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GEOTECHNICAL INVESTIGATION REPORT

RECONSTRUCTION OF 162 (S+9) TENEMENTS AT RAJATHOTTAM SCHEME IN GCC CORP DN 66 ZONE 6, CHENNAI

FOR

THE EXECUTIVE ENGINEER
DIVISION – III

TAMIL NADU URBAN HABITAT DEVELOPMENT BOARD, CHENNAI.

Centre for Urbanization, Buildings & Environment [CUBE]

Ref: TNUHDB Letter No. 866/JE(P)/Dn. III/2018 dated 19 Jan 2022

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GEOTECHNICAL INVESTIGATION REPORT

RECONSTRUCTION OF 162 (S+9) TENEMENTS AT RAJATHOTTAM SCHEME IN GCC CORP DN 66 ZONE 6, CHENNAI.

Summary

S.No.	Description		Details
I	**OVERVIEW**		
	Project	:	Reconstruction of 162 No. (S+9) tenements at Rajathottam scheme.
	Client	:	Tamil Nadu Urban Habitat Development Board
	Location	:	GCC Corp. Dn. 66, Zone 6, Chennai.
	Buildings	:	1 No. – S+9 Floors
	Type of Structure	:	RCC Framed Structure
II	**SOIL INVESTIGATION**		
	Boreholes	:	Four exploratory bores were conducted. Maximum depth of a borewell was advanced up to 20.0 m depth and terminated after encountering very dense condition of soil with at least 3 successive SPT's with "N" values as 50.
	Test conducted	:	Standard Penetration Tests were conducted at every change in stratum or at intervals of not more than 1.5 m whichever is less. Disturbed soil samples were collected at suitable intervals for Laboratory Testing
III	**FINDINGS**		
	Soil at shallow depth	:	Filled-up layer with a thickness ranging from 0.3m to 0.7m followed by soft/stiff/Very stiff silty clay/clay layer and medium dense/dense/very dense sand/clayey sand layer up to 7.5m depth.
	Hard stratum	:	Traces of soft/weathered was found above 7.5m and 10m depth and hard rock layer is found to exist beyond 16m depth.
	Ground water table	:	Ground water table encountered at a depth of about 1.3m to 2m from the existing ground level during investigation.
IV	**FOUNDATION**		
	Recommendation	:	Considering in situ condition, Pile Foundation of depth 14.0m is recommended as per the safe pile load carrying capacity calculations tabulated in relevant section of this report.

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RECONSTRUCTION OF 162 (S+9) TENEMENTS AT RAJATHOTTAM SCHEME IN GCC CORP DN 66 ZONE 6, CHENNAI.

I. Introduction.

Tamil Nadu Urban Habitat Development Board [TNUHDB] has entrusted the Centre for Urbanization, Buildings & Environment [CUBE] with the geotechnical investigation at the proposed project site to evaluate the soil properties, estimating the safe bearing capacity of the soil, and recommend a suitable type of foundation for the proposed reconstruction of 162 Tenements at Rajathottam in GCC Corp. Dn. 66, Zone 6, Chennai.

The site exploration towards the geotechnical investigation was conducted in between 26.01.2022 and 29.01.2022 followed by relevant laboratory tests. This report presents the details of the site characterization based on the field and laboratory investigations, evaluation of the design soil parameters, recommendations on capacity of soil strata and type of foundations to adopted for the proposed buildings.

II. Scope of work.

The scope of works envisaged for this assignment are as under: -

(a) Carry out a detailed geotechnical investigation of the proposed project site by drilling **four number of boreholes** at appropriate locations below the existing ground surface for conducting standard penetration tests.
(b) Conduct standard penetration tests at appropriate intervals as per IS: 2131-1981 till a necessary depth to achieve three consecutive **N values more than 50** or up to 3m into the very dense/hard strata.
(c) Collect soil samples at appropriate intervals for carrying out field and laboratory tests as per IS: 1498-1970.
(d) Compute the bearing capacity of the soil as per IS: 6403-1981 & IS: 8009 (Part-1).
(e) Analysis of the above results and recommend the type & depth of foundations for the proposed structures with a suggested allowable bearing capacity.

III. Methodology.

A broad work methodology is given as under: -
(a) The soil investigation works were conducted through M/s. Ashhirwaad Analytical Laboratory and tested at their ISO & NABL certified Soil Lab.
(b) Conduct field investigation in **four locations** at the site through exploratory bore hole by rotary boring. borehole tests included Standard penetration test, Disturbed soil sampling, identification of different soil layers, Ground water table observation, Complete logging of the bore hole, etc.
(c) The location, number, and position of boreholes, and spacing of boreholes were finalised based on the extent of the site, nature, and type of structure as well as the inhouse structural engineering team.
(d) Depth of borehole was concluded based on condition of soil, penetration capacity of soil, shear failure and hard strata condition.

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(e) Standard Penetration test was conducted at regular intervals and 'N' values were recorded.
(f) The disturbed soil samples were collected and were preserved and transported for examination to Ashhirwaad Analytical Laboratory for detailed identification tests.
(g) The disturbed soil sample was collected from the site and transported for examination to Ashhirwaad Analytical Laboratory.
(h) The field investigation was conducted in the presence of TNUHDB engineers and monitored by experienced civil engineers/ Geotechnical/ Structural Engineer.
(i) The allowable safe bearing capacity of the soil will be calculated based on the field geotechnical investigation, soil properties, GWT and subsequent laboratory experiments.
(j) Based on the field and laboratory tests on the samples collected, the results are furnished in this report.
(k) A detailed workflow chart is depicted below: -

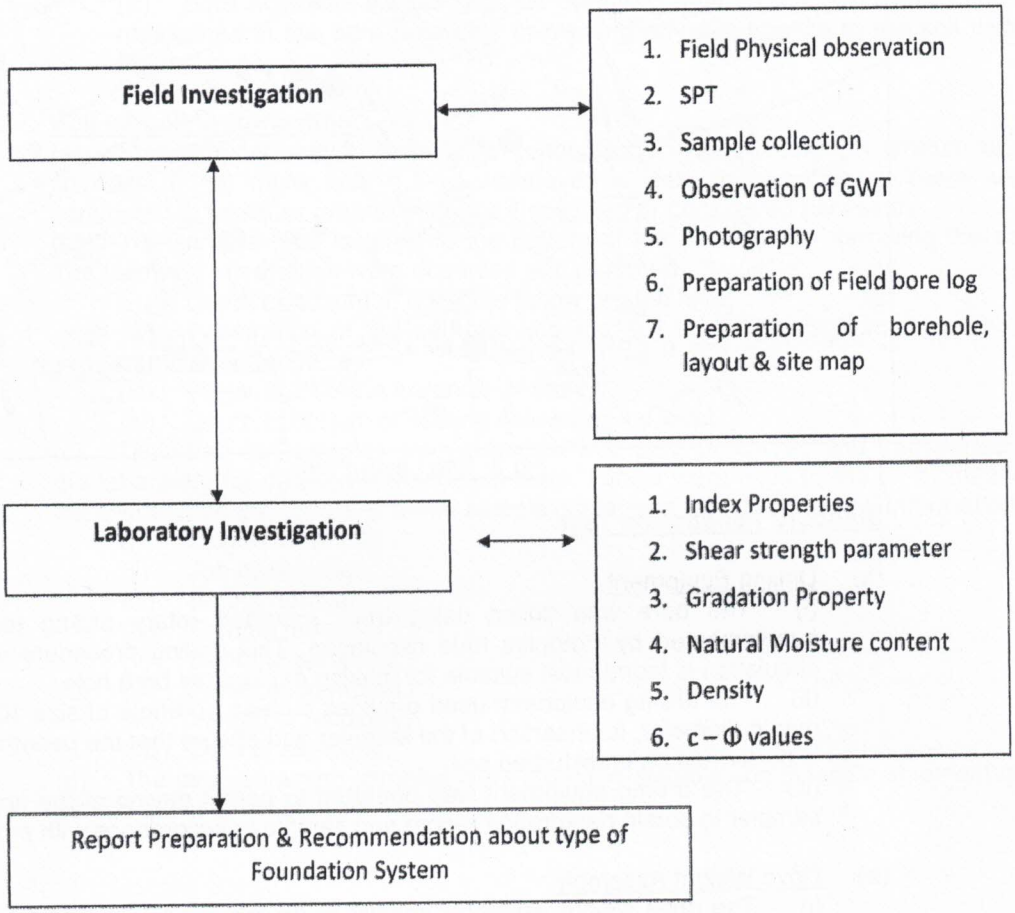


Fig 1: Flow Chart

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IV. Field Investigation.

1. **Site Exploration.**

(a) Subsurface exploration was carried out in a detailed procedure.

(b) Shear strength and compressibility of the soil was determined in the detailed exploration through Standard Penetration Tests and Laboratory Tests.

(c) The method of boring adopted for soil exploration is rotary boring. Rotary boring is carried out by cutting action of the soil. The bit is carried at the end of hollow, jointed drill rods which is rotated by the chuck. A mud laden fluid is pumped continuously, and fluid returns to surface in angular space.

(d) The site layout showing the soil exploration work is depicted below: -

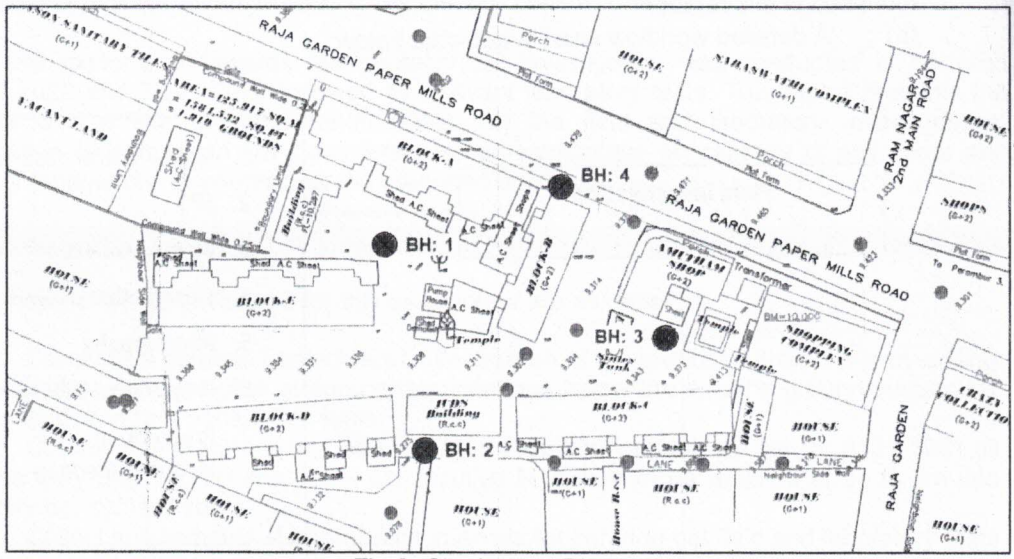


Fig 2: Site Layout Plan

2. **Standard Penetration Test.**

(a) Drilling Equipment.

