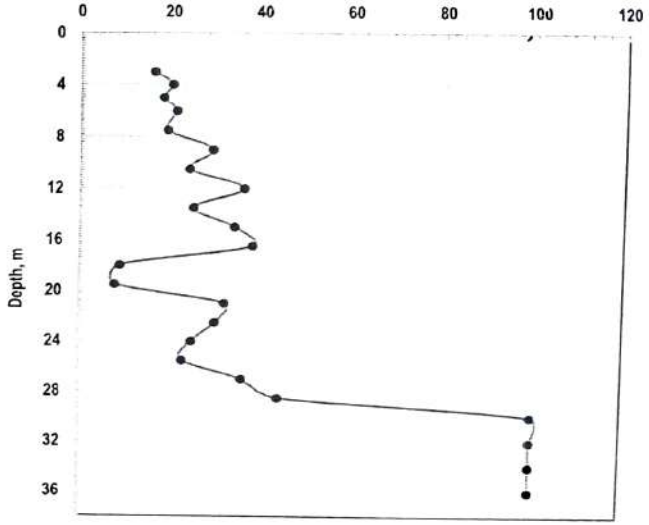


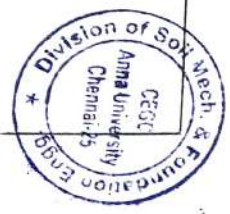
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GEOTECHNICAL DESIGN PARAMETERS OF DIFFERENT LAYERS BELOW GROUND LEVEL

PROJECT: Geotechnical Investigation for the Re-construction of Multi Storied Tenements (G+3 Floors) at Powerkuppam Scheme in Greater Chennai Corporation, Division 43, Zone IV.

BH No:	2				GWT (m):	3.20	Variation of SPT 'N' Value with respect to Depth
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	Design Shear Strength Parameters: Angle of Friction (Φ) in Degrees	
3.00	16	Greyish Silty Sand (SP-SM)	16	16.6	41600	0	30.0	
4.00	20	Brownish Silty Sand (SP-SM)	20	17.3	52000	0	32.0	
5.00	18	Brownish Silty Sand (SM)	18	17.0	46800	0	31.0	
6.00	21	Brownish Silty Sand (SP-SM)	21	17.5	54600	0	32.0	
7.50	19	Brownish Greyish Silty Sand (SP-SM)	19	17.1	49400	0	31.0	
9.00	29	Greyish Silty Sand (SM)	29	18.6	75400	0	34.0	
10.50	24	Greyish Sand (SP)	24	17.9	62400	0	33.0	
12.00	36	Greyish Silty Sand (SM)	36	19.4	93600	0	37.0	
13.50	25	Greyish Silty Sand (SM)	25	18.1	65000	0	34.0	
15.00	34	Greyish Silty Sand (SM)	34	19.2	88400	0	37.0	
16.50	38	Greyish Silty Sand (SP-SM)	38	19.6	98800	0	38.0	
18.00	9	Greyish Sandy Clay (CI)	9	14.8	11200	56	0.0	
19.50	8	Greyish Silty Sand (SM)	8	14.5	20800	0	25.0	
21.00	32	Greyish Silty Sand (SP)	32	19.0	83200	0	35.0	
22.50	30	Greyish Silty / Clayey Sand (SC)	30	18.7	78000	45	30.0	
24.00	25	Greyish Silty / Clayey Sand (SC)	25	18.1	65000	37	28.0	
25.50	23	Greyish Silty / Clayey Sand (SC)	23	17.8	59800	34	27.0	
27.00	36	Greyish Silty Sand (SM)	36	19.4	93600	0	37.0	
28.50	44	Greyish Silty Sand (SM)	44	20.2	114400	0	38.0	
30.00	>100	Greyish Silty / Clayey Sand (SC)	100	20.7	260000	90	40.0	
32.00	>100	Greyish Silty / Clayey Sand (SC)	100	20.9	260000	90	40.0	
34.00	>100	Greyish Silty / Clayey Sand (SC)	100	21.3	260000	90	40.0	
36.00	>100	Greyish Silty / Clayey Sand (SC)	100	21.5	260000	90	40.0	





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

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Bowles, J. (1997). Foundation Analysis and Design, 5th Ed., The McGraw-Hill Companies, Inc., New York, 30

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		$E_s = (3 \text{ to } 8)q_c$

SBC at 3.0 m Depth in Different Borehole Locations — **IS 6403 - 1981 Equation**

Bore hole Locations		**BH -01**	**BH -02**
Length of foundation (L), m	=	**35.00**	**35.00**
Width of foundation (B), m	=	**8.50**	**8.50**
Depth of foundation (D), m	=	**3.00**	**3.00**
Angle of Internal Friction (φ) in Degrees	=	36.70	31.90
Undrained cohesion value below foundation (c), kN/m^2	=	0.00	0.00
Ground Water Table Depth (GWT), m	=	0.00	0.00
Unit weight of soil above foundation level (γ_0), kN/m^3	=	15.70	16.60
Effective overburden pressure at foundation level (q_0), (γ_0 x D), kN/m^2	=	17.10	19.80
Effective unit weight of soil below foundation level (γ_1), kN/m^3	=	9.80	7.50
Bearing Capacity Factor (N_c)	=	54.05	35.20
Bearing Capacity Factor (N_q)	=	41.29	22.91
Bearing Capacity Factor (N_γ)	=	63.04	29.77
Shape factor (s_c)	=	1.05	1.05
Shape factor (s_q)	=	1.05	1.05
Shape factor (s_γ)	=	0.90	0.90
Depth factor (d_c)	=	1.14	1.13
Depth factor (d_q)	=	1.07	1.06
Depth factor (d_γ)	=	1.07	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 Ultimate Bearing Capacity (q_{nu}), kN/m^2	=	**2915**	1147
Factor of Safety	=	**3.00**	3.00
Net Safe Bearing Capacity ($q_{n.safe}$), kN/m^2	=	**972**	382

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Settlement Analysis of Foundation for 35.0 m x 8.5 m Foundation at 3.0 m Depth in BH 01 Location



Length of foundation (L), m	=	35.00
Width of foundation (B), m	=	8.50
Depth of foundation (D), m	=	3.00
L/B Ratio	=	4.12
Average Influence Factor as per Table 2 of 8009 (Part-I)	=	1.677
Stress at the Level of Foundation, (q), kN/m^2	=	160.00
Depth correction factor as per Fig. 12 of 8009 (Part-I)	=	0.98
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'	=	0.00584250
Average Settlement of Foundation (mm)	=	30.73

