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DEPARTMENT OF CIVIL ENGINEERING
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# SOIL INVESTIGATION REPORT

**NAME OF WORK** : **RECOMMENDATION OF FOUNDATION FOR THE PROPOSED RECONSTRUCTION OF DILAPIDATED SLUM TENEMENTS (S+5 Floors) AT ELISPURAM TENEMENTAL SCHEME IN CORPORATION DIVISION 59, ZONE V OF GREATER CHENNAI CORPORATION.**

**CLIENT** : **The Executive Engineer**
Division – IV,
Tamil Nadu Slum Clearance Board,
T.P.Chatram (Opp. K6 Police Station),
Chennai – 600 010.

**Reference** : The Executive Engineer, TNSCB, Chennai, Lr. No. 560/AE(P)/Dn-IV/2021 , Dated 12.08.2021

**JOB No** : SM&FE 205 / Consultancy / 2021

**DATE** : 02nd November 2021

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## 1. INTRODUCTION

The Tamil Nadu Slum Clearance Board (TNSCB), Division – IV, T.P. Chatram, Chennai – 600 010 has proposed to reconstruct dilapidated slum Tenements (S + 5 Floors) at Ellispuram Tenemental Scheme in Corporation Division 59, zone V of Greater Chennai Corporation. The officials of TNSCB, Division – IV, T.P. Chatram, Chennai – 600 010 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 (S + 5 Floors) at Ellispuram Tenemental Scheme in Corporation Division 59, zone V of Greater Chennai Corporation. Accordingly, the work was taken up and field investigation was carried out during 4$^{th}$ August 2021 to 7$^{th}$ August 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, T.P. Chatram, Chennai – 600 010. 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 Elispuram in Corporation Division 59, zone V 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 TNSCB, Division – IV, T.P. Chatram, 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 – 2).

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 2 of Annexure – 1).

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

1. Brown Silty Sand was found at top 1.0 m depth in BH 1 and BH 2 bore-hole locations with SPT 'N' value varying from 9 to 12.
2. Silty Clay was encountered from 2.0 m to 3.0 m depth in BH 1 and BH 2 location with SPT 'N' value varying from 8 to 14.
3. Silty Sand was observed from 4.0 m to 18.0 m depth in BH 1 location and 4.0 m to 19.5 m depth in BH 2 location with SPT 'N' value of 12 to 96.
4. Greyish Brown weathered sediment layer are observed from 19.5 m to 24.0 m in BH 1 location and in 21.0 m depth in BH 2 location with SPT 'N' values of > 100.
5. Brownish Grey Weathered Gneiss Rock layer are found from 25.0 m to maximum termination depth of 28.0 m in BH 1 location and from 22.0 m to maximum termination depth of 23.5 m depth in BH 2 location.
6. The ground water table was observed at 3.2 m to 3.6 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.

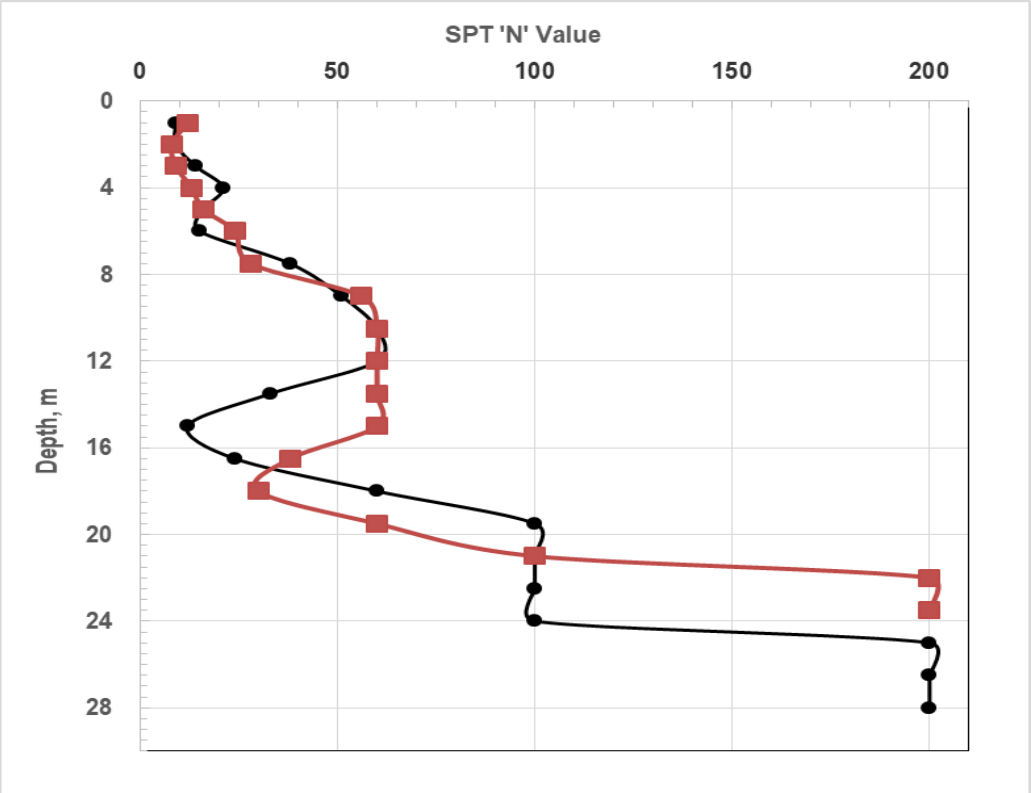


**Figure (1) Variation of SPT 'N' value of different soil layers with respect to depth in Different Borehole Locations of the Site**

## 5.0 COMPUTATION OF SAFE PILE CARRYING CAPACITY

The observed ground water table depths in the proposed site are varying between 3.2 m to 3.5 m depth range in BH 1 and BH 2 locations. The soil layers existing below 3.0 m depth to 13.5 m depth layer are predominately sandy deposits. It is anticipated that heavy seepage of water may occur while excavating soil layer up to 3.5 m depth to place the shallow foundation system which may lead to collapse the supporting system also. Excavation of huge soil mass up to 3.5 m depth and laying Raft Foundation / Strip Raft Foundation is quite cumbersome in high water seepage condition. Hence, attempts are not made to suggest shallow foundation system for the proposed construction of Slum Tenements (S + 5 Floors) at Elispuram Tenemental

Scheme in Corporation Division 59, zone V of Greater Chennai Corporation Attempts are made to suggest pile foundation for varying pile diameter. For computing the load carrying capacity of pile, Indian Standard IS 2911 (Part 1/Sec. 2) 2010 method and Meyerhof 1959 formula (Based on SPT 'N' Value) are used. The diameters of piles are assumed as 450 mm, 500 mm, 600 mm, 700 mm and 900 mm and the length of the pile is taken as 22.0 m to 25.0 m. Safe pile carrying capacity computations were made for all 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 22.0 m to 25.0 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 1. The calculations of pile carrying capacity by static formula (IS 2911: 2010) and Meyerhof formula (1959) are presented in Annexure 3. 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.

**TABLE 1 Safe Load carrying capacity of Bored Cast-In-Situ Pile of 22.0 to 25.0 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 | 1299 | 1522 | 2015 | 2571 | 3871 | 1265 | 1484 | 1969 | 2517 | 3802 |
| BH 2 | 1112 | 1315 | 1766 | 2280 | 3497 | 1070 | 1268 | 1710 | 2215 | 3413 |

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 2 Safe Uplift Capacity of 22.0 to 25.0 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 | 629 | 712 | 883 | 1065 | 1458 |
| BH 2 | 468 | 530 | 662 | 803 | 1110 |

## 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 dilapidated Slum Tenements (S + 5 Floors) at Ellispuram Tenemental Scheme in Corporation Division 59, zone V of Greater Chennai Corporation.

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

2) The recommended safe vertical and lateral pile carrying capacity of the 22.0 m to 25.0 m length of 'bored cast in-situ pile' for varying diameter is shown in Table 9. The required number of piles may be varied with respect to the varying column loads.

3) The bored cast in-situ pile shall be terminated at 22.0 m to 25.0 m in Brownish Grey Weathered Gneiss Stratum.

4) With regard to execution of bored cast-in-situ pile, procedure outlined in IS 2911 Part 1 Section 2: 2010 may be referred and scrupulously followed.

5) Pile load test shall be conducted to ensure the designed pile carrying capacity. The minimum grade of concrete for pile foundation shall be M 30 to M 40.

