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REPORT ON

GEOTECHNICAL INVESTIGATION FOR CONSTRUCTION OF TNSCB MULTI-STOREYED TENEMENTS AT KARGIL NAGAR LAND, THIRUVOTTIYUR, CHENNAI

CLIENT

THE EXECUTIVE ENGINEER,

RECONSTRUCTION NORTH DIVISION

TAMILNADU SLUM CLEARANCE BOARD (TNSCB), CHENNAI

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REPORT ON GEOTECHNICAL INVESTIGATION FOR CONSTRUCTION OFTNSCB MULTI-STOREYED TENEMENTSAT KARGIL NAGAR LAND, THIRUVOTTIYUR, CHENNAI

22/01/2018

1. INTRODUCTION

On a request from the Executive Engineer, Reconstruction North Division, Tamil Nadu Slum Clearance Board (TNSCB), Chennai, the Department of Civil Engineering, Indian Institute of Technology Madras undertook the consultancy for geotechnical Investigation to evaluate the soil properties and to recommend suitable foundations for the construction of multi-storeyed tenement buildings at TS No.1/1, 3/1, Block No: 8, Thiruvottiyurin Corpn. Divn.7, Zone I, GCC ,Chennai.

The field investigation consisting of drilling of boreholes, standard Penetration tests, collection of soil samples and ground water table observation. Thecomplete logging of borehole at the site was carried out from 28thSeptember2017to 29thDecember 2017by Sarathy Geotech& Engineering Services Pvt Ltd, Chennai under the guidance of undersigned in the presence of Engineers from Tamil Nadu Slum Clearance Board. In addition, advanced Multi channel Analysis of Surface Waves (MASW) tests were carried out by IIT Madras. This report presents the details of the site characterization based on the field and laboratory investigations, evaluation of design soil parameters, recommendations on capacity of soil strata and type of foundations to be adopted for the above buildings.

2. FIELD INVESTIGATIONS

2.1 Drilling of Boreholes and SPT Test

The investigation program comprises of sinking six exploratory boreholes at the locations shown in the Figure 1. These boreholes were advanced up to a maximum

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depth of about 40 m below the ground level.

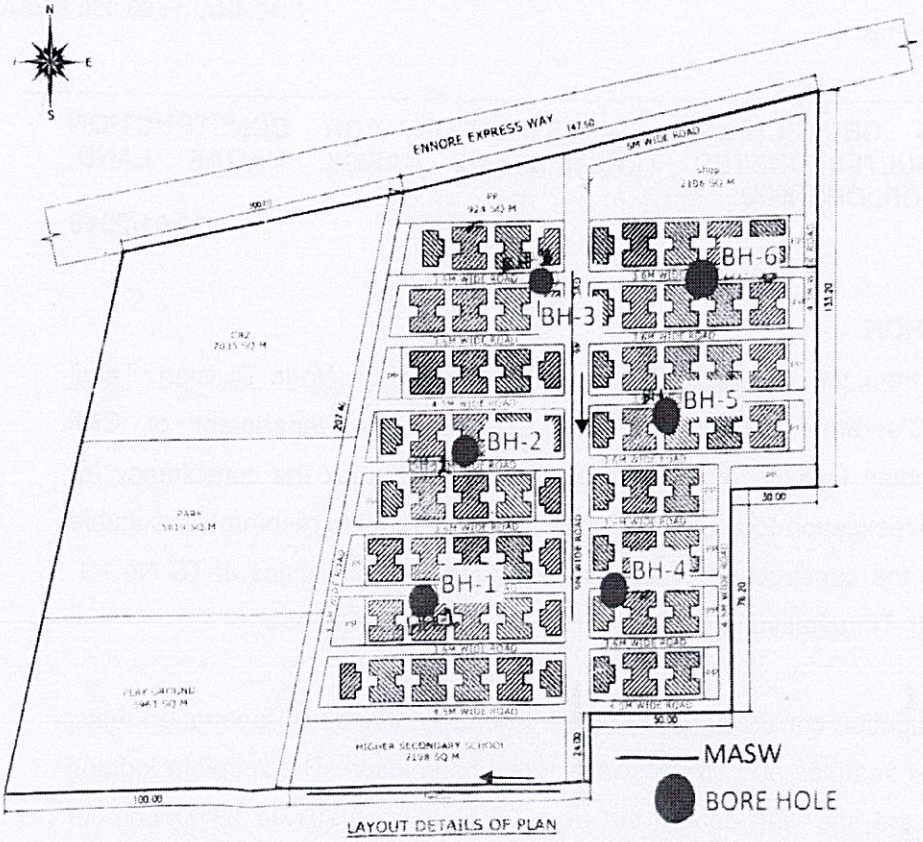


Figure 1: Site plan showing location of boreholes and MASW stretches

Exploratory boreholes were advanced from the existing ground level using rotary drilling technique supplemented by bentonite mud circulation. Mud circulation was used to stabilise the sides and the bottom of the boreholes, and then to bring the soil cuts to the surface. Use of drilling mud will also help in preventing the disturbance to the soil at the borehole bottom during drilling operations.

Standard Penetration Tests were conducted at regular depth intervals in the boreholes and N values were recorded. The samples collected through the SPT sampler were packed in two layers of polythene bags to retain the natural moisture content. These samples were subjected to natural moisture content determination on the next day. Different soil layers collected from different levels were identified and classified.

The borelogs of all boreholes are shown in **Annexure 1.** Field N values at different depths, the depth and thickness of different soil layers are presented in these bore logs.

2.2 MASW Test

The advanced Multi channel Analysis of Surface Waves (MASW) tests have been carried out at the site to establish the continuous soil profile and also to confirm the soil profile obtained from the borehole data. MASW test was conducted at three stretches as shown in Figure 1. The arrow mark on the layout shows the test direction.

MASW test is a non-destructive and non-invasive method of investigation. The method is based on the generation of surface wave (R-wave) using a near-surface impulsive energy which propagates through the soil media and is refracted/reflected along stratigraphic boundaries.

Principle

Seismic methods make use of the variation in elastic properties of the strata which affect the velocity of shock/seismic waves travelling through them, thus providing dynamic elastic moduli determinations in addition to mapping of the subsurface horizons. The required shock waves are generated within the subsurface materials, at the ground surface or at a certain depth below it, by striking a plate on the soil/rock with a hammer by detonating a small charge of explosives in the soil/rock.

A series of receivers, usually geophones, are placed in a linear array. An impulse energy source, which can be mechanical or explosive, is located at or near the ground surface at some offset from the end geophone. The output of all of the receivers is recorded when the impulse load is triggered. This shot record is then processed using a Fast Fourier Transform after which, dispersion curves can be picked representing the fundamental Rayleigh waves. These dispersion curves are used in inversion analysis which provides 1D velocity profiles. Multiple 1D velocity profiles can be used to produce a 2D velocity profile of the survey line. A typical test setup is shown in **Figure 2.**

The common procedure for MASW surveys usually consists of three steps.

1. Data Acquisition: acquiring multichannel field records (commonly called shot gathers in conventional seismic exploration).

2. Dispersion Analysis: extracting dispersion curves (one from each record).

3. Inversion: back-calculating shear-wave velocity (Vs) variation with depth (called1D Vs profile) that gives theoretical dispersion curves closest to the extracted curves(one 1-D Vs profile from each curve).

The MASW tests at the site were carried out using a 24 channel Geode seismic recorder (Make: Geometrics, USA) as shown in **Figure 3**. The data acquisition was done by Seismodule Controller Software (SCS). The vertical geophones of 4.5 Hz (24Nos.) are used to receive the wave fields generated by the active source of 10 kg sledgehammer.

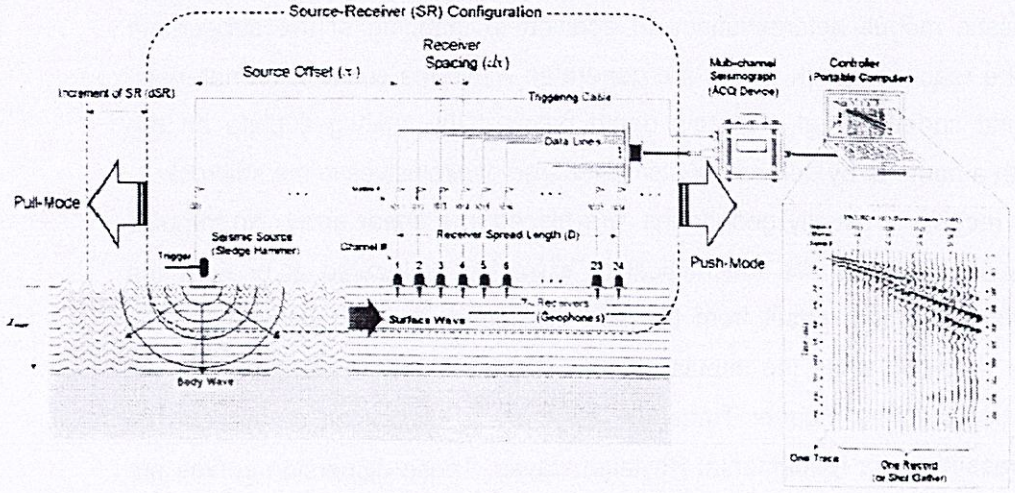


Figure 2. MASW Test Setup

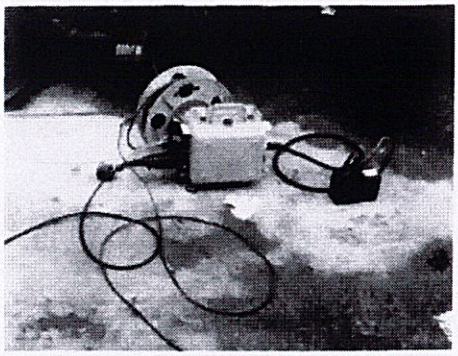


Figure 3. Geode Seismic Recorder

Field Survey Procedure

• Vertical geophones of 4.5 Hz were installed in straight line connected to 24channel seismograph through spread cable. **Figure 4** shows the MASW test arrangement. Geophone spacing of 1.5mwas adopted depending on the length of the survey.• Wave fields are generated by striking a sledge hammer of 10 kg on a base plate located at some offset from the 1st geophone.

• The data is acquired through seismodule controller software installed in a laptop.

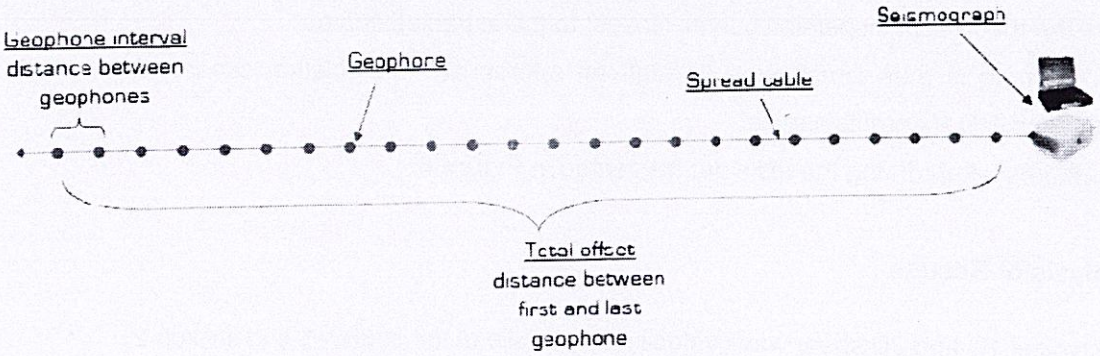


Figure 4. MASW Test Arrangement

• After one set of records is obtained from one shot the SR (source receiver)configuration is moved by a distance of 6d (d is the distance between successive geophones) as shown in **Figure 4**and the test is repeated for the required length of survey.

The acquired data was processed using the Surfseis software with pickwin WaveEq, and GeoPlot modules. The analysis involves the sequence of steps as shown in flow chart (**Figure 5**) and it is discussed below.

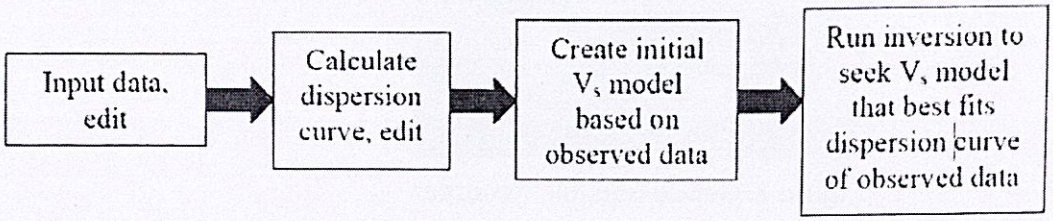


Figure 5.Flow Chart of MASW Analysis

Importing multichannel field record collected during data acquisition in Surfseis.