(i) The bore was drilled using truck mounted rotary drilling techniques supplemented by Betonies mud circulation. This drilling procedure with mud circulation is found most suitable for making exploratory bore hole.

(ii) The drilling equipment used provides a clean borehole of size 100 to 150 mm in diameter, for insertion of the sampler and ensure that the penetration test is performed on undisturbed soil.

(iii) The drilling equipment was operated to permit driving of the split spoon sampler to obtain penetration record and sample in accordance with procedure.

(b) Drive Weight Assembly

(i) The drive weight assembly consist of driving head and a 63.5 kg weight with 75cm free fall.

(ii) It was ensured that the energy of the falling weight is not reduced by

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friction between the drive weight and the guides.

(iii) The rods to which the sampler is attached for driving was put in correct position, tightly coupled and straight in alignment. For driving the casting, a hammer heavier than 63.5 kg was used.

(c) Cleaning the Borehole

(i) The mud circulation was employed through the drill rods and letting it out though the side jets provided in the cutting tool thus preventing any disturbance at the bore hole bottom.

(ii) Mud circulation was used to stabilize the sides and the bottom of the bore hole, and then to bring the soil cuts to the surface. It is important to note that the mud jet is not used to cut the soils as in the case of wash boring technique. Use of drilling mud will also help in preventing the disturbance to the soil at the bore hole bottom during drilling operations.

(iii) Bore hole was always kept full of drilling mud so that a positive head is maintained in the bore hole thus preventing any disturbance to the soil within the test zone.

3. **Soil sampling for testing.**

(a) Standard penetration tests were conducted at every change in stratum or at intervals of not more than 1.5 m whichever is less. In some case, Tests were conducted at lesser or greater intervals if specified or considered necessary.

(b) The sampler was lowered to the bottom of the borehole for sampling the soil. The following information were observed and recorded.

(i) Depth of bottom of borehole below ground level.

(ii) Penetration of the sampler into the soil under the combined weight of sampler and rods.

(iii) Water level in the borehole or casing.

(iv) Depth of bottom of casting below ground level.

(c) Disturbed soil samples were collected and were preserved and transported to the laboratory for detailed identification tests. Labels were fixed to the jar or notation were written on the covers of these sample containers with the following information: -

(i) Origin of sample.
(ii) Job designation.
(iii) Boring number.
(iv) Sample number.
(v) Depth of sampling.
(vi) Penetration record.
(vii) Length of recovery.
(viii) Date of sampling.

(d) The jars containing samples were stored in suitable container for shipment and placed out of direct sunlight.

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4. **Reference Codes.**

S. No	IS Code	Description
1	IS : 1498 – 1970 (Reaffirmed 2007)	Classification & Identification of soil for general engineering purpose (First Revision)
2	IS : 1892 – 1979 (Reaffirmed 2002)	Code of practice for sub surface investigation for foundation (First Revision)
3	IS : 2131 – 1981 (Reaffirmed 2002)	Method of Standard Penetration Test for soil (First Revision)
4	IS : 2132 – 1986 (Reaffirmed 2002)	Code of practice for thin-walled tube sampling of soil (Second Revision)
5	IS : 4968 – 1976 (Reaffirmed 2007)	Method of sub surface sounding of soil: Static cone penetration (First Revision)

5. **Borehole Details.**

(a) Site Map & Location. The site is located at 13º2'0.25" N & 80°13'5.46" E, location map of the same is depicted below: -

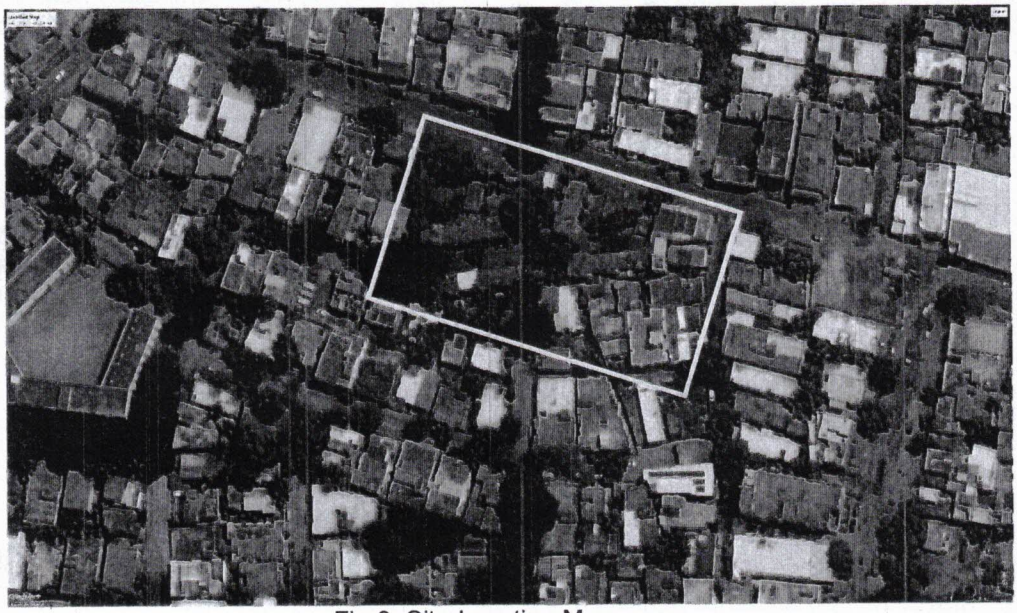


Fig 3: Site Location Map

(b) Bore log summary.

The summary of the four boreholes driven in the field as per IS: 1892 - 1979

(Reaffirmed 2002) consisting of the details of driven depth of the borehole, Ground Water Table, and their corresponding identifications are tabulated below: -

S. No	Borehole Identification Number	Driven Borehole Depth (M)	Ground Water Table (M)	Latitude	Longitude
1	BH-1	12.00	1.30	13°7'4.79"N	80°13'37.61" E
2	BH-2	12.00	1.50	13°7'3.83"N	80°13'37.88" E
3	BH-3	13.50	2.00	13°7'4.05"N	80°13'39.26" E
4	BH-4	20.00	1.80	13°7'5.4"N	80°13'38.69" E

(c) Photographs. Site photographs of each borehole are given below: -



Site Photo Showing the Soil Exploration Work

(d) Detailed Bore log. Bore log details with lithology of boreholes, classification of soil, standard penetration test data and 'N' values are enclosed as **Appendix 'A'**.

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V. Laboratory Testing.

1. Laboratory investigation consisted of classification tests like grain size distribution analysis, determination of specific gravity etc. Unconfined Compression test and Direct shear was conducted on preserved soil samples.

2. **Reference Codes.** All the field and laboratory tests were conducted according to the procedures stipulated in relevant IS codes referred as under: -

S. No.	IS Code	Description
1	IS: 2720 – 1983 (Part – 1) (Reaffirmed 2006)	Methods of test for soil: Preparation of dry soil sample for various test (Second Revision)
2	IS 2720 – 1980 (Part – 2) (Reaffirmed 2010)	Methods of test for soil: Determination of water content (Second Revision)
3	IS 2720 – 1980 (Part – 3) (Section– 1) (Reaffirmed 2002)	Methods of test for soil: Determination of specific gravity: Fine grained soil (First Revision)
4	IS 2720 – 1980 (Part – 3) (Section– 2) (Reaffirmed 2002)	Methods of test for soil: Determination of specific gravity: Fine, Medium, Coarse-grained soil (First Revision)
5	IS 2720 – 1985 (Part – 4) (Reaffirmed 2006)	Methods of test for soil: Grain size analysis (Second Revision)
6	IS 2720 – 1985 (Part – 5) (Reaffirmed 2006)	Methods of test for soil: Determination of liquid and plastic limit (Second Revision)
7	IS 2720 – 1985 (Part – 15) (Reaffirmed 2006)	Methods of test for soil: Determination of consolidation properties (First Revision)
8	IS 1809 – 1972 (Reaffirmed 2006)	Methods of test for soil: Glossary of terms & symbols relating to soil engineering (Third Revision)

3. Laboratory Test Results. Results and analysis of the tests conducted on the disturbed soil samples are enclosed as **Appendix 'A'**.

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VI. Safe Bearing Capacity Calculations.

1. The pile carrying capacity is calculated as per **IS 2911 (part 1/Sec 2):2010 [Reaffirmed 2002]** [Code *of practice for design and construction of pile foundations*: Part 1 Concrete piles, Section 2 Bored cast in-situ piles (CED 43: Soil and Foundation Engineering].

2. Formula for safe bearing capacity for pile foundation as per IS:2911 (Part I / Sec 2) – 1979: -

(a) For Piles in Granular Soils.

(i) The Ultimate Bearing Capacity (Qu)

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

(ii) Safe Load Carrying Capacity (QS) = Qu/F.S

(iii) Net Safe Load Carrying Capacity (Qns) = QS – Wt of Pile

(b) **For Piles in Cohesive Soils**

The Ultimate Bearing Capacity (Qu) $= A_p N_C\,C_P) + \sum_{i=I}^{n} \alpha_i\,C_i\,A_{Si}$

3. Detailed Safe Bearing Capacity calculations are enclosed as **Appendix 'B'**.

VII. Safe Bearing Capacity Analysis and Recommendations.

From the geotechnical exploration and consequent laboratory testing & analysis, the recommendations for the foundation to be adopted are deliberated below.

1. **Selection of Type of Foundation.**

(a) The ground water table has been reported to exist at a depth of about 1.3m to 2m from the existing ground level.

(b) The subsoil profile of the site consists of a 0.3m to 0.7m thick filled up layer. This layer is followed by a medium stiff / stiff / very stiff clayey silt layer or a medium stiff/stiff/very stiff silty clay/clay layer or a medium dense silty sand layer or a sandy gravel/clayey sand/sandy clay layers with SPT N value ranging from 3 to 25.

(c) The strong soil strata such as gravel/soft rock layers are found to be existing at deeper depths i.e., below 10m from the existing ground surface.

(d) Considering the load intensity anticipated by the proposed buildings and nature of the soil strata at this site, shallow isolated footings and or raft foundations are not suitable in this case.

(e) Hence **Bored Cast-In-Situ Pile Foundations are recommended** in these conditions to support the proposed structures.

(f) The load of the structure can be transferred to deeper depths bypassing the upper medium dense layers using pile foundations.

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(g) In view of the presence of Gravel / Soft rock at a depth of about 10m, it is desirable to **terminate the piles into the soft rock at a depth of 14.0m** from the existing ground level to achieve the required pile capacity.