**TABLE 3 Safe Load carrying capacity and Lateral Load Capacity of Bored Cast-In-Situ Pile for varying diameter and for a length of 22.0 to 25.0 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 | 79.20 | 3.47 |
| 500 | 1200 | 93.30 | 3.78 |
| 600 | 1600 | 125.30 | 4.37 |
| 700 | 2100 | 159.70 | 4.95 |
| 900 | 3200 | 239.00 | 6.05 |

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## FIELD BORE LOG PROFILE

**Project : Proposed Reconstruction of Dilapidated Slum Tenements (S + 5 Floors) at Ellispuram Tenemental Scheme in Corporation Division 59, Zone V of Greater Chennai Corporation.**

| | | | |
|---|---|---|---|
| BH NO | BH 1 | DATE OF START | 04-08-2021 |
| SITE | Elispuram | DATE OF COMPLETION | 05-08-2021 |
| DIA OF BORING | 100 / 150 mm | GROUND WATER LEVEL (m) | 3.2 |
| TYPE OF BORING | Rotary - Autotrip SPT | RL with respect to Bed Level (m) | - |

| Depth below EGL(m) | Soil / Rock Profile | Description / Classification of Soil and Rock / Weathering Grade of Rock as per IS 4464 | Standard Penetration Test (SPT) / UDS / Core Drilling | | | | Relative Density or Consistency of Soil / Strength of Rock |
|---|---|---|---|---|---|---|---|
| | | | 15 | 30 | 45 | N | |
| 1.0 | | Brown Silty Sand (SM-SP) | 5 | 6 | 3 | 9 | Loose |
| 2.0 | | Brown Silty Clay (CH) | 4 | 5 | 4 | 9 | Stiff |
| 3.0 | | Brown Silty Clay (CH) | 6 | 6 | 8 | 14 | Stiff |
| 4.0 | | Greyish Silty Sand (SM-SP) | 8 | 11 | 10 | 21 | Medium Dense |
| 5.0 | | Blackish Grey Silty Sand (SM-SP) | 6 | 6 | 10 | 16 | Medium Dense |
| 6.0 | | Blackish Grey Silty Sand (SM-SP) | 5 | 6 | 9 | 15 | Medium Dense |
| 7.5 | | Brown Sand (SP) | 10 | 18 | 20 | 38 | Dense |
| 9.0 | | Greyish Brown Sand (SP) | 15 | 22 | 29 | 51 | Very Dense |
| 10.5 | | Greyish Brown Sand (SP) | 26 | 40 | 46 | 86 | Very Dense |
| 12.0 | | Brown Sand (SP) | 30 | 44 | 52 | 96 | Very Dense |
| 13.5 | | Brown Sand (SP) | 19 | 18 | 15 | 33 | Dense |
| 15.0 | | Greyish Silty Clay (CH) | 3 | 5 | 7 | 12 | Stiff |
| 16.5 | | Greyish Brown Sand (SP) | 9 | 16 | 8 | 24 | Medium Dense |
| 18.0 | | Brownish Grey Silty Sand (SM-SP) | 40 | $55_{(10\ cm)}$ Rebound | | >100 | Very Dense |
| 19.5 | | Greyish Brown Weathered Sediments (Grade VI) | $50_{(0\ cm)}$ Rebound | | | >100 | Hard / Very Weak |
| 21.0 | | Greyish Brown Weathered Sediments (Grade VI) | $50_{(0\ cm)}$ Rebound | | | >100 | Hard / Very Weak |
| 22.5 | | Greyish Brown Weathered Sediments (Grade VI) | $50_{(0\ cm)}$ Rebound | | | >100 | Hard / Very Weak |
| 24.0 | | Greyish Brown Weathered Sediments (Grade VI) | $50_{(0\ cm)}$ Rebound | | | >100 | Hard / Very Weak |
| 25.0 | | Brownish Grey Weathered Gneiss (Grade V) | $20_{(0\ cm)}$ Rebound; TCR=28%; RQD=0% | | | >100 | Weak |
| 26.5 | | Brownish Grey Weathered Gneiss (Grade V) | $15_{(0\ cm)}$ Rebound; TCR=21.33%; RQD=0% | | | >100 | Weak |
| 28.0 | | Brownish Grey Weathered Gneiss (Grade V) | $15_{(0\ cm)}$ Rebound; TCR=30%; RQD=0% | | | >100 | Weak |

Bore hole has been terminated at 28.0 m from the existing ground level (EGL). Nx Size Core Barrel with Diamond Cutter was used to drill from 24.0 m to 28.0 m depth Rock Stratum.

**Figure A-1**

## FIELD BORE LOG PROFILE

**Project : Proposed Reconstruction of Dilapidated Slum Tenements (S + 5 Floors) at Ellispuram Tenemental Scheme in Corporation Division 59, Zone V of Greater Chennai Corporation.**

| | | | |
|---|---|---|---|
| BH NO | BH 2 | DATE OF START | 06-08-2021 |
| SITE | Elispuram | DATE OF COMPLETION | 07-08-2021 |
| DIA OF BORING | 100 / 150 mm | GROUND WATER LEVEL (m) | 3.5 |
| TYPE OF BORING | Rotary - Autotrip SPT | RL with respect to Bed Level (m) | - |

| Depth below EGL(m) | Soil / Rock Profile | Description / Classification of Soil and Rock / Weathering Grade of Rock as per IS 4464 | Standard Penetration Test (SPT) / UDS / Core Drilling | | | | Relative Density or Consistency of Soil / Strength of Rock |
|---|---|---|---|---|---|---|---|
| | | | 15 | 30 | 45 | N | |
| 1.00 | | Brown Silty Sand (SM-SP) | 4 | 6 | 6 | 12 | Medium Dense |
| 2.00 | | Greyish Brown Silty Clay (CH) | 3 | 4 | 4 | 8 | Medium Stiff |
| 3.00 | | Greyish Brown Silty Clay (CH) | 4 | 4 | 5 | 9 | Stiff |
| 4.00 | | Greyish Brown Silty Sand (SM-SP) | 4 | 6 | 7 | 13 | Medium Dense |
| 5.00 | | Greyish Brown Sand (SP) | 6 | 8 | 8 | 16 | Medium Dense |
| 6.00 | | Greyish Brown Sand (SP) | 6 | 12 | 12 | 24 | Medium Dense |
| 7.50 | | Greyish Brown Sand (SP) | 10 | 13 | 15 | 28 | Medium Dense |
| 9.00 | | Brown Sand (SP) | 22 | 26 | 30 | 56 | Very Dense |
| 10.50 | | Brown Sand (SP) | 26 | 32 | 38 | 70 | Very Dense |
| 12.00 | | Brown Sand (SP) | 28 | 33 | 39 | 72 | Very Dense |
| 13.50 | | Greyish Brown Sand (SP) | 26 | 29 | 34 | 63 | Very Dense |
| 15.00 | | Brown Sand (SP) | 26 | 31 | 39 | 70 | Very Dense |
| 16.50 | | Brownish Grey Silty / Clayey Sand (SC) | 11 | 17 | 21 | 38 | Dense |
| 18.00 | | Greyish Silty / Clayey Sand (SC) | 13 | 17 | 13 | 30 | Dense |
| 19.50 | | Brownish Grey Silty / Clayey Sand (SC) | 40 | $50_{(0\ cm)}$ Rebound | | >100 | Very Dense |
| 21.00 | | Greyish Brown Weathered Sediments (Grade VI) | $50_{(0\ cm)}$ Rebound | | | >100 | Hard / Very Weak |
| 22.00 | | Brownish Grey Weathered Gneiss (Grade V) | $20_{(0\ cm)}$ Rebound; TCR=22%; RQD=0% | | | >100 | Weak |
| 23.50 | | Brownish Grey Weathered Gneiss (Grade V) | $20_{(0\ cm)}$ Rebound; TCR=33.3%; RQD=10% | | | >100 | Weak |

Bore hole has been terminated at 23.50 m from the existing ground level (EGL). Nx Size Core Barrel with Diamond Cutter was used to drill from 21.0 m to 23.50 m depth Rock Stratum.

**Figure A-2**

## Table A-1

**Project : Proposed Reconstruction of Dilapidated Slum Tenements (S + 5 Floors) at Ellispuram Tenemental Scheme in Corporation Division 59, Zone V of Greater Chennai Corporation.**

| BH No: | 1 | Ground Water Table Depth (m): | 3.2 |
|---|---|---|---|

**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 | | Cohesion (c), kN/m$^2$ | Angle of Friction (Φ) in Degrees |
| | | | | | | | | | | | | | | Silt | Clay | | |
| 1.0 | 9 | Brown Silty Sand (SM-SP) | 12 | 16.5 | NP | NP | NP | NP | 2.64 | 22 | 10 | 29 | 23 | 16 | | 0 | 25 |
| 2.0 | 9 | Brown Silty Clay (CH) | 22 | 16.5 | 56 | 28 | 28 | 20 | 2.62 | 0 | 0 | 5 | 11 | 84 | | 56 | 0 |
| 3.0 | 14 | Brown Silty Clay (CH) | 26 | 18.0 | 57 | 28 | 29 | 20 | 2.61 | 0 | 0 | 4 | 9 | 87 | | 88 | 0 |
| 4.0 | 21 | Greyish Silty Sand (SM-SP) | 17 | 19.5 | NP | NP | NP | NP | 2.63 | 0 | 0 | 37 | 36 | 27 | | 0 | 32 |
| 5.0 | 16 | Blackish Grey Silty Sand (SM-SP) | 37 | 22.0 | NP | NP | NP | NP | 2.64 | 0 | 0 | 5 | 62 | 33 | | 0 | 30 |
| 6.0 | 15 | Blackish Grey Silty Sand (SM-SP) | 41 | 18.2 | NP | NP | NP | NP | 2.63 | 0 | 0 | 13 | 44 | 43 | | 0 | 29 |
| 7.5 | 38 | Brown Sand (SP) | 46 | 21.8 | NP | NP | NP | NP | 2.64 | 0 | 3 | 75 | 19 | 3 | | 0 | 41 |
| 9.0 | 51 | Greyish Brown Sand (SP) | 15 | 22.0 | NP | NP | NP | NP | 2.64 | 0 | 5 | 77 | 18 | 0 | | 0 | 42 |
| 10.5 | 86 | Greyish Brown Sand (SP) | 15 | 22.0 | NP | NP | NP | NP | 2.63 | 0 | 2 | 71 | 25 | 2 | | 0 | 42 |
| 12.0 | 96 | Brown Sand (SP) | 16 | 22.0 | NP | NP | NP | NP | 2.64 | 0 | 2 | 71 | 26 | 1 | | 0 | 42 |
| 13.5 | 33 | Brown Sand (SP) | 15 | 21.2 | NP | NP | NP | NP | 2.64 | 0 | 3 | 80 | 16 | 1 | | 0 | 38 |
| 15.0 | 12 | Greyish Silty Clay (CH) | 35 | 22.0 | 72 | 29 | 43 | 110 | 2.61 | 0 | 1 | 9 | 17 | 73 | | 75 | 0 |
| 16.5 | 24 | Greyish Brown Sand (SP) | 17 | 22.0 | NP | NP | NP | NP | 2.63 | 0 | 6 | 77 | 16 | 1 | | 0 | 35 |
| 18.0 | >100 | Brownish Grey Silty Sand (SM-SP) | 12 | 22.0 | NP | NP | NP | NP | 2.64 | 31 | 10 | 23 | 18 | 18 | | 0 | 41 |
| | | | | | Porosity of Rock (%) | | | | | Strength of Rock | | | | | | | |
| | | | | | | | | | | UCS, kN/m$^2$ | | | $I_s$, kN/m$^2$ | | | | |
| 19.5 | >100 | Greyish Brown Weathered Sediments (Grade VI) | - | 22.0 | - | | | | 2.67 | - | | | - | | | 0 | 44 |
| 21.0 | >100 | Greyish Brown Weathered Sediments (Grade VI) | - | 22.0 | - | | | | 2.67 | - | | | - | | | 0 | 44 |
| 22.5 | >100 | Greyish Brown Weathered Sediments (Grade VI) | - | 22.0 | - | | | | 2.67 | - | | | - | | | 0 | 44 |
| 24.0 | >100 | Greyish Brown Weathered Sediments (Grade VI) | - | 22.0 | - | | | | 2.67 | - | | | - | | | 0 | 44 |
| 25.0 | >100 | Brownish Grey Weathered Gneiss (Grade V) | 1.65 | 23.2 | 2.76 | | | | 2.68 | - | | | 1874 | | | 0 | 45 |
| 26.5 | >100 | Brownish Grey Weathered Gneiss (Grade V) | 1.63 | 23.4 | 2.68 | | | | 2.68 | - | | | 4527 | | | 0 | 45 |
| 28.0 | >100 | Brownish Grey Weathered Gneiss (Grade V) | 1.66 | 23.2 | 2.72 | | | | 2.68 | - | | | 2272 | | | 0 | 45 |