Dispersion Analysis: Extracting dispersion curves from each record for getting frequency Vs phase velocity plot. Initial shear wave velocity model is created in this step.

• Inversion: Back-calculation of shear-wave velocity (Vs) depth (1D Vs profile)which gives the theoretical dispersion curves closest to the extracted curves.

• A 2-D map is then constructed through an appropriate interpolation scheme by using each 1-D Vs profile curves.

The photos taken during the tests are presented in **Figure 6.**

Analysis of Results

The typical 1D and 2D shear wave velocity (Vs) profile of the stretch 1 and stretch 2 are shown in Figures (a) to (e) (**Annexure 3**).

The adopted geophone interval for all the stretches was 1.5m. The stretch 1 was carried out with five lines while stretch 2 were carried out with 3 lines. The second line of stretch 1 was carried out with the shift of 12 geophones while third to fifth were carried out with the shift of 15 geophones. Meanwhile, the second and third lines of the stretch 2 were carried out with the shift of 15 geophones. The number shows on all the 2D profiles are the location of the geophones in that particular stretch.

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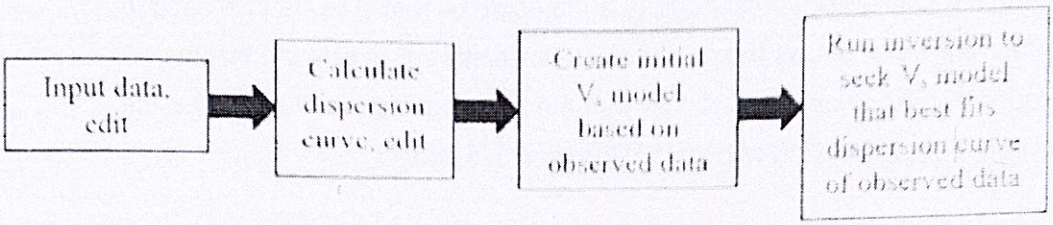


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The 1D and 2D profiles from stretch 1 show that the Vs increases with increase in the depth. The Vs observed from 1D profile varies from 50 to200m/s till 18m which shows that the soft/loose soil present up to a the depth of 15m. The Vs increased to 300m/s after 18m which shows the presence of dense/stiff soil. It is found that the 1D profile (Figure b in Annexure 5) matches with the bore log from BH #3. Further the 2D profile from stretch 1 match with the BH log from 6, 5 and 4.

The 1D and 2D profiles from stretch 2 show that the Vs decreases at about 5m then increases with increase in the depth till 25m. The decrease in Vs shows that the very soft/very loose later present about 5m which is consistent with the bore logs from BH #1, 4 and 5. After 5m, the Vs gradually increases from 75m/s to 240m/s till 18m. It shows the presence of soft/loose layer till 15m. Then the Vs increase to 400m/s at 18m which shows that the dense layer present beyond 18m. The MASW results are consistent with the bore logs from BH #1, 4 and 5.

3. LABORATORY INVESTIGATIONS

Grain size analyses on selected samples were conducted on oven dried samples since accurate dry weights of test specimen prior to washing through 75 micron sieve is necessary in this case. The Liquid limit of the soil is determined with the standard Casagrande liquid limit apparatus. Casagrande grooving tool is used for making groove in the soil sample. The water content corresponds to 25 blows in the flow curve is taken as the liquid limit of the soil. Air dried sample passing through IS sieve 425 micron is used for determining the liquid limit and plastic limit of the soil sample. About 15 g of soil sample is taken for plastic limit determination and is mixed with a sufficient quantity of water which would enable the soil mass to become plastic enough to be easily shaped into a ball.

Laboratory test results such as determination of natural moisture content, specific gravity, Atterberg limits, grain size analysis tests and direct shear test are presented in **Annexure 2**.

The chemical analysis was carried out on ground water samples collected from the boreholes. The results of chemical analysis of water samples are also presented in

Annexure 2. The results show that the chloride and the sulphate content in the ground water are within the permissible limits.

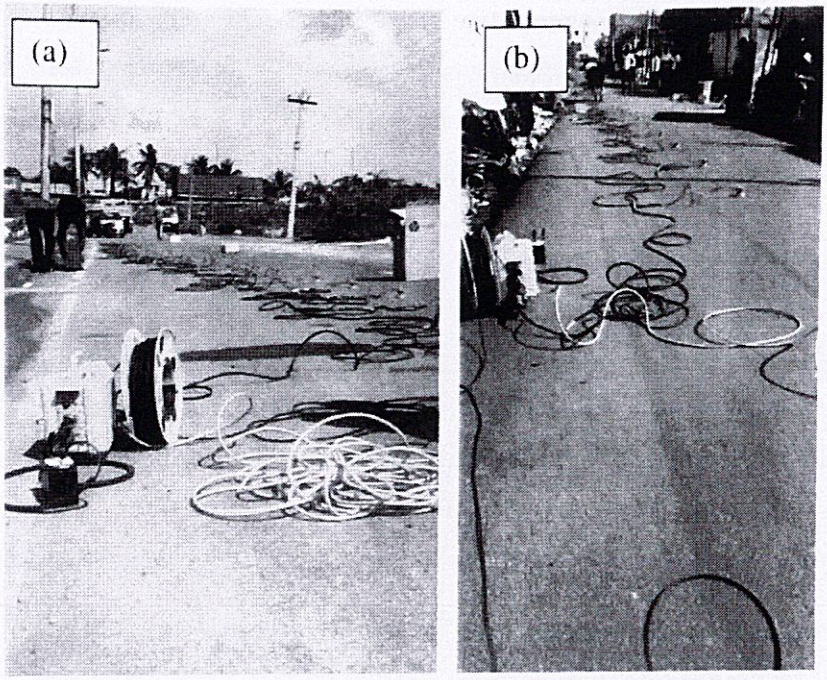


Figure 6: Test in progress images (a) stretch 1 and (b) stretch 2

4. SITE CHARACTERIZATION

4.1. Site Topography and Soil Profile

Bore Hole 1

In BH# 1 the top layer of 3m thick is found to be medium dense sand with SPT N of about 12 is observed. It is followed by a very soft clay layer with SPT N of about 2 up to a depth of 10.5m. Below clayey layer, a sand layer is extended up to 21m with the density varying from loose to medium dense. After that, a clay layer is observed up to 25.5m with stiff to firm consistency. It is followed by medium to dense sandy layer up to the depth of 36m.

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Bore Hole 2

Loose sand layer up to 3m from ground level is observed in BH# 2 with SPT N of about 7. It is followed by a clay layer of very soft to firm consistency with SPT N 2 to 6 up to a depth of about 15m.Thenabout 7.5m thick sandy layer with loose to medium density occurs up to a depth of 22.5m.It is followed by a clay layer with stiff to firm consistency up to 27m. Then sandy layer with SPT N value in the range of 25 to 84 occurs up to a depth of 37.5m below the ground level.

Bore Hole 3

The clayey layer with soft to firm consistency is encountered up to 6m from the ground level. It is followed by loose sand layer with SPT less than 10 up to 15m. is extended up to the termination of bore hole i.e., 35m with SPT refusal. Medium dense to dense sand layer occurs between 15m to 31.5m.Then it is followed by very dense sandy layer with the SPT refusal occurs up to the depth of bore hole termination i.e., 35m.

Bore Hole 4

In BH# 4, 4.5m thick organic soil with soft consistency occurs from the ground level. Then a very loose sand layer 1.5m thick extended up to 6m. It is followed by a thick clayey layer up to a depth of 21m.The clay is found to be soft consistency is up to a depth of 15m with SPT N of about 4 and stiff to firm consistency up to 21m. Within in the clayey layer a medium dense sandy layer occurs between 10.5 to 13.5m. Then medium dense to very dense sandy layer occurs up to a depth of 34.5m.The bore hole is terminated at a depth of 36m where SPT refusal occurs.

Bore Hole 5

In BH# 5, very soft clay and very loose sandy layers occurs up to a depth of 15m from ground. Then there is a medium dense sandy layers encountered up to a depth of 36m with SPT N value ranging from 10 to 32. It is followed by a weathered rock up to a depth of borehole termination i.e., 40m.

Bore Hole 6

In BH# 6, the top surface layer up to a depth of 3m consists of soft clay. Then it is

followed by a loose to medium dense sandy layer up to a depth of 7.5m. Then 6m thick stiff to firm clayey layer encountered up to a depth of 13.5m. Then there is a medium dense to dense sandy layer is found to occur up to a depth of 33m with SPT N value ranging from 12 to 49. It is followed by a weathered rock up to a depth of bore hole termination i.e., 35m.

In general, the soil layer at the site up to a depth of about 15m is found to be very soft to soft clay and very loose to loose sandy layer. The weathered rock stratum encountered at a depth of 33 to 36m in BH# 6 and BH# 5. In the remaining bore holes, dense to very dense sand layer occurs at the bore hole termination depth (33 to 36m).

4.2. Groundwater Table

The ground water table was observed to be at the ground level. Hence, for the foundation analysis, the ground water table level is considered at the ground level.

4.3. Shear strength

Standard Penetration Test blow counts N is measured at different levels in the borehole. Shear strength parameters for cohesionless soils were selected based on SPT results and grain size distribution analyses.

Conventional method of estimating the angle of shearing resistance ϕ corresponding to the corrected SPT N value reported. The N values are corrected for overburden and dilatancy as usual before arriving at the angle of friction. The friction angle of ϕ in the range of 28° to 36° is considered for loose to dense layers.

The shear strength of weathered rock is estimated as per Cole and Stroud recommendations. The shear strength of weathered rock is considered as 800 kPa.

The undrained cohesion values for the clay layers encountered were found using the field SPT value.

5.0. BEARING CAPACITY ESTIMATION

5.1. Type of foundation

It is proposed to construct multi-storyed buildings without basement at the site. In general, the soil layer at the site up to a depth of about 15m is found to be very soft to soft clay and very loose to loose sandy layer. Hence, it is not recommended to adopt shallow foundations such as isolated or raft footing. In addition, the depth of hard strata or SPT refusals varies for every bore holes. In the present situation, ground improvement techniques such as stone column treatment may not be effective considering the requirement of deeper depth of improvement. In view of that and also considering the factor that the dense sand/weathered rock stratum occurs at the depth of about 36m, the pile foundations are recommended for the proposed buildings. In view of the heterogeneity of the soil profiles found at the site the pile capacities are calculated for each bore holes.

5.2. Deep Foundation-Bored cast in-situ piles

The soil stratification shows that the dense/firm clay layers occurs below 16m and extends up to a bore hole termination depth of about 36m. Hence, the load of the structure can be transferred to deeper depths bypassing the upper layers using a pile foundation. Also, for present site condition, bored cast in situ piles are recommended.

5.2.1. Compression and uplift capacity of the piles

The end bearing capacity of the bored cast insitu pile is calculated by the formula given in IS: 2911(Part I/ Sec 2) – 2010.

$$Q_b = A_p (0.5D\gamma N_\gamma + P_D N_q)$$

Where,

D = Stem diameter in m.

A_p = Cross sectional area of pile toe in m^2

γ = Effective unit weight of soil at pile toe in kN/m^2,

N_γ and N_q =Bearing capacity factors depending upon the angle of internal friction at toe

P_D =Effective overburden pressure at pile toe in kN/m^2

The frictional resistance of the cohesionless soil is calculated using the formula given below,

$$Q_{f1} = \Sigma_i^n K P_{Di} \tan\delta A_{si}$$

Where,

K = Coefficient of earth pressure,

P_{Di} = Effective overburden pressure in kN/m^2 for the i^{th} layer where i varies from 1 to n.

δ = Angle of wall friction between pile and soil,

A_{si}= Surface area of pile stem in m^2 in the i^{th} layer where i varies from 1 to n.

The frictional resistance of the cohesive soil is calculated using,

$$Q_{f2} = \alpha C A_s$$

Where,

α = Reduction factor

C = Average cohesion throughout the length of pile in kN/m^2

A_s= Surface area of pile stem in m^2

Negative skin friction is considered whenever very soft clay and very loose sand deposits are present. The parameters used to estimate the bearing capacity of pile were considered based on the corrected SPT N values. Factor of safety of 2.5 is used in the estimation of safe bearing capacity of the piles. However, factor of safety is not used against the negative skin friction for the estimation of safe load carrying capacity of the pile.

