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GEOTECHNICAL INVESTIGATION REPORT

RECONSTRUCTION OF 500 (G+5) TENEMENTS AT GANDHI NAGAR SCHEME IN CORPORATION DIVISION 96, ZONE 8 OF GCC, CHENNAI, TAMILNADU.

FOR

THE EXECUTIVE ENGINEER
DIVISION – III

TAMIL NADU URBAN HABITAT DEVELOPMENT BOARD, CHENNAI.

Centre for Urbanization, Buildings & Environment [CUBE]

Ref: TNUHDB Letter No. /JE(P)/2022 dated 06 April 2022

Vetting report from IIT Madras



TNUHDB - RECONSTRUCTION OF 500 (G+5) TENEMENTS AT GANDHI NAGAR SCHEME IN CORPORATION DIVISION 96, ZONE 8 OF GCC.

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To

Date: 24/08/2022

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

Sub: Comments on the geotechnical investigation report for Reconstruction of 500 Tenements (S+5) at Gandhi Nagar, Chennai, Tamil Nadu.

Ref: Your Email dated 20/06/2022

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 S+5 storeyed 500 Tenements at Gandhi Nagar, Chennai, Tamil Nadu. In relation to this, the following documents have been given to IIT Madras.

(1) Geotechnical investigation report dated 28/05/2022 prepared by Geotechnical Solutions, Chennai.

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

a) A total of 8 number no's of boreholes have been drilled at the present site to assess the subsoil conditions up to a depth ranging from 19.3m to 22m from the existing ground level. Also, the boreholes have been terminated when the weathered rock strata were encountered. It is proposed to construct S+5 storeyed tenements at the present site. Hence, the number of boreholes and depth of exploration are satisfactory for the proposed buildings.
b) The ground water table has been reported to exist at a shallow depth such as 1.2m to 3m 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 1m to 2.2m. This layer is followed by a medium stiff/stiff/very stiff silty clay/silty clay layer with sand content up to varying depths of 5.4m to 9.7m from the existing ground level. A soft clay layer of 2.3m thick

is found at a depth of 7.4m from the ground level in BH1. Whereas loose/medium dense sand layers with silt and clay contents are present up to varying depths of 9.5m to 12.8m from the ground level. Below these layers, dense/very dense sand layers with silt and clay contents and stiff/very stiff/hard silty clay layers with sand content are present up to varying depths of 17.3m to 20.5m from the existing ground level. In general, the clay and sand layers are occurring in an alternate way at the present site as reported in the geotechnical investigation report.

Below these layers, a severely jointed, very weak/weak weathered sandstone/shale rock layer is found to exist up to the borehole termination depth.

d) The soil profile consists of predominantly layers of medium stiff/stiff clayey soil layers and medium dense sand layers at the shallow levels. Very stiff/hard clay soil layers and dense/very dense sand layers are observed to occur at deeper depths. Intermittent loose sand and soft clay soil layers are also present. . In general, the clay and sand layers are occurring in an alternate way at the present site. The strong strata such as weathered rock layers are found to be existing at deeper depths i.e., below 18 to 21m 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 geotechnical investigation report recommends three options, viz., pile foundations, shallow individual footings, and full raft over the treated ground. However, the present review report recommends adopting pile foundations for the construction of the tenements under the scheme. 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 22m from the existing ground level. This shall be the minimum depth to be adopted to get adequate pile capacity.
- Pile cut-off level – 1.5 m below the existing ground level
- Type of soil at pile termination – Weathered rock strata

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

Pile diameter (mm)	500	600	750
Safe compression capacity, tons	120	170	250
Safe uplift capacity, tons	45	55	70

Lateral capacity, tons	6.2	8.5	12.5

- 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 of 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.
- Other recommendations listed in Section 5.10 (except 5.10.3 and 5.10.4) of the geotechnical investigation report can be followed.

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)

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Appendix 'B': Detailed Calculations

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GEOTECHNICAL INVESTIGATION REPORT

RECONSTRUCTION OF 500 (G+5) TENEMENTS AT GANDHI NAGAR SCHEME IN CORPORATION DIVISION 96, ZONE 8 OF GCC, CHENNAI.

Summary

S.No.	Description		Details
I	**OVERVIEW**		
	Project	:	Reconstruction of 500 (G+4) tenements at Gandhi Nagar Scheme.
	Client	:	Tamil Nadu Urban Habitat Development Board
	Location	:	GCC Corp. Dn. 66 Zone 6, Chennai.
	Buildings	:	8 No. – G+4 Floors
	Type of Structure	:	RCC Framed Structure
II	**SOIL INVESTIGATION**		
	Boreholes	:	Eight exploratory bores were conducted. Maximum depth of a borewell was advanced up to 22 m were drilled to assess the subsoil conditions up to a depth ranging from 19.3m to 22m from the existing ground level and terminated after encountering very dense layer with at least 3 successive SPT's with "N" values as 100.
	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 1m to 2.2m followed by medium stiff/stiff/very stiff silty clay/silty clay layer from 5.4m to 9.7m and stiff/very stiff/hard silty clay layer from 17.3m to 20.5m from the existing ground level.
	Hard Stratum	:	Weathered rock layer is found below a depth of 20.5m and a hard rock layer is found to exist beyond termination depth below the ground level.
	Ground Water Table	:	Ground water table encountered at a depth of about 1.2m to 3m from the existing ground level during the investigation.
IV	**FOUNDATION**		
	Recommendation	:	Considering in situ conditions, Pile Foundation with a minimum depth of 22 m is recommended as per the safe pile load carrying capacity calculations tabulated in the relevant section of this report.

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RECONSTRUCTION OF 500 (G+5) TENEMENTS AT GANDHI NAGAR SCHEME IN CORPORATION DIVISION 96, ZONE 8 OF GCC, CHENNAI.

I. Introduction.

Tamil Nadu Urban Habitat Development Board [TNUHDB] has entrusted the Centre for Urbanization, Buildings & Environment [CUBE] with undertaking the geotechnical investigation at the proposed project site to evaluate the soil properties, estimate the safe bearing capacity of the soil, and recommend a suitable type of foundation for the proposed reconstruction of 500 Tenements at Gandhi Nagar in GCC Corp. Dn. 96, Zone VIII, Chennai.

The site exploration towards the geotechnical investigation was conducted between 02.05.2022 to 17.05.2022 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 the capacity of soil strata, and type of foundations to be adopted for the proposed buildings.

II. Scope of work.

The scope of work envisaged for this assignment is as under: -

(a) Carry out a detailed geotechnical investigation of the proposed project site by drilling **eight 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 of more than 100** 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. Geotechnical Solutions and tested at their ISO & NABL certified Soil Lab.

(b) Conduct field investigation in **eight locations** at the site through exploratory bore hole by rotary boring. The field tests included Standard penetration test, Disturbed soil sampling, identification of different soil layers, Ground water table observation, complete logging of the borehole, 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: -

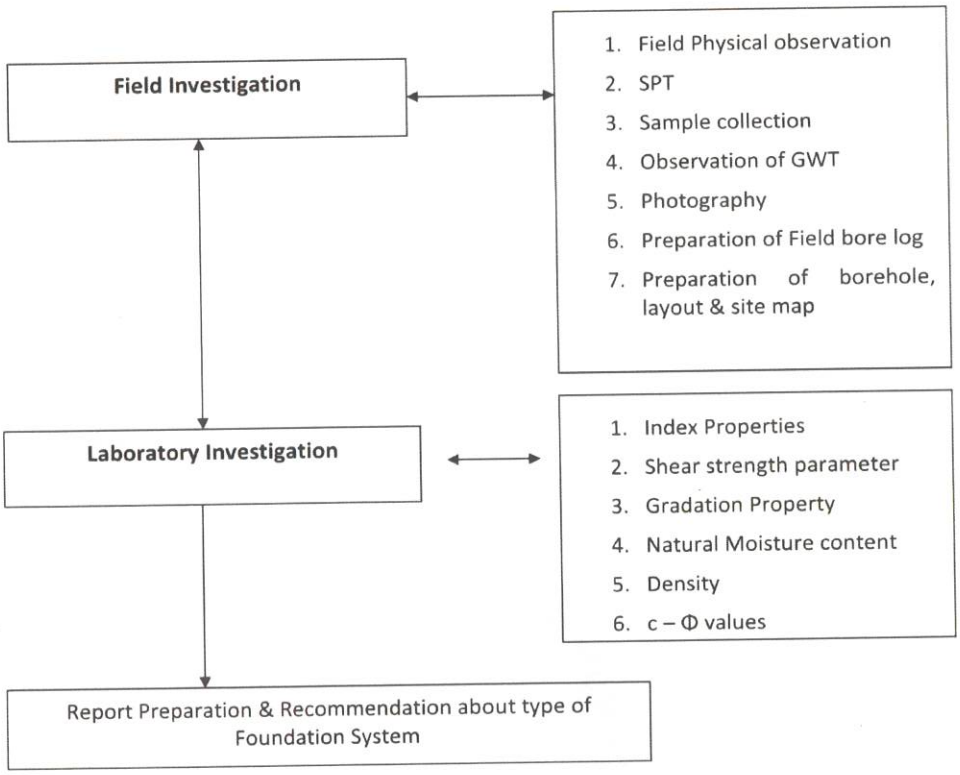


Fig 1: Flow Chart

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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: -

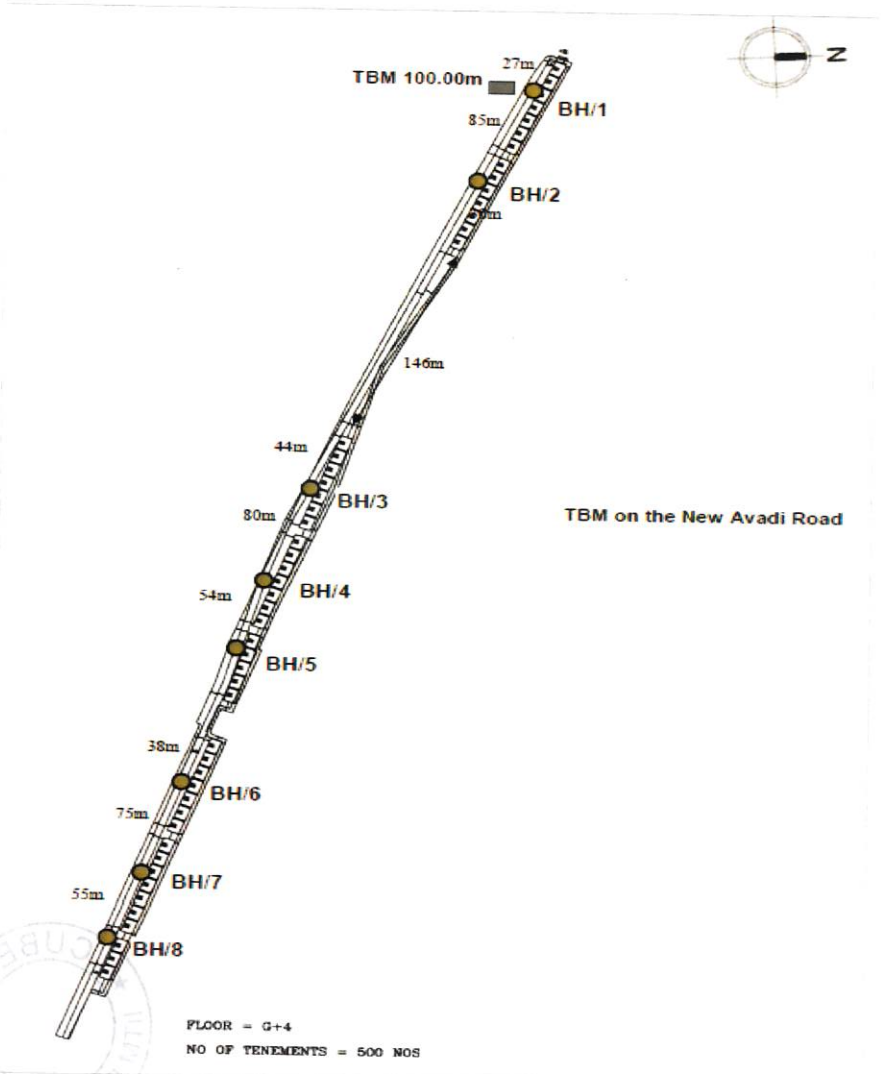


Fig 2: Site Layout Plan

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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 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 mudcirculation 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 caseof wash boring technique. Use of drilling mud will also help in preventing the disturbance tothe 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

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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 a suitable container for shipment and placed out of direct sunlight.

(e) Photographs. Photographs of the soil sampled during the borehole are given below: -



Collected Soil Samples

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)

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5. **Borehole Details.**

(a) Site Map & Location. The site is located at 13° 5'53.08"N & 80°12'55.68"E, location map of the same is depicted below: -



Fig 3: Site Location Map

(b) Bore log summary.

The summary of the eight 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)
1	BH-1	20.5	3.00
2	BH-2	20.5	2.80
3	BH-3	19.4	2.80
4	BH-4	19.8	2.80
5	BH-5	19.3	2.50
6	BH-6	22.0	2.30
7	BH-7	22.4	3.00
8	BH-8	22.5	1.20

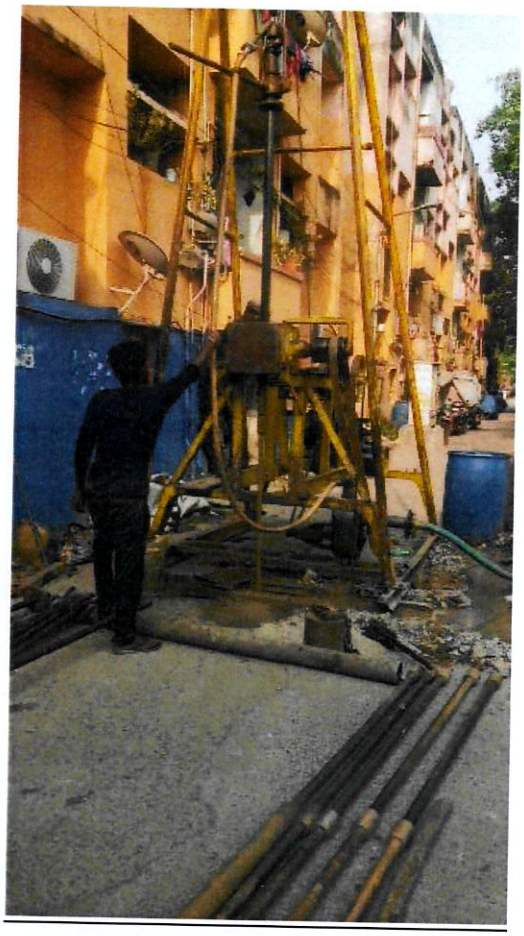
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(c) Photographs. Site photographs of a sample borehole are given below: -





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'**.

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: -

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S. No.	8IS 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'**.

VI. Safe Bearing Capacity Calculations.

The proposed construction has ground floor and five upper floors. The average load intensity at the founding level is expected to be 100 to 120 kN/m^2 as the columns may be spaced at 2.5m to 4.0m. Light to moderate column loads are expected.

1. Calculations for Shallow Foundation – Individual Footings

(a) The soil immediately below the fill has varying stiffness and shear strength. Reasonably uniform sub-soil conditions prevail at 3.0m depth below the average ground level. The soil at this depth is medium to high plasticity silty clay or sandy clay with undrained shear strength 60 kPa to 75 kPa. The shear strength is adequate to offer moderate safe bearing capacity for shallow footings. However, the extended clay profile and the presence of weak high plasticity clay in BH/1 and BH/2 will result relatively large settlements.

(b) The average undrained shear strength of silty clay and sandy silty clay below 3.0m depth near boreholes BH/1 to BH/5 is 70 kPa. The average shear strength near BH/6, BH/7 and BH/8 is about 60 kPa. In preceding section, presented the bearing capacity estimations for shallow individual footings for these two soil conditions. The estimated net safe bearing capacity for different footing sizes is presented below.

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Net SBC near BH/1 to BH/5

Sl No	D	Sh	B	L	NBC
1	3.00	SQ	1.50		218 kN/m^2
2	3.00	SQ	2.00		203 kN/m^2
3	3.00	SQ	2.50		193 kN/m^2
4	3.00	SQ	3.00		187 kN/m^2
5	3.00	RE	2.00	4.00	179 kN/m^2
6	3.00	RE	2.50	5.00	171 kN/m^2

Net SBC near BH/6, BH/7 & BH/8

Sl No	D	Sh	B	L	NBC
1	3.00	SQ	1.50		187 kN/m^2
2	3.00	SQ	2.00		174 kN/m^2
3	3.00	SQ	2.50		166 kN/m^2
4	3.00	SQ	3.00		160 kN/m^2
5	3.00	RE	2.00	4.00	154 kN/m^2
6	3.00	RE	2.50	5.00	147 kN/m^2

(c) The performance of foundation depends on the total and differential settlement under the expected load over the foundation. IS 1904-2021 recommends 50mm to 60mm total settlement for shallow foundations supporting RCC framed structures. Since the range of footing sizes of residential buildings is large, the total settlement is limited to 40mm so that the differential settlement is well within the limits.

(d) Detailed settlement estimations are made using different profiles from all the eight boreholes. Typical estimations using the data from BH/1, BH/3 and BH/6 are presented in Appendix B representing each cluster of the proposed buildings.

(e) The soil profile near BH/1 is the weakest because of the presence of soft clay between 7.0m and 9.0m. The estimated total settlement of different footing sizes under the respective net SBC is in the range of 38mm to 78mm. Borehole BH/2 estimated 24mm to 44mm. Since the blocks are close to each other, the borehole data BH/1 is considered representing in this stretch. Trial and error estimations are made for determining the net bearing pressure limiting the settlement to 40mm. The net bearing pressure under different footing sizes for limiting the settlement to 40mm is in the range of 218 kPa and 92 kPa. Based on these estimations, the recommended net allowable bearing pressure for the footings placed at 3.0m depth is as below.

For the blocks near BH/1 and BH/2

The recommended depth of footing = 3.0m below GL.

Type of Foundation	Square				Rectangular	
Width / dia of foundation m Length of foundation m	1.50	2.00	2.50	3.00	2.00	2.50
	1.50	2.00	2.50	3.00	4.00	5.00
Recommended allowable bearing pressure,	200	162	127	104	110	92

Alternatively, the following net allowable bearing pressures may be used foruniformity in loading.

Net allowable bearing pressure for footings of area ≤ 4 sqm =165 kPa

Net all bearing pressure for footings of area > 4 sqm and ≤ 9 sqm =110 kPa

(f) From the estimations and summaries presented in preceding section, the allowable net bearing pressure for footings placed near BH/3 to 5 and BH/6 to 8 areas follows.

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For the blocks near BH/3, BH/4 and BH/5

The recommended depth of footing = 3.0m below GL.

Type of Foundation	Square				Rectangular	
Width / dia of foundation m	1.50	2.00	2.50	3.00	2.00	2.50
Length of foundation m	1.50	2.00	2.50	3.00	4.00	5.00
Recommended allowable bearing pressure,	200	190	168	137	148	120

Alternatively, the following net allowable bearing pressures may be used for uniformity in loading.

Net allowable bearing pressure for footings of area ≤ 4 sqm =190 kPa

Net all bearing pressure for footings of area > 4 sqm and ≤ 9 sqm =140 kPa

For the blocks near BH/6, BH/7 and BH/8

The recommended depth of footing = 3.0m below GL.

Type of Foundation	Square				Rectangular	
Width / dia of foundation m	1.50	2.00	2.50	3.00	2.00	2.50
Length of foundation m	1.50	2.00	2.50	3.00	4.00	5.00
Recommended allowable bearing pressure,	180	130	106	89	94	79

Alternatively, the following net allowable bearing pressures may be used for uniformity in loading.