Depth (m)	Soil / Rock Type	'μ' Value	'E$_s$' Value (kN/m^2)	Depth Below Footing 'z' (m)	H_i (m)	H_i/B	'I$_f$' (Fig. 11-IS 8009-Part I) at Corner	$q \times B \times ((1-\mu^2) / E_s) \times I_f$
3.00	Greyish Sand (SP)	0.35000	31200	0.50	1.00	0.11111	0.01700	0.0006885
4.00	Brownish Sand (SP)	0.35000	83200	1.50	1.00	0.10000	0.01500	0.0002531
5.00	Brownish Silty Sand (SP-SM)	0.35000	109200	2.50	1.00	0.09091	0.01400	0.0001980
6.00	Brownish Silty Sand (SM)	0.35000	122200	3.75	1.50	0.12245	0.01800	0.0002533
7.50	Brownish Grey Silty Sand (SP-SM)	0.35000	148200	5.25	1.50	0.10909	0.01600	0.0002084
9.00	Greyish Silty Sand (SP-SM)	0.35000	140400	6.75	1.50	0.09836	0.01500	0.0002288
10.50	Greyish Silty Sand (SM)	0.35000	98800	8.25	1.50	0.08955	0.01300	0.0003094
12.00	Greyish Silty Sand (SM)	0.35000	80600	9.75	1.50	0.08219	0.01200	0.0003815
13.50	Greyish Silty Sand (SM)	0.35000	85800	11.25	1.50	0.07595	0.01100	0.0003555
15.00	Greyish Silty Sand (SM)	0.35000	72800	12.75	1.50	0.07059	0.01100	0.0004508
16.50	Greyish Silty Sand (SM)	0.35000	20800	14.25	1.50	0.06593	0.01000	0.0015356
18.00	Greyish Silty Sand (SM)	0.35000	36400	15.75	1.50	0.06186	0.00900	0.00084182
19.50	Greyish Silty Sand (SM)	0.35000	78000	17.00	0.50	0.01961	0.00300	0.0001377
21.00	Greyish Silty / Clayey Sand (SC)	0.35000	49400	18.75	1.50	0.05505	0.00800	0.0006196
22.50	Greyish Silty / Clayey Sand (SC)	0.35000	135200	20.25	1.50	0.05217	0.00800	0.0002388
24.00	Greyish Silty / Clayey Sand (SC)	0.35000	158600	21.75	1.50	0.04959	0.00700	0.0001875
25.50	Greyish Silty / Clayey Sand (SC)	0.35000	80600	23.25	1.50	0.04724	0.00700	0.0003871
27.00	Greyish Silty Sand (SM)	0.35000	85800	24.75	1.50	0.04511	0.00700	0.0003809
28.50	Greyish Silty Sand (SM)	0.35000	150800	26.25	1.50	0.04317	0.00600	0.0001941
30.00	Greyish Silty / Clayey Sand (SC)	0.35000	135200	28.00	2.00	0.05479	0.00800	0.0003032
32.00	Greyish Silty / Clayey Sand (SC)	0.35000	260000	30.00	2.00	0.05195	0.00800	0.0001663
34.00	Greyish Silty / Clayey Sand (SC)	0.35000	260000	32.00	2.00	0.04938	0.00700	0.0001531
36.00	Greyish Silty / Clayey Sand (SC)	0.35000	260000	34.00	2.00	0.04706	0.00700	0.0001607
				Total (2B)=	17.00			0.005843

Settlement Analysis of Foundation for 35.0 m x 8.5 m Foundation at 3.0 m Depth in BH 02 Location

Length of foundation (L), m	=	35.00
Width of foundation (B), m	=	8.50
Depth of foundation (D), m	=	3.00
L/B Ratio	=	4.12
Average Influence Factor as per Table 2 of 8009 (Part-I)	=	1.677
Stress at the Level of Foundation, (q), kN/m^2	=	160.00
Depth correction factor as per Fig. 12 of 8009 (Part-I)	=	0.98
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'	=	0.00833745
Average Settlement of Foundation (mm)	=	43.85

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Depth (m)	Soil / Rock Type	'μ' Value	'E$_s$' Value (kN/m^2)	Depth Below Footing 'z' (m)	H$_i$ (m)	H$_i$/B	'I$_f$' (Fig. 11.15 8009-Part I) at Corner	q x B x ((1-μ^2) / E$_s$) x I$_f$
3.00	Greyish Silty Sand (SP-SM)	0.35000	41600	0.50	1.00	0.11111	0.01700	0.00051638
4.00	Brownish Silty Sand (SP-SM)	0.35000	52000	1.50	1.00	0.10000	0.01500	0.00040500
5.00	Brownish Silty Sand (SM)	0.35000	46800	2.50	1.00	0.09091	0.01400	0.00046200
6.00	Brownish Silty Sand (SP-SM)	0.35000	54600	3.75	1.50	0.12245	0.01800	0.00056700
7.50	Brownish Greyish Silty Sand (SP-SM)	0.35000	49400	5.25	1.50	0.10909	0.01600	0.00062526
9.00	Greyish Silty Sand (SM)	0.35000	75400	6.75	1.50	0.09836	0.01500	0.00042595
10.50	Greyish Sand (SP)	0.35000	62400	8.25	1.50	0.08955	0.01300	0.00048994
12.00	Greyish Silty Sand (SM)	0.35000	93600	9.75	1.50	0.08219	0.01200	0.00032850
13.50	Greyish Silty Sand (SM)	0.35000	65000	11.25	1.50	0.07595	0.01100	0.00046926
15.00	Greyish Silty Sand (SM)	0.35000	88400	12.75	1.50	0.07059	0.01100	0.00037125
16.50	Greyish Silty Sand (SP-SM)	0.35000	98800	14.25	1.50	0.06593	0.01000	0.00032329
18.00	Greyish Sandy Clay (Cl)	0.30000	11200	15.75	1.50	0.06186	0.00900	0.00283725
19.50	Greyish Silty Sand (SM)	0.35000	20800	17.00	0.50	0.01961	0.00300	0.00051638
21.00	Greyish Silty Sand (SP)	0.35000	83200	18.75	1.50	0.05505	0.00800	0.00036788
22.50	Greyish Silty / Clayey Sand (SC)	0.35000	78000	20.25	1.50	0.05217	0.00800	0.00041400
24.00	Greyish Silty / Clayey Sand (SC)	0.35000	59800	21.75	1.50	0.04959	0.00700	0.00049715
25.50	Greyish Silty / Clayey Sand (SC)	0.35000	93600	23.25	1.50	0.04724	0.00700	0.00033338
27.00	Greyish Silty Sand (SM)	0.35000	114400	24.75	1.50	0.04511	0.00700	0.00028565
28.50	Greyish Silty Sand (SM)	0.35000	260000	26.25	1.50	0.04317	0.00600	0.00011259
30.00	Greyish Silty / Clayey Sand (SC)	0.35000	260000	28.00	2.00	0.05479	0.00800	0.00015768
32.00	Greyish Silty / Clayey Sand (SC)	0.35000	260000	30.00	2.00	0.05195	0.00800	0.00016632
34.00	Greyish Silty / Clayey Sand (SC)	0.35000	260000	32.00	2.00	0.04938	0.00700	0.00015309
36.00	Greyish Silty / Clayey Sand (SC)	0.35000	260000	34.00	2.00	0.04706	0.00700	0.00016065
				Total (2B)=	17.00			0.00833745

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)	q_c less than 1 000 kN/m²	$q_c/30 < f_s < q_c/10$
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/m².

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 1

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

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

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	=	34.00 m		From Existing Borehole Level			
Angle of Internal Friction (φ) in Degrees	=	40.00					
Undraind cohesion value at PileTip (c_p), kN/m^2	=	90.00 kN/m^2					
Submerged Unit Weight at PileTip (Υ_p), kN/m^2	=	11.60 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)	=	150.00		Taken from Figure 1 of IS 2911:2010 Part 1 Sec.2			
Bearing Capacity Factor (N_γ)	=	109.41					
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	=	71.55	87.00	100.80	114.23	145.20	
End Bearing Resisrtnce of Pile (q_p), kN/m^2 using 'c' and 'φ'	=	11828.06	14177.29	16310.75	18387.96	23161.12	
End Bearing Resisrtnce of Pile (q_p), kN/m^2 using 'N' values	=	40000.00	40000.00	40000.00	40000.00	40000.00	
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	=	2190.83	2434.25	2921.10	3407.95	4381.65	
Ultimate Frictional Capacity of Pile ($Q_{f\text{-}ult}$), kN using 'N' values	=	2199.51	2443.90	2932.68	3421.46	4399.02	
Negetive Skin Fricton of Pile (Q_{nf}), kN using 'c' and 'φ' values	=	272.95	303.27	363.93	424.58	545.89	
Negetive Skin Friction of Pile (Q_{nf}), kN using 'N' values	=	162.58	180.64	216.77	252.90	325.15	
Safe Frictional Capacity of Pile ($Q_{f\text{-}safe}$), kN using 'c' and 'φ' values	=	603.38	670.43	804.51	938.60	1206.77	
Safe Frictional Capacity of Pile ($Q_{f\text{-}safe}$), kN using 'N' values	=	717.23	796.92	956.30	1115.68	1434.45	
Self Weight of Pile (W), kN	=	135.19	166.90	240.33	327.12	540.75	
Safe Pile Carrying Capacity of Pile (Q_{safe}), kN ('c' and 'φ')	=	1240	1456	1935	2478	3751	
Safe Pile Carrying Capacity of Pile (Q_{safe}), kN ('N' values)	=	1353	1582	2087	2655	3979	
Recommended Safe Pile Carrying Capacity of Pile (Q_{safe}), kN	=	**1296**	**1519**	**2011**	**2567**	**3865**	
Safe Uplift Capacity of Pile (Q_{up}), kN using 'c' and 'φ' values	=	**593**	**675**	**850**	**1039**	**1455**	