The uplift capacity of the pile is calculated with a factor of safety of 4against the positive skin friction. For compression capacity of pile is also considered from only positive side friction. The safe compression and uplift capacity is estimated for entire boreholes and the details are presented in **Appendix A.**

The bearing stratum for the piles is considered as dense layer or weathered rock. The pile capacity is calculated assuming the pile penetrates into the dense layer or weathered rocklayer. The calculated safe compression and uplift capacities of piles for the buildings near the BH# 1 to 6are given in **Tables 1 and 6.**

5.2.2. Lateral Load Capacity of the piles

The safe lateral capacity of piles is governed by the shear strength and modulus of the soil below the pile cut-off level. Generally, soil for a depth of five to seven times the pile diameter influences the resistance to lateral loading. Thus, the safe lateral capacity of piles will depend on the soil present at shallow depth. The safe lateral capacity of pile is estimated restricting the pile head deflection at the cut-off level embedded in soil as 5mm. The equivalent cantilever procedure suggested in IS 2911 (Latest revision) is used for estimating the safe lateral capacity corresponding to 5mm deflection at the pile head.

The safe Lateral Load carrying capacity of piles is calculated using the formula given below (IS 2911 (part I/ sec2):2010).

$$Q = \frac{3\,E\,I\,Y}{(L_1+L_F)^3} \text{for free head pile}$$

$$Q = \frac{12\,E\,I\,Y}{(L_1+L_F)^3} \text{for fixed head pile}$$

Where,

Q is the Lateral load Capacity in kg

E = Young's Modulus of the pile material.

I = Moment of Inertia of the pile cross section.

Y = Permissible Deflection.

L_f = Length of fixity.

Typical estimation of safe lateral capacities corresponding to 5mm allowable deflection at the pile head is presented in **Appendix B.** The lateral load capacity of the pile is calculated and is summarized in **Table 1 to 6.**

Table 1: Safe compression and uplift capacity of piles (BH# 1)

Pile capacity			
Pile Diameter (mm)	500	600	750
Safe compression capacity, kN	1190	1530	2150
Safe uplift capacity, kN	1250	1510	1910
Safe lateral capacity (fixed head) (kN)	13.84	16.61	20.76
Depth of fixity for fixed head piles (m)	6.97	8.36	10.45
Safe lateral capacity (free head) (kN)	4.97	5.96	7.45
Depth of fixity for free head piles (m)	6.18	7.41	9.27

Table 2: Safe compression and uplift capacity of piles (BH# 2)

Pile capacity			
Pile Diameter (mm)	500	600	750
Safe compression capacity, kN	1000	1290	2170
Safe uplift capacity, kN	1070	1290	1650
Safe lateral capacity (fixed head) (kN)	40.44	54.13	77.36
Depth of fixity for fixed head piles (m)	4.87	5.64	6.74
Safe lateral capacity (free head) (kN)	14.52	19.43	27.77
Depth of fixity for free head piles (m)	4.32	5.00	5.97

Table 3: Safe compression and uplift capacity of piles (BH# 3)

Pile capacity			
Pile Diameter (mm)	500	600	750
Safe compression capacity, kN	1610	2220	3460
Safe uplift capacity, kN	1320	1600	2030
Safe lateral capacity (fixed head) (kN)	13.84	16.61	20.76
Depth of fixity for fixed head piles (m)	6.97	8.36	10.45
Safe lateral capacity (free head) (kN)	4.97	5.96	7.45
Depth of fixity for free head piles (m)	6.18	7.41	9.27

Table 4: Safe compression and uplift capacity of piles (BH# 4)

Pile capacity			
Pile Diameter (mm)	500	600	750
Safe compression capacity, kN	1420	1880	2750
Safe uplift capacity, kN	1040	1270	1610
Safe lateral capacity (fixed head) (kN)	13.84	16.61	20.76
Depth of fixity for fixed head piles (m)	6.97	8.36	10.45
Safe lateral capacity (free head) (kN)	4.97	5.96	7.45
Depth of fixity for free head piles (m)	6.18	7.41	9.27

Table 5: Safe compression and uplift capacity of piles (BH# 5)

Pile capacity			
Pile Diameter (mm)	500	600	750
Safe compression capacity, kN	1410	1810	2530
Safe uplift capacity, kN	960	1170	1490
Safe lateral capacity (fixed head) (kN)	40.44	54.13	77.36
Depth of fixity for fixed head piles (m)	4.87	5.64	6.74
Safe lateral capacity (free head) (kN)	14.52	19.43	27.77
Depth of fixity for free head piles (m)	4.32	5.00	5.97

Table 6: Safe compression and uplift capacity of piles (BH# 6)

Pile capacity			
Pile Diameter (mm)	500	600	750
Safe compression capacity, kN	2300	2970	4200
Safe uplift capacity, kN	1360	1650	2090
Safe lateral capacity (fixed head) (kN)	40.44	54.13	77.36
Depth of fixity for fixed head piles (m)	4.87	5.64	6.74
Safe lateral capacity (free head) (kN)	14.52	19.43	27.77
Depth of fixity for free head piles (m)	4.32	5.00	5.97

5.2.4. Pile termination Depth

It is found that at about 30 to 36m dense sand or weathered rock layer is encountered for BH# 1 to 6. Hence, it is recommended to terminate the pile at 30 to 36m below the existing ground level. However, the pile should be terminated only when the hard/dense layer with SPT refusal is encountered.

5.2.5. Boring of soil

DMC boring is preferred here as a significant component of friction capacity is considered in the estimation. It is essential to maintain the density and shear strength of the soil along the borehole sides. A continuous mud circulation using good quality bentonite can only ensure the stability of sides and preserve the in-situ shear strength. Rotary boring can be adopted only with proper arrangement for continuous mud circulation.

The soil just above the pile tip is very dense sand and chisel penetration rate within this layer shall not be used for deciding the pile termination levels. There can be a false recording of hard resistance to chiselling when the sand excavated by the chisel is not effectively removed as and when it is cut by the chisel. Poor quality of drilling mud will have very small capacity to carry the soil cuts along with the mud

leaving the soil cuts in place resulting false resistance to chiselling. Good quality drilling mud prepared in potable water and using good quality sodium based bentonite shall be used for boring purposes.

If the borehole is advanced with DMC chiselling procedure, the chisel energy within the bearing stratum is expected to be more than 200 t-m/m^2/cm when a star shaped chisel with sharp edges is used. If rotary drilling using rotary cutting procedure and direct mud circulation is adopted, the termination depth shall be judged by the penetration into very dense stratum and also the rate of penetration. It is possible to take up the piles very close to the borehole locations so that the rate of penetration and type of stratum can be correlated. Such correlation can be adopted for piles in other locations.

It is difficult to confirm the bearing stratum when hydraulically operated auger boring is adopted for advancing the borehole. The rock augers usually fail to penetrate more than 200mm into the weathered rock stratum with SPT refusal. The conical cutting edge in the case of rock auger reduces the effective cross section of the pile within the weathered rock formation. Few trials with conventional DMC chisel boring procedure side by side with the hydraulically operated machine may be helpful in deciding the termination levels.

6. SUMMARY AND RECOMMENDATIONS

It is proposed to construct multi-storeyed tenementsat Kargil Nagar land, Thiruvottiyur, Chennai. Hence, heavy loads on the columns are anticipated. A detailed subsoil investigation using six exploratory boreholes was carried out to access the subsoil profile. Dense sand with SPT refusal or weathered rock is found to occur at the depth of about 30m to 36m.

Recommendations

The load of structure can be transferred to much deeper depths by bypassing the top soil layers using bored cast-in-situ piles. All the piles shall be penetrated into the bearing stratum i.e., dense sandy layer with SPT refusal.

The safe compression, lateral and uplift capacities of piles with 500 to 700mm diameters are estimated.

EXECUTIVE ENGINEER
DIVISION-I, TNUHDB

The following recommendations can be suggested:

1. Recommended Type of Foundation — Bored Cast In-Situ Pile
2. Pile cutoff level — 1.0 to 1.5m below the existing GL
3. Type of soil at founding depth — Very dense sandy layer with the SPT refusal.
4. Recommended pile capacities by bore hole wise:

BH# 1			
Pile Diameter (mm)	500	600	750
Safe compression capacity, kN	1190	1530	2150
Safe uplift capacity, kN	1250	1510	1910
Safe lateral capacity (fixed head) (kN)	13.84	16.61	20.76
Safe lateral capacity (free head) (kN)	4.97	5.96	7.45
Pile termination depth (m)	35 to 36		

BH# 2			
Pile Diameter (mm)	500	600	750
Safe compression capacity, kN	1000	1290	2170
Safe uplift capacity, kN	1070	1290	1650
Safe lateral capacity (fixed head) (kN)	40.44	54.13	77.36
Safe lateral capacity (free head) (kN)	14.52	19.43	27.77
Pile termination depth (m)	35 to 36		

BH# 3			
Pile Diameter (mm)	500	600	750
Safe compression capacity, kN	1610	2220	3460
Safe uplift capacity, kN	1320	1600	2030
Safe lateral capacity (fixed head) (kN)	13.84	16.61	20.76
Safe lateral capacity (free head) (kN)	4.97	5.96	7.45
Pile termination depth (m)	32 to 33		

BH# 4			
Pile Diameter (mm)	500	600	750
Safe compression capacity, kN	1420	1880	2750
Safe uplift capacity, kN	1040	1270	1610
Safe lateral capacity (fixed head) (kN)	13.84	16.61	20.76
Safe lateral capacity (free head) (kN)	4.97	5.96	7.45
Pile termination depth (m)	32 to 33		

BH# 5			
Pile Diameter (mm)	500	600	750
Safe compression capacity, kN	1410	1810	2530
Safe uplift capacity, kN	960	1170	1490
Safe lateral capacity (fixed head) (kN)	40.44	54.13	77.36
Safe lateral capacity (free head) (kN)	14.52	19.43	27.77
Pile termination depth (m)	30 to 31		

BH# 6			
Pile Diameter (mm)	500	600	750
Safe compression capacity, kN	2300	2970	4200
Safe uplift capacity, kN	1360	1650	2090
Safe lateral capacity (fixed head) (kN)	40.44	54.13	77.36
Safe lateral capacity (free head) (kN)	14.52	19.43	27.77
Pile termination depth (m)	30 to 31		

5. The above recommended safe load carrying capacities of the piles shall be confirmed by carrying out load test on plies as per IS 2911-Part 4 (1985).

6. It is recommended to carry out pile integrity tests on working piles minimum 25 percent of the total number of piles in each block.

7. The site is located in low lying areas and hence it is highly recommended to raise the existing ground level by 1.5 to 2m and also to adopt the appropriate drainage systems to prevent the flooding of the site from rain water inundation.

8. It is recommended to provide at least a two or more piles per pile group using suitable pile diameter instead of single pile – single column by selecting appropriate pile diameter to provide better resistance to bending forces from the column loads. All the pile caps must be rigidly inter-connected with each other in both the directions.

9. Good quality of bentonite with a liquid limit of approx. 350 is recommended to be used as the drilling mud in boring operations. Proper cleaning of borehole bottom after lowering the reinforcement cage shall be strictly employed as quality control measures.

10. The results of chemical analysis carried out on the ground water samples show that the chloride and the sulphate content in the ground water are within the permissible limits as per IS 456:2000. Hence, the ground water present at the site can be used for construction purposes.

11. Proximity of the site to the coastal region requires considerations for reinforced concrete design for saline environments. IS 456:2000 suggests the nominal cover for reinforcement as per the exposure conditions given in clause 8.2.2.45mm is suggested for structures immersed in sea water or exposed to coastal environment (Clause 26.4.2). It is also recommended to use a corrosion resistant steel (CRS) or regular steel with anticorrosive epoxy coat or Cement Polymer Composite Coating, and slag or pozzolana cement instead of OPC, and other recommendations specified in Clause 8.2.8 of IS 456:2000 for the construction of substructures up to plinth level.

12. Portland Pozzolona cement or super slag cement shall be preferred in the construction of piles.

13. The recommended safe capacities of piles can be ensured only by adopting a quality construction procedure with good quality control.