## Table A-2

**Project : Proposed Reconstruction of Dilapidated Slum Tenements (S + 5 Floors) at Ellispuram Tenemental Scheme in Corporation Division 59, Zone V of Greater Chennai Corporation.**

| BH No: | 2 | Ground Water Table Depth (m): | 3.6 |
|---|---|---|---|

**LABORATORY TEST RESULTS**

| Depth (m) | SPT 'N' Value | Description / Classification of Soil and Rock / Weathering Grade of Rock as per IS 4464 | Index Properties | | | | | | Specific Gravity | Grain Size Analysis (%) | | | | | | Direct Shear / Terzaghi and Peck (1974) - Shear Strength Parameters | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Natural Moisture Content, % | Bulk Density (kN/m$^3$) | Liquid Limit, % | Plastic Limit, % | Plasticity Index, % | Free Swell Index | | Gravel | Coarse Sand | Medium Sand | Fine Sand | Fines | | Cohesion (c), kN/m$^2$ | Angle of Friction (Φ) in Degrees |
| | | | | | | | | | | | | | | Silt | Clay | | |
| 1.0 | 12 | Brown Silty Sand (SM-SP) | 18 | 17.5 | NP | NP | NP | NP | 2.63 | 5 | 3 | 48 | 34 | 10 | | 0 | 27 |
| 2.0 | 8 | Greyish Brown Silty Clay (CH) | 33 | 16.1 | 45 | 21 | 24 | 40 | 2.61 | 8 | 0 | 3 | 4 | 85 | | 50 | 0 |
| 3.0 | 9 | Greyish Brown Silty Clay (CH) | 24 | 16.5 | 42 | 19 | 23 | 40 | 2.62 | 0 | 0 | 12 | 16 | 72 | | 56 | 0 |
| 4.0 | 13 | Greyish Brown Silty Sand (SM-SP) | 17 | 17.7 | NP | NP | NP | NP | 2.63 | 0 | 1 | 36 | 52 | 11 | | 0 | 28 |
| 5.0 | 16 | Greyish Brown Sand (SP) | 17 | 18.5 | NP | NP | NP | NP | 2.64 | 0 | 2 | 38 | 53 | 7 | | 0 | 30 |
| 6.0 | 24 | Greyish Brown Sand (SP) | 17 | 20.0 | NP | NP | NP | NP | 2.64 | 0 | 2 | 56 | 40 | 2 | | 0 | 34 |
| 7.5 | 28 | Greyish Brown Sand (SP) | 18 | 20.6 | NP | NP | NP | NP | 2.63 | 1 | 1 | 40 | 51 | 7 | | 0 | 36 |
| 9.0 | 56 | Brown Sand (SP) | 14 | 22.0 | NP | NP | NP | NP | 2.63 | 0 | 1 | 63 | 28 | 8 | | 0 | 42 |
| 10.5 | 70 | Brown Sand (SP) | 15 | 22.0 | NP | NP | NP | NP | 2.63 | 1 | 3 | 70 | 26 | 0 | | 0 | 42 |
| 12.0 | 72 | Brown Sand (SP) | 14 | 22.0 | NP | NP | NP | NP | 2.64 | 0 | 3 | 72 | 23 | 2 | | 0 | 42 |
| 13.5 | 63 | Greyish Brown Sand (SP) | 16 | 22.0 | NP | NP | NP | NP | 2.64 | 0 | 3 | 72 | 23 | 2 | | 0 | 42 |
| 15.0 | 70 | Brown Sand (SP) | 17 | 22.0 | NP | NP | NP | NP | 2.63 | 0 | 3 | 69 | 26 | 2 | | 0 | 42 |
| 16.5 | 38 | Brownish Grey Silty / Clayey Sand (SC) | 19 | 21.8 | 65 | 23 | 42 | 70 | 2.65 | 5 | 1 | 41 | 23 | 30 | | 57 | 37 |
| 18.0 | 30 | Greyish Silty / Clayey Sand (SC) | 16 | 20.9 | 59 | 24 | 35 | 70 | 2.65 | 11 | 3 | 35 | 24 | 27 | | 45 | 33 |
| 19.5 | >100 | Brownish Grey Silty / Clayey Sand (SC) | 14 | 22.0 | 45 | 27 | 18 | 20 | 2.66 | 3 | 2 | 20 | 39 | 36 | | 90 | 40 |
| | | | | | Porosity of Rock (%) | | | | | Strength of Rock | | | | | | | |
| | | | | | | | | | | UCS, kN/m$^2$ | | | $I_s$, kN/m$^2$ | | | | |
| 21.00 | >100 | Greyish Brown Weathered Sediments (Grade VI) | - | 22.0 | - | | | | 2.67 | - | | | - | | | 0 | 44 |
| 22.00 | >100 | Brownish Grey Weathered Gneiss (Grade V) | 1.65 | 23.1 | 2.76 | | | | 2.67 | - | | | 253 | | | 0 | 45 |
| 23.50 | >100 | Brownish Grey Weathered Gneiss (Grade V) | 1.63 | 23.3 | 2.68 | | | | 2.68 | - | | | 1976 | | | 0 | 45 |