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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
3.00	Greyish Sand (SP)	3.00	0	27	15.70	5.70	8.55	0.00	1.00	12
4.00	Brownish Sand (SP)	1.00	0	33	19.00	9.00	21.60	0.00	1.00	32
5.00	Brownish Silty Sand (SP-SM)	1.00	0	38	20.00	10.00	31.10	0.00	1.00	42
6.00	Brownish Silty Sand (SM)	1.00	0	38	20.40	10.40	41.30	0.00	1.00	47
7.50	Brownish Grey Silty Sand (SP-SM)	1.50	0	40	21.20	11.20	54.90	0.00	1.00	57
9.00	Greyish Silty Sand (SP-SM)	1.50	0	40	21.00	11.00	71.55	0.00	1.00	54
10.50	Greyish Silty Sand (SM)	1.50	0	37	19.60	9.60	87.00	0.00	1.00	38
12.00	Greyish Silty Sand (SM)	1.50	0	33	18.80	8.80	100.80	0.00	1.00	31
13.50	Greyish Silty Sand (SM)	1.50	0	34	19.10	9.10	114.23	0.00	1.00	33
15.00	Greyish Silty Sand (SM)	1.50	0	31	18.50	8.50	127.43	0.00	1.00	28
16.50	Greyish Silty Sand (SM)	1.50	0	25	14.50	4.50	137.18	0.00	1.00	8
18.00	Greyish Silty Sand (SM)	1.50	0	29	16.20	6.20	145.20	0.00	1.00	14
19.50	Greyish Silty Sand (SM)	1.50	0	32	18.70	8.70	156.38	0.00	1.00	30
21.00	Greyish Silty / Clayey Sand (SC)	1.50	30	25	17.10	7.10	168.23	0.30	1.00	19
22.50	Greyish Silty / Clayey Sand (SC)	1.50	50	40	20.80	10.80	181.65	0.30	1.00	52
24.00	Greyish Silty / Clayey Sand (SC)	1.50	60	40	21.50	11.50	198.38	0.30	1.00	61
25.50	Greyish Silty / Clayey Sand (SC)	1.50	45	32	18.80	8.80	213.60	0.30	1.00	31
27.00	Greyish Silty Sand (SM)	1.50	0	35	19.10	9.10	227.03	0.00	1.00	33
28.50	Greyish Silty Sand (SM)	1.50	0	40	21.30	11.30	242.33	0.00	1.00	58
30.00	Greyish Silty / Clayey Sand (SC)	1.50	50	40	20.80	10.80	258.90	0.30	1.00	52
32.00	Greyish Silty / Clayey Sand (SC)	2.00	90	40	21.20	11.20	278.20	0.30	1.00	100
34.00	Greyish Silty / Clayey Sand (SC)	2.00	90	40	21.60	11.60	301.00	0.30	1.00	100
36.00	Greyish Silty / Clayey Sand (SC)	2.00	90	40	21.90	11.90	324.50	0.30	1.00	100



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
3.00	Greyish Sand (SP)	4.36	18.48	20.53	24.64	28.74	36.95	20.00	84.82	94.25	113.10	131.95	169.65
4.00	Brownish Sand (SP)	14.03	19.83	22.03	26.44	30.85	39.66	53.33	75.40	83.78	100.53	117.29	150.80
5.00	Brownish Silty Sand (SP-SM)	24.30	34.35	38.17	45.80	53.43	68.70	70.00	84.82	94.25	113.10	131.95	169.65
6.00	Brownish Silty Sand (SM)	32.27	45.62	50.69	60.82	70.96	91.23	78.33	84.82	94.25	113.10	131.95	169.65
7.50	Brownish Grey Silty Sand (SP-SM)	46.07	97.69	108.54	130.25	151.96	195.38	95.00	127.23	141.37	169.65	197.92	254.47
9.00	Greyish Silty Sand (SP-SM)	60.04	127.23	141.37	169.65	197.92	254.47	90.00	127.23	141.37	169.65	197.92	254.47
10.50	Greyish Silty Sand (SM)	65.56	127.23	141.37	169.65	197.92	254.47	63.33	127.23	141.37	169.65	197.92	254.47
12.00	Greyish Silty Sand (SM)	65.46	127.23	141.37	169.65	197.92	254.47	51.67	109.56	121.74	146.08	170.43	219.13
13.50	Greyish Silty Sand (SM)	77.05	127.23	141.37	169.65	197.92	254.47	55.00	116.63	129.59	155.51	181.43	233.26
15.00	Greyish Silty Sand (SM)	76.56	127.23	141.37	169.65	197.92	254.47	46.67	98.96	109.96	131.95	153.94	197.92
16.50	Greyish Silty Sand (SM)	63.97	127.23	141.37	169.65	197.92	254.47	13.33	28.27	31.42	37.70	43.98	56.55
18.00	Greyish Silty Sand (SM)	80.49	127.23	141.37	169.65	197.92	254.47	23.33	49.48	54.98	65.97	76.97	98.96
19.50	Greyish Silty Sand (SM)	97.71	127.23	141.37	169.65	197.92	254.47	50.00	106.03	117.81	141.37	164.93	212.06
21.00	Greyish Silty / Clayey Sand (SC)	87.44	127.23	141.37	169.65	197.92	254.47	31.67	67.15	74.61	89.54	104.46	134.30
22.50	Greyish Silty / Clayey Sand (SC)	167.42	127.23	141.37	169.65	197.92	254.47	86.67	127.23	141.37	169.65	197.92	254.47
24.00	Greyish Silty / Clayey Sand (SC)	184.46	127.23	141.37	169.65	197.92	254.47	101.67	127.23	141.37	169.65	197.92	254.47
25.50	Greyish Silty / Clayey Sand (SC)	146.97	127.23	141.37	169.65	197.92	254.47	51.67	109.56	121.74	146.08	170.43	219.13
27.00	Greyish Silty Sand (SM)	158.96	127.23	141.37	169.65	197.92	254.47	55.00	116.63	129.59	155.51	181.43	233.26
28.50	Greyish Silty Sand (SM)	203.33	127.23	141.37	169.65	197.92	254.47	96.67	127.23	141.37	169.65	197.92	254.47
30.00	Greyish Silty / Clayey Sand (SC)	232.24	127.23	141.37	169.65	197.92	254.47	86.67	127.23	141.37	169.65	197.92	254.47
32.00	Greyish Silty / Clayey Sand (SC)	260.44	169.65	188.50	226.19	263.89	339.29	166.67	169.65	188.50	226.19	263.89	339.29
34.00	Greyish Silty / Clayey Sand (SC)	279.57	169.65	188.50	226.19	263.89	339.29	166.67	169.65	188.50	226.19	263.89	339.29
36.00	Greyish Silty / Clayey Sand (SC)	299.29	169.65	188.50	226.19	263.89	339.29	166.67	169.65	188.50	226.19	263.89	339.29