7. ACKNOWLEDGEMENT

The guidance provided by Er. V. Subramanian, Superintending Engineer, TNSCB for planning the above investigation is greatly acknowledged. The support and cooperation provided during the execution of field investigation by Er. K. Ponn Rockfeller, Assistant Executive Engineer and Er. Ibrahim, Assistant Engineer of Reconstruction North Division of TNSCB, Chennai are greatly acknowledged

22/01/2018

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FINAL BORELOG

Depth (m)	Soil Profile	Sample No. & Type	Soil / Rock Description	Density kN/m³ ○ Dry Density ● Bulk Density (5 10 15 20)	Atterbergs limits WC % (20 40 60 80)	SPT Number of Blows (cm) (15 30)	N Value	Strength Parameters ▪ UCC for Rock (MPa) ▪ UCC for Rock derived from Point Load (MPa) (40 80 120 160)	Run (m) from	Run (m) to	Core Recovery (%)	RQD (%)	Remarks
1			Stiff Gray [10YR 5/1] Silty CLAY										
2		SPT-1				2 5 7	12						
3		SPT-2				2 3 5	8						
4		SPT-3	Very Loose to Loose Gray [10YR 5/1] SAND			1 1 1	2						
5		SPT-4											
6		SPT-5				1 1 1	2						
7		SPT-6	Very Soft Gray [10YR 5/1] SILT with Sand										
8		SPT-7			⊕	1 1 1	2						
9		SPT-8			✦ ✦	1 1 1	2						
10		SPT-9											
11		SPT-10	Loose to Medium Dense Gray [10YR 5/1] SAND			7 7 10	17						
12		SPT-11				4 3 3	6						
13		SPT-12				2 3 2	5						
14		SPT-13				3 4 3	7						
15		SPT-14				4 8 12	20						
16		SPT-15				15 9 7	16						
17		SPT-16				4 7 6	13						
18		SPT-17											
19		SPT-18											
20		SPT-19											
21		SPT-20	Stiff to Very Stiff Gray [10YR 5/1] Clayey SILT with Sand			2 4 3	7						
22		SPT-21				3 5 6	11						
23		SPT-22				4 6 11	17						
24		SPT-23				4 6 8	14	Cohesion(kPa)=17					
25		SPT-24											
26		SPT-25											
27		SPT-26			●	4 4 6	10						
28		SPT-27				5 6 7	13						
29		SPT-28											
30		SPT-29				9 8 10	18						
31		SPT-30	Medium Dense Gray [10YR 5/1] SAND			18 12 10	22						
32		SPT-31											
33		SPT-32				18 23 28	51						
34		SPT-33	Medium Dense to Dense Gray [10YR 5/1] SAND			10 13 15	28						
35		SPT-34											
36		SPT-35				21 21 24	45						
37			Borehole terminated at 36.0m										
38													

Client	:		Date of Boring	: 28-09-2017 to 29-12-2017	20 40 60 80 @Percent passing 75 micron sieve (%)
Project	:	Residential Flats	Borehole	: BH-01	R- Refusal
Location	:	Kargil Nagar, Chennai	Water Table(m)	: At ground level	Coordinates.
Report No.	:	S-1280	Status	: FINAL	4 8 12 16 □ Point Load Index, (MPa)

Legend
SPT: Standard Penetration Test
UDS: Undisturbed Sample
RC: Rock Core

Originator: GP Date: 11-01-2018 Checked by: MS Date: 11-01-2018

Plate 1A

FINAL BORELOG

Depth (m)	Soil Profile	Sample Type	Soil / Rock Description	Density kN/m³ (o Dry Density, ● Bulk Density)	Atterbergs limits WC % (PL, W, LL)	SPT Number of Blows (cm)	N-Value	Strength Parameters (× UCC for Rock (MPa), × UCC for Rock derived from Point Load (MPa))	Run (m) from	Run (m) to	Core Recovery (%)	RQD (%)	Remarks
1		SPT-1	Firm Gray [10YR 5/1] Silty CLAY			3 4 3	7						
2													
3		SPT-2				2 3 5	8						
4		SPT-3	Loose Gray [10YR 5/1] Clayey SAND		⊕	3 6 7	13						
5		SPT-4				1 1 2	3						
6													
7		SPT-5				1 1 1	2						
8		SPT-6	Soft Gray [10YR 5/1] Silty CLAY		●	1 1 2	3	Cohesion(kPa)=18					
9		SPT-7				1 2 2	4						
10		SPT-8				4 3 3	6						
11		SPT-9				4 3 2	5						
12		SPT-10											
13		SPT-11			⊕	7 6 9	15	Cohesion(kPa)=2					
14		SPT-12	Medium Dense Gray [10YR 5/1] Clayey SAND			6 3 5	8	Angle of internal friction(Deg)=37					
15		SPT-13				1 1 1	2						
16		SPT-14				4 5 7	12						
17		SPT-15				6 8 9	17						
18													
19		SPT-16			●	7 9 10	19						
20		SPT-17	Firm to Stiff Gray [10YR 5/1] Clayey SILT			3 5 5	10						
21		SPT-18				3 2 2	4						
22		SPT-19				12 13 18	30						
23		SPT-20	Dense to Very Dense Gray [10YR 5/1] Silty SAND		⊕	12 11 15	26	Cohesion(kPa)=10					
24		SPT-21				10 13 11	24	Angle of internal friction(Deg)=36					
25		SPT-22				18 20 21	41						
26		SPT-23				15 23 22	45						
27		SPT-24				12 25 21	46						
28													
29		SPT-25	Borehole Terminated at 36m			33 38 46	84						
30													

Client : [redacted]
Project : Residential Flats
Location : Kargil Nagar, Chennai
Report No. : S-1280

Date of Boring : 28-09-2017 to 28-12-2017
Borehole : BH-02
Water Table(m) : [redacted] At ground level
Status : FINAL

⊕ Percent passing 75 micron sieve (%)

Coordinates:

R- Refusal

□ Point Load Index, (MPa)

Legend
SPT: Standard Penetration Test
UDS: Undisturbed Sample
RC: Rock Core

Plate 1B

FINAL BORELOG

Depth (m)	Soil Profile	Sample Type	Soil / Rock Description	Density kN/m³ (o Dry Density, ● Bulk Density)	Atterbergs limits WC %	SPT Number of Blows (cm)	N-Value	Strength Parameters	Run (m) from	Run (m) to	Core Recovery (%)	RQD (%)	Remarks
1		SPT-1	Very Soft Gray [10YR 5/1] Silty CLAY			2 2 2	4						
2													
3		SPT-2	Loose to Medium Dense Gray [10YR 5/1] Silty SAND			3 3 4	7						
4													
5		SPT-3	Very Soft Gray [10YR 5/1] Silty CLAY			5 5 7	12						
6		SPT-4				3 2 1	3						
7													
8		SPT-5	Loose to Medium Dense Gray [10YR 5/1] Clayey SAND		⊕	2 1 2	3						
9		SPT-6				2 2 2	4						
10													
11		SPT-7				3 4 6	10						
12		SPT-8			⊕	3 4 5	9	Cohesion(kPa)=5 Angle of internal friction(Deg)=38					
13													
14		SPT-9				7 4 4	8						
15		SPT-10				8 8 8	16						
16													
17		SPT-11				4 4 8	12						
18		SPT-12	Medium Dense Gray [10YR 5/1] SAND with Silt		⊕	6 7 7	14						
19													
20		SPT-13				4 6 5	11						
21		SPT-14				6 7 6	13						
22													
23		SPT-15				9 8 9	17	Cohesion(kPa)=5 Angle of internal friction(Deg)=32					
24		SPT-16				7 9 11	20						
25													
26		SPT-17				8 8 13	21						
27		SPT-18				8 10 13	23						
28													
29		SPT-19	Medium Dense to Very Dense Gray [10YR 5/1] SAND with Silt		⊕	11 15 11	26	Cohesion(kPa)=5 Angle of internal friction(Deg)=35					
30		SPT-20				8 10 20	30						
31													
32		SPT-21	Borehole terminated at 31.5m			14 51/10cm -	R						
33													
34													

Client : [redacted]
Project : Residential Flats
Location : Kargil Nagar, Chennai
Report No. : S-1280

Date of Boring : 09-12-2017 to 13-12-2017
Borehole : BH-03
Water Table(m) : [redacted] At ground level
Status : FINAL

⊕ Percent passing 75 micron sieve (%)

Coordinates.

R- Refusal

□ Point Load Index, (MPa)

Legend
SPT: Standard Penetration Test
UDS: Undisturbed Sample
RC: Rock Core

Plate 1C

Depth (m)	Soil Profile	Sample Type	Soil / Rock Description	Density kN/m³ (○ Dry Density, ● Bulk Density) 5 10 15 20	Atterbergs limits WC % (PL, W, LL) 20 40 60 80	SPT Number of Blows (cm) 15 30	N-Value	Strength Parameters (✱ UCC for Rock (MPa), ✳ UCC for Rock derived from Point Load (MPa)) 40 80 120 160	Run (m) from	Run (m) to	Core Recovery (%)	RQD (%)	Remarks
1		SPT-1	Soft Gray [10YR 5/1] Silty CLAY			2 2 2	4						
2													
3		SPT-2				2 2 2	4						
4													
5		SPT-3	Loose Gray [10YR 5/1] Silty SAND			1 1 2	3						
6		SPT-4	Soft Gray [10YR 5/1] Silty CLAY			2 2 2	4						
7													
8		SPT-5				2 2 2	4						
9													
10		SPT-6				1 2 2	4						
11		SPT-7	Medium Dense Gray [10YR 5/1] Clayey SAND			5 6 7	13						
12		SPT-8				5 6 6	12						
13													
14		SPT-9	Stiff to Very Stiff Gray [10YR 5/1] Silty CLAY			2 2 2	4						
15		SPT-10				6 8 11	19						
16													
17		SPT-11				4 5 6	11						
18		SPT-1				4 7 8	15						
19													
20		SPT-13				3 5 6	11						
21		SPT-14				7 6 8	14						
22													
23		SPT-15				5 7 8	15						
24		SPT-16	Medium Dense to Dense Gray [10YR 5/1] Clayey SAND			9 12 13	25						
25													
26		SPT-1				6 8 22	30						
27		SPT-18	Medium Dense to Very Dense Gray [10YR 5/1] SAND with Silt			15 22 28	50						
28													
29		SPT-19				20 18 12	30						
30		SPT-20				23 32 51/13cm	R						
31													
32		SPT-21				20 21 23	44						
33		SPT-22				17 16 21	37						
34													
35		SPT-23				21 23 51/4cm	R						
36		SPT-24				51/2cm - -	R						
37			Borehole terminated at 36m										
38													

Originator: GP Date: 11-01-2018 Checked by: MS Date: 11-01-2018

Client	: IIT Madras	Date of Boring	: 15-12-2017 to 18-12-2017	20 40 60 80 ⊕ Percent passing 75 micron sieve (%)	R- Refusal
Project	: Residential Flats	Borehole	: BH-04	Coordinates	
Location	: Kargil Nagar, Chennai	Water Table(m)	: Nil ground level		
Report No.	: S-1280	Status	: FINAL		

4 8 12 16 □ Point Load Index, (MPa)

Legend
SPT Standard Penetration Test
UDS Undisturbed Sample
RC Rock Core

SGES

FINAL BORELOG

Depth (m)	Soil Profile	Sample Type	Soil / Rock Description	Density kN/m³ (○ Dry Density, ● Bulk Density)	Atterbergs limits WC % (PL, W, LL)	SPT Number of Blows (cm)	N-Value	Strength Parameters (UCC for Rock (MPa); UCC for Rock derived from Point Load (MPa))	Run (m) from	Run (m) to	Core Recovery (%)	RQD (%)	Remarks
1		SPT-1	Very Loose Gray [10YR 5/1] Silty CLAY			2 1 1	2						
2													
3		SPT-2	Loose to Medium Dense Gray [10YR 5/1] SAND			0 0 0	0						
4		SPT-3				4 6 8	14						
5													
6		SPT-4			⊕	3 2 1	3						
7													
8		SPT-5	Medium Dense Gray [10YR 5/1] Clayey SAND			2 3 3	6						
9		SPT-6	Firm to Stiff Gray [10YR 5/1] SILT with Sand		⊕	2 3 3	6						
10		SPT-7				2 3 3	6						
11		SPT-8				3 3 3	6						
12													
13		SPT-9				6 7 8	15						
14													
15		SPT-1			⊕	3 4 6	10						
16													
17		SPT-1	Medium Dense Gray [10YR 5/1] Silty SAND with Clay			4 5 6	11						
18		SPT-1											
19						4 6 10	16						
20		SPT-1											
21		SPT-1				6 8 9	17						
22													
23		SPT-1				5 10 7	17						
24		SPT-1	Stiff Gray [10YR 5/1] Silty CLAY with Sand		⊕	5 5 6	11						
25		SPT-1											
26						4 6 7	13						
27		SPT-1	Medium Dense Gray [10YR 5/1] Silty SAND			6 9 11	20						
28		SPT-1				9 10 8	18						
29													
30		SPT-2				9 10 13	23						
31													
32		SPT-2				6 9 11	20						
33		SPT-2	Dense to Very Dense Gray [10YR 5/1] SAND			8 11 15	26						
34													
35		SPT-2				10 13 19	32						
36		SPT-2	Weathered Rock			51/2cm - -	R		36.02	37.5	13	Nil	
37		NC							37.5	39	7	Nil	
38		RC-2											
39		RC-3							39	40	Nil	Nil	
40			Borehole Terminated at 40.0m										
41													
42													

Density kN/m³: 5 10 15 20 — Atterbergs limits WC %: 20 40 60 80 — SPT Number of Blows (cm): 15 30 — Strength Parameters: 40 80 120 160