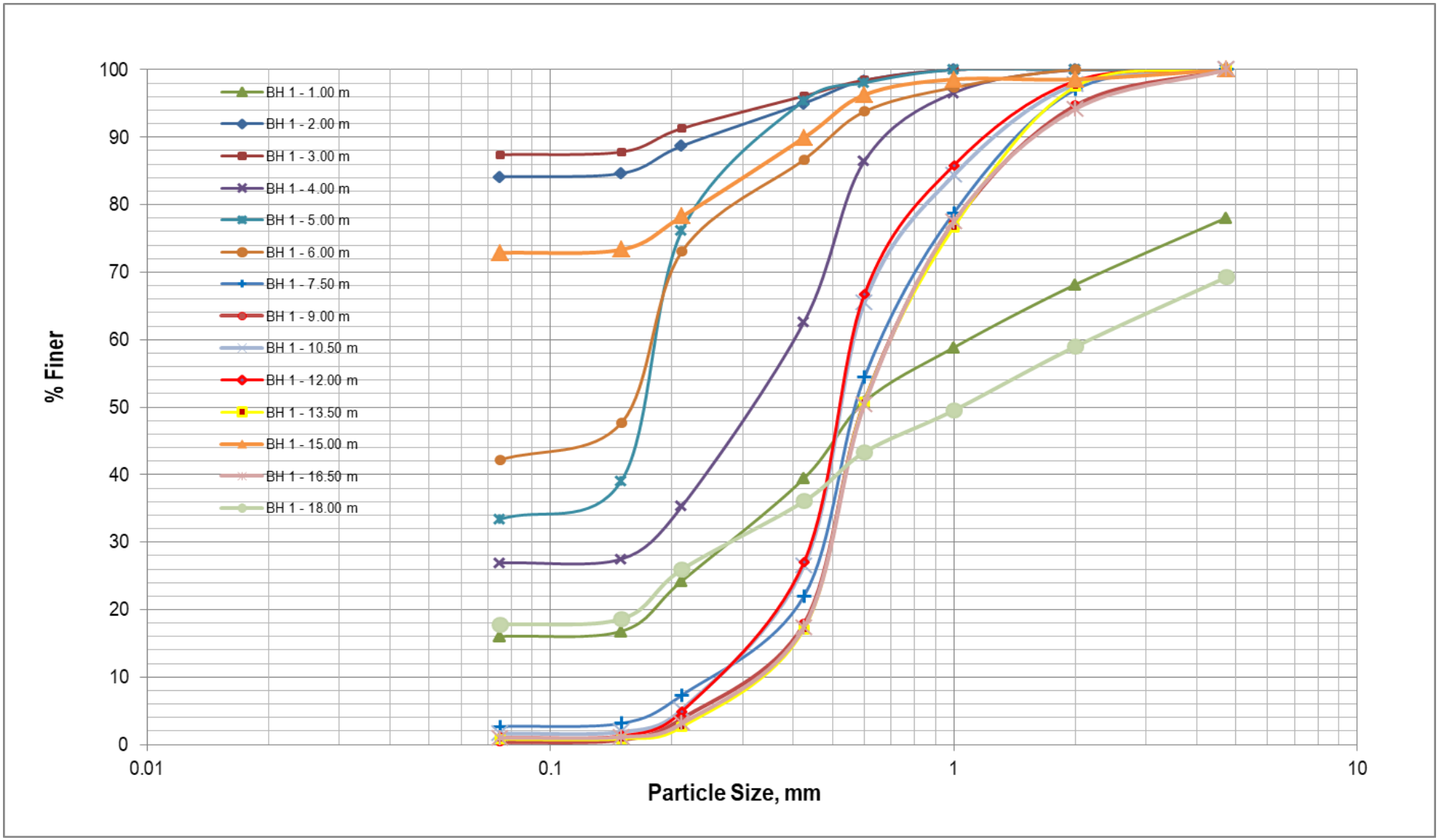



**Figure C- 1 Grain Size Distribution of Soil Samples collected in BH 1 Location**

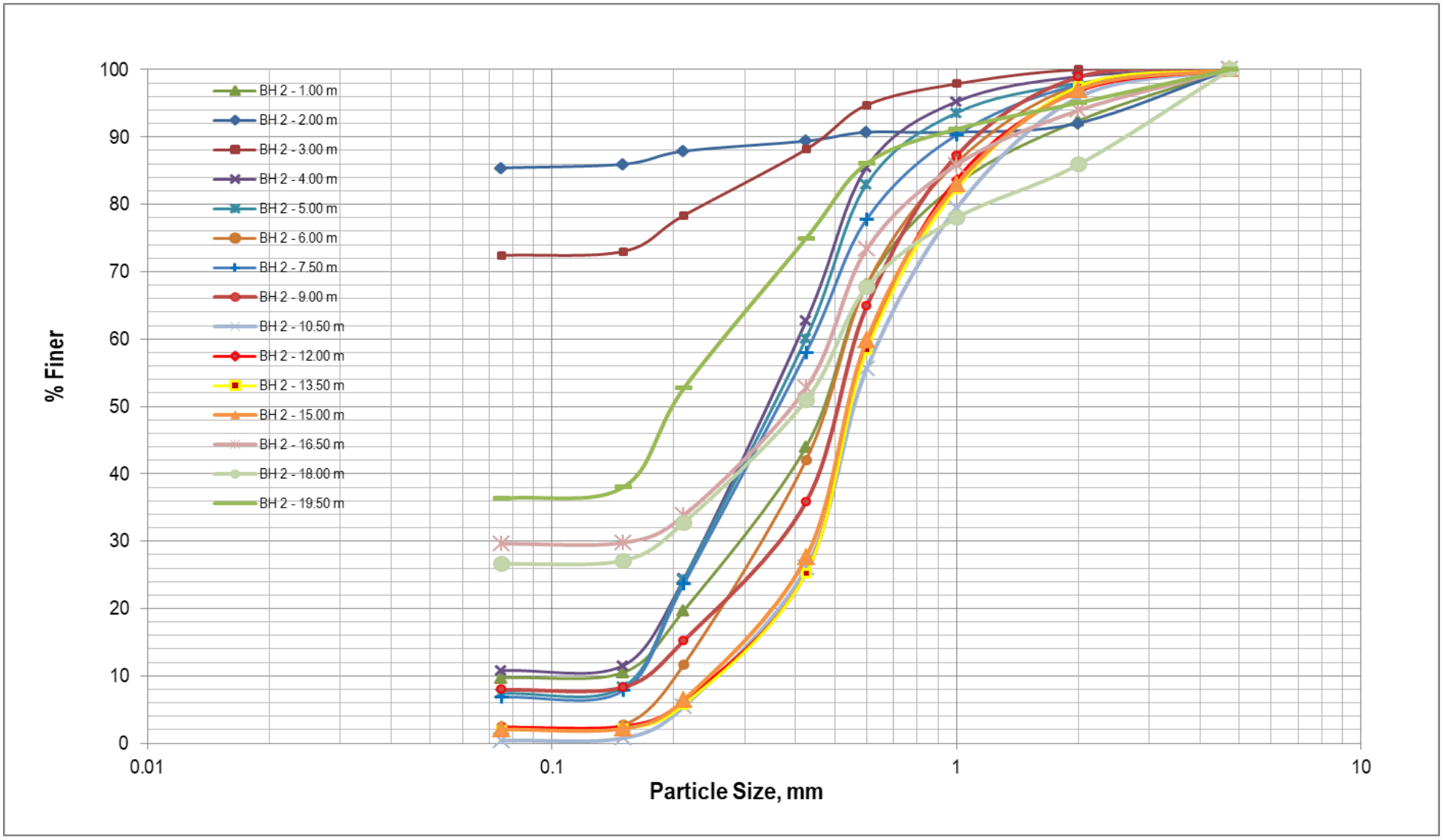



**Figure C-2 Grain Size Distribution of Soil Samples collected in BH 2 Location**

# Annexure – 1

## Site Photographs

Plate 1 SPT test is in progress at the Proposed Reconstruction of Dilapidated Slum Tenements (S + 5 Floors) at Ellispuram Tenemental Scheme in Corporation Division 59, Zone V of Greater Chennai Corporation.

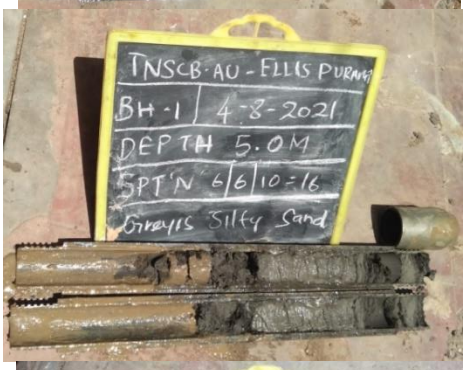

Plate 2 View of Soil Samples collected in 2 Borehole Locations at the Proposed Construction site.

**Annexure – 2 View of Soil Samples collected in BH 1 and BH 2 Locations of the Proposed Reconstruction of Dilapidated Slum Tenements (S + 5 Floors) at Ellispuram Tenemental Scheme in Corporation Division 59, Zone V of Greater Chennai Corporation**

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

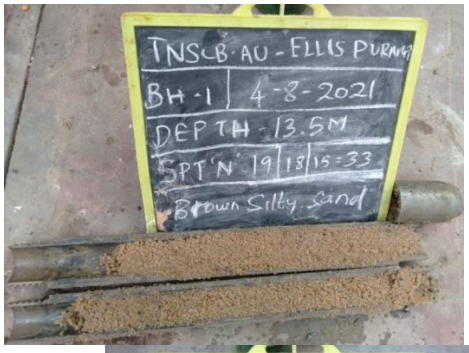










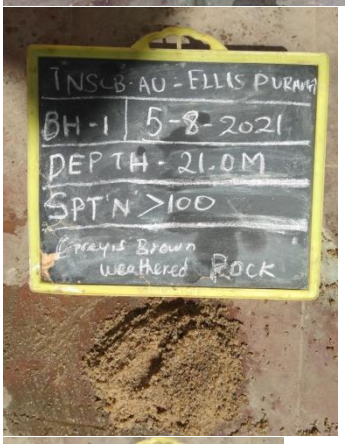


TNSCB-AU - ELLIS PURAM
BH-1 | 4-8-2021
DEPTH - 13.5M
SPT'N 19 | 18 | 15 = 33
Brown Silty Sand

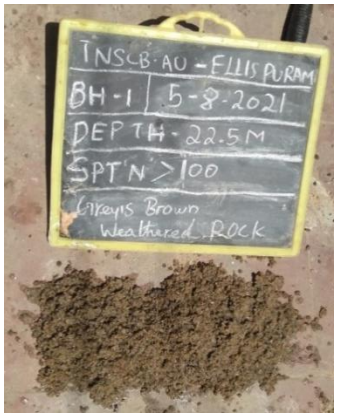

TNSCB-AU - ELLIS PURAM
BH-1 | 4-8-2021
DEPTH - 15.0M
SPT'N 3 | 5 | 7 - 12
Greyish Silty Clay


TNSCB-AU - ELLIS PURAM
BH-1 | 4-8-2021
DEPTH - 16.5M
SPT'N 9 | 16 | 18 = 34
Brownis grey Sand


TNSCB-AU - ELLIS PURAM
BH-1 | 4-8-2021
DEPTH - 18.0M
SPT'N 40 | 55& rebound
Greyish Brown
Weathered ROCK


TNSCB-AU - ELLIS PURAM
BH-1 | 5-8-2021
DEPTH - 19.5M
SPT'N >100
Greyish Brown
Weathered ROCK


TNSCB-AU - ELLIS PURAM
BH-1 | 5-8-2021
DEPTH - 21.0M
SPT'N >100
Greyish Brown
Weathered ROCK


TNSCB-AU - ELLIS PURAM
BH-1 | 5-8-2021
DEPTH - 22.5M
SPT'N >100
Greyis Brown
Weathered ROCK


TNSCB-AU - ELLIS PURAM
BH-1 | 5-8-2021
DEPTH - 24.0M
SPT'N >100
Greyis Brown
Weathered ROCK