Net allowable bearing pressure for footings of area ≤ 4 sqm =135 kPa

Net all bearing pressure for footings of area > 4 sqm and ≤ 9 sqm =95 kPa

(g) Excavation for Individual Footings: The recommended founding level is 3.0m below the existing ground level. The excavation shall be made only after lowering the ground water table using standard procedures without allowing open pit dewatering from the foundation excavations. Since the columns are not widely spaced, there may be a chance for full area excavation, that is not good for the stability of the completed foundation. It is recommended that the full area excavation shall be limited to 1.50mbelow GL and then make individual excavations for footings. Vertical excavation is possible for the next 1.50m for individual footings.

(h) Since the soil below 1.50m is mostly clayey, care shall be taken to keep the groundstable without drying up or softening due to flooding.

2. Calculations for Shallow Foundation – Full Raft Footings

(a) It is expected that the columns are not at large spacing since the proposed construction is to house tenements. Full RCC raft foundation supporting G+5 RCC frame is reasonably rigid to make the settlement uniform in such case. Full raft can be placed at about 2.20m below the ground level. The soil between 1.90m and 2.20m shall be replaced with well compacted stone + sand layer so that the load is uniformly distributed and the contact stress at the corners is minimized.

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(b) The excavated average load intensity at the full raft foundation is about 100 kPa andthe maximum load intensity may be 120 kPa including the plinth filling. The bearing capacity of large foundation is usually large and based on the estimations forindividual footings, the net SC from shear is not less than 120 kPa.

(c) The settlement of full raft foundation is critical because of large influence zone in which weak layers and large thickness clay profile is available. Detailed settlement estimations are made for the expected average load intensity and the maximum and minimum load intensities. The full raft size is assumed as a little larger than the building footprint. Three raft sizes are assumed in the settlement estimations, namely:

1) Full raft of 8.0m x 77m for 7 units (BH/1 & 2, BH/3, BH/4, BH/6, BH/7)
2) Full raft of 8.0m x 55m for five units (BH/5), and
3) Full raft of 8.0m x 33m for three units (BH/8)

(d) In preceding section, calculations are presenting the detailed settlement estimation for typical cases and the summary. The allowable settlement for a rigid RCC raft foundation is about 125mm according to IS 1904-2021. Such large settlement may not be acceptable with respect to the connectivity to the service lines. Hence the total average settlement for full raft foundation is recommended as 75 to 80mm in the present case.

(e) The estimated average settlement of full raft foundation under average net load intensity 100 kPa is in the range of 69mm to 190mm, much larger than 80mm in most cases. Hence full raft foundation over natural soil is not suitable for supporting the proposed G+5 constructions.

(f) Full Raft Foundation over Treated Ground: It is noticed that the significant part of thesettlement is from the compression of top 10.0m thick soil layers. Full raft foundation over stone column treated ground can significantly reduce thecompression of the top 10.0m soil thereby offering satisfactory performance. The design of stone column treatment is not included in this report since it is theresponsibility of the specialist contractor because of the variations in the construction procedures and nominal diameters of the columns.

3. Calculation for Deep Foundation –Bored Cast-in-situ Piles Penetrated into Jointed Soft Rock

(a) Bored cast-is-situ piles resting in severely jointed shale / sandstone can offer good safe compression capacity. The construction of piles requires good quality control measures for ensuring integrity and strength.

(b) The piles penetrated the jointed soft rock is considered for safe compression capacities close to the safe structural capacity corresponding to M25 concrete. Appendix B presents typical safe capacity estimations for 500mm, 600mm and 750mm diameter bored cast-in-situ piles penetrating through very dense stratumbelow 14m and terminated in severely jointed weathered soft rock. The piles are treated as friction cum end bearing and NOT as rock socketed pile since there is no competent rock for socketing. The friction from stiff silty clay, sandy clay, clayey cemented sand, and clayey silty fine sand layers are considered offering the resistance apart from the end bearing from weathered jointed rock.

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(c) The summary of pile capacity estimation is presented below. The minimum pile depthis 19.0m to 21.5 below average ground level.

Particular	Net compression capacity, kN			Uplift CapacitykN		
Pile diameter, mm	500	600	750	500	600	750
Borehole BH/1	1227*	1753	2471	449	548	702
Borehole BH/2	1227*	1767*	2493	458	558	713
Borehole BH/3	1227*	1733	2435	436	531	678
Borehole BH/4	1227*	1744	2454	442	538	687
Borehole BH/5	1227*	1767*	2615	497	604	770
Borehole BH/6	1227*	1767*	2714	546	665	848
Borehole BH/7	1227*	1767*	2708	543	662	844
Borehole BH/8	1227*	1767*	2625	508	619	791
Minimum	1227*	1733	2435	436	531	678
Average	1227*	1755	2550	479	584	746
Recommended	**1200**	**1700**	**2500**	**450**	**550**	**700**
Structural capacity for M25 concrete	1227	1767	2761	Important note: The recommended concrete grade is M30 so that thepile can take any drag force arising from ground water fluctuations.		
* Limited to M25 concrete strength						

Note: The length of pile below the present ground level 98.1m is 19.0m to 21.5m. The length near BH/1 & 2 is about 20m, 19m near BH/3, 4 & 5, and 21.5m for piles near BH/6, 7 & 8.

(d) Appendix B presents typical estimation of lateral capacity from simplified elastic solutions using subgrade modulus recommended in IS 2911. The average undrained shear strength of sandy clay below the pile cut off level (assumed at 1.10m below present ground level) is 50 kPa. The soil stiffness recommended in IS 2911 Section 1, Part 2 is very conservative. Reese[5] has recommended better stiffness values for clay and sand after several studies on instrumented pile and the recommendation by Reese is adopted here for more realistic lateral resistance.

Pile diameter	450	500	600	750
Free head Capacity kN	24	29	40	58
Depth of fixity, free head	3.1 m	3.4 m	3.9 m	4.6 m
Fixed head Capacity kN	51	62	85	125
Depth of fixity, Fixed head	3.9 m	4.2 m	4.8 m	5.7 m

The fixed head capacity shall be used only when the pile head is restrained in all directions. Interpolated values can be used for piles not restrained from all directions.

** k1 recommended by Tomlinson is directly used here. M.J. Tomlinson, Pile Design and ConstructionPractice, 5th Edition, Table 6.5*

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The group efficiency of laterally loaded piles is small when the pile spacing is smaller than 6 times the pile diameter. It is recommended to use 75% of the fixed head lateral capacity for piles in a group of more than 3 piles despite lateral restrain.

4. Deep Foundation –Bored Cast-in-situ Piles Terminated in Fully Weathered Soft Rock

(a) Bored cast-is-situ piles resting in fully weathered and disintegrated rock available 1.0m above the jointed rock level can offer moderate safe compression capacity. This option is added in this revision as advised by the project consultants.

(b) The piles terminated in fully weathered soft rock with SPT N = >100 to rebound is considered for moderate safe compression capacities. Appendix B **p**resent typical safe capacity estimations for 450mm, 500mm and 600mm diameter bored cast-in-situ piles penetrating the very dense stratum below 14m.

(c) The summary of pile capacity estimation is presented below. The minimum pile depthis 18.0m to 20.5 below average ground level.

Particular	Net compression capacity, kN			Uplift Capacity kN		
Pile diameter, mm	450	500	600	450	500	600
Borehole BH/1	657	754	963	331	371	456
Borehole BH/2	696	797	1014	356	399	489
Borehole BH/3	664	761	969	333	374	456
Borehole BH/4	680	779	991	343	385	470
Borehole BH/5	748	854	1080	387	433	527
Borehole BH/6	812	926	1167	434	486	593
Borehole BH/7	812	926	1167	434	486	593
Borehole BH/8	765	873	1104	403	452	552
Minimum	657	754	963	331	371	456
Average	721	825	1046	372	417	510
Recommended	**690**	**800**	**1000**	**350**	**390**	**480**
Structural capacity for M25 concrete	994	1227	1767	Important note: The recommended concrete grade is M30 so that thepile can take any drag force arising from ground water fluctuations.		
The piles shall have minimum safe structural capacitycorresponding to M25 concrete.						

Note: The length of pile below the present ground level 98.1m is 18.0m to 20.5m.The minimum length near BH/1 & 2 is 19.0m, 18m near BH/3, 4 & 5, and 20.5m for piles near BH/6, 7 & 8.

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VII. Recommendations.

1. The following are the foundation recommendations for supporting the proposed Ground + Five Floor tenement buildings.

(a) Option 1– Bored cast-in-situ piles resting in completely weathered soft rock.

Type of foundation - Bored cast-in-situ piles^
Recommended depth of foundation - 18m to 21m^^
Type of soil at founding depth - Weathered disintegrated soft rock with SPT N >>100.
Recommended safe compression capacities – Refer Table below.

^ *The depth of foundation is with respect to the existing ground level that is roughly 2.0 m below the New Avadi Road. The piles shall have a minimum penetration of 0.0m to 0.5minto the fractured and jointed shale with SPT rebound. The very dense soil above this layer may contain weathered stone pieces this layer shall not be mistaken as fracturedrock layer while pile boring.*

^^ *The piles shall be installed using DMC chisel boring or using hydraulically operatedmachines with rock auger cutters and bucket cleaners.*

Table for computing Safe compression, tension and lateral capacities of bored cast-in-situ piles resting in jointed shale / mudstone.

Pile diameter	450	500	600
Safe compression Capacity, kN	690	800	1000
Safe uplift Capacity, kN	350	390	480
Fixed head Capacity kN	51	62	85
Depth of fixity, Fixed head	3.9 m	4.2 m	4.8 m

Important notes:

1. The recommended concrete grade is M30 so that the pile can take any dragforce arising from ground water fluctuations.
2. The fixed head capacity shall be limited to 75% of the recommendedvalues, when the piles are installed in groups.
3. The recommended concrete grade is M30 so that the pile can take any drag force arising from ground water fluctuations.
4. The fixed head capacity shall be limited to 75% of the recommended values, when the piles are installed in groups.
5. Piles shall be restrained from all sides for considering it as fixed head pile.
6. Minimum number of piles under a column may be two as far as possible.
7. The piles shall be checked for integrity and design capacity. Static load test or dynamic load test with CAPWAP analysis can be used to confirm the safe capacity.
8. Safe capacity of piles with different diameter shall be determined from individual tests.

Note: The length of pile below the present ground level 98.1m is 18.0m to 20.5m. The minimum length near BH/1 & 2 is 19.0m, 18m near BH/3, 4 & 5, and 20.5m for piles near BH/6, 7 & 8.

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(b) Option 2– Bored cast-in-situ piles resting in weathered shale/ sandstone.

Type of foundation - Bored cast-in-situ piles^
Recommended depth of foundation -19m to 22m^^
Type of soil at founding depth - Jointed shale interlaced with sandstone and siltstone.
Recommended safe compression capacities – Refer Table below.

^ The depth of foundation is with respect to the existing ground level that is roughly 2.0mbelow the New Avadi Road. The piles shall have a minimum penetration of 1.5m into fractured and jointed shale with SPT rebound. The very dense soil above this layer may contain weathered stone pieces this layer shall not be mistaken as fractured rock layerwhile pile boring.

^^ The piles shall be installed using DMC chisel boring or using hydraulically operated machines with rock auger cutters and bucket cleaners. Light weight tractor mounted rotary drilling machine is not suitable for boring through the shale and mudstone presentbelow 17.5m depth.

Table for Safe compression, tension and lateral capacities of bored cast-in-situ piles resting in jointed shale / mudstone.

Pile diameter	500	600	750
Safe compression Capacity, kN	1200	1700	2500
Safe uplift Capacity, kN	450	550	700
Fixed head Capacity kN	62	85	125
Depth of fixity, Fixed head	4.2 m	4.8 m	5.7 m

Important notes:

1. The recommended concrete grade is M30 so that the pile can take anydrag force arising from ground water fluctuations.
2. The fixed head capacity shall be limited to 75% of the recommendedvalues, when the piles are installed in groups.
3. Piles shall be restrained from all sides for considering it as fixed head pile.
4. Minimum number of piles under a column may be two as far as possible.
5. The piles shall be checked for integrity and design capacity. Static load test or dynamic load test with CAPWAP analysis can be used to confirm the safe capacity.
6. Safe capacity of piles with different diameter shall be determined from individual tests.

Note: The length of pile below the present ground level 98.1m is 19.0m to 21.5m. The length near BH/1 & 2 is about 20m, 19m near BH/3, 4 & 5, and 21.5m for piles near BH/6, 7 & 8.

(c) Option 3 – Individual footings at 3.0m below the present ground level

Type of foundation foundation - Individual footings Recommended depth of - 3.00m below GL*% Type of soil at founding depth - Stiff sandy silty clay Recommended Net SBC@ - Refer table below.

Expected settlement - <40mm total

Design differential settlement - 0.0020L

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** The depth of foundation is with respect to the existing ground level that is roughly2.0mbelow the New Avadi Road.*

%The excavation shall be made only after lowering the ground water table using standardprocedures without allowing open pit dewatering from the foundation excavations. Sincethe columns are not widely spaced, there may be a chance for full area excavation, that is not good for the stability of the completed foundation. It is recommended that the fullarea excavation shall be limited to 1.50m below GL and then make individual excavations for footings. Vertical excavation is possible for the next 1.50m for individualfootings.

@The gross SBC shall be estimated with respect to the present ground level and groundwater table at the ground level. Any site grading shall induce extra load over the foundations.

Table for Allowable Bearing Pressure for Shallow Footings at 3.0m below GL

	Net allowable bearing kPa		
Blocks covered by	BH/1 & 2	BH/3-5	BH6-8
For footing area ≤ 4 sqm	165	190	135
For footing area >4.0 sqm & ≤ 8 sqm	110	140	95

(d) Option 4 – Full Raft Foundation over Stone Column Treated Ground

Type of foundation treatment over stone column	- Full RCC raft at 1.5m below GL Recommended - Stones columns up to 10m below GL Stone pad layer - 500mm thick using broken stones and sand.
Recommended Net SBC@	- 150 kPa.
Expected settlement	-<40mm total Design differential settlement 0.0020L

@Tentatively 800mm diameter stone columns at about 2.20m c/c can be assumed. The stone column spacing, and layout shall be designed by the specialist contractor based on their construction procedure and the use of materials in the construction.

2. The sandy clay from excavation shall not be used for backfilling the foundation excavations. Soil suitable for compaction under restricted space shall be used for backfilling.

3. Any remnants of old foundation or construction shall be completely removed before the construction of new foundation. Any open well or sump shall be adequately trained before the construction of foundations.

4. There are no weak sand layers that should liquefy under the seismic conditions expected in Chennai. The clay has adequate over-consolidation and shear strength to prevent stress reduction under expected seismic activities in the region.

5. There is no advice on the site development works. If the site is to be graded to a higher level, the foundation construction shall be based on the original ground level during the investigation. The present average ground level is 98.10m with respect to 100.0m TBM marked on the New Avadi Road as shown in the borehole location plan. The option of shallow individual footings may not be suitable if site grading is proposed.

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VIII. Conclusion.

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

Based on the existing soil condition, a suitable foundation system may be followed for the reconstruction of 500 (G+5) tenements at Gandhi Nagar scheme as recommend in the preceding sections of this report.

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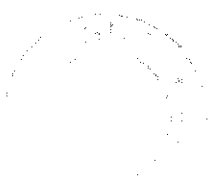
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Appendix A

Detailed Bore log & Laboratory Test Results





FIELD BORE LOG

GEOTECHNICAL Solutions[A1]

ANNEXURE 1

SHEET 1 OF 2

PROJECT NO:	CUBE/TNUHDB/GN/G-1352
BORE HOLE NO:	BH/1

Project : Proposed Construction of (G+5) EWS Tenements
Site : Gandhi Nagar in Corp DN 96 Zone 8 of GCC
Location : As shown in Figure 1
Dia and type of boring : 150mm Rotary boring with drilling mud circulation

Date of start : 2-May-2022
Date of finish : 3-May-2022
GWL from GL : 3.00m
Ground level RL : 98.190m

Depth from GL(m)		Soil Profile	Field Description	Depth of samples collected		SPT / VST						RD / Consistency
						Test depth	Blow Counts					
				UDS	DS	m	15	30	45	60	N**	
1.0	0.7		Greyish sandy silty clay/clayey silty fine to medium sand with brown patches and PCC		0.50							Fill
			Light greyish brown sandy silty clay with stones		0.75	0.75	3	2	1	2	3	
2.0	1.4		Brownish grey silty clay with fine sand		1.50	1.50	2	2	2	3	4	Medium stiff
3.0				2.25	Collected							
					2.75	2.75	2	4	4	5	8	
4.0	3.4		Brownish grey silty clay		3.50	3.50	3	5	8	8	13	Stiff
5.0	4.3		Dark brownish grey silty clay		4.50	4.50	5	6	8	9	14	Stiff
6.0					5.50	5.50	5	8	8	9	16	
7.0					6.50	6.50	4	5	6	6	11	
8.0	7.4		Greyish silty clay with fine sand		7.50	7.50	2	1	2	2	3	Soft
9.0					8.50	8.50	1	1	2	1	3	
10.0	9.7		Light greenish grey and brown sandy silty clay		10.00	10.00	5	7	7	8	14	Very stiff
11.0												
12.0					11.50	11.50	7	12	13	13	25	
13.0												
14.0	14.0				13.00	13.00	7	12	14	15	26	
15.0	14.8		Light greyish and brown sandy silty clay		14.50	14.50	16	21	50		71	Very stiff
16.0			Light yellowish brown clayey silty fine sand		16.00	16.00	50/8cm				>100	Very dense
17.0												
18.0					17.50	17.50	50/6cm				>100	
	18.5					18.50	Rebound				RB	
19.0			Light yellowish brown & grey fractured / severely jointed weathered rock (shale)	18.50-19.50		TC core drilling					R nil	Very weak
						19.50	Rebound				RB	
20.0	20.0			19.50-20.50		DC core drilling					R 25%	

Continued in the next sheet

Borehole terminated at 20.50m

**Note: SPT Conducted using winch cat-head device, N values reported are close to N_{55}

FIELD BORE LOG

GEOTECHNICAL Solutions[A1]

ANNEXURE 1

SHEET 2 OF 2

PROJECT NO:	CUBE/TNUHDB/GN/G-1352
BORE HOLE NO:	BH/1

Project : Proposed Construction of (G+5) EWS Tenements
Site : Gandhi Nagar in Corp DN 96 Zone 8 of GCC
Location : As shown in Figure 1
Dia and type of boring : 150mm Rotary boring with drilling mud circulation

Date of start : 2-May-2022
Date of finish : 3-May-2022
GWL from GL : 3.00m
Ground level RL : 98.190m

Depth from GL(m)		Soil Profile	Field Description	Depth of samples collected		SPT / VST					RD / Consistency
				UDS	DS	Test depth m	Blow Counts 15 30 45 60			N**	
	20.5		Lt yell brown & grey severely jointed weath rock	19.50-20.50		DC core drilling				Q 0%	Weak
21.0											
22.0											
23.0											
24.0											
25.0											
26.0											
27.0											
28.0											
29.0											
30.0											
31.0											
32.0											
33.0											
34.0											
35.0											
36.0											
37.0											
38.0											
39.0											
40.0			TC Core drilling from 18.50m to 19.50m DC core drilling from 19.50m to 20.50m								

Continued from sheet 1

Borehole terminated at 20.50m

**Note: SPT Conducted using winch cat-head device, N values reported are close to N_{55}

FIELD BORE LOG

ANNEXURE 2

GEOTECHNICAL Solutions[A1]

PROJECT NO:	CUBE/TNUHDB/GN/G-1352
BORE HOLE NO:	BH/2

Project : Proposed Construction of (G+5) EWS Tenements
Site : Gandhi Nagar in Corp DN 96 Zone 8 of GCC
Location : As shown in Figure 1
Dia and type of boring : 150mm Rotary boring with drilling mud circulation

Date of start : 4-May-2022
Date of finish : 5-May-2022
GWL from GL : 2.80m
Ground level RL : 98.06m