(h) The specifications for pile foundations are given as under: -

(i)	Type of Foundation.	Bored cast-in-situ pile.
(ii)	Pile termination depth.	14m from the existing ground level.
(iii)	Pile cut off level.	1 m below the existing ground level
(iv)	Type of soil at Pile Termination.	Gravel/Rock strata

2. **Safe Bearing Capacity.**

(a) **Pile Load Carrying Capacity.**

The recommended safe pile carrying capacities for a depth of 14.0m "Bored cast in–situ pile foundation" of different diameters are computed using static analysis as per IS Code: IS 2911(Part1/Sec 2): 2010 and tabulated below: -

Diameter of Pile (m) (1)	Frictional Resistance (Tonnes) (2)	End Bearing Capacity (Tonnes) (3)	Total Pile Capacity (Tonnes) (4) = (2+3)	Factor of Safety (5)	Safe Pile Capacity (Tonnes) (6) = (4) / (5)
0.55	50.90	173.12	224.03	3.0	**74**
0.60	55.53	223.33	278.86	3.0	**93**
0.65	60.16	306.09	366.24	3.0	**122**

(b) **Uplift Capacity of Pile.**

The uplift capacity of piles of different diameters are computed using static analysis as per IS Code: IS 2911(Part1/Sec 2): 2010 and tabulated below: -

S. No	Length of Pile (m)	Uplift Capacity of Pile (Tons)		
		Diameter of Pile (m)		
		0.55m	0.60m	0.65m
1.	14.0	19.7	21.8	23.9

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(c) **Lateral Load Capacity of Pile**

Calculated using IS Code: IS 2911 (Part1/Sec 2 & sec 4): 2010

Length of Pile	Analysis	Diameter of Pile (m)		
		0.55	0.60	0.65
14.0m	Fixed End Moment (kN.m)	143.88	193.41	253.91
	Lateral Load (T)	7.4	9.31	11.4

3. **Recommendations.**

(a) The recommended pile foundation may be of "Bored cast in – situ pile" with casing while driving the pile and pouring the concrete. The casing pipe must be removed slowly and carefully while placing the concrete after giving proper compaction.

(b) The recommended safe load carrying capacities of the piles shall be confirmed by carrying out Initial Load Tests (compression and lateral) on piles before the construction of piles as well as Routine Load Tests as per IS 2911 Part 4 (1985).

(c) Carry out Pile Integrity Tests on working piles for a minimum 25% of the total number of piles in each block.

(d) For pile foundations, it is mandatory to perform necessary SPT (Standard Penetration Test) during piling and it should be ensured that the SPT values so obtained must be greater than or equal to the SPT values recorded during the filed investigation made on 26.01.2022 – 29.01.2022.

(e) 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.

(f) For the substructure [RCC] the environment exposure condition may be considered as 'Moderate', and all the precautions as laid by the relevant code of practice for the design of structures may be adopted.

(g) The Grade of Pile concrete mix shall be of M30 conforming to IS 456: 2000 (Design Mix). Portland Pozzolona cement or super slag cement shall be preferred in the construction.

(h) It is recommended to provide at least two piles per pile group or more 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.

(i) All the pile caps must be rigidly interconnected with each other in both directions.

(j) The entire recommendations as above are based on the four boreholes executed as per the TNUHDB's directions at the location shown by the TNUHDB engineer. The uniformity or otherwise of the soil delineation and strength profile over the entire site shall be verified during the construction if there are variations the same shall be reported to us for review and further advice.

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VIII. Conclusion.

From the Geotechnical Investigation, Shear strength parameters and compressibility parameters of different soil layers are established from the field and laboratory tests.

Based on the existing soil condition, it is recommended to provide "Bored cast in – situ pile" with casing foundation for the Reconstruction of 162 No. (S+9) tenements at Rajathottam scheme as recommend in the preceding sections of this report.

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Vetting report from IIT Madras



TNUHDB - RECONSTRUCTION OF 162 (S+9) TENEMENTS AT RAJATHOTTAM SCHEME IN GCC CORP DN 66 ZONE 6, CHENNAI.

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To

Date: 25/05/2022

Centre for Urbanization, Buildings & Environment (CUBE)
IIT Madras Research Park

Sub: Comments on the geotechnical investigation report for Reconstruction of 115 Tenements at Rajathottam, Pervallur in GCC Corp. Dn. 66 Zone VI, Chennai, Tamil Nadu.

Ref: Your Email dated 6/05/2022

With reference to the email dated above, CUBE, IIT Madras Research Park, Chennai approached the Geotechnical Engineering Division, Department of Civil Engineering, IIT Madras to take up the consultancy to review the geotechnical investigation report for the Reconstruction of 115 Tenements at Rajathottam, Pervallur in GCC Corp. Dn. 66 Zone VI, Chennai, Tamil Nadu. In relation to this, the following documents have been given to IIT Madras.

(1) Geotechnical investigation report dated 04/03/2022 prepared by Aashhirwaad Analytical Laboratory, Puducherry.
(2) Site layout plans

The following are the review comments on the submitted geotechnical investigation report.

a) A total of 4 number no's of boreholes have been drilled at the present site to assess the subsoil conditions up to a depth ranging from 12m to 20m from the existing ground level. Also, the boreholes have been terminated when the rock strata were encountered. It is proposed to construct S+9 tenements at the present site. Hence, the number of boreholes and depth of exploration is satisfactory for the proposed buildings.
b) The ground water table has been reported to exist at a shallow depth such as 1.3m to 2m from the existing ground level.
c) From the geotechnical investigation report provided, the soil profile consists of a filled-up layer with a thickness ranging from 0.3m to 0.7m. This layer is followed by a

soft/stiff/Very stiff silty clay/clay layer of 2.8m to 3.2m thickness in BH1 and BH2 (SPT N value 3 to 14). Whereas medium dense clayey sand/sand of 2.25m to 4.2m thickness exists in BH3 and BH4 (SPT N value 17 to 25). Below this layer, a medium dense/dense/very dense sand/clayey sand layer of 5.1m to 7.5m thickness (SPT N value 11 to 44) is found to occur. Below these layers, a soft/weathered rock layer is found to exist up to the borehole termination depth. In BH4, a hard rock layer is found to exist beyond 16m depth from the ground level up to the borehole termination depth.

d) The soil profile consists of alternate layers of stiff/very stiff clayey soils and medium dense/dense sandy soils. The strong soil strata such as soft/weathered rock layers are found to be existing at deeper depths i.e., below 10m from the existing ground surface. Considering the anticipated load intensity by the proposed buildings and the nature of the soil strata at this site, the pile foundations are recommended in the reports submitted. The following are the specifications for pile foundations:

- Type of foundation – Bored cast-in-situ pile
- Pile termination depth - The piles shall be terminated at a depth of 14m from the existing ground level. This shall be the minimum depth to be adopted to get adequate pile capacity.
- Pile cut off level – 1 m below the existing ground level
- Type of soil at pile termination – soft/weathered rock strata

The following are the calculated pile capacities for various pile diameters:

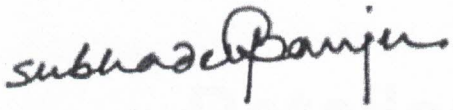
Pile diameter (mm)	550	600	650
Safe compression capacity, tons	74	93	122
Safe uplift capacity, tons	19.7	21.8	23.9
Lateral capacity, tons	7.4	9.3	11.4

- The recommended safe load-carrying capacities of the piles shall be confirmed by carrying out initial load tests (compression and lateral) on piles before the construction of piles and routine load tests as per IS 2911-Part 4 (1985).
- It is recommended to carry out pile integrity tests on working piles for a minimum 25 percent of the total number of piles.

- All the pile caps must be rigidly interconnected with each other in both directions.
- 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 the borehole bottom after lowering the reinforcement cage shall be strictly employed as quality control measures.
- Portland Pozzolana cement or super slag cement shall be preferred in the construction of foundations.
- The recommended safe capacity of the pile foundations can be ensured only by adopting a quality construction procedure with good quality control.

Remarks

It is hereby confirmed that the geotechnical investigation report and the foundation recommendations made in the report submitted are suitable and implementable for the proposed project.



(Prof. Subhadeep Banerjee)

Appendix A

Detailed Bore log & Laboratory Test Results



Name Of The Work :Geotechnical Investigation For The Proposed Reconstruction of 115 Nos Multistoried Tenements (S+9) at Rajathottaam, Peravallur, Chennai, Tamilnadu.

ASHHIRWAAD ANALYTICAL LABORATORY, PUDUCHERRY
(NABL Accredited Laboratory - TC-8619)

ULR : TC861922000000061F

BORE LOG - 1/4

Project No:	AAL.2014/TN/2022	Date:	26.01.2022	Location:	Peravallur,Tamil Nadu.
BH. No :	1	GWT (m):	1.30	Lat: 13°7'4.79" N Long: 80°13'37.61"	
Depth of boring (m) :		12.00m			

Depth Below GL	Soil stratum	Classification of soil	Thickness of Layer (m)	Depth of Sampling(m) UDS	Depth of Sampling(m) DS	Graphical Representation of Standard Penetration Test Data (N) N Value	10 20 30 40 50	Description /consistency	Natural moisture content (%)	Density (γ) t/m³	Index properties (%) Liquid limit (W_L)	Plastic limit (W_P)	Plasticity index(I_P)	Consistency index (I_C)	Free swell index(Cs)	Shear strength parameters Direct shear test C (kg/cm²)	Φ (degrees)	Gradation properties (%) Sieve analysis Gravel	Coarse sand	Medium sand	Fine sand	silt & clay	Cc	Cu
1.0		Fill up earth	0.30		0.5																			
2.0		Silty clay (CI)	3.00		1.5	8		Stiff	27	1.49	50	27	23	1.0	65	0.158	5°47'	0.00	0.00	0.00	5.47	94.53	-	-
3.0					2.0																			
4.0		Clay (CH)	0.20		2.5	14		Very Stiff																
5.0		Sand (SP)	7.00		3.0																			
6.0					3.5	12		Very Stiff	31	1.31	60	30	30	0.97	75	0.201	3°21'	0.00	0.00	0.00	0.00	100.00	-	-
7.0					4.0																			
8.0					4.5	31		Dense	16	1.61	Non-Plastic				Nil	0.014	30°11'	0.00	0.00	68.50	24.62	6.88	0.375	4.16
9.0					5.0																			
10.0					5.5																			
					6.0	18		Medium Dense	14	1.64	Non-Plastic				Nil	0.025	31°07'	0.00	0.00	63.73	29.45	6.82	0.418	4.25
					6.5																			
					7.0																			
					7.5	29		Medium Dense																
					8.0																			
					8.5																			
					9.0	$50_{(23.5cm\downarrow)}$		Very Dense	17	1.69	Non-Plastic				Nil	1.047	30°35'	0.00	0.00	65.47	30.00	4.53	0.566	3.76
					9.5																			
					10.0																			

Legend:

↓- Denotes Penetration of the Split Spoon Sampler

GW Well graded gravel GP Poorly graded gravel GM Silty gravel GC Clayey Gravel ▲ Rebound

SW Well graded sand SP Poorly graded sand SM Silty sand SC Clayey sand * Self Pentration

ML Low compressible silt OL Organic silt/clay(Low) CL Low compressible clay CRR- Core Recovery Ratio (for Rock)

MI Medium compressible OI Organic silt/clay(Medium) CI Medium compressible clay UDS - Undisturbed sample # No Sample

MH Highly compressible sil OH Organic silt/clay(High) CH Highly compressible clay GWT- Ground Water Table UDS Failed

Prepared by
Junior Engineer

Checked by
General Manager

Name Of The Work :Geotechnical Investigation For The Proposed Reconstruction of 115 Nos Multistoried Tenements (S+9) at Rajathottaam, Peravallur, Chennai, Tamilnadu.