⊕ Percent passing 75 micron sieve (%) — R- Refusal — □ Point Load Index, (MPa): 4 8 12 16

Client :
Project : Residential Flats
Location : Kargil Nagar, Chennai
Report No. : S-1280

Date of Boring : 23-12-2017 to 26-12-2017
Borehole : BH-05
Water Table(m) : At ground level
Status : FINAL

Coordinates:

Legend
SPT Standard Penetration Test
UDS Undisturbed Sample
RC: Rock Core

Plate 1D

FINAL BORELOG

Depth (m)	Soil Profile	Sample Type	Soil / Rock Description	Density kN/m³ (o Dry Density, ● Bulk Density)	Atterbergs limits WC % (PL, W, LL)	SPT Number of Blows (cm)	N-Value	Strength Parameters (* UCC for Rock (MPa), * UCC for Rock derived from Point Load (MPa))	Run (m) from	Run (m) to	Core Recovery (%)	RQD (%)	Remarks
1			Very Soft Gray [10YR 5/1] Silty CLAY			1 1 1	2						
2		SPT-1											
3		SPT-2	Loose to Medium Dense Gray [10YR 5/1] SAND with Clay			5 8 6	14						
4					⊕	4 4 5	9						
5		SPT-3											
6		SPT-4				6 7 7	14						
7													
8		SPT-5	Loose to Medium Dense Gray [10YR 5/1] Clayey SAND		⊕	4 6 7	13						
9		SPT-6				3 4 5	9						
10													
11		SPT-7	Firm Gray [10YR 5/1] Silty CLAY			3 3 5	8						
12		SPT-8			●	2 3 5	8						
13													
14		SPT-9	Medium Dense to Dense Gray [10YR 5/1] SAND			6 8 12	20						
15		SPT-10				7 7 8	15						
16													
17		SPT-11				5 6 6	12	Cohesion(kPa)=4 Angle of internal friction(Deg)=38					
18		SPT-12			⊕	6 7 5	12						
19													
20		SPT-13				10 13 9	22						
21		SPT-14				12 11 13	24						
22													
23		SPT-15				13 15 16	31						
24		SPT-16				7 10 12	22						
25		SPT-17				16 11 17	28	Cohesion(kPa)=10 Angle of internal friction(Deg)=40					
26													
27		SPT-18				12 17 21	38						
28					⊕								
29		SPT-19				18 22 27	49						
30		SPT-20				19 23 22	45						
31													
32		SPT-21				20 18 20	38						
33		SPT				31 5/13cm -	R		33.28	33.5	Nil	Nil	
34		HC-1 HC-2	Weathered Rock						33.5	35	12	Nil	
35													
36			Borehole Terminated at 35.0m										

Density kN/m³: o Dry Density, ● Bulk Density (5 10 15 20)

Atterbergs limits WC %: PL, W, LL (20 40 60 80)

SPT Number of Blows (cm): 15 30

Strength Parameters: * UCC for Rock (MPa); * UCC for Rock derived from Point Load (MPa) (40 80 120 160)

Run (m): from / to

Core Recovery (%)

RQD (%)

Remarks

Client	:	Date of Boring	: 22-12-2017 to 26-12-2017
Project	: Residential Flats	Borehole	: BH-06
Location	: Kargil Nagar, Chennai	Water Table(m)	: At ground level
Report No.	: S-1280	Status	: FINAL

20 40 60 80 (%Percent passing 75 micron sieve (%))

Coordinates:

R- Refusal

4 8 12 16 □ Point Load Index, (MPa)

Legend
SPT Standard Penetration Test
UDS Undisturbed Sample
RC Rock Core

Plate 11

SFMMARY OF TEST RESFLTS

Sample ID	Sample Description	Water Content (%) IS 2720 - 2 1973 RA 2015	Liquid Limit (%) IS 2720-Part 5 1985 RA 2015	Plastic Limit (%) IS 2720-Part 5 1985, RA 2015	Plasticity Index (%) IS 2720-Part 5 1985, RA 2015	Specific Gravity IS 2720-Part 3, Section 1 1980	Grain Size Distribution IS 2720 -Part 4 1985, RA 2015			Hydrometer Analysis IS 2720 - Part 4 1985		Free swell Index (%) IS 2720 -Part 40 1977 (RA - 2011)	*Chemical Test			SHEAR STRENGTH			
		SOIL PARAMETERS														UU Triaxial Test IS 2720 - Part 11 1993 (RA - 2011)		* Direct Shear Test IS 2720 - Part 13 1986 (RA - 2011)	
							Gravel %	Sand %	% passing 75 micron	Silt %	Clay %		Organic Matter (by percent)	Sulphate (% by mass)	Chloride (mg/lit)	Cohesion kPa	Angle of internal friction deg	Angle of Internal friction deg	Cohesion kPa
S1280/BH01/3.0	SAND						-	93	7										
S1280/BH01/6.0	Clayey SILT with Sand												13.41	1.77	99.97				
S1280/BH01/7.5	Clayey SILT with Sand					2.69	2	23	75	38	37	100							
S1280/BH01/9.0	Clayey SILT with Sand		76	32	44														
S1280/BH01/13.5	SAND						-	98	2										
S1280/BH01/21.0	Clayey SILT with Sand					2.69	-	15	85	67	18								
S1280/BH01/25.5	Clayey SILT	34.62														17	-		
S1280/BH01/33.0	SAND																	34	6
S1280/BH02/4.5	Clayey SAND						3	75	22										
S1280/BH02/7.5	Silty CLAY		65	26	39														
S1280/BH02/9.0	Silty CLAY	32.25														18	-		
S1280/BH02/15.0	Clayey SAND						-	70	30									37	2
S1280/BH02/22.5	Clayey SILT	25.88				2.66													
S1280/BH02/28.5	Silty SAND						-	80	20									36	10

SFMMARY OF TEST RESFLTS

Sample ID	Sample Description	SOIL PARAMETERS																	
		CLASSIFICATION AND INDEX											*Chemical Test			SHEAR STRENGTH			
							Grain Size Distribution IS: 2720 -Part 4 1985, RA 2015			Hydrometer Analysis IS: 2720 - Part 4						UU Triaxial Test IS 2720 - Part 11,1993 (RA - 2011)		* Direct Shear Test IS 2720 - Part 13 1986 (RA - 2011)	
		Water Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Specific Gravity	Gravel %	Sand %	% passing 75 micron	Silt %	Clay %	Free swell Index (%)	Organic Matter	Sulphate	Chloride	Cohesion	Angle of internal deg	Angle of internal deg	Cohesion
S1280/BH03/6.0	Silty CLAY		70	30	40							80							
S1280/BH03/7.5	SAND with Clay						-	89	11										
S1280/BH03/12.0	Clayey SAND						2	77	21									38	5
S1280/BH03/18.0	SAND with Silt						1	92	7										
S1280/BH03/25.5	SAND with Silt												12.17	1.95	104.97			32	5
S1280/BH03/28.5	SAND with Silt						5	84	11									35	5
S1280/BH04/1.5-4.5	Clay		81	39	41														
S1280/BH04/4.5-6	Sand						-	97	3										
S1280/BH04/6-10.5	Clay		58	27	31														
S1280/BH04/9-10.5	Clay		31	16	15														
S1280/BH04/10.5-13.5	Sand						2	76	22										
S1280/BH04/13.5-21	Clay		38	18	20														
S1280/BH04/21-25.5	Clayey SAND		29	17	13		-	69	31										
S1280/BH04/25.5-36	SAND						3	94	3										

SFMMARY OF TEST RESFLTS

Sample ID	Sample Description	SOIL PARAMETERS																
		CLASSIFICATION AND INDEX					Grain Size Distribution IS: 2720 -Part 4 1985, RA 2015			Hydrometer Analysis IS: 2720 - Part 4			*Chemical Test			SHEAR STRENGTH			
		Water Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Specific Gravity	Gravel %	Sand %	% passing 75 micron	Silt %	Clay %	Free swell Index (%)	Organic Matter	Sulphate	Chloride	UU Triaxial Test IS 2720 - Part 11:1993 (RA - 2011)		* Direct Shear Test IS 2720 - Part 13:1986 (RA - 2011)	
																Cohesion	Angle of internal deg	Angle of internal deg	Cohesion
S1280/BH05/3.0	Silty CLAY												13.57	1.06	94.97				
S1280/BH05/6.0	SAND						2	95	3										
S1280/BH05/9.0	Clayey SILT with Sand					2.69	-	24	76	40	36								
S1280/BH05/15.0	Clayey SILT with Sand						-	13	87										
S1280/BH05/24.0	Silty SAND with Clay					2.66	10	45	45	25	20								
S1280/BH06/4.5	SAND with Clay						-	86	14										
S1280/BH06/7.5	Clayey SAND						-	59	41										
S1280/BH06/10.5	Silty CLAY		37	21	16							20							
S1280/BH06/12.0	Silty CLAY	48.9																	
S1280/BH06/16.5	Silty SAND																	38	4
S1280/BH06/18.0	SAND						13	76	11										
S1280/BH06/28.5	SAND						7	84	9										
S1280/BH06/25.5	SAND																	40	10