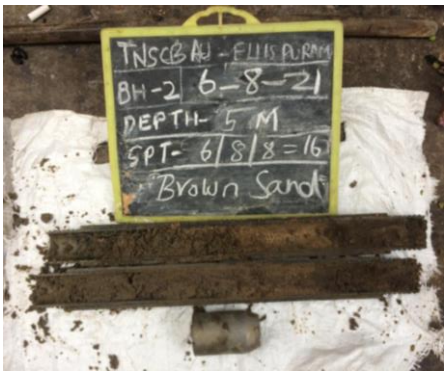

TNSCB-AU - ELLIS PURAM
BH-1 | 5-8-2021
DEPTH - 25.0M
>100 TCR-28% RQD 0%
Greyis Brown
Weathered ROCK


TNSCB-AU - ELLIS PURAM
BH-1 | 5-8-2021
DEPTH - 26.5M
>100 TCR-21.33% RQD 0%
Greyis Brown
Weathered ROCK


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



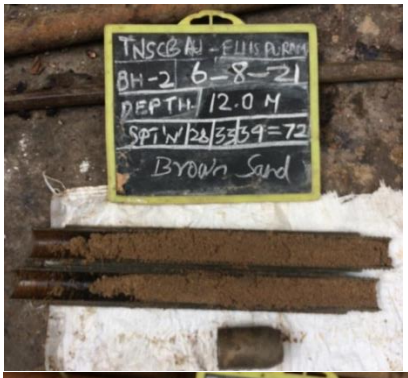








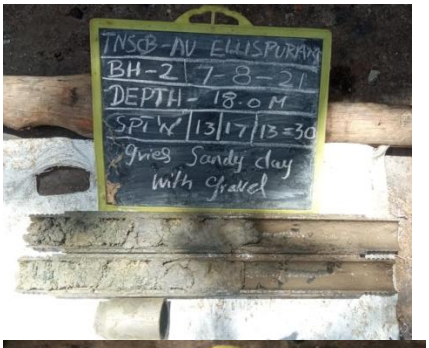
TNSCB AV - ELLISPURAM
BH-2 6-8-21
DEPTH 10.5 M
SPT 'N' 26 32 38 = 70
Brown Silty Sand


TNSCB AV - ELLISPURAM
BH-2 6-8-21
DEPTH 12.0 M
SPT 'N' 28 33 39 = 72
Brown Sand


TNSCB AV - ELLISPURAM
BH-2 6-8-21
DEPTH 13.5 M
SPT 'N' 26 29 34 = 63
Brown Sand


TNSCB-AV ELLISPURAM
BH-2 7-8-21
DEPTH - 15.0 M
SPT 'N' 28 31 39 = 70
Brown Sand


TNSCB-AV ELLISPURAM
BH-2 7-8-21
DEPTH - 16.5 M
SPT 'N' 11 17 21 = 38
Grieg Brown
clayey Sand


TNSCB-AV ELLISPURAM
BH-2 7-8-21
DEPTH - 18.0 M
SPT 'N' 13 17 13 = 30
Grieg Sandy clay
with Gravel


TNSCB-AV ELLISPURAM
BH-2 7-8-21
DEPTH - 19.5 M
SPT 'N' - 40 50b 10CM
Grieg weathered
Rock


TNSCB-AV ELLISPURAM
BH-2 7-8-21
DEPTH - 21.0M
100 > 50b-0CM
Brown weathered
Rock


TNSCB-AV ELLISPURAM
BH-2 7-8-21
DEPTH - 22.5M
100 > TCR-22% RQD-0%
Grieg brown
weathered Rock

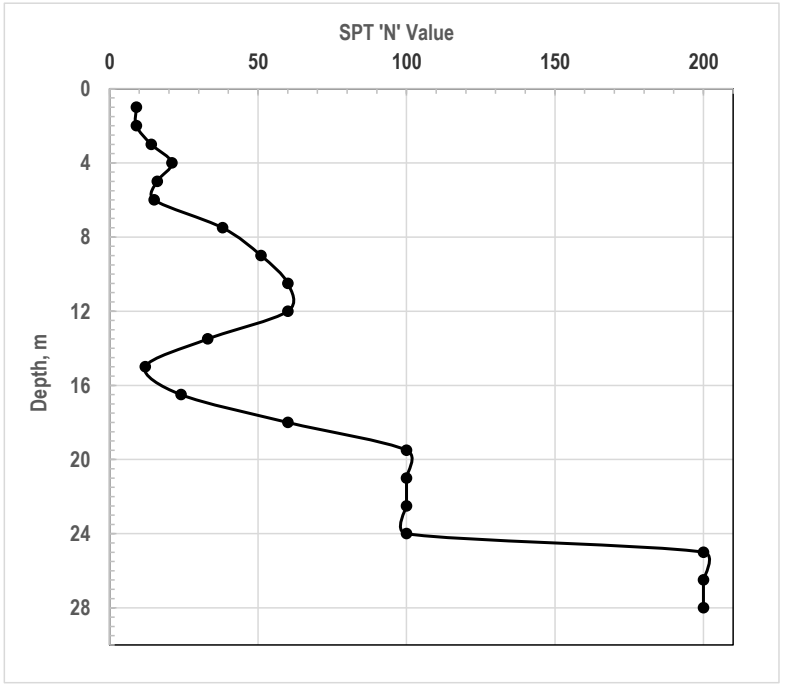

TNSCB-AV ELLISPURAM
BH-2 7-8-21
DEPTH-23.5 M
N'100 > TCR-36.3% RQD-0%
Grey Hard
Rock

## GEOTECHNICAL DESIGN PARAMETERS OF DIFFERENT LAYERS BELOW GROUND LEVEL

**PROJECT:** Proposed Reconstruction of Dilapidated Slum Tenements (S + 5 Floors) at Ellispuram Tenemental Scheme in Corporation Division 59, Zone V of Greater Chennai Corporation.

| BH No: | 1 | | | | | GWT (m): | 3.2 |
|---|---|---|---|---|---|---|---|
| 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 ($\Phi$) in Degrees |
| 1.00 | 9 | Brown Silty Sand (SM-SP) | 9 | 16.5 | 7500 | 0 | 25 |
| 2.00 | 9 | Brown Silty Clay (CH) | 9 | 16.5 | 4800 | 56 | 0 |
| 3.00 | 14 | Brown Silty Clay (CH) | 14 | 18.0 | 6400 | 88 | 0 |
| 4.00 | 21 | Greyish Silty Sand (SM-SP) | 21 | 19.5 | 13500 | 0 | 32 |
| 5.00 | 16 | Blackish Grey Silty Sand (SM-SP) | 16 | 22.0 | 11000 | 0 | 30 |
| 6.00 | 15 | Blackish Grey Silty Sand (SM-SP) | 15 | 18.2 | 10500 | 0 | 29 |
| 7.50 | 38 | Brown Sand (SP) | 38 | 21.8 | 22000 | 0 | 41 |
| 9.00 | 51 | Greyish Brown Sand (SP) | 51 | 22.0 | 28500 | 0 | 42 |
| 10.50 | 86 | Greyish Brown Sand (SP) | 60 | 22.0 | 33000 | 0 | 42 |
| 12.00 | 96 | Brown Sand (SP) | 60 | 22.0 | 33000 | 0 | 42 |
| 13.50 | 33 | Brown Sand (SP) | 33 | 21.2 | 19500 | 0 | 38 |
| 15.00 | 12 | Greyish Silty Clay (CH) | 12 | 22.0 | 5760 | 75 | 0 |
| 16.50 | 24 | Greyish Brown Sand (SP) | 24 | 22.0 | 15000 | 0 | 35 |
| 18.00 | >100 | Brownish Grey Silty Sand (SM-SP) | 60 | 22.0 | 33000 | 0 | 41 |
| 19.50 | >100 | Greyish Brown Weathered Sediments (Grade VI) | 100 | 22.0 | 43000 | 0 | 44 |
| 21.00 | >100 | Greyish Brown Weathered Sediments (Grade VI) | 100 | 22.0 | 43000 | 0 | 44 |
| 22.50 | >100 | Greyish Brown Weathered Sediments (Grade VI) | 100 | 22.0 | 43000 | 0 | 44 |
| 24.00 | >100 | Greyish Brown Weathered Sediments (Grade VI) | 100 | 22.0 | 43000 | 0 | 44 |
| 25.00 | >100 | Brownish Grey Weathered Gneiss (Grade V) | 200 | 23.2 | 197500 | 0 | 45 |
| 26.50 | >100 | Brownish Grey Weathered Gneiss (Grade V) | 200 | 23.4 | 197500 | 0 | 45 |
| 28.00 | >100 | Brownish Grey Weathered Gneiss (Grade V) | 200 | 23.2 | 197500 | 0 | 45 |

Variation of SPT 'N' Value with respect to Depth

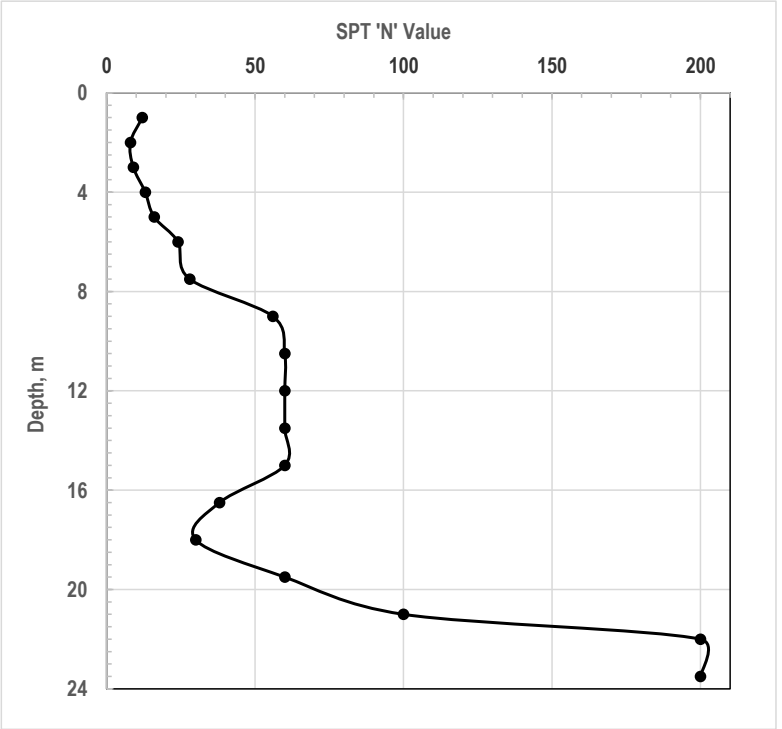


## GEOTECHNICAL DESIGN PARAMETERS OF DIFFERENT LAYERS BELOW GROUND LEVEL

**PROJECT:** Proposed Reconstruction of Dilapidated Slum Tenements (S + 5 Floors) at Ellispuram Tenemental Scheme in Corporation Division 59, Zone V of Greater Chennai Corporation.