ASHHIRWAAD ANALYTICAL LABORATORY, PUDUCHERRY

(NABL Accredited Laboratory - TC-8619)

NABL - TC - 8619

ULR : TC861922000000061F

BORE LOG - 1/4

Project No:	AAL.2014/TN/2022	Date:	26.01.2022	Location:	Peravallur ,Tamil Nadu
BH. No :	1	GWT (m):	1.30m	Lat: 13°7'4.79" N Long: 83°13'37.61"	
Depth of boring (m) :		12.0m			

Depth Below GL	Soil stratum	Classification of soil	Thickness of Layer (m)	Depth of Sampling(m) UDS	Depth of Sampling(m) DS	Graphical Representation of Standard Penetration Test Data (N)	Description /consistency	Natural moisture content (%)	Density (γ) t/m³	Index properties (%) Liquid limit (W_L)	Plastic limit (W_P)	Plasticity index(I_P)	Consistency index (I_C)	Free swell index(Cs)	Shear strength parameters Direct shear test C (kg/cm²)	Φ (degrees)	Gradation properties (%) Sieve analysis Gravel	Coarse sand	Medium sand	Fine sand	silt & clay	Cc	Cu
		Sand (SP)	0.50		10.5	50 (26cm↓)	V.Dense	7	1.98	Non-Plastic				Nil	0.008	35°77'	-	-	-	-	-	-	-
11.0		Weathered Rock (Slate Stone)	1.50		11.0																		
					11.5																		
12.0					12.0	50 (20cm↓)	Very Dense																

Legend:

↓- Denotes Penetration of the Split Spoon Sampler

GW Well graded gravel GP Poorly graded gravel GM Silty gravel GC Clayey Gravel ▲ Rebound

SW Well graded sand SP Poorly graded sand SM Silty sand SC Clayey sand ▲ * Self Pentration

ML Low compressible silt OL Organic silt/clay(Low) CL Low compressible clay CRR- Core Recovery Ratio (for Rock)

MI Medium compressible OI Organic silt/clay(Medium) CI Medium compressible clay UDS - Undisturbed sample # No Sample

MH Highly compressible sil OH Organic silt/clay(High) CH Highly compressible clay GWT- Ground Water Table UDS Failed

Prepared by
Junior Engineer

Checked by
General Manager

Name Of The Work :Geotechnical Investigation For The 8.1 Proposed Reconstruction of 115 Nos Multistoried Tenements (S+9) at Rajathottaam, Peravallur, Chennai, Tamilnadu.

ASHHIRWAAD ANALYTICAL LABORATORY, PUDUCHERRY

(NABL Accredited Laboratory - TC-8619)

NABL-TC-8611

ULR : TC861922000000062F

BORE LOG - 2/4

Project No:	AAL.2014/TN/2022	Date:	26.01.2022	Location:	Peravallur,Tamil Nadu.
BH. No :	2	GWT (m):	1.50m	Lat: 13°7'3.83" N Long: 80°13'37.88"	
Depth of boring (m) :		12.00			

Depth Below GL	Soil stratum	Classification of soil	Thickness of Layer (m)	Depth of Sampling(m) UDS	Depth of Sampling(m) DS	Graphical Representation of Standard Penetration Test Data (N) N Value	Graphical Representation of Standard Penetration Test Data (N) 10 20 30 40 50	Description /consistency	Natural moisture content (%)	Density (γ) t/m³	Index properties (%) Liquid limit (W_L)	Plastic limit (W_P)	Plasticity index(I_P)	Consistency index (I_C)	Free swell index(Cs)	Shear strength parameters Direct shear test C (kg/cm²)	Φ (degrees)	Gradation properties (%) Sieve analysis Gravel	Coarse sand	Medium sand	Fine sand	silt & clay	Cc	Cu
1.0		Fill up earth	0.70		0.5																			
					1.5	12		Very Stiff	32	1.49	50	23	27	0.67	55	0.189	4°15'	0.00	0.00	0.00	6.66	93.34	-	-
2.0					2.0																			
		Silty Clay (CI)	2.80		2.5	14		Very Stiff	34	1.33	53	25	28	0.68	60	0.157	5°78'	0.00	0.00	0.00	5.47	94.53	-	-
3.0					3.0																			
					3.5	3		Soft	36	1.47	58	28	30	0.73	65	.0.144	8°14	0.00	0.00	0.00	4.12	95.88	-	-
4.0					4.0																			
					4.5	16		Medium Dense																
5.0					5.0																			
					5.5																			
6.0					6.0	19		Medium Dense	19	1.65	Non-Plastic				Nil	0.028	30°14'	0.00	0.00	51.74	44.55	3.72	0.327	3.53
					6.5																			
7.0		Sand (SP)	6.40		7.0																			
					7.5	40		Dense																
8.0					8.0																			
					8.5																			
9.0					9.0	50(18.5cm↓)		Very Dense	18	1.69	Non-Plastic				Nil	0.047	30°45'	0.56	2.26	50.63	38.63	7.91	0.400	4.94
					9.5																			
10.0					10.0																			

Legend:

GW Well graded gravel GP Poorly graded gravel GM Silty gravel GC Clayey Gravel

SW Well graded sand SP Poorly graded sand SM Silty sand SC Clayey sand

ML Low compressible silt OL Organic silt/clay(Low) CL Low compressible clay

MI Medium compressible sOI Organic silt/clay(Medium) CI Medium compressible clay

MH Highly compressible sil OH Organic silt/clay(High) CH Highly compressible clay

↓- Denotes Penetration of the Split Spoon Sampler

▲ Rebound

* Self Pentration

CRR- Core Recovery Ratio (for Rock)

UDS - Undisturbed sample # No Sample

GWT- Ground Water Table UDS Failed

Prepared by

Junior Engineer

Checked by

General Manager

Name Of The Work :Geotechnical Investigation For The 8.1 Proposed Reconstruction of 115 Nos Multistoried Tenements (S+9) at Rajathottaam, Peravallur, Chennai, Tamilnadu.

ASHHIRWAAD ANALYTICAL LABORATORY, PUDUCHERRY

(NABL Accredited Laboratory - TC-8619)

ULR : TC861922000000062F

BORE LOG - 2/4

Project No:	AAL.2014/TN/2022	Date:	26.01.2022	Location:	Peravallur ,Tamil Nadu
BH. No :	2	GWT (m):	1.50m	Lat: 13°7'3.83" N Long: 80°13'37.88"	

Depth of boring (m) :			13.5m			Graphical Representation of Standard Penetration Test Data (N)						Description /consistency	Natural moisture content (%)	Density (γ) t/m³	Index properties (%)					Shear strength parameters		Gradation properties (%)						
																				Direct shear test		Sieve analysis						
Depth Below GL	Soil stratum	Classification of soil	Thickness of Layer (m)	Depth of Sampling(m) UDS	Depth of Sampling(m) DS	N Value	10	20	30	40	50				Liquid limit (W_L)	Plastic limit (W_P)	Plasticity index(I_P)	Consistency index (I_C)	Free swell index(Cs)	C (kg/cm²)	Φ (degrees)	Gravel	Coarse sand	Medium sand	Fine sand	silt & clay	Cc	Cu
		Sand (SP)	0.50		10.5	$50_{(25cm\downarrow)}$						V.Dense	19	1.69	Non-Plastic				Nil	0.008	35°25'	-	-	-	-	-	-	-
11.0		Weathered Rock (slate Stone)	1.50		11.0																						
					11.5																						
12.0					12.0	$50_{(12cm\downarrow)}$						Very Dense															

Legend:

↓- Denotes Penetration of the Split Spoon Sampler

GW Well graded gravel GP Poorly graded gravel GM Silty gravel GC Clayey Gravel ▲ Rebound

SW Well graded sand SP Poorly graded sand SM Silty sand SC Clayey sand * Self Pentration

ML Low compressible silt OL Organic silt/clay(Low) CL Low compressible clay CRR- Core Recovery Ratio (for Rock)

MI Medium compressible OI Organic silt/clay(Medium) CI Medium compressible clay UDS - Undisturbed sample # No Sample

MH Highly compressible sil OH Organic silt/clay(High) CH Highly compressible clay GWT- Ground Water Table ⊗ UDS Failed

Prepared by
Junior Engineer

Checked by
General Manager

Name Of The Work :Geotechnical Investigation For The 8.1 Proposed Reconstruction of 115 Nos Multistoried Tenements (S+9) at Rajathottaam, Peravallur, Chennai, Tamilnadu.

ASHHIRWAAD ANALYTICAL LABORATORY, PUDUCHERRY
(NABL Accredited Laboratory - TC-8619)

NABL - TC - 8619

ULR : TC861922000000063P

BORE LOG - 3/4

Project No:	AAL.2014/TN/2022	Date:	27.01.2022	Location:	Peravallur,Tamil Nadu.
BH. No :	3	GWT (m):	2.0m	Lat: 13°7'4.05" N Long: 80°13'39.26"	
Depth of boring (m) :		13.5m			

Depth Below GL	Soil stratum	Classification of soil	Thickness of Layer (m)	Depth of Sampling(m) UDS	Depth of Sampling(m) DS	Graphical Representation of Standard Penetration Test Data (N) N Value	10 20 30 40 50	Description /consistency	Natural moisture content (%)	Density (Y) t/m³	Liquid limit (W_L)	Plastic limit (W_P)	Plasticity index(I_P)	Consistency index (I_C)	Free swell index(Cs)	Shear strength parameters: Direct shear test C (kg/cm²)	Φ (degrees)	Gradation properties (%): Sieve analysis Gravel	Coarse sand	Medium sand	Fine sand	silt & clay	Cc	Cu
1.0		Fill up earth (Bitumen)	0.50		0.5																			
2.0		Clayey Sand (SC)	2.25		1.5	22		Medium	24	1.58		Slightly Plastic			35	0.078	27°14'	3.36	1.41	20.14	62.37	12.72	-	-
3.0					2.0																			
4.0					2.5	17		Medium	29	1.59		Slightly Plastic			38	0.069	28°11'	0.32	0.32	26.05	59.13	14.18	-	-
5.0					3.0																			
6.0		Sand (SP)	6.25		3.5	23		Medium Dense	23	1.64		Non-Plastic			Nil	0.087	30°08'	0.72	0.24	55.43	21.81	3.36	0.46	4.54
7.0					4.0																			
8.0					4.5	20		Medium Dense																
9.0					5.0																			
10.0		Weathered rock (Slate Stone)	1.00		5.5																			
					6.0	11		Medium Dense	14	1.73		Non-Plastic			Nil	0.011	31°55'	1.23	0.31	63.85	27.85	6.77	0.338	5.0
					6.5																			
					7.0																			
					7.5	30		Medium Dense																
					8.0																			
					8.5																			
					9.0	60		Very Dense	18	1.78		Non-Plastic			Nil	0.028	30°14'	0.17	2.38	60.55	27.38	9.52	0.326	4.16
					9.5																			
					10.0																			

Legend:

↓- Denotes Penetration of the Split Spoon Sampler

GW Well graded gravel GP Poorly graded gravel GM Silty gravel GC Clayey Gravel ▲ Rebound

SW Well graded sand SP Poorly graded sand SM Silty sand SC Clayey sand * Self Pentration

ML Low compressible silt OL Organic silt/clay(Low) CL Low compressible clay CRR- Core Recovery Ratio (for Rock)

MI Medium compressible sOI Organic silt/clay(Medium) CI Medium compressible clay UDS - Undisturbed sample # No Sample

MH Highly compressible sil OH Organic silt/clay(High) CH Highly compressible clay GWT- Ground Water Table UDS Failed

Prepared by
Junior Engineer

Checked by
General Manager

Name Of The Work :Geotechnical Investigation For The 8.1 Proposed Reconstruction of 115 Nos Multistoried Tenements (S+9) at Rajathottaam, Peravallur, Chennai, Tamilnadu.