ANNEXURE 3

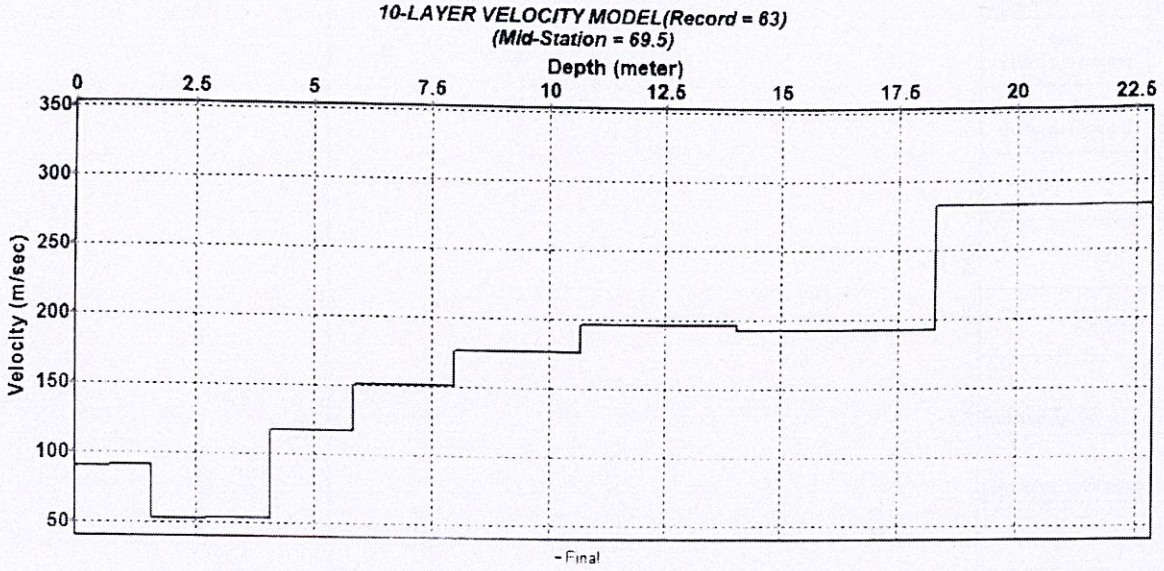


Figure (a): 1D Shear Wave Velocity Profile for stretch 1

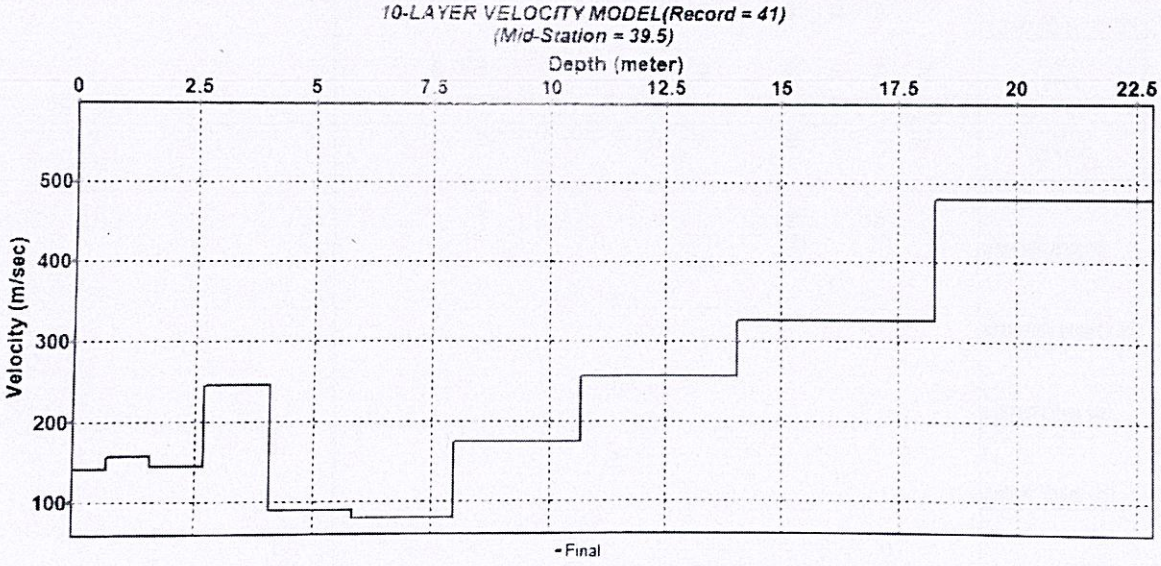


Figure (b): 1D Shear Wave Velocity Profile for stretch 1

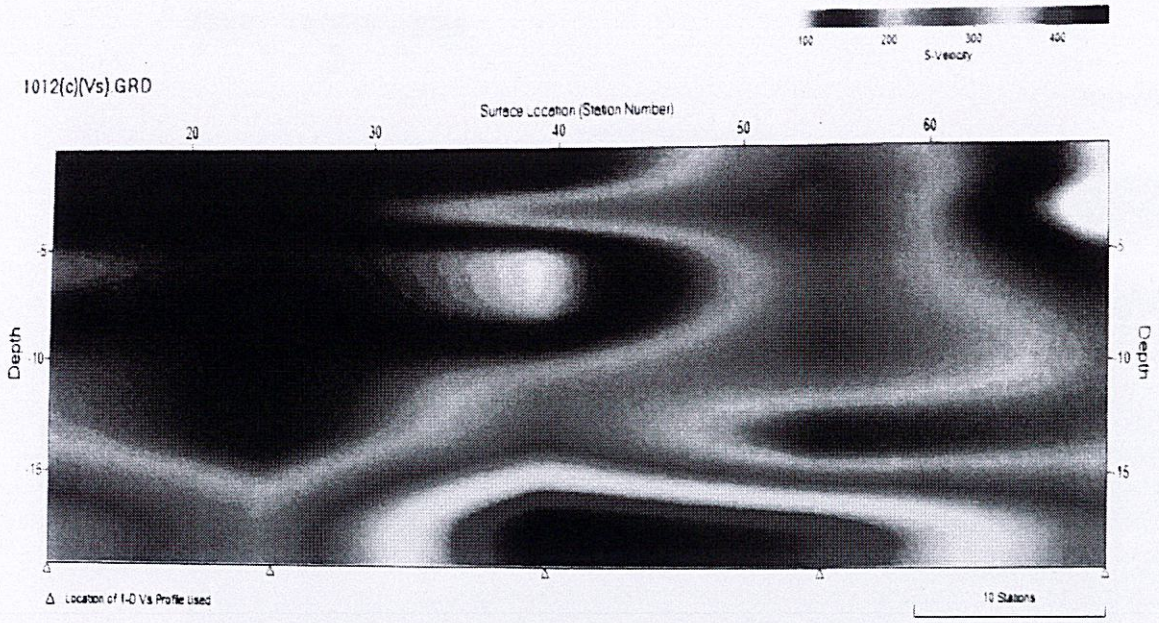


Figure (c): 2D wave velocity profile for stretch 1

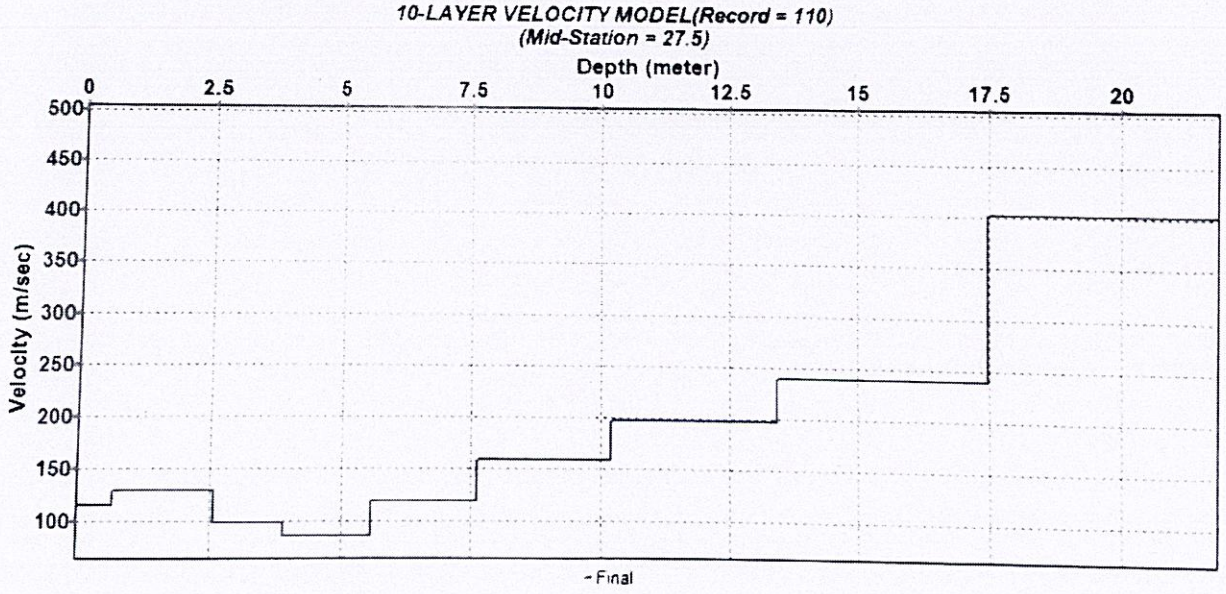


Figure (d): 1D Shear Wave Velocity Profile for stretch 2

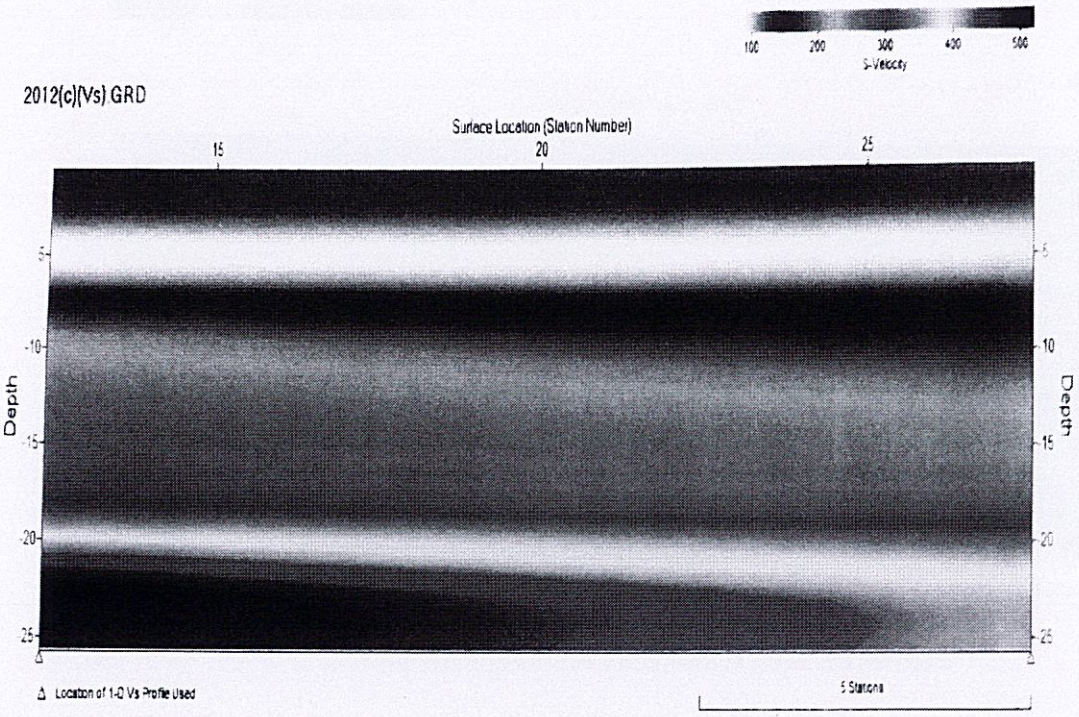


Figure (e): 2D wave velocity profile for stretch 2

Bearing capacity of pile calculation

Reference BH 01

Appendix A

Skin friction Calculation

Classification	Layers		Thickness	N	Sub. density	Relative Density/Consitency	Effective Over burden pressure	N	N'	k	α	φ	δ	C (kPa)	Ultimate unit skin Friction
	from(m)	to(m)	(m)		kN/m3		kN/m2								kPa
Sand	1.5	3	1.5	12	10.19	M.Dense	31	16	15	1		31.5	31.5		19
Clay	3	4.5	1.5	8	8.19	Firm	43	10	10		0.50			50	25
	4.5	6	1.5	2	6.19	V. Soft	52	2	2		0.70			12	8
	6	7.5	1.5	2	6.19	V. Soft	61	2	2		0.70			12	8
	7.5	9	1.5	2	6.19	V. Soft	71	2	2		0.70			12	8
	9	10.5	1.5	2	6.19	V. Soft	80	2	2		0.70			12	8
Sand	10.5	12	1.5	17	10.19	M.Dense	95	17	16	1.20		32.0	32.0		71
	12	13.5	1.5	6	8.19	Loose	108	6	6	1.20		29.0	29.0		72
	13.5	15	1.5	5	8.19	Loose	120	5	5	1.20		28.8	28.8		70
	15	16.5	1.5	7	8.19	Loose	132	6	6	1.20		29.0	29.0		68
	16.5	18	1.5	20	10.19	M.Dense	147	17	16	1.40		32.0	32.0		129
	18	19.5	1.5	16	10.19	M.Dense	163	14	14	1.40		31.0	31.0		137
	19.5	21	1.5	13	10.19	M.Dense	178	11	11	1.40		30.5	30.5		147
Clay	21	22.5	1.5	7	8.19	Firm	190	6	6		0.50			30	15
	22.5	24	1.5	11	8.19	Stiff	203	9	9		0.40			48	19
	24	25.5	1.5	17	8.19	Stiff	215	13	13		0.40			70	28
Sand	25.5	27	1.5	14	10.19	M.Dense	230	10	10	1.40		30.0	30.0		186
	27	28.5	1.5	10	10.19	M.Dense	245	7	7	1.50		29.0	29.0		204
	28.5	30	1.5	13	10.19	M.Dense	261	9	9	1.40		29.5	29.5		206
	30	31.5	1.5	18	10.19	M.Dense	276	12	12	1.50		30.8	30.8		247
	31.5	33	1.5	22	10.19	M.Dense	291	14	14	1.50		31.0	31.0		262
	33	34.5	1.5	51	11.19	Dense	308	32	24	1.50		36.0	36.0		335
	34.5	35	0.5	28	11.19	M.Dense	314	17	16	1.50		32.0	32.0		294
	35	36	1	28	11.19	M.Dense	325	17	16	1.50		32.0	32.0		304
	36	37.5	1.5	45	11.19	Dense	330	27	21	1.50		33.8	33.8		332

	35 m m Pile		
Pile Diameter (m)	0.5	0.6	0.75
C/S Area (sq m)	0.20	0.28	0.44
Nγ from IS 6403	32.4	32.4	32.4
Nq from IS 2911 for ϕ = 32	22	22	22
Pd for 20D (kN/sq m)	111.90	134.28	167.85
Effective unit weight of soil at pile toe (kN/cu.m)	11.19	11.19	11.19
Safe End bearing capacity of the pile (KN)	200.37	346.23	676.24
Total Negative Skin friction (KN)	-912	-1094	-1367
Total Positive skin friction (KN)	4741	5689	7112
Positive skin friction with FOS (KN)	1896	2276	2845
Safe Bearing Capacity of the pile (KN)	1185	1528	2153
Safe Bearing Capacity of the pile (T)	**119**	**153**	**215**
Weight of pile, (KN)	60	87	136
Uplift Capacity of pile (KN)	1246	1509	1914
Uplift Capacity of pile (T)	**125**	**151**	**191**

Note: Pile capacities are estimated based on the procedure suggested in IS 2911 (Part1/Sec 1)-1979. Effective overburden pressure at pile toe is limited to depth equal to 20 times pile diameter

* - the ϕ value is restricted to 36 degree in the case of bored piles as per FHWA