| BH No: | 2 | | | | GWT (m): | 3.6 | |
|---|---|---|---|---|---|---|---|
| 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 | 12 | Brown Silty Sand (SM-SP) | 12 | 17.5 | 9000 | 0 | 27 |
| 2.00 | 8 | Greyish Brown Silty Clay (CH) | 8 | 16.1 | 4480 | 50 | 0 |
| 3.00 | 9 | Greyish Brown Silty Clay (CH) | 9 | 16.5 | 4800 | 56 | 0 |
| 4.00 | 13 | Greyish Brown Silty Sand (SM-SP) | 13 | 17.7 | 9500 | 0 | 28 |
| 5.00 | 16 | Greyish Brown Sand (SP) | 16 | 18.5 | 11000 | 0 | 30 |
| 6.00 | 24 | Greyish Brown Sand (SP) | 24 | 20.0 | 15000 | 0 | 34 |
| 7.50 | 28 | Greyish Brown Sand (SP) | 28 | 20.6 | 17000 | 0 | 36 |
| 9.00 | 56 | Brown Sand (SP) | 56 | 22.0 | 31000 | 0 | 42 |
| 10.50 | 70 | Brown Sand (SP) | 60 | 22.0 | 33000 | 0 | 42 |
| 12.00 | 72 | Brown Sand (SP) | 60 | 22.0 | 33000 | 0 | 42 |
| 13.50 | 63 | Greyish Brown Sand (SP) | 60 | 22.0 | 33000 | 0 | 42 |
| 15.00 | 70 | Brown Sand (SP) | 60 | 22.0 | 33000 | 0 | 42 |
| 16.50 | 38 | Brownish Grey Silty / Clayey Sand (SC) | 38 | 21.8 | 14080 | 57 | 37 |
| 18.00 | 30 | Greyish Silty / Clayey Sand (SC) | 30 | 20.9 | 11520 | 45 | 33 |
| 19.50 | >100 | Brownish Grey Silty / Clayey Sand (SC) | 60 | 22.0 | 21120 | 90 | 40 |
| 21.00 | >100 | Greyish Brown Weathered Sediments (Grade VI) | 100 | 22.0 | 43000 | 0 | 44 |
| 22.00 | >100 | Brownish Grey Weathered Gneiss (Grade V) | 200 | 23.1 | 197500 | 0 | 45 |
| 23.50 | >100 | Brownish Grey Weathered Gneiss (Grade V) | 200 | 23.3 | 197500 | 0 | 45 |

Variation of SPT 'N' Value with respect to Depth



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

## 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;

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

$N_\gamma$ and $N_q$ = bearing capacity factors depending upon the angle of internal friction, $\phi$ at pile tip;

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

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

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

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

$\delta_i$ = angle of wall friction between pile and soil for the $i$th layer; and

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

NOTES

**1** $N_\gamma$ 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 $\phi$ varying between 30° and 40°, $K_i$ values in the range of 1 to 1.5 may be used.

**4** $\delta$, 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;

$\alpha_i$ = adhesion factor for the $i$th layer depending on the consistency of soil, (*see* Note);

$c_i$ = average cohesion for the $i$th layer, in kN/m²; and

$A_{si}$ = surface area of pile shaft in the $i$th 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. (1) | Type of Soil (2) | Local Side Friction, $f_s$ kN/m² (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.

0.6

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 2$D$ below the pile tip, in kN/m²;

$q_{c1}$ = minimum static cone resistance over the same 2$D$ 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 8$D$ above the pile tip, in kN/m²; and

$D$ = diameter of pile shaft.

NOTE — The value of adhesion factor, $\alpha_i$ 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. (1) | Type of Soil (2) | $q_c/N$ (3) |
|---|---|---|
| i) | Clay | 150-200 |
| ii) | Silts, sandy silts and slightly cohesive silt-sand mixtures | 200-250 |
| iii) | Clean fine to medium sand and slightly silty sand | 300-400 |
| iv) | Coarse sand and sands with little gravel | 500-600 |
| v) | Sandy gravel and gravel | 800-1 000 |

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

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

**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 , $kN/m^2$ |
| $\gamma$ | - | Unit weight of soil, $kN/m^3$ |
| D | - | Diameter of pile, m |
| $A_{si}$ | - | Surface Area of Pile at respective soil layers, $m^2$ |
| $\alpha_i$ | - | 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, $kN/m^2$ |
| $\Phi$ | - | Friction angle, degrees |
| $N_c$, $N_q$, $N_\gamma$ | - | 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;

$\alpha$ = 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 |

# Annexure - 3 (Determination of Pile Carrying Capacity as Per IS 2911:2010)

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

**Borehole Location** **BH 1**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Length of Pile (L), m | = | 25.00 | m | From Existing Borehole Level | | | |
| Angle of Internal Friction (φ) in Degrees | = | 45.00 | | | | | |
| Undraind cohesion value at PileTip ($c_p$), kN/m$^2$ | = | 0.00 | kN/m$^2$ | | | | |
| Submerged Unit Weight at PileTip ($\Upsilon_p$), kN/m$^2$ | = | 13.40 | kN/m$^2$ | | | | |
| Ground Water Table Depth (GWT), m | = | 0.00 | m | Submerged Condition | | | |
| Bearing Capacity Factor ($N_c$) | = | 9.00 | | | | | |
| Bearing Capacity Factor ($N_q$) | = | 350.00 | | Taken from Figure 1 of IS 2911:2010 Part 1 Sec.2 | | | |
| Bearing Capacity Factor ($N_\gamma$) | = | 271.75 | | | | | |
| Factor of Safety (FS) | = | 2.50 | | | | | |
| Diameter of Pile (D), mm | = | 450 | 500 | 600 | 700 | 900 | |
| Critical Depth of Pile (20 x D), m | = | 9 | 10 | 12 | 14 | 18 | |
| Effective overburden pressure at Pile Tip ($P_D$), kN/m$^2$ | = | 84.75 | 102.75 | 120.75 | 138.15 | 191.55 | |
| End Bearing Resisrtnce of Pile ($q_p$), kN/m$^2$ using 'c' and 'φ' | = | 30481.82 | 36872.85 | 43354.93 | 49627.00 | 68681.14 | |
| End Bearing Resisrtnce of Pile ($q_p$), kN/m$^2$ using 'N' values | = | 80000.00 | 80000.00 | 80000.00 | 80000.00 | 80000.00 | |
| 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 ($Q_p$), kN using 'c' and 'φ' values | = | 1590.43 | 1963.50 | 2827.43 | 3848.45 | 6361.73 | |
| Ultimate End Bearing Capacity of Pile ($Q_p$), kN using 'N' values | = | 1590.43 | 1963.50 | 2827.43 | 3848.45 | 6361.73 | |
| Safe End Bearing Capacity of Pile ($Q_p$), kN using 'c' and 'φ' values | = | 636.17 | 785.40 | 1130.97 | 1539.38 | 2544.69 | |
| Safe End Bearing Capacity of Pile ($Q_p$), kN using 'N' values | = | 636.17 | 785.40 | 1130.97 | 1539.38 | 2544.69 | |
| Ultimate Frictional Capacity of Pile ($Q_p$), kN using 'c' and 'φ' values | = | 1999.82 | 2222.02 | 2666.42 | 3110.83 | 3999.64 | |
| Ultimate Frictional Capacity of Pile ($Q_p$), kN using 'N' values | = | 1995.70 | 2217.44 | 2660.93 | 3104.42 | 3991.39 | |
| Negetive Skin Fricton of Pile ($Q_{nf}$), kN using 'c' and 'φ' values | = | 136.61 | 151.79 | 182.15 | 212.50 | 273.22 | |
| Negetive Skin Friction of Pile ($Q_{nf}$), kN using 'N' values | = | 169.65 | 188.50 | 226.19 | 263.89 | 339.29 | |
| Safe Frictional Capacity of Pile ($Q_p$), kN using 'c' and 'φ' values | = | 663.32 | 737.02 | 884.42 | 1031.83 | 1326.64 | |
| Safe Frictional Capacity of Pile ($Q_p$), kN using 'N' values | = | 628.63 | 698.48 | 838.18 | 977.87 | 1257.27 | |
| 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' ) | = | 1299 | 1522 | 2015 | 2571 | 3871 | |
| Safe Pile Carrying Capacity of Pile ($Q_{safe}$), kN ('N' values ) | = | 1265 | 1484 | 1969 | 2517 | 3802 | |
| **Recommended Safe Pile Carrying Capacity of Pile ($Q_{safe}$), kN** | **=** | **1282** | **1503** | **1992** | **2544** | **3837** | |
| **Safe Uplift Capacity of Pile ($Q_{up}$), kN using 'c' and 'φ' values** | **=** | **629** | **712** | **883** | **1065** | **1458** | |