ASHHIRWAAD ANALYTICAL LABORATORY, PUDUCHERRY
(NABL Accredited Laboratory - TC-8619)

NABL - TC - 8619

ULR : TC861922000000063P

BORE LOG - 3/4

Project No: AAL.2014/TN/2022	Date:	27.01.2022	Location: Peravallur ,Tamil Nadu
BH. No : 3	GWT (m):	2.0m	Lat: 13°7'4.05" N Long: 80°13'39.26"E
Depth of boring (m) :	13.5m		

Depth Below GL	Soil stratum	Classification of soil	Thickness of Layer (m)	Depth of Sampling(m) UDS	Depth of Sampling(m) DS	Graphical Representation of Standard Penetration Test Data (N) N Value	10 20 30 40 50	Description /consistency	Natural moisture content (%)	Density (γ) t/m³	Index properties (%) Liquid limit (W_L)	Plastic limit (W_P)	Plasticity index(I_P)	Consistency index (I_C)	Free swell index(Cs)	Shear strength parameters Direct shear test C (kg/cm²)	Φ (degrees)	Gradation properties (%) Sieve analysis Gravel	Coarse sand	Medium sand	Fine sand	silt & clay	Cc	Cu
					10.5	$80_{(26cm\downarrow)}$		V.Dense	8	1.95	Non - Plastic				Nil	0.008	35°25'	-	-	-	-	-	-	-
11.0					11.0																			
					11.5																			
12.0		Weathered rock (Slate Stone)	3.50		12.0	$100_{(23cm\downarrow)}$		Very Dense																
					12.5																			
13.0					13.0			Very																
					13.5	$105_{(30cm\downarrow)}$		Dense																

Legend:

↓- Denotes Penetration of the Split Spoon Sampler

GW Well graded gravel	GP Poorly graded gravel	GM Silty gravel	GC Clayey Gravel	▲ Rebound	Prepared by
SW Wellgraded sand	SP Poorly graded sand	SM Silty sand	SC Clayey sand	* Self Pentration	Junior Engineer
ML Low compressible silt	OL Organic silt/clay(Low)	CL Low compressible clay	CRR- Core Recovery Ratio (for Rock)		
MI Medium compressible sOI	Organic silt/clay(Medium)	CI Medium compressible clay	UDS - Undisturbed sample	# No Sample	Checked by
MH Highly compressible sil	OH Organic silt/clay(High)	CH Highly compressible clay	GWT- Ground Water Table	UDS Failed	General Manager

Name Of The Work :Geotechnical Investigation For The 8.1 Proposed Reconstruction of 115 Nos Multistoried Tenements (S+9) at Rajathottaam, Peravallur, Chennai, Tamilnadu.

ASHHIRWAAD ANALYTICAL LABORATORY, PUDUCHERRY
(NABL Accredited Laboratory - TC-8619)

NABL - TC - 8619

ULR : TC861922000000064P

BORE LOG - 4/4

Project No:	AAL.2014/TN/2022	Date:	28.01.2022	Location:	Peravallur,Chennai
BH. No :	4	GWT (m):	1.80m	Lat: 13°7'5.4" N Long: 80°13'38.69"E	
Depth of boring (m) :		20.0m			

Depth Below GL	Soil stratum	Classification of soil	Thickness of Layer (m)	Depth of Sampling(m) UDS	Depth of Sampling(m) DS	Graphical Representation of Standard Penetration Test Data (N) N Value	10 20 30 40 50	Description/consistency	Natural moisture content (%)	Density (γ) t/m³	Index properties (%) Liquid limit (W_L)	Plastic limit (W_P)	Plasticity index(I_P)	Consistency index (Ic)	Free swell index(Cs)	Shear strength parameters Direct shear test C (kg/cm²)	Φ (degrees)	Gradation properties (%) Sieve analysis Gravel	Coarsesand	Medium sand	Fine sand	silt & clay	Cc	Cu
1.0		Fill Up Earth (Sand)	0.70		0.5																			
					1.0																			
2.0					1.5	23		Medium Dense	20	1.68			Non-Plastic		Nil	0.018	30°08'	0.11	3.08	55.89	36.71	4.21	0.460	4.2
					2.0																			
3.0		Sand (SP)	4.20		2.5	25		Medium Dense																
					3.0																			
4.0					3.5	24		Medium Dense	19	1.71			Non-Plastic		Nil	0.028	31°11'	0.00	2.10	58.15	33.92	5.83	.0.392	5.0
					4.0																			
5.0					4.5	24		Medium Dense																
					5.0																			
6.0					5.5																			
					6.0	14		Medium Dense	28	1.58			Slightly- Plastic		35	0.058	28°95'	0.00	0.00	29.16	37.59	18.31	-	-
7.0		Clayey Sand (SC)	4.10		6.5																			
					7.0																			
8.0					7.5	30		Medium Dense																
					8.0																			
9.0					8.5																			
					9.0	44		Dense	27	1.42			Slightly- Plastic		40	0.047	27°14'	1.93	3.09	41.70	24.32	28.96	0.38	5.27
10.0		Sand (SP)	1.00		9.5																			
					10.0																			

Legend:

GW Well graded gravel GP Poorly graded gravel GM Silty gravel GC Clayey Gravel

SW Well graded sand SP Poorly graded sand SM Silty sand SC Clayey sand

ML Low compressible silt OL Organic silt/clay(Low) CL Low compressible clay

MI Medium compressible OI Organic silt/clay(Medium) CI Medium compressible clay

MH Highly compressible si OH Organic silt/clay(High) CH Highly compressible clay

↓- Denotes Penetration of the Split Spoon Sampler

▲ Rebound

* Self Pentration

CRR- Core Recovery Ratio (for Rock)

UDS - Undisturbed sample

GWT- Ground Water Table

No Sample

⊗ UDS Failed

Prepared by
Junior Engineer

Checked by
General Manager

Name Of The Work :Geotechnical Investigation For 8.1 Proposed Reconstruction of 115 Nos Multistoried Tenements (S+9) at Rajathottaam, Peravallur, Chennai, Tamilnadu.

ASHHIRWAAD ANALYTICAL LABORATORY, PUDUCHERRY
(NABL Accredited Laboratory - TC-8619)

NABL-TC-8619

ULR : TC861922000000064P

BORE LOG - 4/4

Project No:	AAL.2014/TN/2022	Date:	29.01.2022	Location:	Peravallur ,Chennai
BH. No :	4	GWT (m):	1.80m	Lat: 13°7'5.4" N Long: 80°13'38.69"E	
Depth of boring (m) :		20.0m			

Depth Below GL	Soil stratum	Classification of soil	Thickness of Layer (m)	Depth of Sampling(m) UDS	Depth of Sampling(m) DS	Graphical Representation of Standard Penetration Test Data (N) N Value	10 20 30 40 50	Description/consistency	Natural moisture content (%)	Density (γ) t/m³	Index properties (%) Liquid limit (W_L)	Plastic limit (W_P)	Plasticity index(I_P)	Consistency Index (Ic)	Free swell index(Cs)	Shear strength parameters Direct shear test C (kg/cm²)	Φ (degrees)	Gradation properties (%) Sieve analysis Gravel	Coarsesand	Medium sand	Fine sand	silt & clay	Cc	Cu
					10.5	40		Dense																
11.0					11.0																			
					11.5																			
12.0					12.0	101(7cm↓)		Very Dense																
					12.5																			
13.0		Weathered Rock (Slate stone)	6.00		13.0			Very Dense																
					13.5	101(5cm↓)																		
14.0					14.0																			
					14.5																			
15.0					15.0	Rebound		Very Dense																
					15.5																			
16.0					16.0	Rebound		Very Dense																
					16.5																			
17.0					17.0	Rebound		Very Dense			RQD = 45%							CRR = 65%						
					17.5																			
18.0					18.0																			
		Hard Rock	4.00		18.5	Rebound		Very Dense			RQD = 32%							CRR = 75%						
19.0					19.0																			
					19.5																			
20.0					20.0	Rebound		Very Dense			RQD = 42%							CRR = 70%						

Legend:

↓- Denotes Penetration of the Split Spoon Sampler

GW Well graded gravel GP Poorly graded gravel GM Silty gravel GC Clayey Gravel ▲ Rebound

SW Well graded sand SP Poorly graded sand SM Silty sand SC Clayey sand * Self Pentration

ML Low compressible silt OL Organic silt/clay(Low) CL Low compressible clay CRR- Core Recovery Ratio (for Rock)

MI Medium compressible OI Organic silt/clay(Medium) CI Medium compressible clay UDS - Undisturbed sample # No Sample

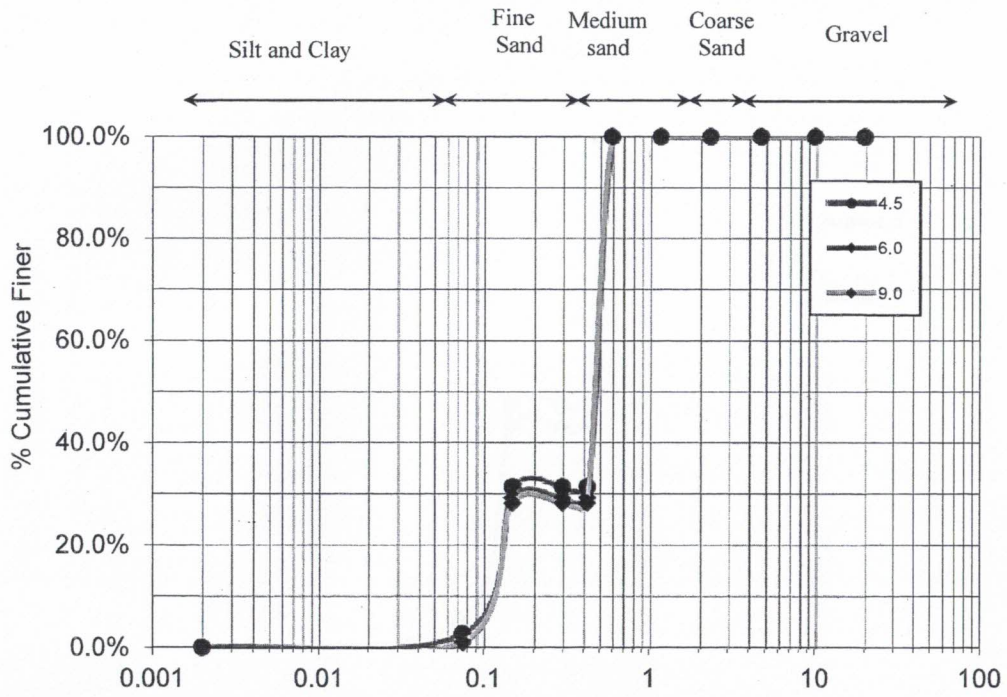
MH Highly compressible si OH Organic silt/clay(High) CH Highly compressible clay GWT- Ground Water Table UDS Failed