DETERMINATION OF PILE CARRYING CAPACITY AS PER IS 2911 : 2010

Borehole Location **BH 2**

Length of Pile (L), m	=	34.00 m					From Existing Borehole Level
Angle of Internal Friction (φ) in Degrees	=	40.00					
Undraind cohesion value at PileTip (c_p), kN/m^2	=	90.00 kN/m^2					
Submerged Unit Weight at PileTip (Υ_p), kN/m^2	=	11.30 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)	=	150.00					Taken from Figure 1 of IS 2911:2010 Part 1 Sec.2
Bearing Capacity Factor (N_γ)	=	109.41					
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	=	58.70	71.08	84.05	97.18	135.05	
End Bearing Resisrtnce of Pile (q_p), kN/m^2 using 'c' and 'φ'	=	9893.18	11780.33	13788.40	15818.97	21623.85	
End Bearing Resisrtnce of Pile (q_p), kN/m^2 using 'N' values	=	40000.00	40000.00	40000.00	40000.00	40000.00	
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	=	1573.44	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	=	629.38	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	=	2060.65	2289.61	2747.53	3205.45	4121.29	
Ultimate Frictional Capacity of Pile ($Q_{f\text{-}ult}$), kN using 'N' values	=	1966.24	2184.72	2621.66	3058.60	3932.49	
Negetive Skin Fricton of Pile (Q_{nf}), kN using 'c' and 'φ' values	=	228.66	254.07	304.89	355.70	457.33	
Negetive Skin Friction of Pile (Q_{nf}), kN using 'N' values	=	236.80	263.11	315.73	368.35	473.60	
Safe Frictional Capacity of Pile ($Q_{f\text{-}safe}$), kN using 'c' and 'φ' values	=	595.59	661.77	794.13	926.48	1191.19	
Safe Frictional Capacity of Pile ($Q_{f\text{-}safe}$), kN using 'N' values	=	549.70	610.78	732.93	855.09	1099.40	
Self Weight of Pile (W), kN	=	135.19	166.90	240.33	327.12	540.75	
Safe Pile Carrying Capacity of Pile (Q_{safe}), kN ('c' and 'φ')	=	1225	1447	1925	2466	3736	
Safe Pile Carrying Capacity of Pile (Q_{safe}), kN ('N' values)	=	1186	1396	1864	2394	3644	
Recommended Safe Pile Carrying Capacity of Pile (Q_{safe}), kN	=	**1205**	**1422**	**1895**	**2430**	**3690**	
Safe Uplift Capacity of Pile (Q_{up}), kN using 'c' and 'φ' values	=	**593**	**676**	**851**	**1040**	**1457**	



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
3.00	Greyish Silty Sand (SP-SM)	3.00	0	30	16.60	6.60	9.90	0.00	1.00	16
4.00	Brownish Silty Sand (SP-SM)	1.00	0	32	17.30	7.30	23.45	0.00	1.00	20
5.00	Brownish Silty Sand (SM)	1.00	0	31	17.00	7.00	30.60	0.00	1.00	18
6.00	Brownish Silty Sand (SP-SM)	1.00	0	32	17.50	7.50	37.85	0.00	1.00	21
7.50	Brownish Greyish Silty Sand (SP-SM)	1.50	0	31	17.10	7.10	46.93	0.00	1.00	19
9.00	Greyish Silty Sand (SM)	1.50	0	34	18.60	8.60	58.70	0.00	1.00	29
10.50	Greyish Sand (SP)	1.50	0	33	17.90	7.90	71.08	0.00	1.00	24
12.00	Greyish Silty Sand (SM)	1.50	0	37	19.40	9.40	84.05	0.00	1.00	36
13.50	Greyish Silty Sand (SM)	1.50	0	34	18.10	8.10	97.18	0.00	1.00	25
15.00	Greyish Silty Sand (SM)	1.50	0	37	19.20	9.20	110.15	0.00	1.00	34
16.50	Greyish Silty Sand (SP-SM)	1.50	0	38	19.60	9.60	124.25	0.00	1.00	38
18.00	Greyish Sandy Clay (CI)	1.50	56	0	14.80	4.80	135.05	0.65	1.00	9
19.50	Greyish Silty Sand (SM)	1.50	0	25	14.50	4.50	142.03	0.00	1.00	8
21.00	Greyish Silty Sand (SP)	1.50	0	35	19.00	9.00	152.15	0.00	1.00	32
22.50	Greyish Silty / Clayey Sand (SC)	1.50	45	30	18.70	8.70	165.43	0.30	1.00	30
24.00	Greyish Silty / Clayey Sand (SC)	1.50	37	28	18.10	8.10	178.03	0.30	1.00	25
25.50	Greyish Silty / Clayey Sand (SC)	1.50	34	27	17.80	7.80	189.95	0.30	1.00	23
27.00	Greyish Silty Sand (SM)	1.50	0	37	19.40	9.40	202.85	0.00	1.00	36
28.50	Greyish Silty Sand (SM)	1.50	0	38	20.20	10.20	217.55	0.00	1.00	44
30.00	Greyish Silty / Clayey Sand (SC)	1.50	90	40	20.70	10.70	233.23	0.30	1.00	100
32.00	Greyish Silty / Clayey Sand (SC)	2.00	90	40	20.90	10.90	252.15	0.30	1.00	100
34.00	Greyish Silty / Clayey Sand (SC)	2.00	90	40	21.30	11.30	274.35	0.30	1.00	100
36.00	Greyish Silty / Clayey Sand (SC)	2.00	90	40	21.50	11.50	297.15	0.30	1.00	100