Bearing capacity of pile calculation

Reference BH 02

Skin friction Calculation

Classification	Layers		Thickness	N	Sub. density	Relative Density/Consitency	Effective Over burden pressure	N'	N''	k	α	φ	δ	C (kPa)	Ultimate unit skin Friction
	from(m)	to(m)	(m)		kN/m3		kN/m2								kPa
Sand	1.5	3	1.5	7	8.19	Loose	25	9	9	1		29.5	29.5		0
	3	4.5	1.5	8	8.19	Loose	37	10	10	1		30	30.0		0
Clay	4.5	6	1.5	13	8.19	Stiff	49	16	15		0.40			75	30
	6	7.5	1.5	3	6.19	Soft	58	3	3		0.70			18	13
	7.5	9	1.5	2	6.19	V.Soft	68	2	2		0.70			12	8
	9	10.5	1.5	3	6.19	Soft	77	3	3		0.70			18	13
	10.5	12	1.5	4	6.19	Soft	86	4	4		0.50			22	11
	12	13.5	1.5	6	8.19	Firm	99	6	6		0.50			30	15
	13.5	15	1.5	5	6.19	Soft	108	5	5		0.50			25	13
Sand	15	16.5	1.5	15	10.19	M.Dense	123	13	13	1.50		31.0	31.0		111
	16.5	18	1.5	8	8.19	Loose	135	7	7	1.30		29.3	29.3		99
	18	19.5	1.5	2	8.19	Loose	148	2	2	1.30		28.0	28.0		102
	19.5	21	1.5	12	10.19	M.Dense	163	10	10	1.50		30.0	30.0		141
	21	22.5	1.5	17	10.19	M.Dense	178	14	14	1.50		31.3	31.3		162
Clay	22.5	24	1.5	19	8.19	Stiff	191	15	15		0.30			75	23
	24	25.5	1.5	10	8.19	Firm	203	8	8		0.40			40	16
	25.5	27	1.5	4	6.19	Soft	212	3	3		0.50			18	9
Sand	27	28.5	1.5	30	10.19	M.Dense	227	22	18	1.50		32.5	32.5		217
	28.5	30	1.5	26	10.19	M.Dense	243	18	17	1.50		32.3	32.3		230
	30	31.5	1.5	24	10.19	M.Dense	258	17	16	1.50		32.0	32.0		242
	31.5	33	1.5	41	11.19	Dense	275	27	21	1.50		33.8	33.8		276
	33	34.5	1.5	45	11.19	Dense	292	29	22	1.50		33.9	33.9		294
	34.5	35	0.5	46	11.19	Dense	297	29	22	1.50		33.9	33.9		299
	35	36	1	46	11.19	Dense	308	28	22	1.50		33.9	33.9		311
	36	37.5	1.5	84	11.19	Dense	325	0	8	1.50		36.0	36.0		354

	35 m m Pile		
Pile Diameter (m)	0.5	0.6	0.75
C/S Area (sq m)	0.20	0.28	0.44
Ny from IS 6403	42	42	42
Nq from IS 2911 for φ = 33.9	40	40	40
Pd for 20D (kN/sq.m)	111.90	134.28	167.85
Effective unit weight of soil at pile toe (kN/cu.m)	11.19	11.19	11.19
Safe End bearing capacity of the pile (KN)	360.59	623.10	1216.99
Total Negative Skin friction (KN)	-974	-1169	-1462
Total Positive skin friction (KN)	4025	4830	6037
Positive skin friction with FOS (KN)	1610	1932	2415
Safe Bearing Capacity of the pile (KN)	996	1386	2170
Safe Bearing Capacity of the pile (T)	100	139	217
Weight of pile, (KN)	60	87	136
Uplift Capacity of pile (KN)	1067	1295	1645
Uplift Capacity of pile (T)	107	129	165

Note :Pile capacities are estimated based on the procedure suggested in IS:2911 (Part1/Sec 1)-1979. Effective overburden pressure at pile toe is limited to depth equal to 20 times pile diameter

-* - the φ value is restricted to 36 degree in the case of bored piles as per FHWA

Bearing capacity of pile calculation

Reference BH 03

Skin friction Calculation

Classification	Layers		Thickness	N	Sub. density	Relative Density/Consitency	Effective Over burden pressure	N'	N''	k	α	φ	δ	C (kPa)	Ultimate unit skin Friction
	from(m)	to(m)	(m)		kN/m3		kN/m2								kPa
Clay	1.5	3	1.5	4	6.19	Soft	19	6	6		0.50			30	15
	3	4.5	1.5	7	8.19	Firm	31	9	9		0.50			45	23
	4.5	6	1.5	12	8.19	Stiff	43	15	15		0.40			75	30
Sand	6	7.5	1.5	3	8.19	Loose	55	3	3	1.2		28	28.0		35
	7.5	9	1.5	3	8.19	Loose	68	3	3	1.2		28.0	28.0		43
	9	10.5	1.5	4	8.19	Loose	80	4	4	1.2		28.0	28.0		51
	10.5	12	1.5	10	8.19	Loose	92	10	10	1.20		30.0	30.0		64
	12	13.5	1.5	9	8.19	Loose	105	9	9	1.20		29.8	29.8		72
	13.5	15	1.5	8	8.19	Loose	117	7	7	1.20		29.5	29.5		79
	15	16.5	1.5	16	10.19	M.Dense	132	14	14	1.50		31.5	31.5		121
	16.5	18	1.5	12	10.19	M.Dense	147	10	10	1.50		30.0	30.0		128
	18	19.5	1.5	14	10.19	M.Dense	163	12	12	1.50		30.5	30.5		144
	19.5	21	1.5	11	10.19	M.Dense	178	9	9	1.50		29.8	29.8		153
	21	22.5	1.5	13	10.19	M.Dense	193	10	10	1.50		30.0	30.0		167
	22.5	24	1.5	17	10.19	M.Dense	209	13	13	1.50		31.0	31.0		188
	24	25.5	1.5	20	10.19	M.Dense	224	15	15	1.50		31.8	31.8		208
	25.5	27	1.5	21	10.19	M.Dense	239	15	15	1.50		31.8	31.8		222
	27	28.5	1.5	23	10.19	M.Dense	254	16	15	1.50		31.8	31.8		236
	28.5	30	1.5	26	10.19	M.Dense	270	17	16	1.50		32.0	32.0		253
	30	31	1	30	11.19	Dense	281	19	17	1.80		32.2	32.2		318
	31	31.5	0.5	30	11.19	Dense	286	19	17	1.80		32.2	32.2		325
	31.5	33	1.5	100	12.19	V.Dense	299	63	39	1.80		36.0	36.0		391
	33	35	2	100	12.19	V.Dense	324	61	38	1.80		36.0	36.0		423

		33 m m Pile	
Pile Diameter (m)	0.5	0.6	0.75
C/S Area (sq.m)	0.20	0.28	0.44
N_γ from IS 6403	60	60	60
N_q from IS 2911 for ϕ = 36	57	57	57
Pd for 20D (kN/sq.m)	121.90	146.28	182.85
Effective unit weight of soil at pile toe (kN/cu.m)	12.19	12.19	12.19
Safe End bearing capacity of the pile (KN)	559.80	967.33	1889.31
Total Negative Skin friction (KN)	-970	-1164	-1455
Total Positive skin friction (KN)	5040	6049	7561
Positive skin friction with FOS (KN)	2016	2419	3024
Safe Bearing Capacity of the pile (KN)	1606	2222	3458
Safe Bearing Capacity of the pile (T)	161	222	346
Weight of pile, (KN)	60	87	136
Uplift Capacity of pile (KN)	1321	1599	2026
Uplift Capacity of pile (T)	132	160	203

Note: Pile capacities are estimated based on the procedure suggested in IS:2911 (Part1/Sec 1)-1979. Effective overburden pressure at pile toe is limited to depth equal to 20 times pile diameter

-* - the ϕ value is restricted to 36 degree in the case of bored piles as per FHWA.

Bearing capacity of pile calculation

Reference BH 04

Skin friction Calculation

Classification	Layers		Thickness	N	Sub. density	Relative Density/Consitency	Effective Over burden pressure	N'	N''	k	α	ψ	δ	C (kPa)	Ultimate unit skin Friction
	from(m)	to(m)	(m)		kN/m3		kN/m2								kPa
Organic soil	1.5	3	1.5	4	4.19	Soft	13	7	7		0.50			35	18
Sand	3	4.5	1.5	4	4.19	Soft	19	6	6		0.50			30	15
Clay	4.5	6	1.5	3	7.19	V.Loose	30	4	4	1		28	28.0		16
	6	7.5	1.5	4	6.19	Soft	39	5	5		0.50			25	13
	7.5	9	1.5	4	6.19	Soft	48	5	5		0.50			25	13
	9	10.5	1.5	4	6.19	Soft	57	5	5		0.50			25	13
Sand	10.5	12	1.5	13	7.19	M.Dense	68	14	14	1.20		31.2	31.2		50
	12	13.5	1.5	12	7.19	M.Dense	79	13	13	1.20		31.0	31.0		57
Clay	13.5	15	1.5	4	6.19	Soft	88	4	4		0.50			20	10
	15	16.5	1.5	19	8.19	Stiff	101	19	17		0.30			85	26
	16.5	18	1.5	11	10.19	Firm	116	10	10		0.40			50	20
	18	19.5	1.5	15	8.19	Stiff	128	13	13		0.40			65	26
	19.5	21	1.5	11	10.19	Firm	143	10	10		0.40			50	20
Sand	21	22.5	1.5	14	10.19	M.Dense	159	12	12	1.25		30.8	30.8		118
	22.5	24	1.5	15	10.19	M.Dense	174	12	12	1.25		30.8	30.8		130
	24	25.5	1.5	25	10.19	M.Dense	189	20	18	1.30		32.5	32.5		157
	25.5	27	1.5	30	10.19	Dense	205	23	19	1.40		33.0	33.0		186
	27	28.5	1.5	50	10.19	Dense	220	38	26	1.50		35.3	35.3		233
	28.5	30	1.5	30	10.19	Dense	235	22	18	1.40		32.5	32.5		210
	30	31.5	1.5	100	11.19	V.Dense	252	69	42	1.50		36.0	36.0		274
	31.5	33	1.5	44	10.19	Dense	267	30	22	1.50		34.0	34.0		270
	33	34.5	1.5	37	10.19	Dense	283	24	19	1.50		33.0	33.0		275
	34.5	35	0.5	100	11.19	V.Dense	288	64	40	1.50		36.0	36.0		314
	35	36	1	100	11.19	V.Dense	299	63	39	1.50		36.0	36.0		326

		33 m m Pile	
Pile Diameter (m)	0.5	0.6	0.75
C/S Area (sq.m)	0.20	0.28	0.44
Ny from IS 6403	43	43	43
Nq from IS 2911 for ϕ = 34	40	40	40
Pd for 200 (kN/sq.m)	101.90	122.28	152.85
Effective unit weight of soil at pile toe (kN/cu m)	10.19	10.19	10.19
Safe End bearing capacity of the pile (KN)	328.57	567.76	1108.91
Total Negative Skin friction (KN)	-476	-572	-715
Total Positive skin friction (KN)	3932	4719	5898
Positive skin friction with FOS (KN)	1573	1887	2359
Safe Bearing Capacity of the pile (KN)	1425	1883	2754
Safe Bearing Capacity of the pile (T)	**142**	**188**	**275**
Weight of pile, (KN)	60	87	136
Uplift Capacity of pile (KN)	1043	1267	1611
Uplift Capacity of pile (T)	104	127	161

Note: Pile capacities are estimated based on the procedure suggested in IS 2911 (Part1/Sec 1)-1979. Effective overburden pressure at pile toe is limited to depth equal to 20 times pile diameter.