# Annexure - 3 (Determination of Pile Carrying Capacity as Per IS 2911:2010)

| Depth (m) | Soil Description | $H_i$ (m) | 'c' kN/m$^2$ | 'φ' | 'ϒ' kN/m$^3$ | '$ϒ_{sub}$' kN/m$^3$ | $P_{Di}$ (kN/m$^2$) | '$α_i$' | '$K_i$' | N' Value |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.00 | Brown Silty Sand (SM-SP) | 1.00 | 0 | 25 | 16.50 | 6.50 | 6.50 | 0.00 | 1.00 | 9 |
| 2.00 | Brown Silty Clay (CH) | 1.00 | 56 | 0 | 16.50 | 6.50 | 13.00 | 0.65 | 1.00 | 9 |
| 3.00 | Brown Silty Clay (CH) | 1.00 | 88 | 0 | 18.00 | 8.00 | 20.25 | 0.65 | 1.00 | 14 |
| 4.00 | Greyish Silty Sand (SM-SP) | 1.00 | 0 | 32 | 19.50 | 9.50 | 29.00 | 0.00 | 1.00 | 21 |
| 5.00 | Blackish Grey Silty Sand (SM-SP) | 1.00 | 0 | 30 | 22.00 | 12.00 | 39.75 | 0.00 | 1.00 | 16 |
| 6.00 | Blackish Grey Silty Sand (SM-SP) | 1.50 | 0 | 29 | 18.20 | 8.20 | 51.90 | 0.00 | 1.00 | 15 |
| 7.50 | Brown Sand (SP) | 1.50 | 0 | 41 | 21.80 | 11.80 | 66.90 | 0.00 | 1.00 | 38 |
| 9.00 | Greyish Brown Sand (SP) | 1.50 | 0 | 42 | 22.00 | 12.00 | 84.75 | 0.00 | 1.00 | 51 |
| 10.50 | Greyish Brown Sand (SP) | 1.50 | 0 | 42 | 22.00 | 12.00 | 102.75 | 0.00 | 1.00 | 60 |
| 12.00 | Brown Sand (SP) | 1.50 | 0 | 42 | 22.00 | 12.00 | 120.75 | 0.00 | 1.00 | 60 |
| 13.50 | Brown Sand (SP) | 1.50 | 0 | 38 | 21.20 | 11.20 | 138.15 | 0.00 | 1.00 | 33 |
| 15.00 | Greyish Silty Clay (CH) | 1.50 | 75 | 0 | 22.00 | 12.00 | 155.55 | 0.65 | 1.00 | 12 |
| 16.50 | Greyish Brown Sand (SP) | 1.50 | 0 | 35 | 22.00 | 12.00 | 173.55 | 0.00 | 1.00 | 24 |
| 18.00 | Brownish Grey Silty Sand (SM-SP) | 1.50 | 0 | 41 | 22.00 | 12.00 | 191.55 | 0.00 | 1.00 | 60 |
| 19.50 | Greyish Brown Weathered Sediments (Grade VI) | 1.50 | 0 | 44 | 22.00 | 12.00 | 209.55 | 0.00 | 1.00 | 100 |
| 21.00 | Greyish Brown Weathered Sediments (Grade VI) | 1.50 | 0 | 44 | 22.00 | 12.00 | 227.55 | 0.00 | 1.00 | 100 |
| 22.50 | Greyish Brown Weathered Sediments (Grade VI) | 1.50 | 0 | 44 | 22.00 | 12.00 | 245.55 | 0.00 | 1.00 | 100 |
| 24.00 | Greyish Brown Weathered Sediments (Grade VI) | 1.00 | 0 | 44 | 22.00 | 12.00 | 260.55 | 0.00 | 1.00 | 100 |
| 25.00 | Brownish Grey Weathered Gneiss (Grade V) | 1.50 | 0 | 45 | 23.20 | 13.20 | 276.45 | 0.00 | 1.00 | 200 |
| 26.50 | Brownish Grey Weathered Gneiss (Grade V) | 1.50 | 0 | 45 | 23.40 | 13.40 | 296.40 | 0.00 | 1.00 | 200 |
| 28.00 | Brownish Grey Weathered Gneiss (Grade V) | 2.00 | 0 | 45 | 23.20 | 13.20 | 319.65 | 0.00 | 1.00 | 200 |

# Annexure - 3 (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 (SM-SP) | 3.03 | 4.28 | 4.76 | 5.71 | 6.67 | 8.57 | 15.00 | 21.21 | 23.56 | 28.27 | 32.99 | 42.41 |
| 2.00 | Brown Silty Clay (CH) | 36.40 | 51.46 | 57.18 | 68.61 | 80.05 | 102.92 | 45.00 | 63.62 | 70.69 | 84.82 | 98.96 | 127.23 |
| 3.00 | Brown Silty Clay (CH) | 57.20 | 80.86 | 89.85 | 107.82 | 125.79 | 161.73 | 70.00 | 84.82 | 94.25 | 113.10 | 131.95 | 169.65 |
| 4.00 | Greyish Silty Sand (SM-SP) | 18.12 | 25.62 | 28.46 | 34.16 | 39.85 | 51.24 | 35.00 | 49.48 | 54.98 | 65.97 | 76.97 | 98.96 |
| 5.00 | Blackish Grey Silty Sand (SM-SP) | 22.95 | 32.44 | 36.05 | 43.26 | 50.47 | 64.89 | 26.67 | 37.70 | 41.89 | 50.27 | 58.64 | 75.40 |
| 6.00 | Blackish Grey Silty Sand (SM-SP) | 28.77 | 61.01 | 67.78 | 81.34 | 94.90 | 122.01 | 25.00 | 53.01 | 58.90 | 70.69 | 82.47 | 106.03 |
| 7.50 | Brown Sand (SP) | 58.16 | 123.32 | 137.03 | 164.43 | 191.84 | 246.65 | 63.33 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 |
| 9.00 | Greyish Brown Sand (SP) | 76.31 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 | 85.00 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 |
| 10.50 | Greyish Brown Sand (SP) | 92.52 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 | 100.00 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 |
| 12.00 | Brown Sand (SP) | 108.72 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 | 100.00 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 |
| 13.50 | Brown Sand (SP) | 107.93 | 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 Clay (CH) | 48.75 | 103.38 | 114.86 | 137.84 | 160.81 | 206.76 | 60.00 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 |
| 16.50 | Greyish Brown Sand (SP) | 121.52 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 | 40.00 | 84.82 | 94.25 | 113.10 | 131.95 | 169.65 |
| 18.00 | Brownish Grey Silty Sand (SM-SP) | 166.51 | 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 Weathered Sediments (Grade VI) | 202.36 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 | 166.67 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 |
| 21.00 | Greyish Brown Weathered Sediments (Grade VI) | 219.74 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 | 166.67 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 |
| 22.50 | Greyish Brown Weathered Sediments (Grade VI) | 237.12 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 | 166.67 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 |
| 24.00 | Greyish Brown Weathered Sediments (Grade VI) | 251.61 | 84.82 | 94.25 | 113.10 | 131.95 | 169.65 | 166.67 | 84.82 | 94.25 | 113.10 | 131.95 | 169.65 |
| 25.00 | Brownish Grey Weathered Gneiss (Grade V) | 276.45 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 | 333.33 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 |
| 26.50 | Brownish Grey Weathered Gneiss (Grade V) | 296.40 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 | 333.33 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 |
| 28.00 | Brownish Grey Weathered Gneiss (Grade V) | 319.65 | 169.65 | 188.50 | 226.19 | 263.89 | 339.29 | 333.33 | 169.65 | 188.50 | 226.19 | 263.89 | 339.29 |