Prepared by
Junior Engineer

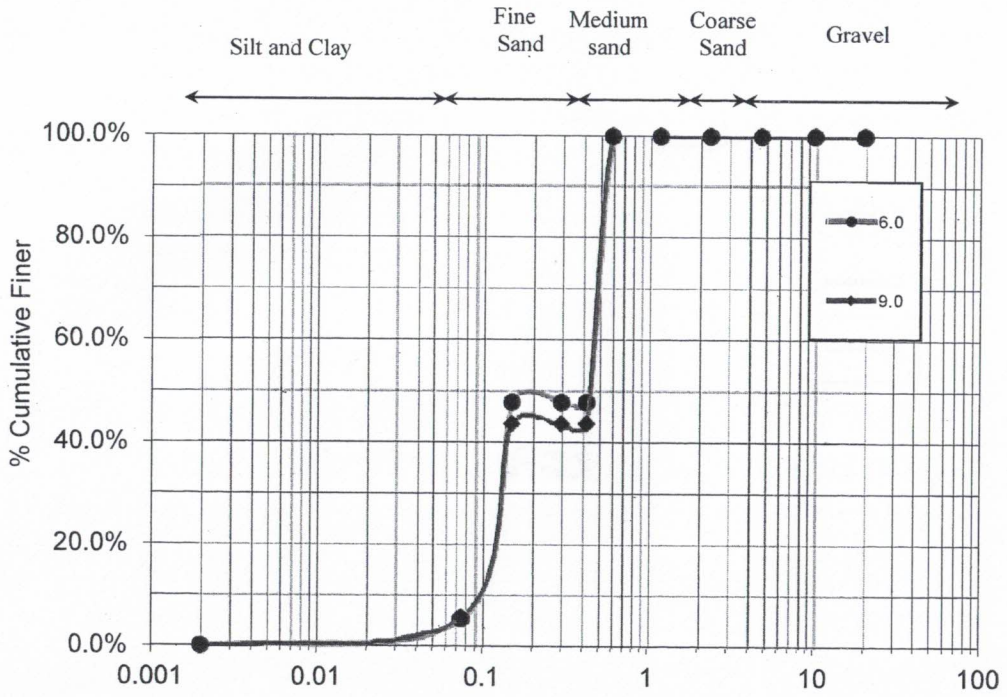
Checked by
General Manager

BH - 1

GRAIN SIZE DISTRIBUTION CURVE

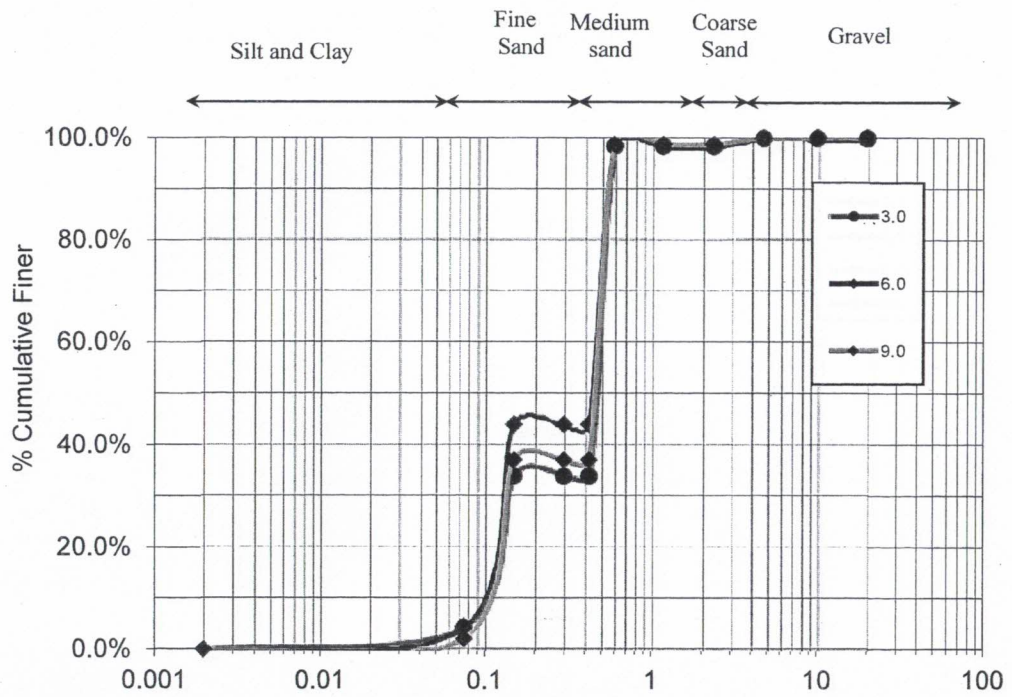


BH - 2
GRAIN SIZE DISTRIBUTION CURVE



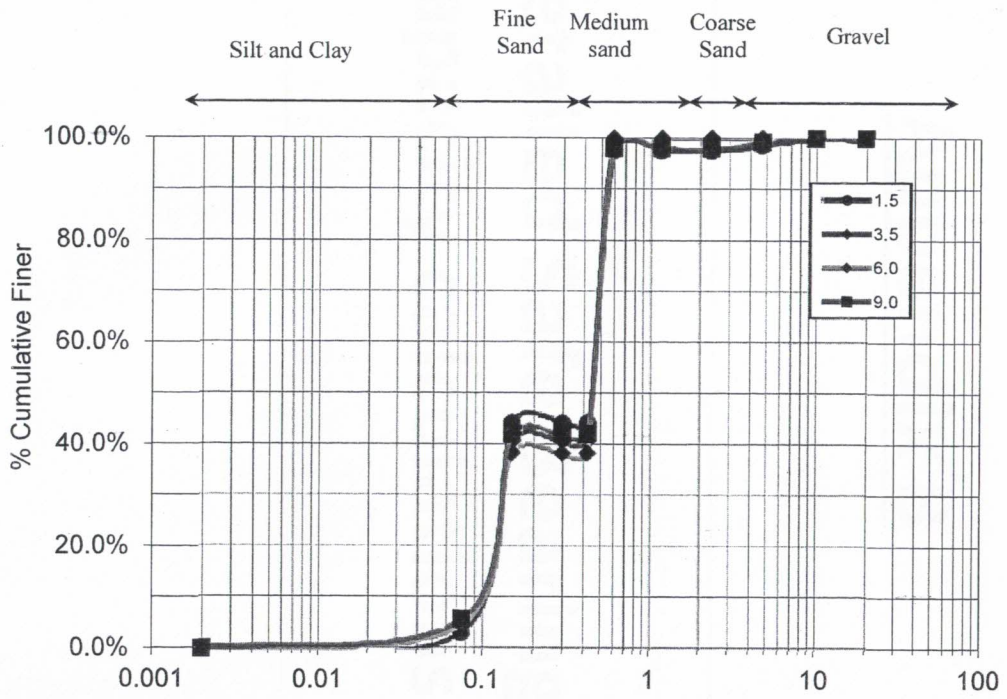
BH - 3

GRAIN SIZE DISTRIBUTION CURVE



BH - 4

GRAIN SIZE DISTRIBUTION CURVE



Appendix B

Detailed Safe Bearing Capacity calculations

CUBE
IITM RESEARCH PARK

SAFE BEARING CAPACITY FOR PILE FOUNDATION AS PER IS:2911 (Part I / Sec 2) – 1979:

Frictional Capacity of pile:

Dia of Pile = 0.55m ; Length of Pile = 14.0m Bore Hole : BH1

Layer 0-3.8m (Considered Cohesive Soil)

$Qs_1 = \alpha_i C_i A_{si}$

α_i = Adhesion Factor (or) Reduction Factor = 0.4 (Taken from graph (fig 2) in IS 2911 Part 1 sec2)

A_{si} = п DL = 3.14 X 0.55 X 3.8 = 6.56m²

Qs_1 = 0.4 x 1.80 x 6.56 = **4.72 T**

***Layer 3.8 – 10.5m (Considered Granular Soil)**

$Qs_2 = KiP_{Di} \tan \delta_i A_{Si}$

K_i = Co efficient of earth pressure = K_i (1-sin Ø) = 0.48

P_{Di} = Effective over burden pressure = γ x Length of pile (Thickness of layer)

Over Burden Pressure	Layer 1 (m)	Layer2 (m)
Layers	**0 – 3.8**	**3 – 10.5**
Density of soil ( ) in t/m²	(1.49 + 1.31) /2 = 1.4	1.72
Thickness (D) in m	3.8	6.7
Overburden Pressure (t/m²) - x D	5.32	11.52
Total Depth from GL of this Layer (m)	10.5	
Water Table in m	1.3m	
Pore Pressure (t/m²)	(10.5 -1.3) x 0.981 = 9.02 t/m²	
Eff. Overburden Pressure (t/m²)	(5.32 + 11.52) – 9.02 = **7.82 t/m²**	

δ = angle of wall friction between pile and soil = 30°

A_{Si} = Surface area of pile shaft

п DL = 3.14 x 0.55 x 6.7

= 11.57m²

Qs_2 = 0.48 X 7.82 x tan 31 x 11.57 = **26.08 T**

***Layer 10.5 – 14.0m (Considered Granular Soil)**

$K_i (1-\sin \emptyset) = 0.42$

Over Burden Pressure (PD_i)	Layer 1 (m)	Layer2 (m)	Layer3 (m)	
Layers	**0 – 3.8**	**3.8 – 10.5**	**10.5 – 14.0**	
Density of soil ( ) in t/m²	(1.49 + 1.31) /2 = 1.4	1.72	1.98	
Thickness (D) in m	3.8	6.7	3.5	
Overburden Pressure (t/m²) - x D	5.32	11.52	6.93	
Total Depth from GL of this Layer (m)	14.0			
Water Table in m	1.3m			
Pore Pressure (t/m²)	(14.0 -1.3) x 0.981 = 12.45t/m²			
Eff. Overburden Pressure (t/m²)	(5.32 + 11.52 + 6.93) – 12.45 = **11.33 t/m²**			