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
3.00	Greyish Silty Sand (SP-SM)	5.72	24.24	26.93	32.32	37.71	48.48	26.67	113.10	125.66	150.80	175.93	226.19
4.00	Brownish Silty Sand (SP-SM)	14.65	20.72	23.02	27.62	32.22	41.43	33.33	47.12	52.36	62.83	73.30	94.25
5.00	Brownish Silty Sand (SM)	18.39	25.99	28.88	34.66	40.43	51.99	30.00	42.41	47.12	56.55	65.97	84.82
6.00	Brownish Silty Sand (SP-SM)	23.65	33.44	37.15	44.58	52.01	66.87	35.00	49.48	54.98	65.97	76.97	98.96
7.50	Brownish Greyish Silty Sand (SP-SM)	28.20	59.79	66.43	79.72	93.01	119.58	31.67	67.15	74.61	89.54	104.46	134.30
9.00	Greyish Silty Sand (SM)	39.59	83.96	93.29	111.95	130.61	167.92	48.33	102.49	113.88	136.66	159.44	204.99
10.50	Greyish Sand (SP)	46.16	97.88	108.75	130.50	152.26	195.76	40.00	84.82	94.25	113.10	131.95	169.65
12.00	Greyish Silty Sand (SM)	63.34	127.23	141.37	169.65	197.92	254.47	60.00	127.23	141.37	169.65	197.92	254.47
13.50	Greyish Silty Sand (SM)	65.55	127.23	141.37	169.65	197.92	254.47	41.67	88.36	98.17	117.81	137.44	176.71
15.00	Greyish Silty Sand (SM)	83.00	127.23	141.37	169.65	197.92	254.47	56.67	120.17	133.52	160.22	186.92	240.33
16.50	Greyish Silty Sand (SP-SM)	97.07	127.23	141.37	169.65	197.92	254.47	63.33	127.23	141.37	169.65	197.92	254.47
18.00	Greyish Sandy Clay (CI)	36.40	77.19	85.77	102.92	120.07	154.38	45.00	95.43	106.03	127.23	148.44	190.85
19.50	Greyish Silty Sand (SM)	66.23	127.23	141.37	169.65	197.92	254.47	13.33	28.27	31.42	37.70	43.98	56.55
21.00	Greyish Silty Sand (SP)	106.54	127.23	141.37	169.65	197.92	254.47	53.33	113.10	125.66	150.80	175.93	226.19
22.50	Greyish Silty / Clayey Sand (SC)	109.01	127.23	141.37	169.65	197.92	254.47	50.00	106.03	117.81	141.37	164.93	212.06
24.00	Greyish Silty / Clayey Sand (SC)	105.76	127.23	141.37	169.65	197.92	254.47	41.67	88.36	98.17	117.81	137.44	176.71
25.50	Greyish Silty / Clayey Sand (SC)	106.98	127.23	141.37	169.65	197.92	254.47	38.33	81.29	90.32	108.38	126.45	162.58
27.00	Greyish Silty Sand (SM)	152.86	127.23	141.37	169.65	197.92	254.47	60.00	127.23	141.37	169.65	197.92	254.47
28.50	Greyish Silty Sand (SM)	169.97	127.23	141.37	169.65	197.92	254.47	73.33	127.23	141.37	169.65	197.92	254.47
30.00	Greyish Silty / Clayey Sand (SC)	222.70	127.23	141.37	169.65	197.92	254.47	166.67	127.23	141.37	169.65	197.92	254.47
32.00	Greyish Silty / Clayey Sand (SC)	238.58	169.65	188.50	226.19	263.89	339.29	166.67	169.65	188.50	226.19	263.89	339.29
34.00	Greyish Silty / Clayey Sand (SC)	257.21	169.65	188.50	226.19	263.89	339.29	166.67	169.65	188.50	226.19	263.89	339.29
36.00	Greyish Silty / Clayey Sand (SC)	276.34	169.65	188.50	226.19	263.89	339.29	166.67	169.65	188.50	226.19	263.89	339.29



Appendix - 3 (DETERMINATION OF PILE CARRYING CAPACITY AS PER IS 2911:2010)

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

Length of Pile (L), m	=	**34.00 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 L**	
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)	=	1400.00 kN/m^3		**From Table 3 of IS 2911 Part 1 S**	
Grade of Concrete	=	**35.00 N/mm^2**		**M 35**	
Young's Modulus of Pile Materia (E), kN/m^2	=	29580398.92 kN/m^2			
Diametr of Pile (D), mm	=	450	500	600	700
Moment of Inertia of Pile Section (I), m^4	=	0.00201	0.00307	0.00636	0.01179
Stiffness Factor, (T)	=	2.12	2.30	2.66	3.01
Criteria for Behaviour of Pile as per Table 5 of IS 2911 Part I Sec. 2	=	Long Pile	Long Pile	Long Pile	Long Pile
(e/R)	=	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
Depth of Fixity (Z_f), m	=	4.02	4.38	5.06	5.73
Allowable Deflection as per IS 2911 Part 4 : 1985, Page No. 10 in mm	=	5.00	5.00	5.00	5.00
Lateral Load Capacity of Pile (H), kN	=	**55.00**	**64.80**	**87.20**	**111.20**

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

Appendix – D

Site Photographs

Division of Soil Mech. & Foundation Engg
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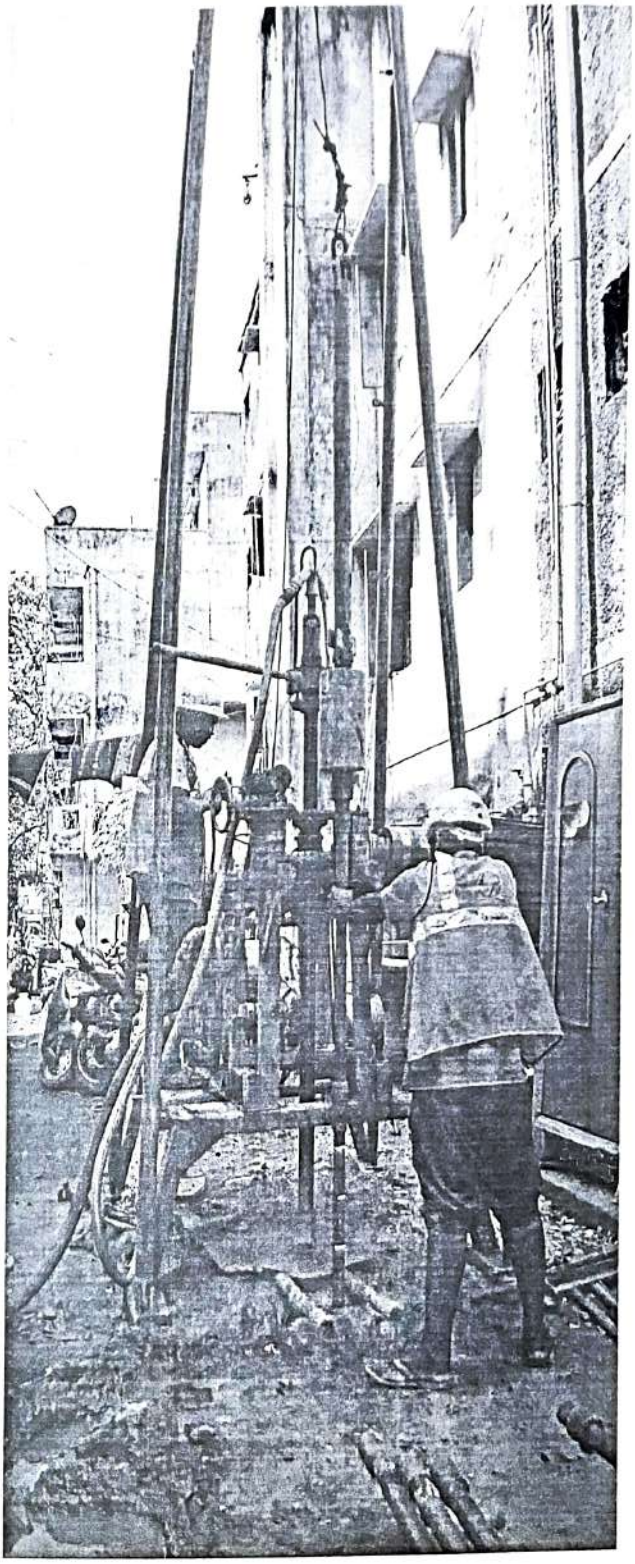


Plate 1 SPT test is in progress at the Reconstruction of Multi Storied Tenements (G+3 Floors) at Powerkuppam Scheme in Greater Chennai Corporation, Division 43, Zone IV.