# Annexure - 3 (Determination of Pile Carrying Capacity as Per IS 2911:2010)

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

**Borehole Location** **BH 2**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Length of Pile (L), m | = | 22.00 | m | From Existing Borehole Level | | | |
| Angle of Internal Friction (φ) in Degrees | = | 45.00 | | | | | |
| Undraind cohesion value at PileTip ($c_p$), kN/m$^2$ | = | 0.00 | kN/m$^2$ | | | | |
| Submerged Unit Weight at PileTip ($\Upsilon_p$), kN/m$^2$ | = | 13.40 | kN/m$^2$ | | | | |
| Ground Water Table Depth (GWT), m | = | 0.00 | m | Submerged Condition | | | |
| Bearing Capacity Factor ($N_c$) | = | 9.00 | | | | | |
| Bearing Capacity Factor ($N_q$) | = | 350.00 | | Taken from Figure 1 of IS 2911:2010 Part 1 Sec.2 | | | |
| Bearing Capacity Factor ($N_\gamma$) | = | 271.75 | | | | | |
| Factor of Safety (FS) | = | 2.50 | | | | | |
| Diameter of Pile (D), mm | = | 450 | 500 | 600 | 700 | 900 | |
| Critical Depth of Pile (20 x D), m | = | 9 | 10 | 12 | 14 | 18 | |
| Effective overburden pressure at Pile Tip ($P_D$), kN/m$^2$ | = | 114.85 | 132.85 | 150.85 | 168.70 | 217.90 | |
| End Bearing Resisrtnce of Pile ($q_p$), kN/m$^2$ using 'c' and 'φ' | = | 41016.82 | 47407.85 | 53889.93 | 60319.50 | 77903.64 | |
| End Bearing Resisrtnce of Pile ($q_p$), kN/m$^2$ using 'N' values | = | 80000.00 | 80000.00 | 80000.00 | 80000.00 | 80000.00 | |
| 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 ($Q_p$), kN using 'c' and 'φ' values | = | 1590.43 | 1963.50 | 2827.43 | 3848.45 | 6361.73 | |
| Ultimate End Bearing Capacity of Pile ($Q_p$), kN using 'N' values | = | 1590.43 | 1963.50 | 2827.43 | 3848.45 | 6361.73 | |
| Safe End Bearing Capacity of Pile ($Q_p$), kN using 'c' and 'φ' values | = | 636.17 | 785.40 | 1130.97 | 1539.38 | 2544.69 | |
| Safe End Bearing Capacity of Pile ($Q_p$), kN using 'N' values | = | 636.17 | 785.40 | 1130.97 | 1539.38 | 2544.69 | |
| Ultimate Frictional Capacity of Pile ($Q_p$), kN using 'c' and 'φ' values | = | 1440.06 | 1600.07 | 1920.08 | 2240.09 | 2880.12 | |
| Ultimate Frictional Capacity of Pile ($Q_p$), kN using 'N' values | = | 1562.16 | 1735.73 | 2082.88 | 2430.02 | 3124.31 | |
| Negetive Skin Fricton of Pile ($Q_{nf}$), kN using 'c' and 'φ' values | = | 99.78 | 110.86 | 133.04 | 155.21 | 199.55 | |
| Negetive Skin Friction of Pile ($Q_{nf}$), kN using 'N' values | = | 190.85 | 212.06 | 254.47 | 296.88 | 381.70 | |
| Safe Frictional Capacity of Pile ($Q_p$), kN using 'c' and 'φ' values | = | 476.25 | 529.16 | 635.00 | 740.83 | 952.49 | |
| Safe Frictional Capacity of Pile ($Q_p$), kN using 'N' values | = | 434.01 | 482.23 | 578.68 | 675.13 | 868.02 | |
| Self Weight of Pile (W), kN | = | 87.47 | 107.99 | 155.51 | 211.66 | 349.89 | |
| Safe Pile Carrying Capacity of Pile ($Q_{safe}$), kN ('c' and 'φ' ) | = | 1112 | 1315 | 1766 | 2280 | 3497 | |
| Safe Pile Carrying Capacity of Pile ($Q_{safe}$), kN ('N' values ) | = | 1070 | 1268 | 1710 | 2215 | 3413 | |
| **Recommended Safe Pile Carrying Capacity of Pile ($Q_{safe}$), kN** | **=** | **1091** | **1291** | **1738** | **2247** | **3455** | |
| **Safe Uplift Capacity of Pile ($Q_{up}$), kN using 'c' and 'φ' values** | **=** | **468** | **530** | **662** | **803** | **1110** | |

# Annexure - 3 (Determination of Pile Carrying Capacity as Per IS 2911:2010)

| Depth (m) | Soil Description | $H_i$ (m) | 'c' kN/$m^2$ | 'φ' | 'ϒ' kN/$m^3$ | '$ϒ_{sub}$' kN/$m^3$ | $P_{Di}$ (kN/$m^2$) | '$α_i$' | '$K_i$' | N' Value |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.00 | Brown Silty Sand (SM-SP) | 1.00 | 0 | 27 | 17.50 | 7.50 | 7.50 | 0.00 | 1.00 | 12 |
| 2.00 | Greyish Brown Silty Clay (CH) | 1.00 | 50 | 0 | 16.10 | 6.10 | 12.20 | 0.65 | 1.00 | 8 |
| 3.00 | Greyish Brown Silty Clay (CH) | 1.00 | 56 | 0 | 16.50 | 6.50 | 19.50 | 0.65 | 1.00 | 9 |
| 4.00 | Greyish Brown Silty Sand (SM-SP) | 1.00 | 0 | 28 | 17.70 | 7.70 | 26.60 | 0.00 | 1.00 | 13 |
| 5.00 | Greyish Brown Sand (SP) | 1.00 | 0 | 30 | 18.50 | 8.50 | 34.70 | 0.00 | 1.00 | 16 |
| 6.00 | Greyish Brown Sand (SP) | 1.50 | 0 | 34 | 20.00 | 10.00 | 46.45 | 0.00 | 1.00 | 24 |
| 7.50 | Greyish Brown Sand (SP) | 1.50 | 0 | 36 | 20.60 | 10.60 | 61.90 | 0.00 | 1.00 | 28 |
| 9.00 | Brown Sand (SP) | 1.50 | 0 | 42 | 22.00 | 12.00 | 78.85 | 0.00 | 1.00 | 56 |
| 10.50 | Brown Sand (SP) | 1.50 | 0 | 42 | 22.00 | 12.00 | 96.85 | 0.00 | 1.00 | 60 |
| 12.00 | Brown Sand (SP) | 1.50 | 0 | 42 | 22.00 | 12.00 | 114.85 | 0.00 | 1.00 | 60 |
| 13.50 | Greyish Brown Sand (SP) | 1.50 | 0 | 42 | 22.00 | 12.00 | 132.85 | 0.00 | 1.00 | 60 |
| 15.00 | Brown Sand (SP) | 1.50 | 0 | 42 | 22.00 | 12.00 | 150.85 | 0.00 | 1.00 | 60 |
| 16.50 | Brownish Grey Silty / Clayey Sand (SC) | 1.50 | 57 | 37 | 21.80 | 11.80 | 168.70 | 0.30 | 1.00 | 38 |
| 18.00 | Greyish Silty / Clayey Sand (SC) | 1.50 | 45 | 33 | 20.90 | 10.90 | 185.73 | 0.30 | 1.00 | 30 |
| 19.50 | Brownish Grey Silty / Clayey Sand (SC) | 1.50 | 90 | 40 | 22.00 | 12.00 | 202.90 | 0.30 | 1.00 | 60 |
| 21.00 | Greyish Brown Weathered Sediments (Grade VI) | 1.00 | 0 | 44 | 22.00 | 12.00 | 217.90 | 0.00 | 1.00 | 100 |
| 22.00 | Brownish Grey Weathered Gneiss (Grade V) | 1.50 | 0 | 45 | 23.10 | 13.10 | 233.73 | 0.00 | 1.00 | 200 |
| 23.50 | Brownish Grey Weathered Gneiss (Grade V) | 1.50 | 0 | 45 | 23.30 | 13.30 | 253.53 | 0.00 | 1.00 | 200 |

# Annexure - 3 (Determination of Pile Carrying Capacity as Per IS 2911:2010)

| | | Ultimate Frictional Capacity, kN using 'c' and 'φ' values | | | | | | Ultimate Frictional Capacity, kN using 'N' values | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Depth (m)** | **Soil Description** | **$q_s$ (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 (SM-SP) | 3.82 | 5.40 | 6.00 | 7.20 | 8.40 | 10.80 | 20.00 | 28.27 | 31.42 | 37.70 | 43.98 | 56.55 |
| 2.00 | Greyish Brown Silty Clay (CH) | 32.50 | 45.95 | 51.05 | 61.26 | 71.47 | 91.89 | 13.33 | 18.85 | 20.94 | 25.13 | 29.32 | 37.70 |
| 3.00 | Greyish Brown Silty Clay (CH) | 36.40 | 51.46 | 57.18 | 68.61 | 80.05 | 102.92 | 15.00 | 21.21 | 23.56 | 28.27 | 32.99 | 42.41 |
| 4.00 | Greyish Brown Silty Sand (SM-SP) | 14.14 | 19.99 | 22.22 | 26.66 | 31.10 | 39.99 | 65.00 | 84.82 | 94.25 | 113.10 | 131.95 | 169.65 |
| 5.00 | Greyish Brown Sand (SP) | 20.03 | 28.32 | 31.47 | 37.76 | 44.06 | 56.64 | 80.00 | 84.82 | 94.25 | 113.10 | 131.95 | 169.65 |
| 6.00 | Greyish Brown Sand (SP) | 31.33 | 66.44 | 73.82 | 88.59 | 103.35 | 132.88 | 40.00 | 84.82 | 94.25 | 113.10 | 131.95 | 169.65 |
| 7.50 | Greyish Brown Sand (SP) | 44.97 | 95.37 | 105.97 | 127.16 | 148.35 | 190.74 | 46.67 | 98.96 | 109.96 | 131.95 | 153.94 | 197.92 |
| 9.00 | Brown Sand (SP) | 71.00 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 | 93.33 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 |
| 10.50 | Brown Sand (SP) | 87.20 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 | 100.00 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 |
| 12.00 | Brown Sand (SP) | 103.41 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 | 100.00 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 |
| 13.50 | Greyish Brown Sand (SP) | 119.62 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 | 100.00 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 |
| 15.00 | Brown Sand (SP) | 135.83 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 | 100.00 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 |
| 16.50 | Brownish Grey Silty / Clayey Sand (SC) | 144.22 | 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 Silty / Clayey Sand (SC) | 134.11 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 | 50.00 | 106.03 | 117.81 | 141.37 | 164.93 | 212.06 |
| 19.50 | Brownish Grey Silty / Clayey Sand (SC) | 197.25 | 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 Weathered Sediments (Grade VI) | 210.42 | 84.82 | 94.25 | 113.10 | 131.95 | 169.65 | 166.67 | 84.82 | 94.25 | 113.10 | 131.95 | 169.65 |
| 22.00 | Brownish Grey Weathered Gneiss (Grade V) | 233.73 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 | 333.33 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 |
| 23.50 | Brownish Grey Weathered Gneiss (Grade V) | 253.53 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 | 333.33 | 127.23 | 141.37 | 169.65 | 197.92 | 254.47 |

# Annexure - 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** | = | **25.00** | **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 ($n_h$) | = | 2700.00 | $kN/m^3$ | **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) | = | 1.83 | 1.99 | 2.30 | 2.60 | 3.18 | |
| 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 | = | 3.47 | 3.78 | 4.37 | 4.95 | 6.05 | |
| 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** | = | **79.20** | **93.30** | **125.30** | **159.70** | **239.00** | |

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Building plan approvals, construction, layout and sub-division approvals, zone conversion, and occupancy certification.

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