Depth from GL(m)		Soil Profile	Field Description	Depth of samples collected		SPT / VST						RD / Consistency
						Test depth	Blow Counts					
				UDS	DS	m	15	30	45	60	N**	
1.0			Brownish and light grey sandy silty clay with 30mm PCC		0.50 0.75							Fill
2.0	1.1		Brownish and light grey sandy silty clay/clayey silty sand		1.50	1.50	2	3	5	6	8	Loose
3.0	2.2		Brownish and light grey sandy silty clay		2.25	2.25	2	4	6	7	10	Medium stiff to stiff
4.0	3.7				3.00	3.00	4	6	8	10	14	
5.0			Brownish grey silty clay with fine sand patches		3.75 4.50	3.75 4.50	5 6	7 7	8 9	9 10	15 16	Stiff
6.0	5.4		Light grey silty fine sand with traces of clay		5.50	5.50	5	10	15	12	25	Medium dense
7.0	6.3		Light grey fine sand		6.50	6.50	9	11	13	15	24	Medium dense
8.0	7.5		Light brownish grey fine sand		7.50	7.50	12	10	8	12	18	Loose to medium dense
9.0					8.50	8.50	6	4	6	6	10	
10.0	9.5		Greyish silty clay with sand patches		10.00	10.00	2	3	2	3	5	Soft to medium
11.0												
12.0	11.1		Light greenish grey sandy silty clay with brown patches		11.50	11.50	5	10	10	12	20	Stiff
13.0												
14.0					13.00	13.00	6	10	12	13	22	
15.0	14.2		Light yellowish brown clayey silty fine sand		14.50	14.50	14	22	33		55	Very dense
16.0												
17.0					16.00	16.00	50/10cm				>100	
18.0					17.50	17.50	50/5cm				>100	
19.0	18.8					18.80	Rebound				RB	
	19.5		Yellowish brown weathered fractured sandstone	18.80-19.50		TC core drilling 19.50	Rebound				RB	Very weak
20.0	20.0		Lt greyish brown severely jointed weath shale	19.50-20.50		DC core drilling					R 31%	Weak

Continued in the next sheet

Borehole terminated at 20.50m

**Note: SPT Conducted using winch cat-head device, N values reported are close to N_{55}

FIELD BORE LOG

GEOTECHNICAL Solutions[A1]

ANNEXURE 2

SHEET 2 OF 2

PROJECT NO:	**CUBE/TNUHDB/GN/G-1352**
BORE HOLE NO:	**BH/2**

Project : Proposed Construction of (G+5) EWS Tenements
Site : Gandhi Nagar in Corp DN 96 Zone 8 of GCC
Location : As shown in Figure 1
Dia and type of boring : 150mm Rotary boring with drilling mud circulation

Date of start : 4-May-2022
Date of finish : 5-May-2022
GWL from GL : 2.80m
Ground level RL : 98.06m

Depth from GL(m)	Soil Profile	Field Description	Depth of samples collected		SPT / VST					RD / Consistency
					Test depth	Blow Counts				
			UDS	DS	m	15	30	45	60	N**
20.5		Lt greyish brown severely jointed weath shale	19.50-20.50		DC core drilling					Q 0% / Weak
21.0										
22.0										
23.0										
24.0										
25.0										
26.0										
27.0										
28.0										
29.0										
30.0										
31.0										
32.0										
33.0										
34.0										
35.0										
36.0										
37.0										
38.0										
39.0										
40.0		TC Core drilling from 18.80m to 19.50m DC core drilling from 19.50m to 20.50m								

Continued from sheet 1 | **Borehole terminated at 20.50m**

**Note: SPT Conducted using winch cat-head device, N values reported are close to N_{55}

FIELD BORE LOG

ANNEXURE 3

GEOTECHNICAL Solutions[A1]

PROJECT NO:	CUBE/TNUHDB/GN/G-1352
BORE HOLE NO:	BH/3

Project : Proposed Construction of (G+5) EWS Tenements
Site : Gandhi Nagar in Corp DN 96 Zone 8 of GCC
Location : As shown in Figure 1
Dia and type of boring : 150mm Rotary boring with drilling mud circulation

Date of start : 5-May-2022
Date of finish : 6-May-2022
GWL from GL : 2.80m
Ground level RL : 98.065m

Depth from GL(m)	Soil Profile	Field Description	Depth of samples collected		SPT / VST						RD / Consistency
			UDS	DS	Test depth m	Blow Counts 15	30	45	60	N**	
1.0		Brownish grey fine to medium sand with stones and 300mm PCC		0.50							Fill
				0.75							
2.0	1.1	Brownish grey fine sandy silty clay		1.50	1.50	3	4	5	5	9	Medium stiff
3.0	2.8			2.25	2.25	4	5	6	7	11	
4.0	3.6	Brownish grey silty clay with fine sand	3.00	Collected							Medium stiff
		Brownish grey and greyish brown silty clay		3.50	3.50	5	10	10	13	20	Stiff
5.0				4.50	4.50	4	10	11	15	21	
6.0				5.50	5.50	5	10	10	12	20	
7.0				6.50	6.50	6	8	10	12	18	
8.0	7.4	Light greenish grey clayey silty fine to medium sand		7.50	7.50	3	3	4	3	7	Loose
9.0				8.50	8.50	3	3	3	3	6	
10.0	9.5	Light grey and brown clayey silty cemented fine to medium sand		10.00	10.00	10	13	13	15	26	Dense
11.0											
12.0				11.50	11.50	13	20	21	23	41	
13.0	12.6	Light greenish grey sandy silty clay		13.00	13.00	7	15	15	17	30	Very stiff to hard
14.0											
15.0				14.50	14.50	12	20	25		45	
16.0	15.6	Yellowish brown clayey silty fine sand		16.00	16.00	50/12cm				>100	Very dense
17.0											
18.0	17.5	Yellowish brown weathered fractured rock			17.50	Rebound				RB	Very weak
19.0	18.4	Lt grey & brown severely jointed weathered rock with black patches	18.40-19.40		18.40	Rebound				RB	Weak
20.0	19.4	TC core drilling from 17.50m to 18.40m DC core drilling from 18.40m to 19.40m			DC core drilling					R 25% Q 0%	

Borehole terminated at 19.40m

**Note: SPT Conducted using winch cat-head device, N values reported are close to N_{55}

FIELD BORE LOG

ANNEXURE 4

GEOTECHNICAL Solutions[A1]

PROJECT NO:	CUBE/TNUHDB/GN/G-1352
BORE HOLE NO:	BH/4

Project : Proposed Construction of (G+5) EWS Tenements
Site : Gandhi Nagar in Corp DN 96 Zone 8 of GCC
Location : As shown in Figure 1
Dia and type of boring : 150mm Rotary boring with drilling mud circulation

Date of start : 6-May-2022
Date of finish : 7-May-2022
GWL from GL : 2.80m
Ground level RL : 98.06m

Depth from GL(m)		Soil Profile	Field Description	Depth of samples collected		SPT / VST						RD / Consistency
						Test depth	Blow Counts					
				UDS	DS	m	15	30	45	60	N**	
1.0	1.0		Brownish grey fine to medium sand with stones with 300mm PCC		0.50							Fill
					0.75							
2.0			Greyish brown sandy silty clay		1.50	1.50	4	4	5	6	9	Medium stiff
3.0	2.1 / 2.7		Greyish brown clayey silty fine sand		2.25	2.25	3	5	8	10	13	Medium stiff
4.0	3.7		Brownish grey silty clay with fine sand		3.00	3.00	3	3	5	5	8	Medium stiff
					3.75	3.75	6	10	12	14	22	
5.0			Brownish grey clayey silty fine sand with sandy clay pockets		4.50	4.50	7	10	15	12	25	Medium dense
6.0	5.4				5.50	5.50	4	7	9	10	16	
7.0			Brownish grey silty clay with fine sand patches		6.50	6.50	4	8	10	10	18	Stiff
8.0	7.5				7.50	7.50	7	10	10	10	20	
9.0	9.0		Light grey and brown sandy silty clay		8.50	8.50	7	10	10	11	20	Stiff
10.0	9.7		Grey and brown clayey silty fine sand									Med dense
11.0					10.00	10.00	8	12	13	15	25	
12.0			Light grey and brown sandy silty clay/ clayey cemented sand		11.50	11.50	10	20	27		47	Very stiff to hard
13.0	12.6											
14.0					13.00	13.00	10	17	20	22	37	
15.0			Light greenish grey sandy silty clay with brown patches		14.50	14.50	11	17	25	25	42	Very stiff to hard
16.0	15.7											
17.0			Yellowish brown clayey silty sand with weathered stones		16.00	16.00	50/14cm				>100	Very dense
18.0	17.5					17.50	Rebound				RB	
19.0	18.8		Greyish brown weathered fractured rock	17.50-18.80		TC core drilling 18.50	Rebound				RB	Very weak
20.0	19.8		Light greyish brown severely jointed weathered rock (sandstone)	18.80-19.80		DC core drilling					R 32% Q 0%	Weak
			TC core drilling from 17.50m to 18.50m DC core drilling from 18.50m to 19.50m									
			Borehole terminated at 19.80m									
			**Note: SPT Conducted using winch cat-head device, N values reported are close to N_{55}									

FIELD BORE LOG

ANNEXURE 5

GEOTECHNICAL Solutions[A1]

PROJECT NO:	CUBE/TNUHDB/GN/G-1352
BORE HOLE NO:	BH/5

Project : Proposed Construction of (G+5) EWS Tenements
Site : Gandhi Nagar in Corp DN 96 Zone 8 of GCC
Location : As shown in Figure 1
Dia and type of boring : 150mm Rotary boring with drilling mud circulation

Date of start : 9-May-2022
Date of finish : 9-May-2022
GWL from GL : 2.50m
Ground level RL : 98.059m

Depth from GL(m)		Soil Profile	Field Description	Depth of samples collected		SPT / VST						RD / Consistency
				UDS	DS	Test depth m	Blow Counts 15	30	45	60	N**	
1.0	1.0		Brownish grey fine to medium sand with stones with 300mm PCC		0.50 0.75							Fill
2.0			Light grey clayey silty fine sand / sandy silty clay		1.50	1.50	3	2	3	3	5	Loose
3.0	2.1		Brownish grey silty clay with brown patches		2.25	2.25	3	6	8	10	14	Stiff
4.0	3.4 3.8		Brownish grey sandy silty clay		3.00	3.00	4	7	9	13	16	
5.0			Brownish grey silty clay		3.75 4.50	3.75 4.50	6 6	10 10	10 11	15 13	20 21	Stiff
6.0					5.50	5.50	7	11	12	16	23	
7.0	6.3		Brownish grey silty clay with red patches		6.50	6.50	5	8	9	10	17	Stiff
8.0	7.3		Light grey clayey silty fine to medium sand		7.50	7.50	8	10	10	10	20	Medium dense
9.0	9.0				8.50	8.50	10	12	13	13	25	
10.0			Light grey and brown clayey silty cemented fine to medium sand		10.00	10.00	9	12	15	15	27	Medium dense to dense
11.0												
12.0					11.50	11.50	10	15	19	20	34	
13.0	12.7		Light greenish grey sandy silty clay with brown patches		13.00	13.00	10	15	25		40	Hard
14.0												
15.0					14.50	14.50	14	16	26	25	42	
16.0	15.8		Yellowish brown clayey silty fine sand		16.00	16.00	50/15cm				>100	Very dense
17.0						17.30	Rebound				RB	
18.0	17.3		Light greyish brown fractured shale & sandstone	17.30-18.30		TC core drilling 18.30	Rebound				RB	Very weak
19.0	18.3		Light greyish brown jointed weathered rock (shale & sandstone)	18.30-19.30		DC core drilling					R 31% Q 22%	Weak
20.0	19.3		TC core drilling from 17.30m to 18.30m DC core drilling from 18.30m to 19.30m									
			Borehole terminated at 19.30m									
			**Note: SPT Conducted using winch cat-head device, N values reported are close to N_{55}									

FIELD BORE LOG

GEOTECHNICAL Solutions[A1]

ANNEXURE 6

PROJECT NO:	CUBE/TNUHDB/GN/G-1352
BORE HOLE NO:	BH/6

Project : Proposed Construction of (G+5) EWS Tenements
Site : Gandhi Nagar in Corp DN 96 Zone 8 of GCC
Location : As shown in Figure 1
Dia and type of boring : 150mm Rotary boring with drilling mud circulation

Date of start : 11-May-2022
Date of finish : 12-May-2022
GWL from GL : 2.30m
Ground level RL : 98.062m

Depth from GL(m)	Soil Profile	Field Description	Depth of samples collected UDS	Depth of samples collected DS	SPT / VST Test depth m	Blow Counts 15	30	45	60	N**	RD / Consistency
1.0		Light greyish brown fine sand with 200mm PCC		0.50							Fill
	1.1			0.75							
2.0		Light greyish brown silty clay with fine sand		1.50	1.50	3	4	5	4	9	Medium stiff
3.0	2.9			2.25	2.25	4	3	4	4	7	
4.0		Greyish silty clay with brown patches	3.00	Collected							Stiff
				3.50	3.50	3	5	5	4	10	
5.0				4.50	4.50	5	5	7	7	12	
6.0				5.50	5.50	4	6	7	7	13	
7.0				6.50	6.50	3	6	5	6	11	
	7.3										
8.0		Light grey and brown sandy silty clay		7.50	7.50	7	9	10	10	19	Very stiff
9.0				8.50	8.50	7	10	11	13	21	
10.0	9.7										
11.0		Light greyish brown clayey silty fine sand with medium sand		10.00	10.00	8	10	13	15	23	Medium dense
12.0				11.50	11.50	12	14	20	20	34	
13.0	12.5										
14.0		Light greenish grey and brown sandy silty clay		13.00	13.00	16	20	25		45	Hard
15.0				14.50	14.50	14	22	25		47	
	15.4										
16.0		Light greenish grey and brown clayey silty cemented fine to medium sand		16.00	16.00	15	24	30		54	Dense
17.0											
	17.1										
18.0		Light grey and brown sandy silty clay		17.50	17.50	20	33	37		70	Hard
19.0	18.8										
20.0	20.0	Brownish grey sandy silty clay		19.00	19.00	50/10cm				>100	Hard
					20.20	Rebound				RB	

Continued in the next sheet

Borehole terminated at 22.00m

**Note: SPT Conducted using winch cat-head device, N values reported are close to N_{55}

FIELD BORE LOG

GEOTECHNICAL Solutions[A1]

ANNEXURE 6

SHEET 2 OF 2

PROJECT NO:	**CUBE/TNUHDB/GN/G-1352**
BORE HOLE NO:	**BH/6**

Project : Proposed Construction of (G+5) EWS Tenements
Site : Gandhi Nagar in Corp DN 96 Zone 8 of GCC
Location : As shown in Figure 1
Dia and type of boring : 150mm Rotary boring with drilling mud circulation

Date of start : 11-May-2022
Date of finish : 12-May-2022
GWL from GL : 2.30m
Ground level RL : 98.062m

Depth from GL(m)		Soil Profile	Field Description	Depth of samples collected		SPT / VST					RD / Consistency
				UDS	DS	Test depth m	Blow Counts 15	30	45	60	N**	
21.0	21.0		Light grey and brown weathered fractured rock	20.20-21.00		TC core drilling 21.00	Rebound				RB	Very weak
22.0	22.0		Light grey and brown severely jointed weathered rock (shale /sandstone)	21.00-22.00		DC core drilling					R 30% Q nil	Weak
23.0												
24.0												
25.0												
26.0												
27.0												
28.0												
29.0												
30.0												
31.0												
32.0												
33.0												
34.0												
35.0												
36.0												
37.0												
38.0												
39.0			TC Core drilling from 20.20m to 21.20m DC core drilling from 21.20m to 22.20m									
40.0												
			Continued from sheet 1	**Borehole terminated at 22.00m**								

**Note: SPT Conducted using winch cat-head device, N values reported are close to N_{55}

FIELD BORE LOG

ANNEXURE 7

GEOTECHNICAL Solutions[A1]

PROJECT NO:	CUBE/TNUHDB/GN/G-1352
BORE HOLE NO:	BH/7

Project : Proposed Construction of (G+5) EWS Tenements
Site : Gandhi Nagar in Corp DN 96 Zone 8 of GCC
Location : As shown in Figure 1
Dia and type of boring : 150mm Rotary boring with drilling mud circulation

Date of start : 12-May-2022
Date of finish : 14-May-2022
GWL from GL : 3.00m
Ground level RL : 98.25m

Depth from GL(m)	Soil Profile	Field Description	Depth of samples collected UDS	Depth of samples collected DS	SPT / VST Test depth m	Blow Counts 15	30	45	60	N**	RD / Consistency
1.0		Greyish brown sandy silty clay with 200mm PCC		0.50							Fill
				0.75							
2.0				1.50	1.50	3	4	6	4	10	
	2.2										
3.0	3.0	Light grey sandy silty clay		2.25	2.25	2	4	5	5	9	Medium stiff
				3.00	3.00	4	7	8	8	15	Stiff
4.0		Greyish silty clay									
				3.75	3.75	4	8	8	8	16	
5.0				4.50	4.50	4	6	8	9	14	
6.0				5.50	5.50	5	8	9	10	17	
7.0				6.50	6.50	5	6	7	8	13	
8.0				7.50	7.50	4	5	7	8	12	
	8.2										
9.0		Light grey sandy silty clay		8.50	8.50	5	7	8	2	15	Stiff
10.0	9.7										
				10.00	10.00	10	13	13	15	26	Very stiff / dense
11.0		Light grey and yell brown sandy silty clay / clayey cemented sand									
12.0				11.50	11.50	11	14	16	22	30	
13.0	12.8										
				13.00	13.00	14	20	24	25	44	Dense
14.0		Light greenish grey clayey silty fine to medium sand									
15.0				14.50		15	23	25		48	
	15.4										
16.0		Light grey and brown sandy silty clay / clayey cemented sand		16.00	16.00	22	32	40		72	Hard / very dense
17.0											
18.0				17.50	17.50	40	50/10cm			>100	
19.0	18.7										
		Light yellowish brown clayey silty fine sand		19.00	19.00	50/10cm				>100	Very dense
20.0	20.0										

Continued in the next sheet

Borehole terminated at 21.40m

**Note: SPT Conducted using winch cat-head device, N values reported are close to N_{55}

FIELD BORE LOG

GEOTECHNICAL Solutions[A1]

ANNEXURE 7

SHEET 2 OF 2

PROJECT NO:	**CUBE/TNUHDB/GN/G-1352**
BORE HOLE NO:	**BH/7**

Project : Proposed Construction of (G+5) EWS Tenements
Site : Gandhi Nagar in Corp DN 96 Zone 8 of GCC
Location : As shown in Figure 1
Dia and type of boring : 150mm Rotary boring with drilling mud circulation

Date of start : 12-May-2022
Date of finish : 14-May-2022
GWL from GL : 3.00m
Ground level RL : 98.25m

Depth from GL(m)		Soil Profile	Field Description	Depth of samples collected		SPT / VST			RD / Consistency
				UDS	DS	Test depth m	Blow Counts 15 30 45 60	N**	
	20.5		Light yellowish brown clayey silty fine sand			20.50	Rebound	RB	Dense
21.0			Light grey and brown weathered fractured rock	20.50-21.40		TC core drilling 21.40	Rebound	RB	Very weak
	21.4								
22.0			Light grey and brown severely jointed / fracturedweathered rock	21.40-22.40		DC core drilling		R 20% Q nil	Weak
	22.4								
23.0									
24.0									
25.0									
26.0									
27.0									
28.0									
29.0									
30.0									
31.0									
32.0									
33.0									
34.0									
35.0									
36.0									
37.0									
38.0									
39.0			TC Core drilling from 20.50m to 21.40m DC core drilling from 21.40m to 22.40m						
40.0									
			Continued from sheet 1			**Borehole terminated at 21.40m**			

**Note: SPT Conducted using winch cat-head device, N values reported are close to N_{55}

FIELD BORE LOG

GEOTECHNICAL Solutions[A1]

ANNEXURE 8

SHEET 1 OF 2

PROJECT NO:	CUBE/TNUHDB/GN/G-1352
BORE HOLE NO:	BH/8

Project : Proposed Construction of (G+5) EWS Tenements
Site : Gandhi Nagar in Corp DN 96 Zone 8 of GCC
Location : As shown in Figure 1
Dia and type of boring : 150mm Rotary boring with drilling mud circulation