-* - the ϕ value is restricted to 36 degree in the case of bored piles as per FHWA

Bearing capacity of pile calculation

Reference BH 05

Skin friction Calculation

Classification	Layers		Thickness	N	Sub. density	Relative Density/Consitency	Effective Over burden pressure	N'	N''	k	α	φ	δ	C (kPa)	Ultimate unit skin Friction
	from(m)	to(m)	(m)		kN/m3		kN/m2							kPa
Clay	1.5	3	1.5	2	6.19	Soft	19	3	3		0.50			18	9
Sand	3	4.5	1.5	0	8.19	Loose	31	0	0	1		28	28.0		0
	4.5	6	1.5	14	10.19	M.Dense	46	17	16	1		28	28.0		25
	6	7.5	1.5	3	6.19	Soft	55	3	3		0.70			18	13
	7.5	9	1.5	6	8.19	Firm	68	7	7		0.50			35	18
Clay	9	10.5	1.5	6	8.19	Firm	80	6	6		0.50			30	15
	10.5	12	1.5	6	8.19	Firm	92	6	6		0.50			30	15
	12	13.5	1.5	6	8.19	Firm	105	6	6		0.50			30	15
	13.5	15	1.5	15	8.19	Stiff	117	14	14		0.40			70	28
	15	16.5	1.5	10	8.19	M.Dense	129	9	9	1.25		29.6	29.6		92
	16.5	18	1.5	8	8.19	Loose	141	7	7	1.25		29.0	29.0		98
	18	19.5	1.5	11	10.19	M.Dense	157	9	9	1.25		29.6	29.6		111
	19.5	21	1.5	16	10.19	M.Dense	172	13	13	1.25		31.0	31.0		129
	21	22.5	1.5	17	10.19	M.Dense	187	14	14	1.25		31.3	31.3		142
	22.5	24	1.5	17	10.19	M.Dense	203	13	13	1.25		31.0	31.0		152
	24	25.5	1.5	11	10.19	M.Dense	218	8	8	1.30		29.5	29.5		160
Sand	25.5	27	1.5	13	10.19	M.Dense	233	9	9	1.40		29.6	29.6		185
	27	28.5	1.5	20	10.19	M.Dense	248	14	14	1.50		31.3	31.3		226
	28.5	30	1.5	13	10.19	M.Dense	264	9	9	1.40		29.6	29.6		210
	30	31.5	1.5	23	10.19	M.Dense	279	15	15	1.50		31.7	31.7		258
	31.5	33	1.5	20	10.19	M.Dense	294	13	14	1.50		31.3	31.3		268
	33	34.5	1.5	26	10.19	M.Dense	310	16	16	1.50		32.0	32.0		290
	34.5	35	0.5	32	10.19	M.Dense	315	20	18	1.50		32.3	32.3		298
	35	36	1	32	10.19	M.Dense	325	20	17	1.50		32.3	32.3		308
	36	37.5	1.5		11.19		331	0	8		0.20			800	160
W. Rock	37.5	39	1.5		11.19		348	0	8		0.20			1200	240
	39	40	1		11.19		359	0	8		0.20			2000	400

	31 m m Pile		
Pile Diameter (m)	0.5	0.6	0.75
C/S Area (sq m)	0.20	0.28	0.44
Ny from IS 6403	31	31	31
Nq from IS 2911 for φ = 31.7	27	27	27
Pd for 200 (kN/sq m)	101.90	122.28	152.85
Effective unit weight of soil at pile toe (kN/cu m)	10.19	10.19	10.19
Safe End bearing capacity of the pile (KN)	222.18	383.92	749.85
Total Negative Skin friction (KN)	-256	-307	-384
Total Positive skin friction (KN)	3612	4334	5417
Positive skin friction with FOS (KN)	1445	1734	2167
Safe Bearing Capacity of the pile (KN)	1411	1811	2533
Safe Bearing Capacity of the pile (T)	**141**	**181**	**253**
Weight of pile, (KN)	60	87	136
Uplift Capacity of pile (KN)	963	1171	1490
Uplift Capacity of pile (T)	**96**	**117**	**149**

Note: Pile capacities are estimated based on the procedure suggested in IS.2911 (Part1/Sec 1)-1979. Effective overburden pressure at pile toe is limited to depth equal to 20 times pile diameter.

-* - the φ value is restricted to 36 degree in the case of bored piles as per FHWA.

Bearing capacity of pile calculation

Reference BH 06

Skin friction Calculation

Classification	Layers		Thickness	N	Sub. density	Relative Density/Consitency	Effective Over burden pressure	N'	N''	k	α	φ	δ	C (kPa)	Ultimate unit skin Friction
	from(m)	to(m)	(m)		kN/m3		kN/m2								kPa
Clay	1.5	3	1.5	2	6.19	Soft	19	3	3		0.70			18	13
Sand	3	4.5	1.5	14	10.19	M.Dense	34	18	17	1.3		33	33.0		29
	4.5	6	1.5	9	8.19	Loose	46	11	11	1.3		30.6	30.6		35
	6	7.5	1.5	14	10.19	M.Dense	61	16	16	1.3		32	32.0		50
Clay	7.5	9	1.5	13	8.19	Stiff	74	14	14		0.40			70	28
	9	10.5	1.5	9	8.19	Firm	86	9	9		0.40			45	18
	10.5	12	1.5	8	8.19	Firm	98	8	8		0.40			40	16
	12	13.5	1.5	8	8.19	Firm	111	8	8		0.40			40	16
Sand	13.5	15	1.5	20	10.19	M.Dense	126	18	16	1.40		33.0	33.0		114
	15	16.5	1.5	15	10.19	M.Dense	141	13	13	1.40		31.5	31.5		121
	16.5	18	1.5	12	10.19	M.Dense	156	10	10	1.40		30.0	30.0		126
	18	19.5	1.5	12	10.19	M.Dense	172	10	10	1.40		30.0	30.0		139
	19.5	21	1.5	22	10.19	M.Dense	187	18	16	1.40		33.0	33.0		170
	21	22.5	1.5	24	10.19	M.Dense	202	19	17	1.40		32.2	32.2		178
	22.5	24	1.5	31	11.19	Dense	219	23	19	1.50		33.5	33.5		217
	24	25.5	1.5	22	11.19	Dense	236	16	15	1.50		32.0	32.0		221
	25.5	27	1.5	28	11.19	Dense	253	19	17	1.50		32.2	32.2		238
	27	28.5	1.5	38	11.19	Dense	269	26	20	1.50		33.5	33.5		267
	28.5	30	1.5	49	11.19	Dense	286	32	23	1.50		34.5	34.5		295
	30	31.5	1.5	45	11.19	Dense	303	29	22	1.50		34.3	34.3		310
	31.5	33	1.5	38	11.19	Dense	320	24	20	1.50		33.5	33.5		317
W Rock	33	33.5	0.5		11.19		325				0.20			800	160
	33.5	35	1.5		11.19		342				0.20			800	160

	31 m m Pile		
Pile Diameter (m)	0.5	0.6	0.75
C/S Area (sq.m)	0.20	0.28	0.44
Ny from IS 6403	45	45	45
Nq from IS 2911 for Φ = 34.5	44	44	44
Pd for 20D (kN/sq.m)	111.90	134.28	167.85
Effective unit weight of soil at pile toe (kN/cu.m)	11.19	11.19	11.19
Safe End bearing capacity of the pile (KN)	396.38	684.95	1337.80
Total Negative Skin friction (KN)	-180	-217	-271
Total Positive skin friction (KN)	5217	6260	7826
Positive skin friction with FOS (KN)	2087	2504	3130
Safe Bearing Capacity of the pile (KN)	2303	2973	4197
Safe Bearing Capacity of the pile (T)	**230**	**297**	**420**
Weight of pile, (KN)	60	87	136
Uplift Capacity of pile (KN)	1365	1652	2092
Uplift Capacity of pile (T)	**136**	**165**	**209**

Note. Pile capacities are estimated based on the procedure suggested in IS.2911 (Part1/Sec 1)-1979. Effective overburden pressure at pile toe is limited to depth equal to 20 times pile diameter

.* - the Φ value is restricted to 36 degree in the case of bored piles as per FHWA.

Appendix B

Lateral Load Carrying capacity of the pile (IS 2911) BH# 1, 3, & 4

Loading Type = Normal
Type of pile = bored cast-in-situ piles
Length of pile = 36 m
Grade of Concrete = M25
fck = 25 N/mm2
Elastic modulus of concrete, Ec = 5000 √fck Mpa
Soil below Pile cutoff level is Wathered rock / Weak rock
Coefficient of modulus variation = 7.75 kg/cm2
Ground water table is assumed at or above pile cutoff level
Pile cut off level = 1m below ground level
Length of pile below cutoff level = 34.5 m
Allowable deflection at pile head = 5 mm

	Fixed head	Free head
Diameter of the pile (cm)	75	75
Characteristic strength of concrete (Mpa)	25	25
Characteristic strength of concrete (kg/sq.cm)	255	255
E (Mpa)	25000	25000
E (kg/sq.cm)	255000	255000
I (cm^4)	1552368.2	1552368.2
η_h (kg/cm^2) *	7.75	7.75
R (cm)	475.40	475.40
L_1	0.00	0.00
L_f/R **	2.20	1.95
L_f (cm)	1045.88	927.03
Y (permissible deflection) cm	0.50	0.50
Q (kg)	2076.08	745.33
Q in KN	20.76	7.45
Q in tonnes	2.08	0.75

Pile Dia (m)	Lateral Load Capacity of the piles (KN)		Lateral Load Capacity of the piles (tons)	
	Fixed Head	Free Head	Fixed Head	Free Head
0.5	13.84	4.97	1.38	0.50
0.6	16.61	5.96	1.66	0.60
0.75	20.76	7.45	2.08	0.75

**L_f/R, ratio between depth of fixity and T read from IS 2911 corresponding to the ratio L_1/R, L_1 being the free standing length

*η_h, modulus of subgrade reaction, in a loose / very soft soil is recommended as 7.75 kg/cm2 as per IS 2911

NOTE: The total depth of fixity below the pile head is sum of cantilevel length L_1 and L_f

Appendix B

BH# 1, 3, & 4

Lateral Load Carrying capacity of the pile (IS 2911)

Loading Type = Normal
Type of pile = bored cast-in-situ piles
Length of pile = 36 m
Grade of Concrete = M25
fck = 25 N/mm2
Elastic modulus of concrete, Ec = 5000 √fck Mpa
Soil below Pile cutoff level is Wathered rock / Weak rock
Coefficient of modulus variation = 7.75 kg/cm2
Ground water table is assumed at or above pile cutoff level
Pile cut off level = 1m below ground level
Length of pile below cutoff level = 34.5 m
Allowable deflection at pile head = 5 mm

	Fixed head	Free head
Diameter of the pile (cm)	75	75
Characteristic strength of concrete (Mpa)	25	25
Characteristic strength of concrete (kg/sq.cm)	255	255
E (Mpa)	25000	25000
E (kg/sq.cm)	255000	255000
I (cm^4)	1552368.2	1552368.2
η_h (kg/cm^2) *	7.75	7.75
R (cm)	475.40	475.40
L_1	0.00	0.00
L_f/R **	2.20	1.95
L_f (cm)	1045.88	927.03
Y (permissible deflection) cm	0.50	0.50
Q (kg)	2076.08	745.33
Q in KN	20.76	7.45
Q in tonnes	2.08	0.75

Pile Dia (m)	Lateral Load Capacity of the piles (KN)		Lateral Load Capacity of the piles (tons)	
	Fixed Head	Free Head	Fixed Head	Free Head
0.5	13.84	4.97	1.38	0.50
0.6	16.61	5.96	1.66	0.60
0.75	20.76	7.45	2.08	0.75

**L_f/R, ratio between depth of fixity and T read from IS 2911 corresponding to the ratio L_1/R, L_1 being the free standing length

*η_h, modulus of subgrade reaction, in a loose / very soft soil is recommended as 7.75 kg/cm2 as per IS 2911

NOTE: The total depth of fixity below the pile head is sum of cantilevel length L_1 and L_f

Appendix B

Lateral Load Carrying capacity of the pile (IS 2911) BH# 2, 5, 6

Loading Type = Normal
Type of pile = bored cast-in-situ piles
Length of pile = 36 m
Grade of Concrete = M25
fck = 25 N/mm2
Elastic modulus of concrete, Ec = 5000 √fck Mpa
Soil below Pile cutoff level is Wathered rock / Weak rock
Coefficient of modulus variation = 1.46 MN/m3
Ground water table is assumed at or above pile cutoff level
Pile cut off level = 1m below ground level
Length of pile below cutoff level = 34.5 m
Allowable deflection at pile head = 5 mm

	Fixed head	Free head
Diameter of the pile (cm)	75	75
Characteristic strength of concrete (Mpa)	25	25
Characteristic strength of concrete (kg/sq.cm)	255	255
E (Mpa)	25000	25000
E (kg/sq.cm)	255000	255000
I (cm^4)	1552368.2	1552368.2
η_h (kg/cm^3) *	0.146	0.146
T (cm)	306.65	306.65
L_1	0.00	0.00
L_f/T **	2.20	1.95
L_f (cm)	674.62	597.96
Y (permissible deflection) cm	0.50	0.50
Q (kg)	7735.87	2777.24
Q in KN	77.36	27.77
Q in tonnes	7.74	2.78

Pile Dia (m)	Lateral Load Capacity of the piles (KN)		Lateral Load Capacity of the piles (tons)	
	Fixed Head	Free Head	Fixed Head	Free Head
0.5	40.44	14.52	4.04	1.45
0.6	54.13	19.43	5.41	1.94
0.75	77.36	27.77	7.74	2.78

**L_f/T, ratio between depth of fixity and T read from IS 2911 corresponding to the ratio L_1/T, L_1 being the free standing length

*η_h, modulus of subgrade reaction, in a loose / very soft soil is recommended as 1.46 MN/m3 as per IS 2911

NOTE: The total depth of fixity below the pile head is sum of cantilevel length L_1 and L_f

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