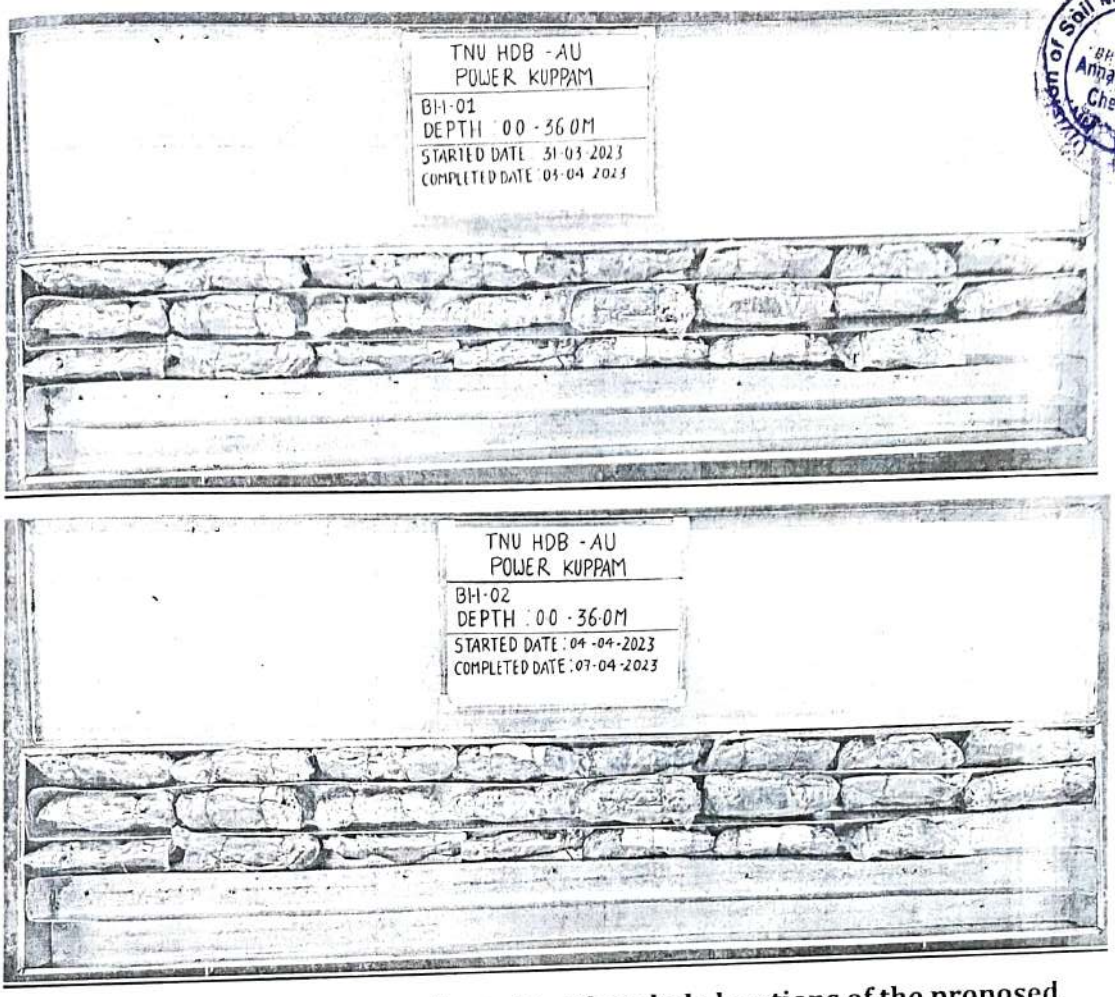
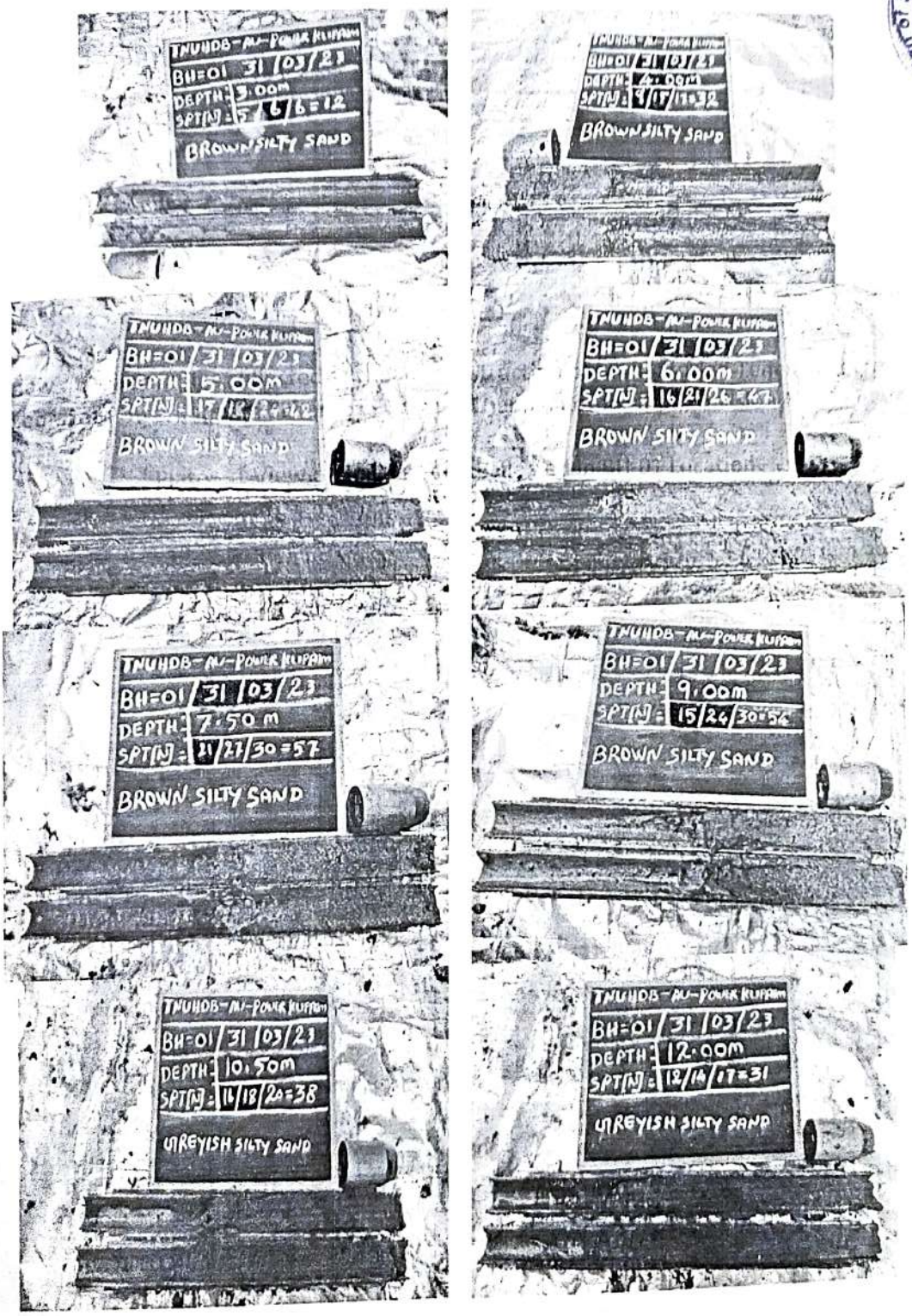


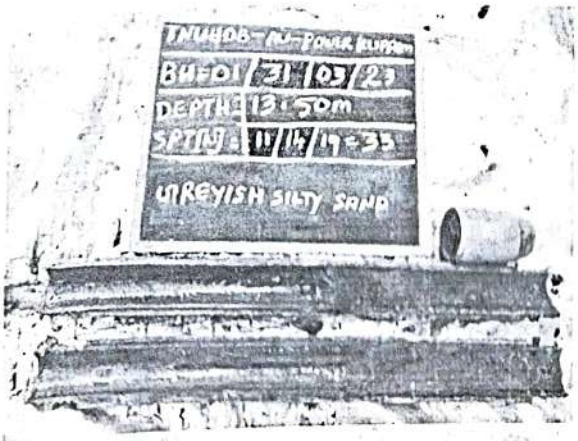
Plate 2 View of Soil Samples collected in 2 borehole locations of the proposed site

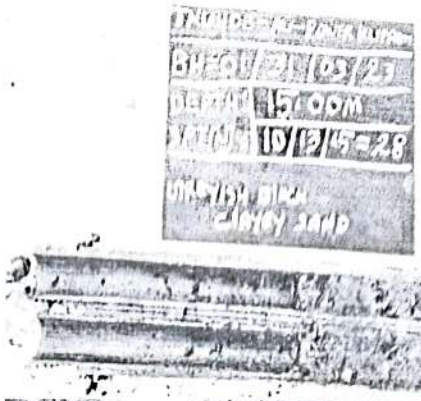
View of Soil Samples collected at the Re-construction of Multi Storied Tenements (G+3 Floors) at Powerkuppam Scheme in Greater Chennai Corporation, Division 43, Zone IV.