Date of start : 16-May-2022
Date of finish : 17-May-2022
GWL from GL : 1.20m
Ground level RL : 98.255m

Depth from GL(m)	Soil Profile	Field Description	Depth of samples collected UDS	Depth of samples collected DS	SPT / VST Test depth m	Blow Counts 15	30	45	60	N**	RD / Consistency
1.0		Brownish grey sandy silty clay		0.50							Fill
	1.1			0.75							
2.0	1.8	Greyish brown silty clay		1.50	1.50	2	2	2	5	4	Soft
3.0		Brownish grey silty clay	2.25	Collected							
				2.75	2.75	2	4	5	6	9	Medium stiff
4.0				3.50	3.50	3	5	5	6	10	
5.0	4.3	Greyish silty clay		4.50	4.50	5	6	7	7	13	Stiff
6.0	5.4	Light grey silty clay with brown patches		5.50	5.50	3	5	4	5	9	Medium stiff
7.0	6.4	Light greenish grey and brown clayey silty fine to medium sand		6.50	6.50	5	7	7	6	14	Medium dense
8.0				7.50	7.50	4	6	5	7	11	
9.0				8.50	8.50	4	5	7	7	12	
10.0	9.5	Light grey and brown clayey silty fine to medium sand		10.00	10.00	9	12	13	13	25	Medium dense
11.0											
12.0				11.50	11.50	10	13	15	17	28	
13.0	12.8	Light greenish grey clayey silty cemented fine to medium sand		13.00	13.00	13	16	17	20	33	Dense
14.0											
15.0				14.50	14.50	14	17	19	22	36	
16.0	15.6	Light greenish grey and brown sandy silty clay/ clayey cemented sand		16.00	16.00	16	25	26		51	Dense/hard
17.0											
18.0				17.50	17.50	17	30	35		65	
19.0	18.7	Brownish grey sandy silty clay		19.00	19.00	50/15cm				>100	Hard
20.0	20.0										

Continued in the next sheet

Borehole terminated at 21.50m

**Note: SPT Conducted using winch cat-head device, N values reported are close to N_{55}

FIELD BORE LOG

ANNEXURE 8

SHEET 2 OF 2

GEOTECHNICAL Solutions[A1]

PROJECT NO:	**CUBE/TNUHDB/GN/G-1352**
BORE HOLE NO:	**BH/8**

Project : Proposed Construction of (G+5) EWS Tenements
Site : Gandhi Nagar in Corp DN 96 Zone 8 of GCC
Location : As shown in Figure 1
Dia and type of boring : 150mm Rotary boring with drilling mud circulation

Date of start : 16-May-2022
Date of finish : 17-May-2022
GWL from GL : 1.20m
Ground level RL : 98.255m

Depth from GL(m)		Soil Profile	Field Description	Depth of samples collected		SPT / VST					RD / Consistency
						Test depth	Blow Counts				
				UDS	DS	m	15	30	45	60	N**	
	20.5		Brownish grey sandy silty clay			20.50	Rebound				RB	Hard
21.0			Yellowish brown and grey weathered fractured rock	20.50-21.50		TC core drilling						Very weak
	21.5					21.50	Rebound				RB	
22.0			Light grey and brown severely jointed weathered rock (shale /sandstone)	21.50-22.50		DC core drilling					R 25% Q nil	Weak
	22.5											
23.0												
24.0												
25.0												
26.0												
27.0												
28.0												
29.0												
30.0												
31.0												
32.0												
33.0												
34.0												
35.0												
36.0												
37.0												
38.0												
39.0			TC Core drilling from 20.50m to 21.50m DC core drilling from 21.50m to 22.50m									
40.0												
			Continued from sheet 1	**Borehole terminated at 21.50m**								

**Note: SPT Conducted using winch cat-head device, N values reported are close to N_{55}

SHEAR STRENGTH PARAMETERS FOR DIFFERENT LAYERS
PROPOSED CONSTRUCTION OF (G+5) EWS TENEMENTS, GANDHI NAGAR IN CORP DN 96 ZONE 8 OF GCC

Borehole BH/1 Ground level = 98.19m, GWL 3.00m below GL (May 2022).

Depth Below GL	Soil	N	Design N''	Angle of friction	Shear Strength c_u	PI % or D50	Compressibility
0.00m to 0.70m	Greyish sandy silty clay/clayey silty fine to medium sand with brown patches and PCC						
0.70m to 1.40m	Light greyish brown sandy silty clay with stones	3	3		$cu=3.0\ t/m^2$	D50=0.098	C using $q_c= 16\ N\ t/m^2$
1.40m to 2.30m	Brownish grey silty clay with fine sand	4	4		$cu=3.4\ t/m^2$	PI=27.5%	C using $q_c= 16\ N\ t/m^2$
2.30m to 3.40m	Brownish grey silty clay with fine sand	8,8	8		$cu=5.2\ t/m^2$	PI=27.5%	C using $q_c= 16\ N\ t/m^2$
3.40m to 4.30m	Brownish grey silty clay	13	13		$cu=7.8\ t/m^2$	PI=36.9%	C using $q_c= 15\ N\ t/m^2$
4.30m to 7.40m	Dark brownish grey silty clay	14,16,11	14		$cu=8.4\ t/m^2$	PI=29.6%	C using $q_c= 16\ N\ t/m^2$
7.40m to 9.70m	Greyish silty clay with fine sand	3	3		$cu=3.0\ t/m^2$	PI=28.6%	C using $q_c= 16\ N\ t/m^2$
9.70m to 11.0m	Light greenish grey and brown sandy silty clay	14	14		$cu=8.4\ t/m^2$	PI=15%	C using $q_c= 18\ N\ t/m^2$
11.00m to 14.00m	Light greenish grey and brown sandy silty clay	25,26	25		$cu=15\ t/m^2$	PI=50.5%	C using $q_c= 14\ N\ t/m^2$
14.00m to 14.80m	Light greyish and brown sandy silty clay		26		$cu=15\ t/m^2$	PI=30.8%	C using $q_c= 15\ N\ t/m^2$
14.80m to 18.50m	Light yellowish brown clayey silty fine sand	>70		$\phi = 40°$		D50=0.15	C using $q_c= 24\ N\ t/m^2$
18.50m to 20.00m	Light yellowish brown & grey fractured / severely jointed weathered rock (shale)	RB	>200		$Su=120\ t/m^2$		
20.00m to 20.50m	Lt yell brown & grey severely jointed weathered rock						

SHEAR STRENGTH PARAMETERS FOR DIFFERENT LAYERS
PROPOSED CONSTRUCTION OF (G+5) EWS TENEMENTS, GANDHI NAGAR IN CORP DN 96 ZONE 8 OF GCC

Borehole BH/2 Ground Level 98.06m, Ground water table = 2.80m below GL (May 2022).

Depth Below GL	Soil	N	Design N''	Angle of friction	Shear Strength c_u	PI % or D50	Compressibility
0.00m to 1.10m	Brownish and light grey sandy silty clay with 30mm PCC						
1.10m to 2.20m	Brownish and light grey sandy silty clay/clayey silty sand	8	8		cu=5.2 t/m²	PI=20.6%	C using q_c= 18 N t/m²
2.20m to 3.70m	Brownish and light grey sandy silty clay	10,14	12		cu=7.0 t/m²	PI=24.3%	C using q_c= 18 N t/m²
3.70m to 5.40m	Brownish grey silty clay with fine sand patches	15,16	15		cu=9.0 t/m²	PI=30%	C using q_c= 15 N t/m²
5.40m to 6.30m	Light grey silty fine sand with traces of clay	25	21	ϕ = 31.5°		D50=0.151	C using q_c= 22 N t/m²
6.30m to 7.50m	Light grey fine sand	24	25	ϕ = 33°		D50=0.168	C using q_c= 23 N t/m²
7.50m to 9.50m	Light brownish grey fine sand	18,10	15	ϕ = 30°		D50=0.166	C using q_c= 23 N t/m²
9.50m to 11.10m	Greyish silty clay with sand patches	5	5		cu=3.7 t/m²	PI=28.4%	C using q_c= 17 N t/m²
11.10m to 14.20m	Light greenish grey sandy silty clay with brown patches	20,22	20		cu=12 t/m²	PI=25%	C using q_c= 17 N t/m²
14.20m to 16.00m	Light yellowish brown clayey silty fine sand	55	>45	ϕ = 36°		D50=0.147	C using q_c= 22 N t/m²
16.00m to 18.80m	Light yellowish brown clayey silty fine sand	>100	>85	ϕ = 40.5°		D50=0.143	C using q_c= 22 N t/m²
18.80m to 19.50m	Yellowish brown weathered fractured sandstone	RB	>200		Su=120 t/m²		
19.50m to 20.50m	Lt greyish brown severely jointed weathered shale						

SHEAR STRENGTH PARAMETERS FOR DIFFERENT LAYERS
PROPOSED CONSTRUCTION OF (G+5) EWS TENEMENTS, GANDHI NAGAR IN CORP DN 96 ZONE 8 OF GCC

Borehole BH/3 Ground Level 98.065m, Ground water table = 2.80m below GL (May 2022).

Depth Below GL	Soil	N	Design N''	Angle of friction	Shear Strength c_u	PI % or D50	Compressibility
0.00m to 1.10m	Brownish grey fine to medium sand with stones and 300mm PCC						
1.10m to 2.80m	Brownish grey fine sandy silty clay	9,11	10		cu=6.2 t/m²	PI=17%	C using q_c= 19 N t/m²
2.80m to 3.60m	Brownish grey silty clay with fine sand	11	11		cu=6.6 t/m²	PI=37.8%	C using q_c= 15 N t/m²
3.60m to 7.40m	Brownish grey and greyish brown silty clay	20,21,20,18	20		cu=12 t/m²	PI=35%	C using q_c= 15 N t/m²
7.40m to 9.50m	Light greenish grey clayey silty fine to medium sand	7,6	7	ϕ = 27.5°		D50=0.27	C using q_c= 26 N t/m²
9.50m to 12.60m	Light grey and brown clayey silty cemented fine to medium sand	26,41	25	ϕ = 33°		D50=0.40	C using q_c= 26 N t/m²
12.60m to 15.60m	Light greenish grey sandy silty clay	30,45	30		cu=15 t/m²	PI=25.4%	C using q_c= 17 N t/m²
15.60m to 17.50m	Yellowish brown clayey silty fine sand	>100	89	ϕ = 41°		D50=0.146	C using q_c= 21 N t/m²
17.50m to 18.40m	Yellowish brown weathered fractured rock	RB	>200		Su=120 t/m²		
18.40m to 19.40m	Lt grey & brown severely jointed weathered rock with black patches						

SHEAR STRENGTH PARAMETERS FOR DIFFERENT LAYERS
PROPOSED CONSTRUCTION OF (G+5) EWS TENEMENTS, GANDHI NAGAR IN CORP DN 96 ZONE 8 OF GCC

Borehole BH/4 Ground Level 98.06m, Ground water table = 2.80m below GL (May 2022).

Depth Below GL	Soil	N	Design N''	Angle of friction	Shear Strength c_u	PI % or D50	Compressibility
0.00m to 1.00m	Brownish grey fine to medium sand with stones with 300mm PCC						
1.00m to 2.10m	Greyish brown sandy silty clay	9	9		cu=5.6 t/m²	PI=15.7%	C using q_c= 19 N t/m²
2.10m to 2.70m	Greyish brown clayey silty fine sand	13	14	ϕ = 28.5°		D50=0.11	C using q_c= 22 N t/m²
2.70m to 3.70m	Brownish grey silty clay with fine sand	8	8		cu=5.2 t/m²	PI=22.5%	C using q_c= 17 N t/m²
3.70m to 5.40m	Brownish grey clayey silty fine sand with sandy clay pockets	22,25	25	ϕ = 31.5°		D50=0.109	C using q_c= 22 N t/m²
5.40m to 7.50m	Brownish grey silty clay with fine sand patches	16,18	17		cu=10 t/m²	PI=45%	C using q_c= 15 N t/m²
7.50m to 9.00m	Light grey and brown sandy silty clay	20	20		cu=12 t/m²	PI=<20%	C using q_c= 18 N t/m²
9.00m to 9.70m	Grey and brown clayey silty fine sand		20	ϕ = 30°		D50=0.11	C using q_c= 22 N t/m²
9.70m to 12.60m	Light grey and brown sandy silty clay/ clayey cemented sand	25,47	25		cu=15 t/m²	D50=0.30	C using q_c= 24 N t/m²
12.60m to 15.70m	Light greenish grey sandy silty clay with brown patches	37,42	40		cu=23 t/m²	PI=22.2%	C using q_c= 18 N t/m²
15.70m to 17.50m	Yellowish brown clayey silty sand with weathered stones	>100	88	ϕ = 41°		D50=0.105	C using q_c= 22 N t/m²
17.50m to 18.80m	Greyish brown weathered fractured rock	RB	>200		Su=120 t/m²		
18.80m to 19.80m	Light greyish brown severely jointed weathered rock (sandstone)						

SHEAR STRENGTH PARAMETERS FOR DIFFERENT LAYERS
PROPOSED CONSTRUCTION OF (G+5) EWS TENEMENTS, GANDHI NAGAR IN CORP DN 96 ZONE 8 OF GCC

Borehole BH/5 Ground Level = 98.059m, Ground water table = 2.50m below GL (May 2022).

Depth Below GL	Soil	N	Design N''	Angle of friction	Shear Strength c_u	PI % or D50	Compressibility
0.00m to 1.00m	Brownish grey fine to medium sand with stones with 300mm PCC						
1.00m to 2.10m	Light grey clayey silty fine sand / sandy silty clay	5	7	ϕ = 26°		PI=18%	C using q_c= 20 N t/m²
2.10m to 3.40m	Brownish grey silty clay with brown patches	14,16	15		cu=9.0 t/m²	PI=19.6%	C using q_c= 20 N t/m²
3.40m to 3.80m	Brownish grey sandy silty clay		20		cu=12 t/m²	PI=20%	C using q_c= 19 N t/m²
3.80m to 6.30m	Brownish grey silty clay	20,21,23	20		cu=12 t/m²	PI=37.3%	C using q_c= 15 N t/m²
6.30m to 7.30m	Brownish grey silty clay with red patches	17	17		cu=10.2 t/m²	PI=61.6%	C using q_c= 13 N t/m²
7.30m to 9.00m	Light grey clayey silty fine to medium sand	20,25	20	ϕ = 31.5°		D50=0.252	C using q_c= 27 N t/m²
9.00m to 12.70m	Light grey and brown clayey silty cemented fine to medium sand	27,34	24	ϕ = 32.5°		D50=0.33	C using q_c= 28 N t/m²
12.70m to 15.80m	Light greenish grey sandy silty clay with brown patches	40,42	40		cu=24 t/m²	PI=25%	C using q_c= 17 N t/m²
15.80m to 17.30m	Yellowish brown clayey silty fine sand	>100	87	ϕ = 41°		D50=0.145	C using q_c= 22 N t/m²
17.30m to 18.30m	Light greyish brown fractured shale & sandstone	RB	>200		Su=120 t/m²		
18.30m to 19.30m	Light greyish brown jointed weathered rock (shale & sandstone)						

SHEAR STRENGTH PARAMETERS FOR DIFFERENT LAYERS
PROPOSED CONSTRUCTION OF (G+5) EWS TENEMENTS, GANDHI NAGAR IN CORP DN 96 ZONE 8 OF GCC

Borehole BH/6 Ground Level = 98.062m, Ground water table = 2.30m below GL (May 2022).

Depth Below GL	Soil	N	Design N''	Angle of friction	Shear Strength c_u	PI % or D50	Compressibility
0.00m to 1.10m	Light greyish brown fine sand with 200mm PCC						
1.10m to 2.90m	Light greyish brown silty clay with fine sand	9,7	8		cu=5.0 t/m²	PI=17.6%	C using q_c= 19 N t/m²
2.90m to 7.30m	Greyish silty clay with brown patches	10,12,13,11	11		cu=6.6 t/m²	PI=38-53%	C using q_c= 15 N t/m²
7.30m to 9.70m	Light grey and brown sandy silty clay	19,21	20		cu=12 t/m²	PI=29.9%	C using q_c= 16 N t/m²
9.70m to 11.00m	Light greyish brown clayey silty fine sand	23	22	ϕ = 31°		D50=0.166	C using q_c= 24 N t/m²
11.00m to 12.50m	Light greyish brown clayey silty fine sand with medium sand	34	22	ϕ = 34°		D50=0.416	C using q_c= 30 N t/m²
12.50m to 15.40m	Light greenish grey and brown sandy silty clay	45,47	45		cu=27 t/m²	PI=45%	C using q_c= 15 N t/m²
15.40m to 17.10m	Light greenish grey and brown clayey silty cemented fine to medium sand	54	44	ϕ = 37.5°		D50=0.292	C using q_c= 26 N t/m²
17.10m to 18.80m	Light grey and brown sandy silty clay	70	70		cu=42 t/m²	PI=<20%	C using q_c= 18 N t/m²
18.80m to 20.00m	Brownish grey sandy silty clay	>100	110		cu=66 t/m²	D50=0.247	C using q_c= 17 N t/m²
20.00m to 21.00m	Light grey and brown weathered fractured rock	RB	>200		Su=120 t/m²		
21.00m to 22.00m	Light grey and brown severely jointed weathered rock (shale /sandstone)						

SHEAR STRENGTH PARAMETERS FOR DIFFERENT LAYERS
PROPOSED CONSTRUCTION OF (G+5) EWS TENEMENTS, GANDHI NAGAR IN CORP DN 96 ZONE 8 OF GCC

Borehole BH/7 Ground Level = 98.250m, Ground water table = 3.00m below GL (May 2022).

Depth Below GL	Soil	N	Design N''	Angle of friction	Shear Strength c_u	PI % or D50	Compressibility
0.00m to 2.20m	Greyish brown sandy silty clay with 200mm PCC	10	10		cu=6.1 t/m²	D50=0.166	C using q_c= 18 N t/m²
2.20m to 3.00m	Light grey sandy silty clay	9	9		cu=5.6 t/m²	PI=22%	C using q_c= 18 N t/m²
3.00m to 6.50m	Greyish silty clay	15,16,14,17	15		cu=9.0 t/m²	PI=36.5%	C using q_c= 15 N t/m²
6.50m to 8.20m	Greyish silty clay	13,12	12		cu=7.2 t/m²	PI=62.5%	C using q_c= 14 N t/m²
8.20m to 9.70m	Light grey sandy silty clay	15	15		cu=9.0 t/m²	D50=0.249	C using q_c= 18 N t/m²
9.70m to 12.80m	Light grey and yell brown sandy silty clay / clayey cemented sand	26,30	27		cu=16 t/m²	D50=0.271	C using q_c= 18 N t/m²
12.80m to 15.40m	Light greenish grey clayey silty fine sand	44,48	39	ϕ = 36.5°		D50=0.089	C using q_c= 20 N t/m²
15.40m to 18.70m	Light grey and brown sandy silty clay / clayey cemented sand	72,>100	72		cu=43 t/m²	D50=0.152	C using q_c= 18 N t/m²
18.70m to 20.50m	Light yellowish brown clayey silty fine sand	>100	82	ϕ = 40.5°		D50=0.146	C using q_c= 20 N t/m²
20.50m to 21.40m	Light grey and brown weathered fractured rock	RB	>200		Su=120 t/m²		
21.40m to 22.40m	Light grey and brown severely jointed / fractured weathered rock						

SHEAR STRENGTH PARAMETERS FOR DIFFERENT LAYERS
PROPOSED CONSTRUCTION OF (G+5) EWS TENEMENTS, GANDHI NAGAR IN CORP DN 96 ZONE 8 OF GCC

Borehole BH/8 Ground Level = 98.062m, Ground water table = 2.30m below GL (May 2022).