Tan δ = 35°

Asi = π DL = 3.14 x 0.55 x 3.5

= 3.14 x 0.55 x 3.5 = 6.04m²

Qs_3 = 0.42 x 11.33 x tan 35° x 6.04 = **20.12T**

For calculating End Bearing Capacity

$$A_p(\frac{1}{2} D \gamma N_\gamma + P_D N_q)$$

P_{Di} = Effective over burden pressure = γ x Effective Length of pile (15D of pile)

Over Burden Pressure (PD_i)	Layer 1 (m)	Layer2 (m)		
Layers	**0 – 3.8**	**3.8 – 8.25**		
Density of soil ( ) in t/m²	(1.49 + 1.31) /2 = 1.4	1.62		
Thickness (D) in m	3.8	4.45		
Overburden Pressure (t/m²) - x D	5.32	7.20		

Effective Length of pile	15 D of pile = **8.25m**
Water Table in m	1.3m
Pore Water Pressure (t/m^2)	(8.25-1.3) = 6.95
Eff. Overburden Pressure (t/m^2)	(5.32 + 7.20)-6.95 = **5.58 t/m^2**

Tan δ = 40° (Assume)

N_γ = General Shear Failure (IS 6403) = 109.41

N_q = Taken from the graph (fig 1) in IS 2911 part 1 sec 2 = 120.0

Ap = $\pi (0.55)^2 / 4$ = $0.237 m^2$

Q_{End} = 0.237 (0.5 x 0.55 x 1.98 x 109.41 + 5.58 x 120.0)

= **173.12 T**

Total Frictional Capacity = $Qs_1 + Qs_2 + Qs_3 + Qs_4 + Qs_5 + Qs_6$

= 4.72 + 26.08 + 20.12

= **50.90T**

Ultimate pile load Carrying Capacity = $Q_{\text{Frictional Capacity}} + Q_{\text{End Bearing Capacity}}$

= 50.90 + 173.12 = **224.02T**

Safe pile load Carrying Capacity = 224.02/ F.O.S = 224.02 / 3.0 = **74T**

UPLIFT CAPACITY OF PILE as per IS 2911 (Part 1/ sec2): 2010 clause 6.3.2

Uplift Capacity = (Total Frictional Resistance + self-weight of pile) / FOS

Self Weight of pile = Area of pile x Length of pile x Unit wt. of concrete

= 0.237 x 14.0 x 2.5

= **8.29 T**

Uplift Capacity = 50.90 + 8.29 / 3.0 = **19.73T**

Dia of Pile = 0.60m ; Length of Pile = 14.0m Bore Hole : BH1

Layer 0-3.8m (Considered Cohesive Soil)

$Qs_1 = \alpha_i C_i A_{si}$

α_i = Adhesion Factor (or) Reduction Factor = 0.4 (Taken from graph (fig 2) in IS 2911 Part 1 sec2)

$A_{si} = \pi DL = 3.14 \times 0.60 \times 3.8 = 7.16m^2$

$Qs_1 = 0.4 \times 1.80 \times 7.16 =$ **5.15 T**

***Layer 3.8 – 10.5m (Considered Granular Soil)**

$Qs_2 = KiP_{Di} \tan \delta_i A_{Si}$

K_i = Co efficient of earth pressure = K_i (1-sin Ø) = 0.48

P_{Di} = Effective over burden pressure = γ x Length of pile (Thickness of layer)

Over Burden Pressure	Layer 1 (m)	Layer2 (m)
Layers	**0 – 3.8**	**3 – 10.5**
Density of soil ( ) in t/m²	(1.49 + 1.31) /2 = 1.4	1.72
Thickness (D) in m	3.8	6.7
Overburden Pressure (t/m²) - x D	5.32	11.52
Total Depth from GL of this Layer (m)	10.5	
Water Table in m	1.3m	
Pore Pressure (t/m²)	(10.5 -1.3) x 0.981 = 9.02 t/m²	
Eff. Overburden Pressure (t/m²)	(5.32 + 11.52) – 9.02 = **7.82 t/m²**	

δ = angle of wall friction between pile and soil = 30°

A_{Si} = Surface area of pile shaft

$\pi DL = 3.14 \times 0.60 \times 6.7$

$= 12.62m^2$

Qs_2 = 0.48 X 7.82 x tan 31 x 12.62 = **28.46 T**

*Layer 10.5 – 14.0m (Considered Granular Soil)

$K_i (1-\sin \emptyset) = 0.42$

Over Burden Pressure (PD_i)	Layer 1 (m)	Layer2 (m)	Layer3 (m)	
Layers	**0 – 3.8**	**3.8 – 10.5**	**10.5 – 14.0**	
Density of soil ($\frac{si}{\gamma}$) in t/m²	(1.49 + 1.31) /2 = 1.4	1.72	1.98	
Thickness (D) in m	3.8	6.7	3.5	
Overburden Pressure (t/m²) - γ x D	5.32	11.52	6.93	
Total Depth from GL of this Layer (m)	14.0			
Water Table in m	1.3m			
Pore Pressure (t/m²)	(14.0 -1.3) x 0.981 = 12.45t/m²			
Eff. Overburden Pressure (t/m²)	(5.32 + 11.52 + 6.93) – 12.45 = **11.31 t/m²**			

Tan δ = 35°

Asi = π DL = 3.14 x 0.60 x 3.5 = 6.59 m²

Qs_3 = 0.42 x 11.31 x tan 35° x 6.59 = **22.0T**

For calculating End Bearing Capacity

$$A_p(\frac{1}{2} D \gamma N_\gamma + P_D N_q)$$

P_{Di} = Effective over burden pressure = γ x Effective Length of pile (15D of pile)

Over Burden Pressure (PD_l)	Layer 1 (m)	Layer2 (m)		
Layers	**0 – 3.8**	**3.8 – 9.0**		
Density of soil ($\frac{s_i}{\gamma}$) in t/m²	(1.49 + 1.31) /2 = 1.4	1.62		
Thickness (D) in m	3.8	5.2		
Overburden Pressure (t/m²) - $\frac{s_i}{d_i}$ x D	5.32	8.42		
Effective Length of pile	15 D of pile = **9.0m**			
Water Table in m	1.3m			
Pore Water Pressure (t/m²)	(9.0-1.3) = 7.7			
Eff. Overburden Pressure (t/m²)	(5.32 + 8.42)-7.7 = **6.04 t/m²**			

Tan δ = 40° (Assume)

N_γ = General Shear Failure (IS 6403) = 109.41

N_q = Taken from the graph (fig 1) in IS 2911 part 1 sec 2 = 120.0

Ap = $\pi (0.60)^2 / 4$ = 0.282m²

Q_{End} = 0.282 (0.5 x 0.60 x 1.98 x 109.41 + 6.04 x 120.0)

= 223.33 T

Total Frictional Capacity = $Qs_1 + Qs_2 + Qs_3 + Qs_4 + Qs_5 + Qs_6$

= 5.15 + 28.45 + 22.0

= 55.6T

Ultimate pile load Carrying Capacity = $Q_{\text{Frictional Capacity}} + Q_{\text{End Bearing Capacity}}$

= 55.6 + 223.33 **= 278.93T**

Safe pile load Carrying Capacity = 278.93/ F.O.S = 278.93/ 3.0 **= 92T**

UPLIFT CAPACITY OF PILE as per IS 2911 (Part 1/ sec2): 2010 clause 6.3.2

Uplift Capacity = (Total Frictional Resistance + self-weight of pile) / FOS

Self Weight of pile = Area of pile x Length of pile x Unit wt. of concrete

= 0.282 x 14.0 x 2.5

= **9.87 T**

Uplift Capacity = 55.6 + 9.87 / 3.0 = **21.82T**

Dia of Pile = 0.65m ; Length of Pile = 14.0m Bore Hole : BH1

Layer 0-3.8m (Considered Cohesive Soil)

$Qs_1 = \alpha_i C_i A_{si}$

α_i = Adhesion Factor (or) Reduction Factor = 0.4 (Taken from graph (fig 2) in IS 2911 Part 1 sec2)

$A_{si} = \pi DL = 3.14 \times 0.65 \times 3.8 = 7.76m^2$

$Qs_1 = 0.4 \times 1.80 \times 7.76 =$ **5.58 T**

***Layer 3.8 – 10.5m (Considered Granular Soil)**

$Qs_2 = KiP_{Di} \tan \delta_i A_{Si}$

K_i = Co efficient of earth pressure = K_i (1-sin Ø) = 0.48

P_{Di} = Effective over burden pressure = γ x Length of pile (Thickness of layer)

Over Burden Pressure	Layer 1 (m)	Layer2 (m)
Layers	**0 – 3.8**	**3 – 10.5**
Density of soil ( ) in t/m²	(1.49 + 1.31) /2 = 1.4	1.72
Thickness (D) in m	3.8	6.7
Overburden Pressure (t/m²) - x D	5.32	11.52
Total Depth from GL of this Layer (m)	10.5	
Water Table in m	1.3m	
Pore Pressure (t/m²)	(10.5 -1.3) x 0.981 = 9.02 t/m²	
Eff. Overburden Pressure (t/m²)	(5.32 + 11.52) – 9.02 = **7.82 t/m²**	

δ = angle of wall friction between pile and soil = 30°

A_{Si} = Surface area of pile shaft

π DL = 3.14 x 0.65 x 6.7

= 13.67m^2

Qs_2 = 0.48 X 7.82 x tan 31 x 13.67 = **30.82 T**

***Layer 10.5 – 14.0m (Considered Granular Soil)**

K_i (1-sin Ø) = 0.42

Over Burden Pressure (PD_i)	Layer 1 (m)	Layer2 (m)	Layer3 (m)	
Layers	**0 – 3.8**	**3.8 – 10.5**	**10.5 – 14.0**	
Density of soil ( ) in t/m^2	(1.49 + 1.31) /2 = 1.4	1.72	1.98	
Thickness (D) in m	3.8	6.7	3.5	
Overburden Pressure (t/m^2) - x D	5.32	11.52	6.93	
Total Depth from GL of this Layer (m)	14.0			
Water Table in m	1.3m			
Pore Pressure (t/m^2)	(14.0 -1.3) x 0.981 = 12.45t/m^2			
Eff. Overburden Pressure (t/m^2)	(5.32 + 11.52 + 10.89) – 12.45 = **11.32 t/m^2**			

Tan δ = 35°

Asi = π DL = 3.14 x 0.65 x 3.5 = 7.14 m^2

Qs_3 = 0.42 x 11.32 x tan 35° x 7.14 = **23.7T**

For calculating End Bearing Capacity

$$A_p(\frac{1}{2} \text{D}\, \gamma\, N_\gamma + P_D N_q)$$

P_{Di} = Effective over burden pressure = γ x Effective Length of pile (15D of pile)