Plate – 1 View of Soil Samples collected in BH-01 Location



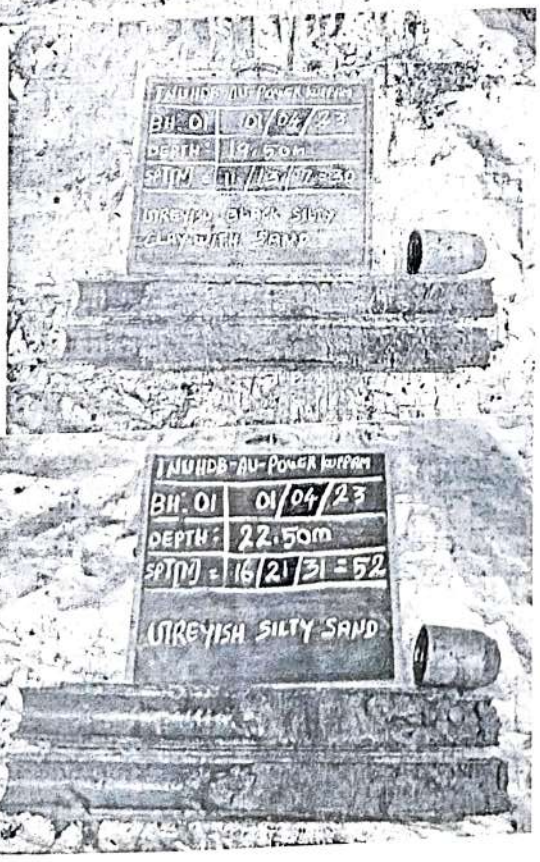
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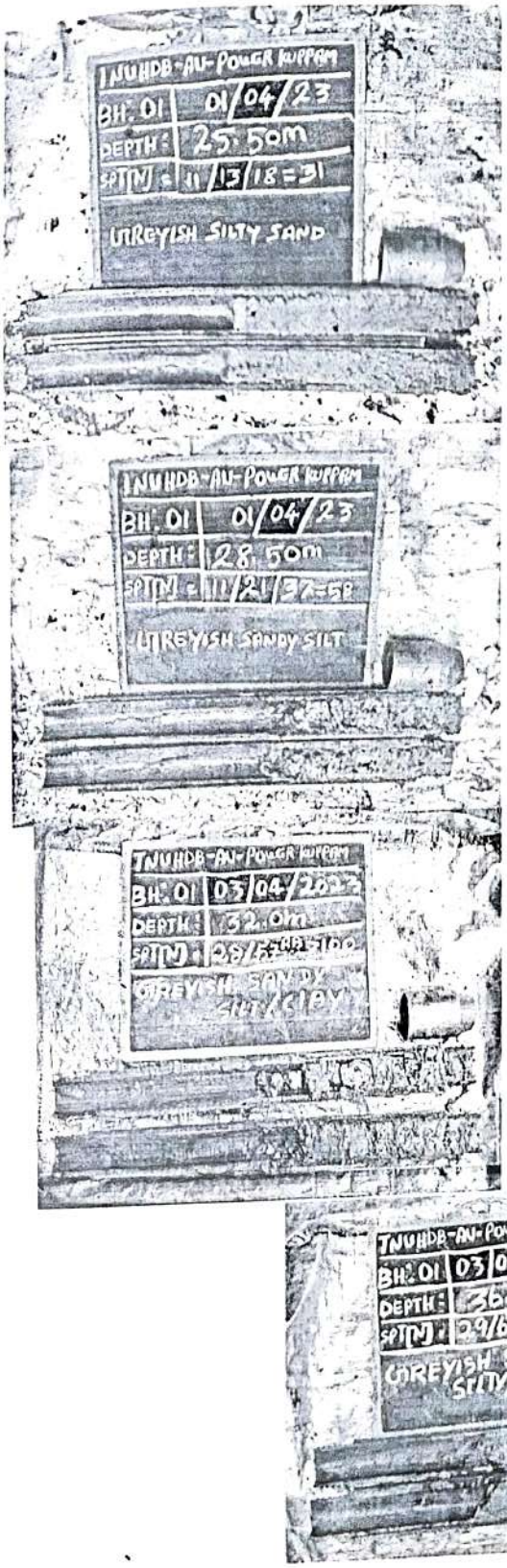








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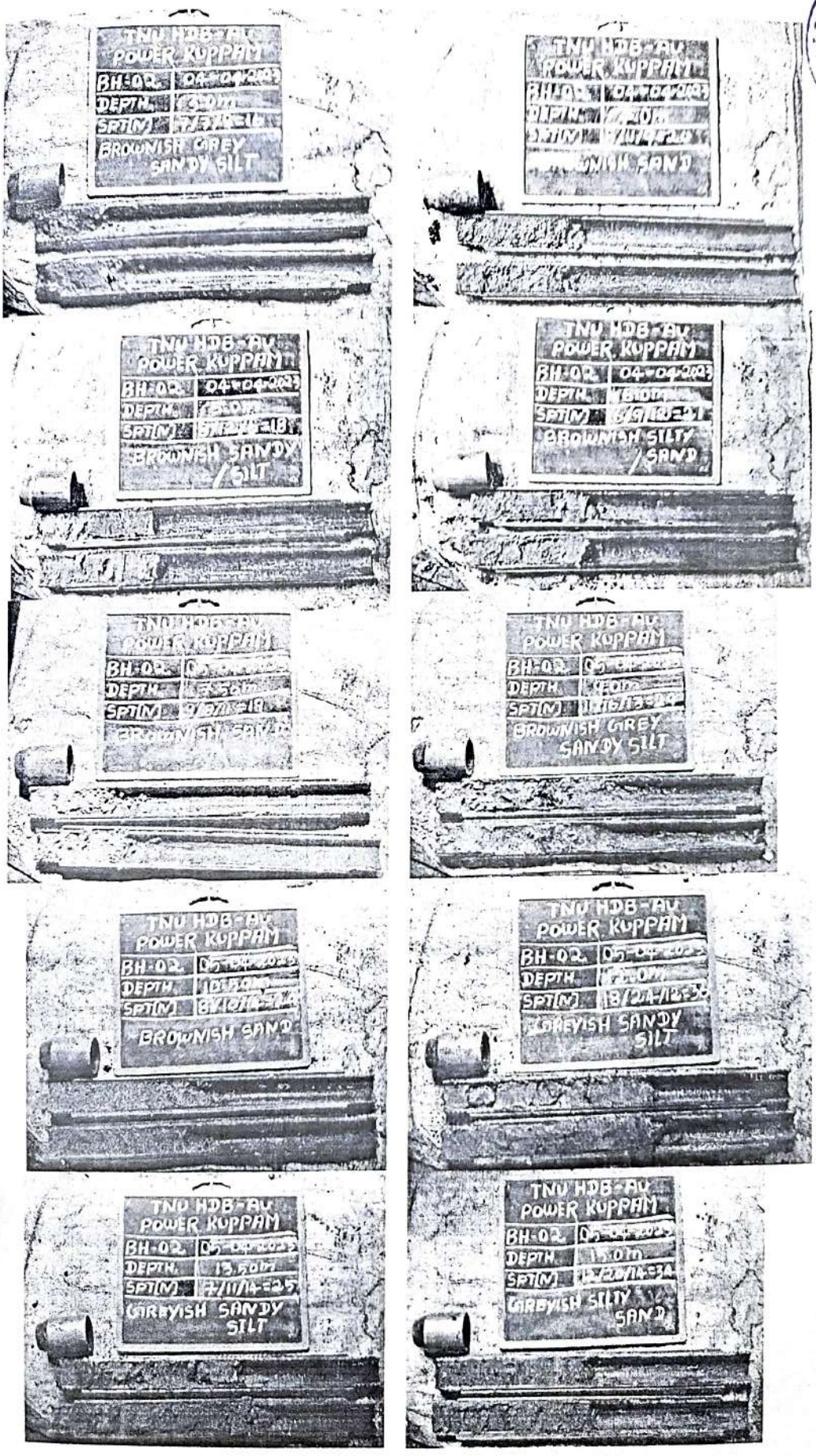