Depth Below GL	Soil	N	Design N''	Angle of friction	Shear Strength c_u	PI % or D50	Compressibility
0.00m to 1.10m	Brownish grey sandy silty clay						
1.10m to 1.80m	Greyish brown silty clay	4	4		cu=3.4 t/m²	PI=17.9%	C using q_c= 20 N t/m²
1.80m to 4.30m	Brownish grey silty clay	9,10	9		cu=5.0 t/m²	PI=27.2%	C using q_c= 16 N t/m²
4.30m to 5.40m	Greyish silty clay	13	13		cu=7.8 t/m²	PI=33.5%	C using q_c= 15 N t/m²
5.40m to 6.40m	Light grey silty clay with brown patches	9	9		cu=5.6 t/m²	PI=43.2%	C using q_c= 15 N t/m²
6.40m to 9.50m	Light greenish grey and brown clayey silty fine to medium sand	14,11,12	12	ϕ = 29°		D50=0.281	C using q_c= 26 N t/m²
9.50m to 12.80m	Light grey and brown clayey silty fine to medium sand	25,28	25	ϕ = 32.5°		D50=0.416	C using q_c= 28 N t/m²
12.80m to 15.60m	Light greenish grey clayey silty cemented fine to medium sand	33,36	30	ϕ = 34°		D50=0.244	C using q_c= 25 N t/m²
15.60m to 18.70m	Light greenish grey and brown sandy silty clay/ clayey cemented sand	51,65	55		cu=32 t/m²	PI=24.2%	C using q_c= 17 N t/m²
18.70m to 20.50m	Brownish grey sandy silty clay	>100	110		cu=66 t/m²	PI=25%	C using q_c= 17 N t/m²
20.50m to 21.50m	Yellowish brown and grey weathered fractured rock	RB	>200		Su=120 t/m²		
21.50m to 22.50m	Light grey and brown severely jointed weathered rock (shale /sandstone)						

Appendix B

Detailed Calculations





BEARING CAPACITY **INDIVIDUALFOOTINGS AT 3.00M BELOW GL - BH/1 THROUGH BH/5**

Project:	Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC		
Structure	G+5 RCC Building		
Ultimate Bearing Capacity	$= cN_c s_c d_c i_c g_c + 1/2 B\gamma N_\gamma s_\gamma d_\gamma i_\gamma g_\gamma + \gamma D(N_q-1)s_q d_q i_q g_q$		
Soil Data		Bearing Capacity Estimation using	IS Code 6403 -1981
Reference Bore Hole	BH/1 to BH/5		
Type of Soil	Clay		
		Failure Case	
Angle of friction ϕ	0 deg		
Bulk density above gwl	18.0 kN/m^3	*General failure case is considered in all cases assuming no punching shear because of wide base*	
Bulk density below gwl	19.0 kN/m^3		
Ground water table	0.00 m		
Factor of safety	3.00		

ESTIMATION 1

Depth of Foundation *	3.00 m							
Shape of Footing	Square	Cohesion c		70.0 kN/m^2				
Width of Foundation	2.00 m							
			N_i	s_i	d_i	i_i	N**	Ultimate
* depth of embedment		N_c	5.14	1.30	1.30	1.00	8.7	608.4
		N_q	1.00	1.20	1.00	1.00	0.0	0.0
		N_r	0.00	0.60	1.00	1.00	0.0	0.0
N** Product of bearing capacity factors and other correction factors		Total Ultimate Bearing capacity					608.4	kN/m^2
		Net Safe Bearing Capacity					203	kN/m^2

ESTIMATION 2

Depth of Foundation *	3.00 m							
Shape of Footing	Rectangle	Cohesion c		70.0 kN/m^2				
Width of Foundation	2.00 m							
Length of Foundation m	4.00		N_i	s_i	d_i	i_i	N**	Ultimate
* depth of embedment		N_c	5.14	1.15	1.30	1.00	7.7	538.2
		N_q	1.00	1.10	1.00	1.00	0.0	0.0
		N_r	0.00	0.80	1.00	1.00	0.0	0.0
N** Product of bearing capacity factors and other correction factors		Total Ultimate Bearing capacity					538.2	kN/m^2
		Net Safe Bearing Capacity					179	kN/m^2

SUMMARY OF ESTIMATIONS

Sl No	D	Sh	B	L	NBC	
1	3.00	SQ	1.50		218	kN/m^2
2	3.00	SQ	2.00		203	kN/m^2
3	3.00	SQ	2.50		193	kN/m^2
4	3.00	SQ	3.00		187	kN/m^2
5	3.00	RE	2.00	4.00	179	kN/m^2
6	3.00	RE	2.50	5.00	171	kN/m^2

D is depth in m
Sh is footing shape
B is footing width or diameter, m
L is footing length, m
NBC is net safe bearing capacity

Note: If loading is eccentric, total load shall be estimated for corrected area = L' x B' where L'=L-2e_l and B'= B-2e_b

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BEARING CAPACITY **INDIVIDUALFOOTINGS AT 3.00M BELOW GL - BH/6, BH/7 & BH/8**

Project:	Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC
Structure	G+5 RCC Building

Ultimate Bearing Capacity $= cN_c s_c d_c i_c g_c + 1/2 B \gamma N_\gamma s_\gamma d_\gamma i_\gamma g_\gamma + \gamma D(N_q - 1) s_q d_q i_q g_q$

Soil Data		Bearing Capacity Estimation using	IS Code 6403 -1981
Reference Bore Hole	BH/6 to BH/8		
Type of Soil	Clay		
		Failure Case	
Angle of friction ϕ	0 deg		
Bulk density above gwl	18.0 kN/m^3	*General failure case is considered in all cases assuming no punching shear because of wide base*	
Bulk density below gwl	19.0 kN/m^3		
Ground water table	0.00 m		
Factor of safety	3.00		

ESTIMATION 1

Depth of Foundation *	3.00 m							
Shape of Footing	Square	Cohesion c		60.0 kN/m^2				
Width of Foundation	2.00 m							
			N_i	s_i	d_i	i_i	N**	Ultimate
* depth of embedment		N_c	5.14	1.30	1.30	1.00	8.7	521.5
		N_q	1.00	1.20	1.00	1.00	0.0	0.0
		N_γ	0.00	0.60	1.00	1.00	0.0	0.0
N** Product of bearing capacity factors and other correction factors		Total Ultimate Bearing capacity					521.5	kN/m^2
		Net Safe Bearing Capacity					174	kN/m^2

ESTIMATION 2

Depth of Foundation *	3.00 m							
Shape of Footing	Rectangle	Cohesion c		60.0 kN/m^2				
Width of Foundation	2.00 m							
Length of Foundation m	4.00							
			N_i	s_i	d_i	i_i	N**	Ultimate
* depth of embedment		N_c	5.14	1.15	1.30	1.00	7.7	461.3
		N_q	1.00	1.10	1.00	1.00	0.0	0.0
		N_γ	0.00	0.80	1.00	1.00	0.0	0.0
N** Product of bearing capacity factors and other correction factors		Total Ultimate Bearing capacity					461.3	kN/m^2
		Net Safe Bearing Capacity					154	kN/m^2

SUMMARY OF ESTIMATIONS

Sl No	D	Sh	B	L	NBC	
1	3.00	SQ	1.50		187	kN/m^2
2	3.00	SQ	2.00		174	kN/m^2
3	3.00	SQ	2.50		166	kN/m^2
4	3.00	SQ	3.00		160	kN/m^2
5	3.00	RE	2.00	4.00	154	kN/m^2
6	3.00	RE	2.50	5.00	147	kN/m^2

D is depth in m
Sh is footing shape
B is footing width or diameter, m
L is footing length, m
NBC is net safe bearing capacity

Note: If loading is eccentric, total load shall be estimated for corrected area = L' x B' where L'=L-2e_l and B'= B-2e_b

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SETTLEMENT ANALYSIS FOR SHALLOW FOOTINGS AT 3.00M - BH/1
DE BEER & MARTENE'S PROCEDURE, TERZAGHI CONSOLIDATION PROCEDURE AND m_v
Using Buismann Compressibilty Parameter C and Terzaghi Consolidation Equations

PROJECT: **Proposed Construction of (G+5) EWS Tenements, Gandhi Nagar in Corp DN 96 Zone 8 of GCC**
Structure: **Ground +5 RCC Building**

Depth of foundation: 3.00 m
Depth of Ground water Table: 2.00 m
Foundation Size: 2.50 m Sq

Reference Bore Hole/SCPT: **BH/1**
Net load intensity 193 kN/m²
Relief in Load intensity: 0 kN/m²
Effective load intensity: 193 kN/m²

Load dispersion 1 Hor- 2.00 Vert
Meyerhof correction for sand layers χ Yes

From	to	Thick	Den	Soil	SPT N	q_c	Pc	CR	m_v	Depth	Z	po'	Δp	po'+Δp	Sett
m	m	H mm	kN/m³	Type	Blows	kN/m²	kN/m²	coef	m²/MN	m	m	kN/m²	kN/m²	kN/m²	mm
0.00	0.00	0		Fill						0.00					
0.00	0.70	700	17.5	Fill	5	1100				0.35		6.1			
0.70	1.40	700	15.8	SSI Clay	3	480				1.05		17.8			
1.40	2.20	800	16.0	SI Clay	4	640				1.80		28.9			
2.20	3.00	800	16.7	SI Clay	8	1280				2.60		36.0			
3.00	3.40	400	16.7	SI Clay	8	1280				3.20	0.20	40.0	165.7	205.7	13.46
3.40	4.30	900	17.5	SI Clay	13	1950				3.85	0.85	45.0	104.8	149.8	16.69
4.30	5.50	1200	17.7	SI Clay	14	2240				4.90	1.90	52.6	62.7	115.3	14.62
5.50	6.50	1000	18.0	SI Clay	16	2560				6.00	3.00	61.2	40.2	101.4	7.97
6.50	7.40	900	17.2	SI Clay	11	1760				6.95	3.95	68.9	28.8	97.6	8.21
7.40	8.50	1100	15.8	SI Clay	3		90.0	0.220		7.95	4.95	75.3	21.6	96.9	10.24
8.50	9.70	1200	15.8	SI Clay	3		98.0	0.220		9.10	6.10	81.7	16.4	98.1	3.69
9.70	11.00	1300	17.7	SSI Clay	14	2520				10.35	7.35	90.5	12.4	102.9	4.01
11.00	13.00	2000	19.3	SSI Clay	25	3500				12.00	9.00	104.3	9.2	113.5	3.35
13.00	14.00	1000	19.4	SSI Clay	26	3640				13.50	10.50	118.3	7.2	125.5	1.27
14.00	14.80	800	20.4	SSI Clay	34	5100				14.40	11.40	127.1			0.25
14.80	16.00	1200	23.2	C Sand	71	17040				15.40	12.40	139.1			
16.00	17.50	1500	23.0	C Sand	120	28800				16.75	13.75	157.4			
17.50	18.50	1000	23.0	C Sand	150	36000				18.00	15.00	173.0			
														Total	83.7

Each layers are subdevided into 0.10m thick sublayers in the estimation. Hence there can be small differences in the computational results.	Corrected settlement considering rigidity, mm 83.7
	Corrected settlement considering embedment correction, mm 60.3

Comp. of sand layers $\chi \frac{H}{C} \ln \frac{p'_o + \Delta p}{p'_o}$ where $C = \frac{3}{2p'_o} q_c$ Buismann's Compressibilty parameter, where p'_o is effective overburden pressure and q_c is cone resistance in same unit. q_c from SPT N using q_c= 20 to 40 N t/m² or directly from CPT.

Compression of stiff clay / sandy clay layers using expression $m_v \times \Delta p \times H$, where m_v is coefficient of volume compressibility Δp is incremental load and H is the thickness in mm. Coefficient of volume compressibility $m_v = 1/\beta$ N m²/t depending on the plasticity, where N is SPT N. β is 42 to 60 depending on PI and sand percentage. Recompression and consolidation settlement of clay layers using equation (Ref. Terzaghi & Peck),

$H\left(RR \log \frac{p_c}{p'_o} + CR \log \frac{p'_o + \Delta p}{p_c}\right)$ where RR is recompression ratio, $c_r/(1+e_o)$ and CR is compression ratio $c_c/(1+e_o)$. CR/RR= 7

1-Ref: M.J. Tomlinson, 'Foundation Design and Construction', Fifth Edition, ELBS, Fig 1.11, pp 24 and IS 8009

Sample calculations

For layer between 4.30 m & 5.50 m
Thickness H = 1200 mm

$C = \frac{3 q_c}{2p'_o} = \frac{3 \times 2240}{2 \times 52.6} = \frac{6720}{105.3} = 63.84$

Meyerhof correction factor = Yes 1.0

$p'_o + \Delta p$ = 115.3 kPa p'_o = 52.6 kPa

$\frac{p'_o + \Delta p}{p'_o} = \frac{115.3}{52.6} = 2.19$

$I_c \frac{p'_o + \Delta p}{p'_o} = 0.785$

Compression $= 1.0 \frac{1200}{63.8} \times 0.785 = 14.75$ mm

For layer between 7.40 m & 8.50 m Thickness H = 1100 mm
p'_o = 75.3 kPa Preconsolidation pressure Pc = 90.0 kPa
Compression ratio CR = 0.220 Recompression ratio RR = 0.031
$p'_o + \Delta p$ = 96.9 Case 2: recompression + consolidation

$\frac{p'_o + \Delta p}{p'_o} = \frac{96.9}{75.3} = 1.29$, $\frac{p'_o + \Delta p}{p_c} = \frac{96.9}{90.0} = 1.0768$, $\frac{p_c}{p'_o} = \frac{90.0}{75.3} = 1.20$

$I_c \frac{p'_o + \Delta p}{p'_o} = 0.1095$ $I_{cs} \frac{p'_o + \Delta p}{p_c} = 0.0321$ $I_{cs} \frac{p_c}{p'_o} = 0.0774$

For case 1, compression = H x RR x $\log \frac{p'_o + \Delta p}{p'_o}$

For case 2, compression = H x [RR x $\log \frac{p_c}{p'_o}$ + $\log \frac{p'_o + \Delta p}{p_c}$]

Compression = 1100 { 0.031 x 0.0774 + 0.220 x 0.0321 } [recompression + consolidation]
Compression = 1100 { 0.0024 + 0.00707 } = 10.5 mm

SETTLEMENT ANALYSIS FOR SHALLOW FOOTINGS AT 3.00M - BH/1
DE BEER & MARTENE'S PROCEDURE, TERZAGHI CONSOLIDATION PROCEDURE AND m_v
Using Buismann Compressibilty Parameter C and Terzaghi Consolidation Equations

PROJECT: **Proposed Construction of (G+5) EWS Tenements, Gandhi Nagar in Corp DN 96 Zone 8 of GCC**
Structure: **Ground +5 RCC Building**

SUMMARY OF SETTLEMENT ESTIMATION AND ALLOWABLE BEARING PRESSURES - BH/1 and BH/2

Depth of Foundation m 3.00 m
Stress distribution 1 Hor- 2.00 Vert
Depth of water table m 2.00 m
Reference Bore hole BH/1

Type of Foundation	Square				Rectangular	
Width / dia of foundation m	1.50	2.00	2.50	3.00	2.00	2.50
Length of foundation m	1.50	2.00	2.50	3.00	4.00	5.00
Net load intensity based on shear kN/m^2	218	203	193	187	179	171
Total settlement @ net SBC with rigidity mm	56.2	68.9	83.7	99.8	83.4	102.1
Fox depth correction factor, IS 8009	0.68	0.71	0.72	0.74	0.73	0.76
Total settlement @ net SBC with depth factor mm	38.2	48.9	60.3	73.9	60.9	77.6
Estimated bearing pressure for 50mm Settlement, kN/m2	305	208	161	130	148	114
Estimated bearing pressure for 40mm Settlement, kN/m2	231	162	127	104	118	92
Recommended allowable bearing pressure, kN/m^2	218	162	127	104	118	92

Reference Bore hole BH/2

Type of Foundation	Square				Rectangular	
Width / dia of foundation m	1.50	2.00	2.50	3.00	2.00	2.50
Length of foundation m	1.50	2.00	2.50	3.00	4.00	5.00
Net load intensity based on shear kN/m^2	218	203	193	187	179	171
Total settlement with rigidity under net SBC, mm	37.2	44.6	51.6	57.5	51.2	57.8
Fox depth correction factor, IS 8009	0.68	0.71	0.72	0.74	0.73	0.76
Total settlement @ net SBC with depth factor mm	25.3	31.7	37.2	42.6	37.4	43.9
Estimated bearing pressure for 50mm Settlement, kN/m2	555	376	291	234	267	204
Estimated bearing pressure for 40mm Settlement, kN/m2	400	273	213	172	196	151
Recommended allowable bearing pressure, kN/m^2	218	203	193	172	179	151

SETTLEMENT ANALYSIS FOR SHALLOW FOOTINGS AT 3.00M - BH/3
DE BEER & MARTENE'S PROCEDURE, TERZAGHI CONSOLIDATION PROCEDURE AND m_v
Using Buismann Compressibilty Parameter C and Terzaghi Consolidation Equations

PROJECT: **Proposed Construction of (G+5) EWS Tenements, Gandhi Nagar in Corp DN 96 Zone 8 of GCC**
Structure: **Ground +5 RCC Building**

Depth of foundation: 3.00 m
Depth of Ground water Table: 2.00 m
Foundation Size: 2.50 m Sq
Load dispersion 1 Hor.- 2.00 Vert

Reference Bore Hole/SCPT: **BH/3**
Net load intensity 193 kN/m²
Relief in Load intensity: 0 kN/m²
Effective load intensity: 193 kN/m²
Meyerhof correction for sand layers χ Yes

From	to	Thick	Den	Soil	SPT N	q_c	Pc	CR	m_v	Depth	Z	po'	Δ p	po'+Δp	Sett.
m	m	H mm	kN/m³	Type	Blows	kN/m²	kN/m²	coef	m²/MN	m	m	kN/m²	kN/m²	kN/m²	mm
0.00	0.00	0		Fill						0.00					
0.00	1.10	1100	18.0	Fill	9	1980				0.55		9.9			
1.10	2.20	1100	16.8	SSi Clay	9	1710				1.65		29.0			
2.20	2.80	600	17.2	SSi Clay	11	2090				2.50		37.6			
2.80	3.00	200	17.2	Si Clay	11	1650				2.90		40.5			
3.00	3.60	600	17.2	Si Clay	11	1650				3.30	0.30	43.3	154.2	197.5	15.73
3.60	4.50	900	18.6	Si Clay	20	3000				4.05	1.05	49.7	93.5	143.3	10.55
4.50	5.50	1000	18.7	Si Clay	21	3150				5.00	2.00	57.5	60.0	117.5	8.60
5.50	6.50	1000	18.6	Si Clay	20	3000				6.00	3.00	66.2	40.2	106.3	6.91
6.50	7.40	900	18.3	Si Clay	18	2700				6.95	3.95	74.6	28.8	103.4	5.42
7.40	8.50	1100	17.8	C Sand	7	1820				7.95	4.95	82.7	21.6	104.3	6.21
8.50	9.50	1000	17.6	C Sand	6	1560				9.00	6.00	90.4	16.8	107.2	5.23
9.50	11.00	1500	19.9	C Sand	26	6760				10.25	7.25	102.0	12.7	114.6	1.42
11.00	12.60	1600	21.3	C Sand	41	10660				11.80	8.80	117.9	9.5	127.4	0.73
12.60	14.00	1400	20.0	SSi Clay	30	5100				13.30	10.30	134.0	7.4	141.4	1.05
14.00	15.60	1600	21.6	SSi Clay	45	7650				14.80	11.80	150.2			
15.60	17.00	1400	24.0	C Sand	110	23100				16.30	13.30	169.1			
17.00	17.50	500	23.0	C Sand	150	31500				17.25	14.25	182.9			
														Total	61.8

Each layers are subdevided into 0.10m thick sublayers in the estimation. Hence there can be small differences in the computational results.

Corrected settlement considering rigidity, mm	61.8
Corrected settlement considering embedment correction, mm	44.5

Comp. of sand layers $\chi \frac{H}{C} \ln \frac{p'_o + \Delta p}{p'_o}$ where $C = \frac{3}{2p'_o} q_c$ Buismann's Compressibilty parameter, where p'_o is effective overburden pressure and q_c is cone resistance in same unit. q_c from SPT N using q_c= 20 to 40 N t/m² or directly from CPT.