Over Burden Pressure (PD_i)	Layer 1 (m)	Layer2 (m)		
Layers	**0 – 3.8**	**3.8 – 9.75**		
Density of soil ($\frac{\gamma_1}{\gamma}$) in t/m²	(1.49 + 1.31) /2 = 1.4	1.72		
Thickness (D) in m	3.8	5.95		
Overburden Pressure (t/m²) - $\frac{\gamma_1}{\gamma}$ x D	5.32	10.23		
Effective Length of pile	15 D of pile = **9.75m**			
Water Table in m	1.3m			
Pore Water Pressure (t/m²)	(9.75-1.3) = 8.45			
Eff. Overburden Pressure (t/m²)	(5.32 + 10.23)-8.45 = **7.10 t/m²**			

Tan δ = 40° (Assume)

N_γ = General Shear Failure (IS 6403) = 109.41

N_q = Taken from the graph (fig 1) in IS 2911 part 1 sec 2 = 120.0

Ap = $\pi (0.65)^2 / 4$ = $0.332 m^2$

Q_{End} = 0.332 (0.5 x 0.65 x 1.98 x 109.41 + 7.10 x 120.0)

= **306.09 T**

Total Frictional Capacity = $Qs_1 + Qs_2 + Qs_3 + Qs_4 + Qs_5 + Qs_6$

= 5.58 + 30.82 + 23.76

= **60.16T**

Ultimate pile load Carrying Capacity = $Q_{\text{Frictional Capacity}} + Q_{\text{End Bearing Capacity}}$

= 60.16 + 306.09 = **366.24T**

Safe pile load Carrying Capacity = 366.24/ F.O.S = 366.24 / 3.0 = **122T**

UPLIFT CAPACITY OF PILE as per IS 2911 (Part 1/ sec2): 2010 clause 6.3.2

Uplift Capacity = (Total Frictional Resistance + self-weight of pile) / FOS

Self Weight of pile = Area of pile x Length of pile x Unit wt. of concrete

= 0.332 x 14.0 x 2.5

= **11.62 T**

Uplift Capacity = 60.16 + 11.62 / 3.0 = **23.92 T**

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PILE CARYING CAPACITY CALCULATION (AS PER IS METHOD)

PROJECT NO: AAL2014/2022

BH NO: 1

		0-3.8	3.8 -10.5	10.5-11.0
		Clay	Sand	Gravel
Pile Shaft Carrying Capacity	Diameter of Pile (m)	0.55	0.55	0.55
	Soil Classification			
	Thickness of Layer(m)	3.8	6.7	3.5
	Length of Pile(m)	**3.8**	**10.5**	**14**
	Cohesion (t/m^2)	1.8	0.27	0.08
	Angle of Internal Friction	3	31	35
	Bulk Unit Weight(t/m^3)	1.4	1.72	1.98
	Average N Value	11	36	50
	Reduction Factor (a)	0.4	0.3	0.3
	Surface area of shaft	6.56	11.57	6.04
	Overburden Pressure (t/m2)	5.32	11.52	6.93
	Pore Pressure ((t/m2)	-	9.03	12.46
Eff.Overburden Pressure (t/m2)			7.82	11.32
Frictional Resistence per Layer (t)		**4.73**	**26.08**	**20.10**
Total Frictional Resistence (t)		50.90		

End Bearing Capacity	Diameter of Pile (m)	0.55
	Total Length of Pile (m)	14.0
	Effective Length of Pile	**8.25**
	Cohesion (t/m^2)	0.08
	Angle of Internal Friction	40
	Bulk Unit Weight(t/m^3)	1.98
	Pore Pressure ((t/m2)	6.95
	Eff.Overburden Pr. (t/m2)	5.58
	Nq	120.00
	Nr	109.41
	CS Area	0.237
	End Bearing Capacity (t)	**173.12**
	Total Pile Capacity	224.03
	Total Safe Pile Capacity (t)	**74.68**

Self Weight of Pile	
Length of Pile (m)	14.0
Diameter of pile	0.55
Unit weight of concrete(t/m^3)	2.5
Self Weight of Pile(t)	8.31
Net Load carring capcity (t)	66.36

Uplift of Pile (t)	19.74

Ashhirwaad Analytical Laboratory

(A Unit of Ashhirwaad Associates)

PILE CARYING CAPACITY CALCULATION **(AS PER IS METHOD)**

PROJECT NO: AAL2014/2022

BH NO: 1

		0-3.8	3.8 -10.5	10.5-11.0
		Clay	Sand	Gravel
Pile Shaft Carrying Capacity	Diameter of Pile (m)	0.6	0.6	0.6
	Soil Classification			
	Thickness of Layer(m)	3.8	6.7	3.5
	Length of Pile(m)	3.8	10.5	14
	Cohesion (t/m^2)	1.8	0.27	0.08
	Angle of Internal Friction	3	31	35
	Bulk Unit Weight(t/m^3)	1.4	1.72	1.98
	Average N Value	11	36	50
	Reduction Factor (a)	0.4	-	-
	Surface area of shaft	7.16	12.62	6.59
	Overburden Pressure (t/m2)	5.32	11.52	6.93
	Pore Pressure ((t/m2)	-	9.03	12.46
Eff.Overburden Pressure (t/m2)		*	7.82	11.32
Frictional Resistence per Layer (t)		5.15	28.45	21.93
Total Frictional Resistence (t)		55.53		

End Bearing Capacity	Diameter of Pile (m)	0.6
	Total Length of Pile (m)	14.0
	Effective Length of Pile	9
	Cohesion (t/m^2)	0.08
	Angle of Internal Friction	40
	Bulk Unit Weight(t/m^3)	1.98
	Pore Pressure ((t/m2)	7.7
	Eff.Overburden Pr. (t/m2)	6.04
	Nq	120.00
	Nr	109.41
	CS Area	0.283
	End Bearing Capacity (t)	**223.33**
	Total Pile Capacity	278.86
	Total Safe Pile Capacity (t)	**92.95**

Self Weight of Pile	
Length of Pile (m)	14.0
Diameter of pile	0.6
Unit weight of concrete(t/m^3)	2.5
Self Weight of Pile(t)	**9.89**
Net Load carring capcity (t)	**83.06**

Uplift of Pile (t)	21.81

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PILE CARYING CAPACITY CALCULATION (AS PER IS METHOD)

PROJECT NO: AAL2014/2022

BH NO: 1

		0-3.8	3.8 -10.5	10.5-11.0
		Clay	Sand	Gravel
Pile Shaft Carrying Capacity	Diameter of Pile (m)	0.65	0.65	0.65
	Soil Classification			
	Thickness of Layer(m)	3.8	6.7	3.5
	Length of Pile(m)	3.8	10.5	14
	Cohesion (t/m^2)	1.8	0.27	0.08
	Angle of Internal Friction	3	31	35
	Bulk Unit Weight(t/m^3)	1.4	1.72	1.98
	Average N Value	11	36	50
	Reduction Factor (a)	0.4	-	-
	Surface area of shaft	7.76	13.67	7.14
	Overburden Pressure (t/m2)	5.32	11.52	6.93
	Pore Pressure ((t/m2)	-	9.03	12.46
Eff.Overburden Pressure (t/m2)		*	7.82	11.32
Frictional Resistence per Layer (t)		5.58	30.82	23.76
Total Frictional Resistence (t)		60.16		

End Bearing Capacity	Diameter of Pile (m)	0.65
	Total Length of Pile (m)	14.0
	Effective Length of Pile	9.75
	Cohesion (t/m^2)	0.08
	Angle of Internal Friction	40
	Bulk Unit Weight(t/m^3)	1.98
	Pore Pressure ((t/m2)	8.45
	Eff.Overburden Pr. (t/m2)	7.10
	Nq	120.00
	Nr	109.41
	CS Area	0.332
	End Bearing Capacity (t)	306.09
	Total Pile Capacity	366.24
	Total Safe Pile Capacity (t)	122.08

Self Weight of Pile	
Length of Pile (m)	14.0
Diameter of pile	0.65
Unit weight of concrete(t/m^3)	2.5
Self Weight of Pile(t)	11.61
Net Load carring capcity (t)	110.47

Uplift of Pile (t)	23.92

Lateral Load Calculation as per IS 2911 (Part 1/ Sec 2) : 2010

BH-1

Length of pile = 14 m
Dia of Pile = 0.65 m
N avg = 26
Water table = 1.3 m
Grade of concrete = 30
Young's Modulus of Pile material (E) = 27386.128 N/mm2
Moment of Inertia of pile (I) = 0.0087608

As per IS Table -3 For pile in sand and normally loaded clay

Submerged Soil	
10	1.4
26	x
50	5.0

To find (x) as per calculation
x = 2.8

η_h = 2.5
Stiffness Factor T = 2.48
Condition I ; L ≤ 2T
14 ≤ 5.0
Condition I is failed

Condition II ; L ≥ 4T
14 ≥ 9.9
Condition II is pass; so, it is long pile

For Fixed Head Pile Condition
$y = H (e + z_f)^3/12EI$
From fig 4
Z_f or L_f/T = 2.2 Taken from fig 4
Depth of Fixity Z_f = 5.46

Y' taken as 1% of Dia of pile

Eccentricity (e) = 0
H = 114.75 kN

Fixed End Moment (M_f)
$M_f = H (e + z_f)/2$
Fixed End Moment = 313.5 kN.m

Determination of Reduction Factor for fixed head pile
From fig 5, reduction factor of fixed head is = 0.81
Fixed End Moment 253.91 KN.m

Lateral Load H = 114.75 kN

Table 3 Modulus of Subgrade Reaction for Granular Soils, η_h, in kN/m³
(Clause C-2.1)

Sl No.	Soil Type	N (Blows/30 cm)	Range of η_h kN/m³ × 10³	
			Dry	Submerged
(1)	(2)	(3)	(4)	(5)
i)	Very loose sand	0-4	< 0.4	< 0.2
ii)	Loose sand	4-10	0.4-2.5	0.2-1.4
iii)	Medium sand	10-35	2.5-7.5	1.4-5.0
iv)	Dense sand	> 35	7.5-20.0	5.0-12.0

NOTE — The η_h values may be interpolated for intermediate standard penetration values, N.

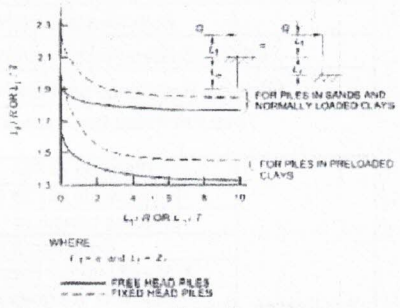
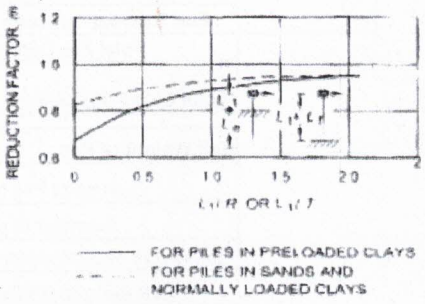


Fig. 4 Depth of Fixity



5B For Fixed Head Pile



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