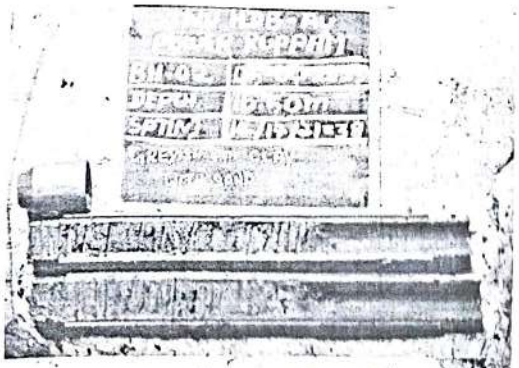
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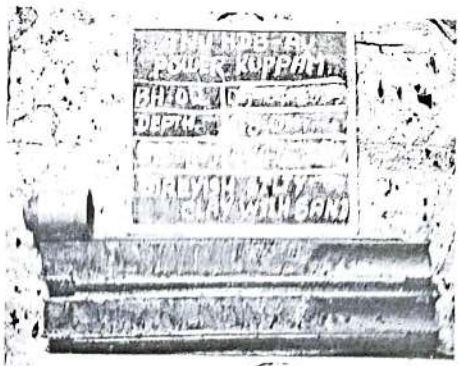
Plate – 2 View of Soil Samples collected in BH-02 Location

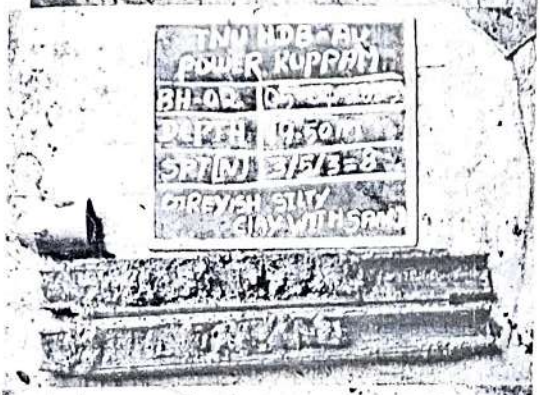
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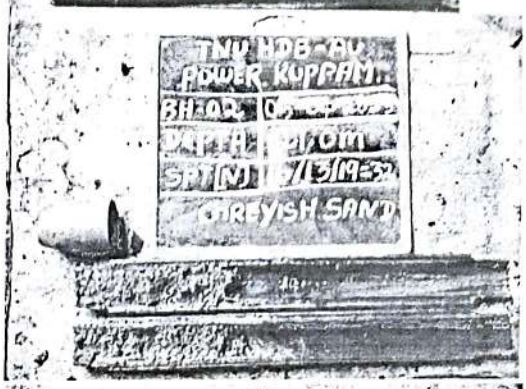


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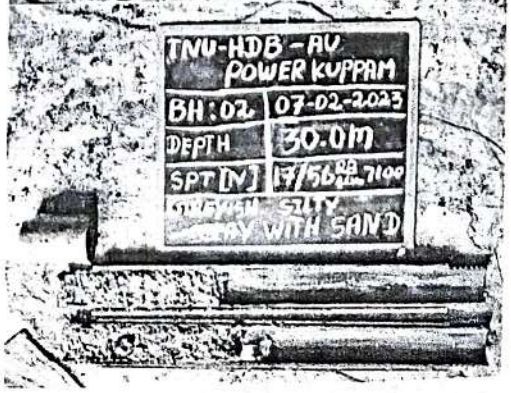


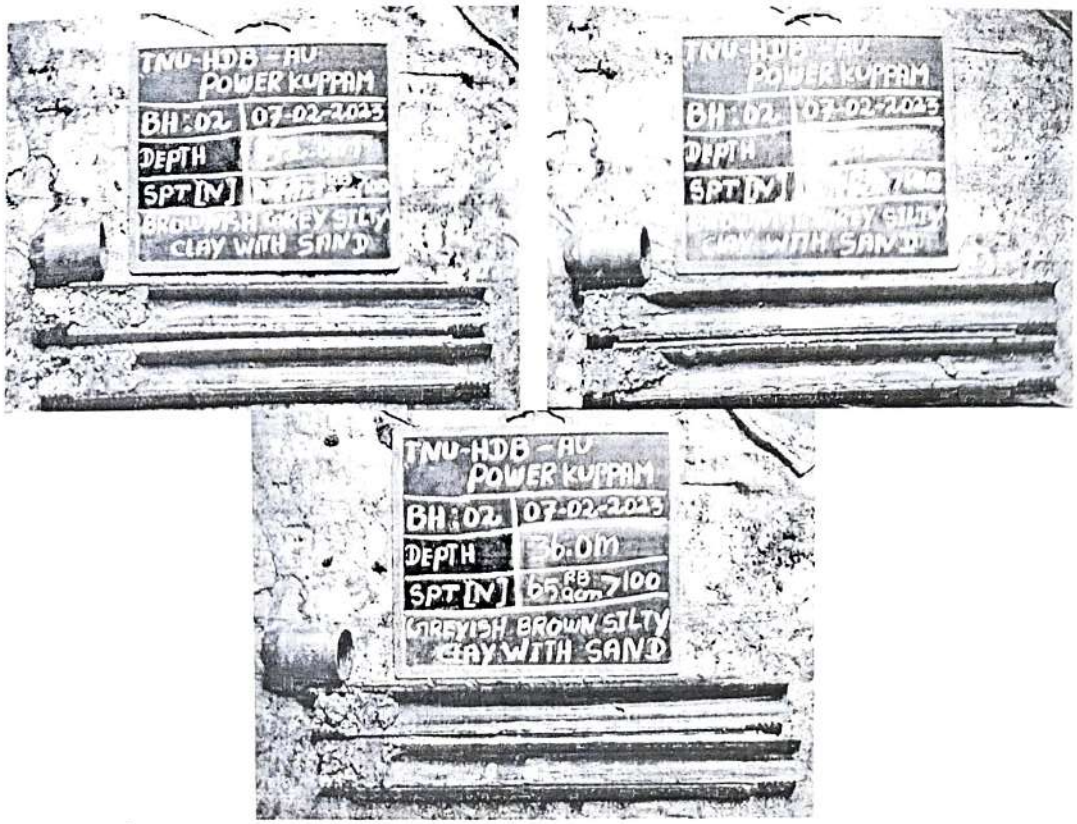












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Property Development & Approvals

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NRI & Investment Services

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Compliance & Special Services

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empowering your real estate decisions with smart tools

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Zoning & Land Use Analysis

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Property Documentation & Workflow Tools

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Vastu & Property Management Tools

Home Vastu Shastra, Plot Vastu Shastra, Property Management

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