[1]Compression of stiff clay / sandy clay layers using expression m_v x Δp x H, where m_v is coefficient of volume compressibility Δp is incremental load and H is the thickness in mm. Coefficient of volume compressibility $m_v = 1/\beta N$ m²/t depending on the plasticity, where N is SPT N. β is 42 to 60 depending on PI and sand percentage. Recompression and cosolidation settlement of clay layers using equation (Ref. Terzaghi & Peck),

$H\left\{ RR \log \frac{p_c}{p'_o} + CR \log \frac{p'_o + \Delta p}{p_c} \right\}$ where RR is recompression ratio, $c_r/(1+e_0)$ and CR is compression ratio $c_c/(1+e_0)$. CR/RR= 7

1-Ref: M.J. Tomlinson, 'Foundation Design and Construction', Fifth Edition, ELBS, Fig 1.11, pp 24 and IS 8009

Sample Calculation

For layer between 4.50 m & 5.50 m
Thickness H = 1000 mm

$C = \frac{3\ q_c}{2p_o'} = \frac{3 \times 3150}{2 \times 57.5} = \frac{9450}{115.0} = 82.16$

Meyerhof correction factor = Yes

$p_o'+\Delta p$ = 117.5 kPa p_o' = 57.5 kPa

$\frac{p_o'+\Delta p}{p_o'} = \frac{117.5}{57.5} = 2.04$

$I_\rho \frac{p_o'+\Delta p}{p_o'} = 0.714$

Compression $= 1.0 \frac{1000}{82.2} \times 0.714 = 8.69$ mm

SETTLEMENT ANALYSIS FOR SHALLOW FOOTINGS AT 3.00M - BH/3
DE BEER & MARTENE'S PROCEDURE, TERZAGHI CONSOLIDATION PROCEDURE AND m_v
Using Buismann Compressibilty Parameter C and Terzaghi Consolidation Equations

PROJECT: **Proposed Construction of (G+5) EWS Tenements, Gandhi Nagar in Corp DN 96 Zone 8 of GCC**
Structure: **Ground +5 RCC Building**

SUMMARY OF SETTLEMENT ESTIMATION AND ALLOWABLE BEARING PRESSURES - BH/3, BH/4 & BH/5

Depth of Foundation m 3.00 m
Stress distribution 1 Hor- 2.00 Vert
Depth of water table m 2.00 m
Reference Bore hole BH/3

Type of Foundation	Square				Rectangular	
Width / dia of foundation m	1.50	2.00	2.50	3.00	2.00	2.50
Length of foundation m	1.50	2.00	2.50	3.00	4.00	5.00
Net load intensity based on shear kN/m^2	218	203	193	187	179	171
Total settlement @ net SBC with rigidity mm	46.1	54.1	61.8	69.1	61.3	69.6
Fox depth correction factor, IS 8009	0.68	0.71	0.72	0.74	0.73	0.76
Total settlement @ net SBC with depth factor mm	31.3	38.4	44.5	51.1	44.7	52.9
Estimated bearing pressure for 50mm Settlement, kN/m2	422	289	225	182	207	159
Estimated bearing pressure for 40mm Settlement, kN/m2	307	215	168	137	155	120
Recommended allowable bearing pressure, kN/m^2	218	203	168	137	155	120

Reference Bore hole BH/4

Type of Foundation	Square				Rectangular	
Width / dia of foundation m	1.50	2.00	2.50	3.00	2.00	2.50
Length of foundation m	1.50	2.00	2.50	3.00	4.00	5.00
Net load intensity based on shear kN/m^2	218	203	193	187	179	171
Total settlement with rigidity under net SBC, mm	42.4	48.9	54.9	60.7	54.3	61.0
Fox depth correction factor, IS 8009	0.68	0.71	0.72	0.74	0.73	0.76
Total settlement @ net SBC with depth factor mm	28.8	34.7	39.5	44.9	39.6	46.4
Estimated bearing pressure for 50mm Settlement, kN/m2	494	340	266	215	246	189
Estimated bearing pressure for 40mm Settlement, kN/m2	353	248	196	161	181	141
Recommended allowable bearing pressure, kN/m^2	218	203	193	161	179	141

Reference Bore hole BH/5

Type of Foundation	Square				Rectangular	
Width / dia of foundation m	1.50	2.00	2.50	3.00	2.00	2.50
Length of foundation m	1.50	2.00	2.50	3.00	4.00	5.00
Net load intensity based on shear kN/m^2	218	203	193	187	179	171
Total settlement @ net SBC with rigidity mm	32.1	38.2	43.7	49.1	43.3	49.5
Fox depth correction factor, IS 8009	0.68	0.71	0.72	0.74	0.73	0.76
Total settlement @ net SBC with depth factor mm	21.8	27.1	31.5	36.3	31.6	37.6
Estimated bearing pressure for 50mm Settlement, kN/m2	697	464	358	287	329	250
Estimated bearing pressure for 40mm Settlement, kN/m2	501	339	263	212	241	185
Recommended allowable bearing pressure, kN/m^2	218	203	193	187	179	171

SETTLEMENT ANALYSIS FOR SHALLOW FOOTINGS AT 3.00M - BH/6
DE BEER & MARTENE'S PROCEDURE, TERZAGHI CONSOLIDATION PROCEDURE AND m_v
Using Buismann Compressibilty Parameter C and Terzaghi Consolidation Equations

PROJECT: **Proposed Construction of (G+5) EWS Tenements, Gandhi Nagar in Corp DN 96 Zone 8 of GCC**
Structure: **Ground +5 RCC Building**

Depth of foundation: 3.00 m
Depth of Ground water Table: 3.50 m
Foundation Size: 2.50 m Sq

Reference Bore Hole/SCPT: **BH/6**
Net load intensity 166 kN/m²
Relief in Load intensity: 0 kN/m²
Effective load intensity: 166 kN/m²

Load dispersion 1 Hor- 2.00 Vert
Meyerhof correction for sand layers χ Yes

From	to	Thick	Den	Soil	SPT N	q_c	Pc	CR	m_v	Depth	Z	po'	Δ p	po'+Δp	Sett.
m	m	H mm	kN/m³	Type	Blows	kN/m²	kN/m²	coef	m²/MN	m	m	kN/m²	kN/m²	kN/m²	mm
0.00	0.00	0		Fill						0.00					
0.00	1.10	1100	17.9	Fill	8	1760				0.55		9.8			
1.10	2.20	1100	16.8	SSi Clay	9	1710				1.65		28.9			
2.20	2.90	700	16.5	SSi Clay	7	1330				2.55		43.9			
2.90	3.00	100	17.0	Si Clay	10	1500				2.95		50.6			
3.00	4.50	1500	17.0	Si Clay	10	1500				3.75	0.75	61.2	95.7	156.8	38.69
4.50	5.50	1000	17.4	Si Clay	12	1800				5.00	2.00	69.8	51.6	121.3	14.15
5.50	6.50	1000	17.5	Si Clay	13	1950				6.00	3.00	77.2	34.5	111.7	9.66
6.50	7.30	800	17.2	Si Clay	11	1650				6.90	3.90	83.8	25.5	109.4	7.12
7.30	8.50	1200	18.5	Si Clay	19	3040				7.90	4.90	91.8	19.1	110.8	4.53
8.50	9.70	1200	18.7	Si Clay	21	3360				9.10	6.10	102.1	14.1	116.2	3.13
9.70	11.00	1300	19.6	C Sand	23	5520				10.35	7.35	114.0	10.7	124.6	1.28
11.00	12.50	1500	20.7	Sand	34	10200				11.75	8.75	128.2	8.2	136.4	0.55
12.50	14.00	1500	21.6	Si Clay	45	6750				13.25	10.25	145.0			0.14
14.00	15.40	1400	21.8	C Sand	47	12220				14.70	11.70	161.3			
15.40	17.10	1700	22.3	C Sand	54	14040				16.25	13.25	180.6			
17.10	18.80	1700	23.1	SSi Clay	70	12600				17.95	14.95	202.2			
18.80	20.50	1700	23.0	SSi Clay	120	20400				19.65	16.65	224.4			
														Total	79.3

Each layers are subdevided into 0.10m thick sublayers in the estimation. Hence there can be small differences in the computational results.	Corrected settlement considering rigidity, mm 79.3
	Corrected settlement considering embedment correction, mm 57.1

Comp. of sand layers $\chi \frac{H}{C} \ln \frac{p'_o + \Delta p}{p'_o}$ where $C = \frac{3}{2p'_o} q_c$ Buismann's Compressibilty parameter, where p'$_o$ is effective overburden pressure and q_c is cone resistance in same unit. q_c from SPT N using q_c= 20 to 40 N t/m² or directly from CPT.

[1]Compression of stiff clay / sandy clay layers using expression $m_v \times \Delta p \times H$, where m_v is coefficient of volume compressibility Δp is incremental load and H is the thickness in mm. Coefficient of volume compressibility $m_v = 1/\beta$ N m²/t depending on the plasticity, where N is SPT N. β is 42 to 60 depending on PI and sand percentage. Recompression and cosolidation settlement of clay layers using equation (Ref. Terzaghi & Peck),

$H\left\{ RR \log \frac{p_c}{p'_o} + CR \log \frac{p'_o + \Delta p}{p_c} \right\}$ where RR is recompression ratio, $c_r/(1+e_0)$ and CR is compression ratio $c_c/(1+e_0)$. CR/RR= 7

1-Ref: M.J. Tomlinson, 'Foundation Design and Construction', Fifth Edition, ELBS, Fig 1.11, pp 24 and IS 8009

Sample Calculation

For layer between 5.50 m & 6.50 m
Thickness H = 1000 mm

$C = \frac{3\ q_c}{2p_o'} = \frac{3 \times 1950}{2 \times 77.2} = \frac{5850}{154.4} = 37.89$

Meyerhof correction factor = Yes

$p_o'+\Delta p$ = 111.7 kPa p_o' = 77.2 kPa

$\frac{p_o'+\Delta p}{p_o'} = \frac{111.7}{77.2} = 1.45$

$I_n \frac{p_o'+\Delta p}{p_o'} = 0.370$

Compression $= 1.0 \frac{1000}{37.9} \times 0.370 = 9.76$ mm

SETTLEMENT ANALYSIS FOR SHALLOW FOOTINGS AT 3.00M - BH/6
DE BEER & MARTENE'S PROCEDURE, TERZAGHI CONSOLIDATION PROCEDURE AND m_v
Using Buismann Compressibilty Parameter C and Terzaghi Consolidation Equations

PROJECT: **Proposed Construction of (G+5) EWS Tenements, Gandhi Nagar in Corp DN 96 Zone 8 of GCC**
Structure: **Ground +5 RCC Building**

SUMMARY OF SETTLEMENT ESTIMATION AND ALLOWABLE BEARING PRESSURES - BH/6, BH/7 and BH/8

Depth of Foundation m 3.00 m
Stress distribution 1 Hor- 2.00 Vert
Depth of water table m 3.50 m
Reference Bore hole BH/6

Type of Foundation	Square				Rectangular	
Width / dia of foundation m	1.50	2.00	2.50	3.00	2.00	2.50
Length of foundation m	1.50	2.00	2.50	3.00	4.00	5.00
Net load intensity based on shear kN/m^2	187	174	166	160	154	147
Total settlement @ net SBC with rigidity mm	60.6	70.7	79.3	86.9	78.1	87.0
Fox depth correction factor, IS 8009	0.68	0.71	0.72	0.74	0.73	0.76
Total settlement @ net SBC with depth factor mm	41.2	50.2	57.1	64.3	57.0	66.1
Estimated bearing pressure for 50mm Settlement, kN/m2	241	173	140	116	130	104
Estimated bearing pressure for 40mm Settlement, kN/m2	180	130	106	89	99	79
Recommended allowable bearing pressure, kN/m^2	180	130	106	89	99	79

Reference Bore hole BH/7

Type of Foundation	Square				Rectangular	
Width / dia of foundation m	1.50	2.00	2.50	3.00	2.00	2.50
Length of foundation m	1.50	2.00	2.50	3.00	4.00	5.00
Net load intensity based on shear kN/m^2	187	174	166	160	154	147
Total settlement with rigidity under net SBC, mm	47.2	57.1	66.0	73.5	65.3	74.1
Fox depth correction factor, IS 8009	0.68	0.71	0.72	0.74	0.73	0.76
Total settlement @ net SBC with depth factor mm	32.1	40.5	47.5	54.4	47.7	56.3
Estimated bearing pressure for 50mm Settlement, kN/m2	326	225	177	144	163	127
Estimated bearing pressure for 40mm Settlement, kN/m2	245	171	135	110	125	98
Recommended allowable bearing pressure, kN/m^2	187	171	135	110	125	98

Reference Bore hole BH/8

Type of Foundation	Square				Rectangular	
Width / dia of foundation m	1.50	2.00	2.50	3.00	2.00	2.50
Length of foundation m	1.50	2.00	2.50	3.00	4.00	5.00
Net load intensity based on shear kN/m^2	187	174	166	160	154	147
Total settlement @ net SBC with rigidity mm	55.7	64.4	71.7	78.0	70.6	77.9
Fox depth correction factor, IS 8009	0.68	0.71	0.72	0.74	0.73	0.76
Total settlement @ net SBC with depth factor mm	37.9	45.7	51.6	57.7	51.5	59.2
Estimated bearing pressure for 50mm Settlement, kN/m2	274	196	159	133	148	118
Estimated bearing pressure for 40mm Settlement, kN/m2	201	146	119	100	112	90
Recommended allowable bearing pressure, kN/m^2	187	146	119	100	112	90

SETTLEMENT ANALYSIS FOR FULL RAFT AT 2.20M - BH/1 and BH/2
DE BEER & MARTENE'S PROCEDURE AND m_v
Using Buismann Compressibilty Parameter C and Terzaghi Consolidation Equations

PROJECT: **Proposed Construction of (G+5) EWS Tenements, Gandhi Nagar in Corp DN 96 Zone 8 of GCC**
Structure: **Ground +5 RCC Building**

Depth of foundation: **2.20 m**
Depth of Ground water Table: **2.00 m**
Foundation Size: **8.00 x 77.00**

Reference Bore Hole/SCPT: **BH/1**
Net load intensity **100 kN/m²**
Relief in Load intensity: **0 kN/m²**
Effective load intensity: **100 kN/m²**

Load dispersion **Boussinesq's Equation**
Meyerhof correction for sand layers χ Yes

From	to	Thick	Den	Soil	SPT N	q_c	Pc	CR	m_v	Depth	Z	po'	Δ p	po'+Δp	Sett.
m	m	H mm	gm/cc	Type	Blows	kN/m²	kN/m²	coef	m²/MN	m	m	kN/m²	kN/m²	kN/m²	mm
0.00	0.70	700	17.50	Fill	5	1100				0.35		6.1			
0.70	1.40	700	15.80	SSi Clay	3	480				1.05		17.8			
1.40	2.20	800	16.00	Si Clay	4	640				1.80		28.9			
2.20	3.40	1200	16.70	Si Clay	8	1280				2.80	0.60	37.3	99.9	137.2	30.43
3.40	4.30	900	17.50	Si Clay	13	1950				3.85	1.65	45.0	97.5	142.6	15.95
4.30	5.50	1200	17.70	Si Clay	14	2240				4.90	2.70	52.6	92.1	144.7	18.98
5.50	6.50	1000	18.00	Si Clay	16	2560				6.00	3.80	61.2	83.8	145.1	13.72
6.50	7.40	900	17.20	Si Clay	11	1760				6.95	4.75	68.9	75.9	144.8	17.43
7.40	8.50	1100	15.80	Si Clay	3		90	0.2200		7.95	5.75	75.3	68.5	143.8	51.62
8.50	9.70	1200	15.80	Si Clay	3		98	0.2200		9.10	6.90	81.7	61.3	143.0	45.94
9.70	11.00	1300	17.70	SSi Clay	14	2520				10.35	8.15	90.5	54.2	144.6	14.60
11.00	13.00	2000	19.30	SSi Clay	25	3500				12.00	9.80	104.3	47.1	151.4	14.76
13.00	14.00	1000	19.40	SSi Clay	26	3640				13.50	11.30	118.3	41.7	160.0	6.53
14.00	14.80	800	20.40	SSi Clay	34	5100				14.40	12.20	127.1	39.0	166.1	3.55
14.80	16.00	1200	23.20	C Sand	71	17040				15.40	13.20	139.1	36.4	175.4	1.21
16.00	17.50	1500	23.00	C Sand	120	28800				16.75	14.55	157.4	33.1	190.5	0.84
17.50	18.50	1000	23.00	C Sand	150	36000				18.00	15.80	173.0	30.8	203.7	0.42
												Settlement at centre considering flexible foundation, mm			236.0
												Settlement at edges considering flexible foundation, mm			143.9
												Corrected settlement considering rigidity, mm			188.8

Comp. of sand layers $\chi \frac{H}{C} \ln \frac{p'_o+\Delta p}{p'_c}$ where $C = \frac{3}{2p'_o} q_c$ Buismann's Compressibilty parameter, where p'_o is effective overburden pressure and q_c is cone resistance in same unit. q_c from SPT N using q_c= 20 to 40 N t/m² or directly from CPT.

[1]Compression of stiff clay / sandy clay layers using expression $m_v \times \Delta p \times H$, where m_v is coefficient of volume compressibility Δp is incremental load and H is the thickness in mm. Coefficient of volume compressibility $m_v = 1/\beta$ N m²/t depending on the plasticity, where N is SPT N. β is 42 to 60 depending on PI and sand percentage. Recompression and cosolidation settlement of clay layers using equation (Ref. Terzaghi & Peck),

$H\left(RR \log \frac{p_c}{p'_o} + CR \log \frac{p'_o+\Delta p}{p_c} \right)$ where RR is recompression ratio, $c_r/(1+e_0)$ and CR is compression ratio $c_c/(1+e_0)$.

1-Ref: M.J. Tomlinson, 'Foundation Design and Construction', Fifth Edition, ELBS, Fig 1.11, pp 24 and IS 8009

SUMMARY OF SETTLEMENT ESTIMATION

Depth of Foundation m 2.20 m
Depth of water table m 2.00 m
Stress distribution Boussinesq's Equation

Reference Bore hole	BH/1			BH/2		
Width / diameter of foundation m	8.00	8.00	8.00	8.00	8.00	8.00
Length of foundation m	77.00	77.00	77.00	77.00	77.00	77.00
Net load intensity, kN/m²	80	100	120	80	100	120
Settlement at centre considering flexibility, mm	195.2	236.0	273.0	106.5	132.6	156.5
Settlement at edges considering flexibility, mm	114.3	143.9	171.4	60.9	76.2	93.8
Average settlement considering rigidity, mm	156.2	188.8	218.4	85.2	106.1	125.2
Modulus of subgrade reaction kN/m²/m	512	530	549	939	943	958

SETTLEMENT ANALYSIS FOR FULL RAFT AT 2.20M - BH/3, BH/4 & BH/5
DE BEER & MARTENE'S PROCEDURE AND m_v
Using Buismann Compressibilty Parameter C and Terzaghi Consolidation Equations

PROJECT: **Proposed Construction of (G+5) EWS Tenements, Gandhi Nagar in Corp DN 96 Zone 8 of GCC**
Structure: **Ground +5 RCC Building**

Depth of foundation: **2.20 m** Reference Bore Hole/SCPT: **BH/3**
Depth of Ground water Table: **2.00 m** Net load intensity **100 kN/m²**
Foundation Size: **8.00 x 77.00** Relief in Load intensity: **0 kN/m²**
Effective load intensity: **100 kN/m²**
Load dispersion **Boussinesq's Equation** Meyerhof correction for sand layers χ Yes

From	to	Thick	Den	Soil	SPT N	q_c	Pc'	CR	m_v	Depth	Z	po'	Δ p	po'+Δp	Sett.
m	m	H mm	gm/cc	Type	Blows	kN/m²	kN/m²	coef	m²/MN	m	m	kN/m²	kN/m²	kN/m²	mm
0.00	1.10	1100	18.00	Fill	9	1980				0.55		9.9			
1.10	2.20	1100	16.80	SSi Clay	9	1710				1.65		29.0			
2.20	2.80	600	17.20	SSi Clay	11	2090				2.50	0.30	37.6	100.0	137.6	9.37
2.80	3.60	800	17.20	Si Clay	11	1650				3.20	1.00	42.6	99.5	142.1	16.62
3.60	4.50	900	18.60	Si Clay	20	3000				4.05	1.85	49.7	96.7	146.4	10.73
4.50	5.50	1000	18.70	Si Clay	21	3150				5.00	2.80	57.5	91.4	148.9	11.57
5.50	6.50	1000	18.60	Si Clay	20	3000				6.00	3.80	66.2	83.8	150.0	12.01
6.50	7.40	900	18.30	Si Clay	18	2700				6.95	4.75	74.6	75.9	150.5	11.63
7.40	8.50	1100	17.80	C Sand	7	1820				7.95	5.75	82.7	68.5	151.2	16.08
8.50	9.50	1000	17.60	C Sand	6	1560				9.00	6.80	90.4	61.9	152.3	16.08
9.50	11.00	1500	19.90	C Sand	26	6760				10.25	8.05	102.0	54.7	156.6	5.18
11.00	12.60	1600	21.30	C Sand	41	10660				11.80	9.60	117.9	47.9	165.7	3.21
12.60	14.00	1400	20.00	SSi Clay	30	5100				13.30	11.10	134.0	42.4	176.4	6.72
14.00	15.60	1600	21.60	SSi Clay	45	7650				14.80	12.60	150.2	37.9	188.1	4.70
15.60	17.00	1400	24.00	C Sand	110	23100				16.30	14.10	169.1	34.2	203.4	1.00
17.00	17.50	500	23.00	C Sand	150	31500				17.25	15.05	182.9	32.1	215.0	0.25

Settlement at centre considering flexible foundation, mm	125.1
Settlement at edges considering flexible foundation, mm	81.6
Corrected settlement considering rigidity, mm	100.1

Comp. of sand layers $\chi \frac{H}{C} \ln \frac{p'_o + \Delta p}{p'_o}$ where $C = \frac{3}{2p'_o} q_c$ [1] Buismann's Compressibilty parameter, where p'_o is effective overburden pressure and q_c is cone resistance in same unit. q_c from SPT N using q_c= 20 to 40 N t/m² or directly from CPT.

[1]Compression of stiff clay / sandy clay layers using expression m_v x Δp x H, where m_v is coefficient of volume compressibility Δp is incremental load and H is the thickness in mm. Coefficient of volume compressibility $m_v = 1/\beta$ N m²/t depending on the plasticity, where N is SPT N. β is 42 to 60 depending on PI and sand percentage. Recompression and cosolidation settlement of clay layers using equation (Ref. Terzaghi & Peck),

$H\left\{ RR \log \frac{p_c}{p'_o} + CR \log \frac{p'_o + \Delta p}{p_c} \right\}$ where RR is recompression ratio, $c_r/(1+e_0)$ and CR is compression ratio $c_c/(1+e_0)$.

1-Ref: M.J. Tomlinson, 'Foundation Design and Construction', Fifth Edition, ELBS, Fig 1.11, pp 24 and IS 8009

SUMMARY OF SETTLEMENT ESTIMATION

Depth of Foundation m 2.20 m
Depth of water table m 2.00 m
Stress distribution Boussinesq's Equation

Reference Bore hole	BH/3			BH/4			BH/5		
Width / diameter of foundation m	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Length of foundation m	77.00	77.00	77.00	77.00	77.00	77.00	55.00	55.00	55.00
Net load intensity, kN/m²	80	100	120	80	100	120	80	100	120
Settlement at centre considering flexibility, mm	106.5	125.1	142.0	90.4	106.1	120.3	73.8	86.8	98.6
Settlement at edges considering flexibility, mm	68.2	81.6	94.1	57.7	69.1	79.6	47.0	56.3	65.0
Average settlement considering rigidity, mm	85.2	100.1	113.6	72.3	84.9	96.2	59.0	69.4	78.9
Modulus of subgrade reaction kN/m²/m	939	999	1056	1107	1178	1247	1356	1441	1521

SETTLEMENT ANALYSIS FOR FULL RAFT AT 2.20M - BH/6, BH/7 & BH/8
DE BEER & MARTENE'S PROCEDURE AND m_v
Using Buismann Compressibilty Parameter C and Terzaghi Consolidation Equations

PROJECT: **Proposed Construction of (G+5) EWS Tenements, Gandhi Nagar in Corp DN 96 Zone 8 of GCC**
Structure: **Ground +5 RCC Building**

Depth of foundation: **2.20 m**
Depth of Ground water Table: **3.50 m**
Foundation Size: **8.00 x 77.00**

Reference Bore Hole/SCPT: **BH/6**
Net load intensity **80 kN/m²**
Relief in Load intensity: **0 kN/m²**
Effective load intensity: **80 kN/m²**

Load dispersion **Boussinesq's Equation**
Meyerhof correction for sand layers χ Yes

From	to	Thick	Den	Soil	SPT N	q_c	Pc	CR	m_v	Depth	Z	po'	Δ p	po'+Δp	Sett.
m	m	H mm	gm/cc	Type	Blows	kN/m²	kN/m²	coef	m²/MN	m	m	kN/m²	kN/m²	kN/m²	mm
0.00	1.10	1100	17.90	Fill	8	1760				0.55		9.8			
1.10	2.20	1100	16.80	SSi Clay	9	1710				1.65		28.9			
2.20	2.90	700	16.50	SSi Clay	7	1330				2.55	0.35	43.9	80.0	123.9	15.96
2.90	4.50	1600	17.00	Si Clay	10	1500				3.70	1.50	60.5	78.6	139.1	35.51
4.50	5.50	1000	17.40	Si Clay	12	1800				5.00	2.80	69.8	73.1	142.9	18.48
5.50	6.50	1000	17.50	Si Clay	13	1950				6.00	3.80	77.2	67.1	144.3	16.45
6.50	7.30	800	17.20	Si Clay	11	1650				6.90	4.70	83.8	61.3	145.2	14.83
7.30	8.50	1200	18.50	Si Clay	19	3040				7.90	5.70	91.8	55.4	147.1	11.36
8.50	9.70	1200	18.70	Si Clay	21	3360				9.10	6.90	102.1	49.1	151.1	9.51
9.70	11.00	1300	19.60	C Sand	23	5520				10.35	8.15	114.0	43.3	157.3	4.61
11.00	12.50	1500	20.70	Sand	34	10200				11.75	9.55	128.2	38.3	166.5	2.30
12.50	14.00	1500	21.60	Si Clay	45	6750				13.25	11.05	145.0	33.9	178.8	4.51
14.00	15.40	1400	21.80	C Sand	47	12220				14.70	12.50	161.3	30.5	191.9	1.70
15.40	17.10	1700	22.30	C Sand	54	14040				16.25	14.05	180.6	27.4	208.0	1.65
17.10	18.80	1700	23.10	SSi Clay	70	12600				17.95	15.75	202.2	24.6	226.8	2.09
18.80	20.50	1700	23.00	SSi Clay	120	20400				19.65	17.45	224.4	22.3	246.7	1.18

Settlement at centre considering flexible foundation, mm	140.2
Settlement at edges considering flexible foundation, mm	87.8
Corrected settlement considering rigidity, mm	112.1

Comp. of sand layers $\chi \frac{H}{C} \ln \frac{p'_o + \Delta p}{p'_o}$ where $C = \frac{3}{2p'_o} q_c$ Buismann's Compressibilty parameter, where p'_o is effective overburden pressure and q_c is cone resistance in same unit. q_c from SPT N using q_c= 20 to 40 N t/m² or directly from CPT.

[1]Compression of stiff clay / sandy clay layers using expression $m_v \times \Delta p \times H$, where m_v is coefficient of volume compressibility Δp is incremental load and H is the thickness in mm. Coefficient of volume compressibility $m_v = 1/\beta$ N m²/t depending on the plasticity, where N is SPT N. β is 42 to 60 depending on PI and sand percentage. Recompression and cosolidation settlement of clay layers using equation (Ref. Terzaghi & Peck),

$H\left(RR \log \frac{p_c}{p'_o} + CR \log \frac{p'_o + \Delta p}{p_c} \right)$ where RR is recompression ratio, $c_r/(1+e_0)$ and CR is compression ratio $c_c/(1+e_0)$.

1-Ref. M.J. Tomlinson, 'Foundation Design and Construction', Fifth Edition, ELBS, Fig 1.11, pp 24 and IS 8009

SUMMARY OF SETTLEMENT ESTIMATION

Depth of Foundation m 2.20 m
Depth of water table m 3.50 m
Stress distribution Boussinesq's Equation

Reference Bore hole	BH/6			BH/7			BH/8		
Width / diameter of foundation m	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Length of foundation m	77.00	77.00	77.00	77.00	77.00	77.00	33.00	33.00	33.00
Net load intensity, kN/m²	80	100	120	80	100	120	80	100	120
Settlement at centre considering flexibility, mm	140.2	164.8	187.2	129.8	153.4	174.9	122.8	144.3	163.8
Settlement at edges considering flexibility, mm	87.8	105.3	121.6	81.6	98.2	113.8	77.1	92.4	106.7
Average settlement considering rigidity, mm	112.2	131.8	149.8	103.8	122.7	139.9	98.2	115.4	131.0
Modulus of subgrade reaction kN/m²/m	713	759	801	771	815	858	815	867	918

General details		Pile tip level RL	78.1 m				Tip level 1	Tip level 2	Tip level 3	Procedure ○ IS2911 ◉ Reese
Ground level RL	98.1 m	Soil at tip	wr			Depth of pile from GL	20.0 m			☐ CFA construction (Reese, adding 20%)
Scour / basement level, RL	98.1 m	SPT N	200			Reduced level pile tip	78.1 m			Skin friction limiting to critical depth NO
Pile cut-off level RL	97.0 m	side friction from, RL	94.7 m			Angle of friction, degrees				Predominent soil profile CLAY
Design ground water table RL	98.1 m	Temporary casing depth, RL	94.7 m			Bearing capacity factor N_q (IS)				
Critical depth for end bearing 15 to 20D above tip		Bulk unit weight up to this depth	17.50	kN/m³	0.6	Undrained cohesion c_u kN/m²	900			Reference Test Data **BH/1**

Description	For drag force	For side friction										
From depth RL		98.0 m	96.7 m	95.8 m	94.7 m	93.8 m	90.7 m	88.4 m	87.1 m	84.1 m	83.3 m	79.6 m	78.1 m
To depth RL		96.7 m	95.8 m	94.7 m	93.8 m	90.7 m	88.4 m	87.1 m	84.1 m	83.3 m	79.6 m	78.1 m	77.6 m
Soil type		SaClay	SiClay	SiClay	SiClay	SiClay	SiClay	SaClay	SaClay	SaClay	CSiSand	WR	WShale
Field N value (N_{60})		3	4	8	13	14	3	14	25	26	100	200	300
Corrected SPT N		3	4	8	13	14	3	14	25	26	70	200	300
Bulk unit weight kN/m³		15.8	16.0	16.7	17.6	17.7	15.8	17.7	19.3	19.4	23.2	23.0	23.0
Undrained cohesion c_u kN/m²		30	34	52	78	84	30	84	150	150		1200	1500
Angle of friction deg											40.0°		
Adhesion factor		1.00	1.00	0.86	0.59	0.55	1.00	0.55	0.30	0.30	0.00	0.10	0.10
Earth pressure constant **		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.48	0.00	0.00
Friction between pile & soil deg											40.0°		
k tan δ											1.242		
Side Friction factor beta											0.500		
Selected friction factor-Beta											0.500		
Thickness		1.3 m	0.9 m	1.1 m	0.9 m	3.1 m	2.3 m	1.3 m	3.0 m	0.8 m	3.7 m	1.5 m	0.5 m
Mid depth		97.4 m	96.3 m	95.3 m	94.3 m	92.3 m	89.6 m	87.8 m	85.6 m	83.7 m	81.5 m	78.9 m	77.9 m
Effective overburden kN/m²		4.5	11.0	17.4	24.4	39.7	58.4	70.0	89.0	106.7	134.9	169.0	182.0
Ultimate unit side friction kN/m2		30.0	34.0	44.7	46.0	46.2	30.0	46.2	45.0	45.0	67.4	120.0	150.0

Pile tip level RL	78.1 m (20.0 m below GL)											
Pile diameter, mm	500 mm	600 mm	750 mm									
Effective overburden pressure at 15-20 D kN/m²	95	114	143									
Ultimate end bearing resistance kN/m²	8100	8100	8100									
Ultimate end bearing capacity, kN	1590	2290	3578									
Ultimate side friction capacity, kN	1389	1655	2048									
Ultimate side friction capacity for full length, kN	1389	1655	2048									
Total ultimate capacity, kN (for set=5% D)	2979	3945	5626									
Safe end bearing capacity, kN (for PFS)	578	833	1301									
Safe side friction, kN (for PFS)	794	946	1170									
Total safe capacity with common FS, kN	1324	1753	2500									
Total safe capacity with partial FS, kN	1372	1779	2471									
Safe uplift capacity, kN	397	473	585									
Weight of pile, kN	52	75	117									
Safe compression capacity - structural, kN	1227	1767	2761									
Safe compression capacity kN (DL+LL)	1227 kN	1753 kN	2471 kN									
Total drag kN												
Net safe compression capacity kN (for Drag)												
Total ultimate capacity, kN (for full length)	2979 kN	3945 kN	5626 kN									
FoS against full length friction	2.43	2.25	2.28									
Net safe uplift capacity kN	449 kN	548 kN	702 kN									

Effective Grade of Concrete	M25
Percentage steel	0.40
Safe compressive strength, kN/m²	6250
Partial FS for end bearing (Reese)	2.75
Partial FS for side friction (Reese)	1.75
Common factor of safety (Reese)	2.25
Factor of safety for uplift	3.50

Uplift is assumed roughly 2/3 of the positive friction +self weight

The design capacity under drag force is the least of (1) [Min of ultimate geotechnical capacity ÷ 1.5 & safe structural capacity]-Total drag and (2) Safe capacity with factor of safety.

ESTIMATION OF SAFE COMPRESSION AND TENSION CAPACITY OF BORED CAST-IN-SITU PILES

PROJECT

Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC

STRUCTURE

GROUND + FIVE RCC FRAME

Note: Pile capacities are estimated based on the procedure suggested in Appendix B of IS:2911 (Part1/Sec.2)-2010 with relevant amendments in IS2911 procedure OR O'Neill Reese (1988, 1999) procedure.

$Q_u = A_p q_p + \Sigma\, k_i P_{di} \tan\delta_i A_{si}$ (for sand layers) $+ \Sigma\, \alpha\, c_{ui} A_{si}$ (for clay layers) A_p is cross section area of pile, q_p is end bearing resistance = $p_o N_q$ or $c_u \times N_c$ depending on type of soil; k_i is earth pressure constant 0.7 to 1.5; P_{di} is effective overburden

N_q is from IS 2911. Effective overburden perssure p_o at pile tip is limited to depth equal to 15 to 20 times pile diameter using submerged unit weight of the bearing stratum for the end bearing estimation. δ is interface friction angle equal to angle of shearing resistance ϕ. A_{si} is surface area of pile segment in consideration. Effective overburden perssure p_o at mid depth of the respective layer is used in the skin friction estimation. The term $k_s \tan\delta$ is limited to β= 1.5-0.245vZ(m)in beta procedure (Ref Analysis and Design of Shallow and Deep Foundations, LC Reese, W.M. Isenhower and S.T Wang, Wiley, 2006, section 11.6.3). For Reese procedure, end bearing is 57.5 N kN/m² limited to 2900 kN/m² for sand, where N is corrected N_{60} ** is negative skin friction factor beta for -ve friction estimation

General details		Pile tip level RL	79.0 m				Tip level 1	Tip level 2	Tip level 3	Procedure ○ IS2911 ◉ Reese
Ground level RL	98.1 m	Soil at tip	wr			Depth of pile from GL	19.1 m			☐ CFA construction (Reese, adding 20%)
Scour / basement level, RL	98.1 m	SPT N	300			Reduced level pile tip	79.0 m			Skin friction limiting to critical depth NO
Pile cut-off level RL	97.0 m	side friction from, RL	94.5 m			Angle of friction, degrees				Predominent soil profile CLAY
Design ground water table RL	98.1 m	Temporary casing depth, RL	94.5 m			Bearing capacity factor N_q (IS)				
Critical depth for end bearing 15 to 20D above tip		Bulk unit weight up to this depth	17.50	kN/m³	0.6	Undrained cohesion c_u kN/m²	900			Reference Test Data **BH/3**

Description	For drag force	For side friction									
From depth RL		98.0 m	95.3 m	94.5 m	90.7 m	88.6 m	85.5 m	82.5 m	80.6 m	79.7 m	79.0 m
To depth RL		95.3 m	94.5 m	90.7 m	88.6 m	85.5 m	82.5 m	80.6 m	79.7 m	79.0 m	78.7 m
Soil type		SaClay	SaClay	SiClay	CSiSand	CSiSand	SaClay	CSiSand	WShale	WR	WR
Field N value (N_{60})		9	11	20	7	26	30	100	200	300	300
Corrected SPT N		10	11	20	7	25	30	89	200	300	300
Bulk unit weight kN/m³		16.8	17.2	18.6	17.8	19.9	20.0	24.0	23.0	23.0	23.0
Undrained cohesion c_u kN/m²		62	66	120			150		1200	1500	1500
Angle of friction deg					27.5°	33.0°		41.0°			
Adhesion factor		0.74	0.70	0.37	0.00	0.00	0.30	0.00	0.10	0.10	0.10
Earth pressure constant **		0.00	0.00	0.00	0.88	1.14	0.00	1.50	0.00	0.00	0.00
Friction between pile & soil deg					27.5°	33.0°		41.0°			
k tan δ					0.458	0.740		1.304			
Side Friction factor beta					0.368	0.686		0.503			
Selected friction factor-Beta					0.368	0.686		0.503			
Thickness		2.7 m	0.8 m	3.8 m	2.1 m	3.1 m	3.0 m	1.9 m	0.9 m	0.7 m	0.3 m
Mid depth		96.7 m	94.9 m	92.6 m	89.7 m	87.1 m	84.0 m	81.6 m	80.2 m	79.4 m	78.9 m
Effective overburden kN/m²		9.9	22.0	41.2	65.7	89.3	119.6	147.9	167.1	177.5	184.0
Ultimate unit side friction kN/m2		45.9	46.2	44.4	24.2	61.2	45.0	74.4	120.0	150.0	150.0

Pile tip level RL	79.0 m (19.1 m below GL)											
Pile diameter, mm	500 mm	600 mm	750 mm									
Effective overburden pressure at 15-20 D kN/m²	95	114	143									
Ultimate end bearing resistance kN/m²	8100	8100	8100									
Ultimate end bearing capacity, kN	1590	2290	3578									
Ultimate side friction capacity, kN	1353	1609	1985									
Ultimate side friction capacity for full length, kN	1353	1609	1985									
Total ultimate capacity, kN (for sett=5% D)	2943	3899	5563									
Safe end bearing capacity, kN (for PFS)	578	833	1301									
Safe side friction, kN (for PFS)	773	919	1134									
Total safe capacity with common FS, kN	1308	1733	2472									
Total safe capacity with partial FS, kN	1351	1752	2435									
Safe uplift capacity, kN	387	460	567									
Weight of pile, kN	49	71	111									
Safe compression capacity - structural, kN	1227	1767	2761									
Safe compression capacity kN (DL+LL)	1227 kN	1733 kN	2435 kN									
Total drag kN												
Net safe compression capacity kN (for Drag)												
Total ultimate capacity, kN (for full length)	2943 kN	3899 kN	5563 kN									
FoS against full length friction	2.40	2.25	2.28									
Net safe uplift capacity kN	436 kN	531 kN	678 kN									

Effective Grade of Concrete		M25
Percentage steel		0.40
Safe compressive strength, kN/m²		6250
Partial FS for end bearing	(Reese)	2.75
Partial FS for side friction	(Reese)	1.75
Common factor of safety	(Reese)	2.25
Factor of safety for uplift		3.50

Uplift is assumed roughly 2/3 of the positive friction +self weight

The design capacity under drag force is the least of (1) [Min of ultimate geotechnical capacity ÷ 1.5 & safe structural capacity]-Total drag and (2) Safe capacity with factor of safety.

ESTIMATION OF SAFE COMPRESSION AND TENSION CAPACITY OF BORED CAST-IN-SITU PILES

PROJECT

Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC

STRUCTURE

GROUND + FIVE RCC FRAME

Note: Pile capacities are estimated based on the procedure suggested in Appendix B of IS:2911 (Part1/Sec.2)-2010 with relevant amendments in IS2911 procedure OR O'Neill Reese (1988, 1999) procedure.

$Q_u = A_p q_b + \Sigma\, k_i P_{di} \tan\delta_i A_{si}$ (for sand layers) $+ \Sigma\, \alpha\, c_{ui} A_{si}$ (for clay layers)

A_p is cross section area of pile, q_b is end bearing resistance = $p_o' N_q$ or $c_u \times N_c$ depending on type of soil; k_i is earth pressure constant 0.7 to 1.5; P_{di} is effective overburden

N_q is from IS 2911. Effective overburden perssure p_o at pile tip is limited to depth equal to 15 to 20 times pile diameter using submerged unit weight of the bearing stratum for the end bearing estimation. δ is interface friction angle equal to angle of shearing resistance ϕ. A_{si} is surface area of pile segment in consideration. Effective overburden perssure p_o at mid depth of the respective layer is used in the skin friction estimation. The term $k_i \tan\delta$ is limited to β= 1.5-0.245√Z(m) in beta procedure (Ref Analysis and Design of Shallow and Deep Foundations, LC Reese, W.M. Isenhower and S.T Wang. Wiley. 2006, section 11.6.3). For Reese procedure, end bearing is 57.5 N kN/m² limited to 2900 kN/m² for sand, where N is corrected N_{60}.** is negative skin friction factor beta for -ve friction estimation

APPENDIX E-2

General details		Pile tip level RL	76.6 m				Tip level 1	Tip level 2	Tip level 3	Procedure ○ IS2911 ◉ Reese
Ground level RL	98.1 m	Soil at tip	wr			Depth of pile from GL	21.5 m			☐ CFA construction (Reese, adding 20%)
Scour / basement level, RL	98.1 m	SPT N	300			Reduced level pile tip	76.6 m			Skin friction limiting to critical depth NO
Pile cut-off level RL	97.0 m	side friction from, RL	94.4 m			Angle of friction, degrees				Predominent soil profile CLAY
Design ground water table RL	98.1 m	Temporary casing depth, RL	94.4 m			Bearing capacity factor N_q (IS)				
Critical depth for end bearing 15 to 20D above tip		Bulk unit weight up to this depth	17.50	kN/m³	0.6	Undrained cohesion c_u kN/m²	900			Reference Test Data **BH/7**

Description	For drag force	For side friction											
From depth RL		98.0 m	95.3 m	94.4 m	91.8 m	90.1 m	88.6 m	85.5 m	82.9 m	79.8 m	77.8 m	76.9 m	76.6 m
To depth RL		95.3 m	94.4 m	91.8 m	90.1 m	88.6 m	85.5 m	82.9 m	79.8 m	77.8 m	76.9 m	76.6 m	75.9 m
Soil type		SaClay	SiClay	SiClay	SiClay	SaClay	SaClay	CSiSand	SaClay	CSiSand	WShale	WR	WR
Field N value (N_{60})		9	15	15	12	15	26	44	72	100	200	300	300
Corrected SPT N		9	15	15	12	15	27	39	72	82	200	300	300
Bulk unit weight kN/m³		16.8	17.8	17.8	18.4	18.7	19.4	21.6	23.2	24.0	23.0	23.0	23.0
Undrained cohesion c_u kN/m²		56	90	90	72	90	160		430		1200	1500	1500
Angle of friction deg								36.5°		40.5°			
Adhesion factor		0.81	0.51	0.51	0.64	0.51	0.28	0.00	0.17	0.00	0.10	0.10	0.10
Earth pressure constant **		0.00	0.00	0.00	0.00	0.00	0.00	1.31	0.00	1.50	0.00	0.00	0.00
Friction between pile & soil deg								36.5°		40.5°			
k tan δ								0.959		1.281			
Side Friction factor beta								0.587		0.421			
Selected friction factor-Beta								0.587		0.421			
Thickness		2.7 m	0.9 m	2.6 m	1.7 m	1.5 m	3.1 m	2.6 m	3.3 m	1.8 m	0.9 m	0.3 m	0.7 m
Mid depth		96.7 m	94.9 m	93.1 m	91.0 m	89.4 m	87.1 m	84.2 m	81.3 m	78.7 m	77.4 m	76.8 m	76.3 m
Effective overburden kN/m²		9.9	22.6	36.3	53.6	67.2	88.3	118.0	154.8	189.2	207.7	215.5	222.0
Ultimate unit side friction kN/m2		45.4	45.9	45.9	46.1	45.9	44.8	69.2	73.1	79.7	120.0	150.0	150.0

Pile tip level RL	76.6 m (21.5 m below GL)											
Pile diameter, mm	500 mm	600 mm	750 mm									
Effective overburden pressure at 15-20 D kN/m²	95	114	143									
Ultimate end bearing resistance kN/m²	8100	8100	8100									
Ultimate end bearing capacity, kN	1590	2290	3578									
Ultimate side friction capacity, kN	1705	2032	2514									
Ultimate side friction capacity for full length, kN	1705	2032	2514									
Total ultimate capacity, kN (for sett=5% D)	3295	4322	6092									
Safe end bearing capacity, kN (for PFS)	578	833	1301									
Safe side friction, kN (for PFS)	974	1161	1437									
Total safe capacity with common FS, kN	1464	1921	2708									
Total safe capacity with partial FS, kN	1552	1994	2738									
Safe uplift capacity, kN	487	581	718									
Weight of pile, kN	56	81	126									
Safe compression capacity - structural, kN	1227	1767	2761									
Safe compression capacity kN (DL+LL)	1227 kN	1767 kN	2708 kN									
Total drag kN												
Net safe compression capacity kN (for Drag)												
Total ultimate capacity, kN (for full length)	3295 kN	4322 kN	6092 kN									
FoS against full length friction	2.69	2.45	2.25									
Net safe uplift capacity kN	543 kN	662 kN	844 kN									

Effective Grade of Concrete		M25
Percentage steel		0.40
Safe compressive strength, kN/m²		6250
Partial FS for end bearing	(Reese)	2.75
Partial FS for side friction	(Reese)	1.75
Common factor of safety	(Reese)	2.25
Factor of safety for uplift		3.50

Uplift is assumed roughly 2/3 of the positive friction +self weight

The design capacity under drag force is the least of (1) [Min of ultimate geotechnical capacity ÷ 1.5 & safe structural capacity]-Total drag and (2) Safe capacity with factor of safety.

ESTIMATION OF SAFE COMPRESSION AND TENSION CAPACITY OF BORED CAST-IN-SITU PILES

PROJECT

Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC

STRUCTURE

GROUND + FIVE RCC FRAME

Note: Pile capacities are estimated based on the procedure suggested in Appendix B of IS:2911 (Part1/Sec.2)-2010 with relevant amendments in IS2911 procedure OR O'Neill Reese (1988, 1999) procedure.

$Q_u = A_p q_e + \Sigma k_i P'_{di} \tan\delta_i A_{si}$ (For sand layers) $+ \Sigma \alpha c_u A_{si}$ (For clay layers) A_p is cross section area of pile, q_e is end bearing resistance = $p_0'N_q$ or $c_u \times N_c$ depending on type of soil; k_i is earth pressure constant 0.7 to 1.5; P_{di} is effective overburden

N_q is from IS 2911. Effective overburden perssure p_0 at pile tip is limited to depth equal to 15 to 20 times pile diameter using submerged unit weight of the bearing stratum for the end bearing estimation. δ is interface friction angle equal to angle of shearing resistance ϕ. A_{si} is surface area of pile segment in consideration. Effective overburden perssure p_0 at mid depth of the respective layer is used in the skin friction estimation. The term K_sTanδ is limited to β= 1.5-0.245√Z(m)in beta procedure (Ref Analysis and Design of Shallow and Deep Foundations, LC Reese, W.M. Isenhower and S.T Wang, Wiley, 2006, section 11.6.3). For Reese procedure, end bearing is 57.5 N kN/m² limited to 2900 kN/m² for sand, where N is corrected N_{60}.** is negative skin friction factor beta for -ve friction estimation

LATERAL CAPACITIES OF CAST-IN-SITU PILES **APPENDIX F**

Constant Modulus Case (Medium stiff to stiff clays)

FOR PILES WITH COL AT ABOUT 1.10M BELOW GL

Project: **Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC**

Structure: G+5 RCC frame

Loading Type Normal

Type of pile - bored cast-in-situ piles

Length of pie, m =	18.0				
Size of pile, mm =	450	500	600	750	750
Inner dia of pile, mm	0	0	0	0	0

Grade of Concrete M25 f_{ck} = 25 N/mm^2

Elastic modulus of concrete Ec 5000 √fck MPa

Soil below cut-off level

Type of Soil	Medium stiff clay
Average corrected N over a length of 3D to 6D^	8
Average unconfined compresison strength qu	50 KN/m^2
Ground water table is assumed at cutoff level or above	
Pile cut-off level	1.10 m below GL
Free standing pile length above COL	0.00 m
Length of pile below COL - L	16.9 m
Allowable deflection at pile head	5 mm

Load sharing factor recommended in case of groups

Load sharing between piles will have group effect, reducing the safe resistance of piles in the back rows

Single pile group - 1.0

Two pile - along the pile alignment 1 & 0.75

Two pile - perpendicular to the pile alignment 1.0 & 1.0

Four pile group - 1.0 & 0.75

Six piles in two rows - Longitudinal - 1.0, 0.75, and 0.50

Free head condition (conservative)

All these as fixed head condition

PILES WITH FREE HEAD CONDITION

Pile dia	f_{ck} N/mm^2	Ec MN/m^2	I M4	L m	q_u kN/m^2	k* MN/m^3	β 1/m	β x L	R m	e m	e/R	Z_f/R** m	Z_f m	y m	H tonnes
450	25	25000	0.002013	16.9	50.0	7.5	0.33	5.50	1.965	0.00	0.00	1.600	3.14	0.005	2.4
500	25	25000	0.003068	16.9	50.0	7.5	0.30	5.08	2.127	0.00	0.00	1.600	3.40	0.005	2.9
600	25	25000	0.006362	16.9	50.0	7.5	0.26	4.43	2.438	0.00	0.00	1.600	3.90	0.005	4.0
750	25	25000	0.015532	16.9	50.0	7.5	0.22	3.75	2.882	0.00	0.00	1.600	4.61	0.005	5.8

PILES WITH FIXED HEAD CONDINTION

Pile dia	f_{ck} N/mm^2	Ec MN/m^2	I M4	L m	q_u kN/m^2	k* MN/m^3	β 1/m	β x L	R m	e m	e/R	Z_f/R** m	Z_f m	y m	H tonnes
450	25	25000	0.002013	16.9	50.0	7.5	0.33	5.50	1.965	0.00	0.00	1.970	3.87	0.005	5.1
500	25	25000	0.003068	16.9	50.0	7.5	0.30	5.08	2.127	0.00	0.00	1.970	4.19	0.005	6.2
600	25	25000	0.006362	16.9	50.0	7.5	0.26	4.43	2.438	0.00	0.00	1.970	4.80	0.005	8.5
750	25	25000	0.015532	16.9	50.0	7.5	0.22	3.75	2.882	0.00	0.00	1.970	5.68	0.005	12.5

^N less than 1 is not to be used

* k_l recommended by Tomlinsonis directly used here. M.J. Tomlinson, Pile Design and Construction Practice, 5th Edition, Table 6.5

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

Consider varying modulus for soft normally consolidated clays$_l$ = 350 to 700 kN/m^3

NOTE: The total depth of fixity below the pile head is sum of cantilever length e and Z

General details		Pile tip level RL	79.1 m				Tip level 1	Tip level 2	Tip level 3	Procedure ○ IS2911 ◉ Reese
Ground level RL	98.1 m	Soil at tip	wr			Depth of pile from GL	19.0 m			☐ CFA construction (Reese, adding 20%)
Scour / basement level, RL	98.1 m	SPT N	200			Reduced level pile tip	79.1 m			Skin friction limiting to critical depth NO
Pile cut-off level RL	97.0 m	side friction from, RL	94.7 m			Angle of friction, degrees	36.0°			Predominent soil profile CLAY
Design ground water table RL	98.1 m	Temporary casing depth, RL	94.7 m			Bearing capacity factor N_q (IS)	35.0			
Critical depth for end bearing 15 to 20D above tip		Bulk unit weight up to this depth	17.50	kN/m³	0.6	Undrained cohesion c_u kN/m²				Reference Test Data BH/1

Description	For drag force	For side friction												
From depth RL		98.0 m	96.7 m	95.8 m	94.7 m	93.8 m	90.7 m	88.4 m	87.1 m	84.1 m	83.3 m	79.6 m	78.6 m	78.1 m
To depth RL		96.7 m	95.8 m	94.7 m	93.8 m	90.7 m	88.4 m	87.1 m	84.1 m	83.3 m	79.6 m	78.6 m	78.1 m	77.6 m
Soil type		SaClay	SiClay	SiClay	SiClay	SiClay	SiClay	SaClay	SaClay	SaClay	CSiSand	WR	WR	WShale
Field N value (N_{60})		3	4	8	13	14	3	14	25	26	100	200	200	300
Corrected SPT N		3	4	8	13	14	3	14	25	26	70	200	200	300
Bulk unit weight kN/m³		15.8	16.0	16.7	17.5	17.7	15.8	17.7	19.3	19.4	23.2	23.0	23.0	23.0
Undrained cohesion c_u kN/m²		30	34	52	78	84	30	84	150	150		1200	1200	1500
Angle of friction deg											40.0°			
Adhesion factor		1.00	1.00	0.86	0.59	0.55	1.00	0.55	0.30	0.30	0.00	0.10	0.10	0.10
Earth pressure constant **		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.48	0.00	0.00	0.00
Friction between pile & soil deg											40.0°			
k tan δ											1.242			
Side Friction factor beta											0.500			
Selected friction factor-Beta											0.500			
Thickness		1.3 m	0.9 m	1.1 m	0.9 m	3.1 m	2.3 m	1.3 m	3.0 m	0.8 m	3.7 m	1.0 m	0.5 m	0.5 m
Mid depth		97.4 m	96.3 m	95.3 m	94.3 m	92.3 m	89.6 m	87.8 m	85.6 m	83.7 m	81.5 m	79.1 m	78.4 m	77.9 m
Effective overburden kN/m²		4.5	11.0	17.4	24.4	39.7	58.4	70.0	89.0	106.7	134.9	165.8	175.5	182.0
Ultimate unit side friction kN/m2		30.0	34.0	44.7	46.0	46.2	30.0	46.2	45.0	45.0	87.4	120.0	120.0	150.0

Pile tip level RL	79.1 m (19.0 m below GL)												Effective Grade of Concrete		M25
Pile diameter, mm	450 mm	500 mm	600 mm	750 mm									Percentage steel		0.40
Effective overburden pressure at 15-20 D kN/m²	77	86	103	128									Safe compressive strength, kN/m²		6250
Ultimate end bearing resistance kN/m²	2900	2900	2900	2900									Partial FS for end bearing	(Reese)	2.75
Ultimate end bearing capacity, kN	461	569	820	1281									Partial FS for side friction	(Reese)	1.75
Ultimate side friction capacity, kN	1017	1127	1346	1670									Common factor of safety	(Reese)	2.25
Ultimate side friction capacity for full length, kN	1017	1127	1346	1670											
Total ultimate capacity, kN (for sett=5% D)	1478	1696	2166	2951									Factor of safety for uplift		3.50
Safe end bearing capacity, kN (for PFS)	168	207	298	466									Uplift is assumed roughly 2/3 of the positive friction +self weight		
Safe side friction, kN (for PFS)	581	644	769	954									The design capacity under drag force is the least of (1) [Min of ultimate geotechnical capacity ÷ 1.5 & safe structural capacity]-Total drag and (2) Safe capacity with factor of safety.		
Total safe capacity with common FS, kN	657	754	963	1312											
Total safe capacity with partial FS, kN	749	851	1067	1420									**ESTIMATION OF SAFE COMPRESSION AND TENSION CAPACITY OF BORED CAST-IN-SITU PILES**		
Safe uplift capacity, kN	291	322	385	477											
Weight of pile, kN	40	49	71	111											
Safe compression capacity - structural, kN	994	1227	1767	2761									PROJECT		
Safe compression capacity kN (DL+LL)	657 kN	754 kN	963 kN	1312 kN									**Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC**		
Total drag kN															
Net safe compression capacity kN (for Drag)															
Total ultimate capacity, kN (for full length)	1478 kN	1696 kN	2166 kN	2951 kN									STRUCTURE		
FoS against full length friction	2.25	2.25	2.25	2.25									**GROUND + FIVE RCC FRAME**		
Net safe uplift capacity kN	331 kN	371 kN	456 kN	588 kN											

Note: Pile capacities are estimated based on the procedure suggested in Appendix B of IS:2911 (Part1/Sec.2)-2010 with relevant amendments in IS2911 procedure OR O'Neill Reese (1988, 1999) procedure.

$Q_u \approx A_p q_u + \Sigma k_i P_{di} \tan\delta_i A_{si}$ (for sand layers) $+ \Sigma \alpha c_u A_{si}$ (for clay layers) A_p is cross section area of pile, q_u is end bearing resistance = $p_0' N_q$ or $c_u \times N_c$ depending on type of soil; k_i is earth pressure constant 0.7 to 1.5; P_{di} is effective overburden

N_q is from IS 2911. Effective overburden perssure p_0 at pile tip is limited to depth equal to 15 to 20 times pile diameter using submerged unit weight of the bearing stratum for the end bearing estimation. δ is interface friction angle equal to angle of shearing resistance ϕ. A_{si} is surface area of pile segment in consideration. Effective overburden perssure p_0 at mid depth of the respective layer is used in the skin friction estimation. The term k_sTanδ is limited to β= 1.5-0.245√Z(m)in beta procedure (Ref Analysis and Design of Shallow and Deep Foundations, LC Reese, W.M. Isenhower and S.T Wang, Wiley, 2006, section 11.6.3). For Reese procedure, end bearing is 57.5 N kN/m² limited to 2900 kN/m² for sand, where N is corrected N_{60}.** is negative skin friction factor beta for -ve friction estimation

General details		Pile tip level RL	80.0 m					Tip level 1	Tip level 2	Tip level 3	Procedure ○ IS2911 ◉ Reese
Ground level RL	98.1 m	Soil at tip	wr			Depth of pile from GL		18.1 m			☐ CFA construction (Reese, adding 20%)
Scour / basement level, RL	98.1 m	SPT N	300			Reduced level pile tip		80.0 m			Skin friction limiting to critical depth NO
Pile cut-off level RL	97.0 m	side friction from, RL	94.5 m			Angle of friction, degrees		36.0°			Predominent soil profile CLAY
Design ground water table RL	98.1 m	Temporary casing depth, RL	94.5 m			Bearing capacity factor N_q (IS)		35.0			
Critical depth for end bearing 15 to 20D above tip		Bulk unit weight up to this depth	17.50	kN/m³	0.6	Undrained cohesion c_u kN/m²					Reference Test Data **BH/3**

Description	For drag force	For side friction										
From depth RL		98.0 m	95.3 m	94.5 m	90.7 m	88.6 m	85.5 m	82.5 m	80.6 m	80.0 m	79.5 m	79.0 m
To depth RL		95.3 m	94.5 m	90.7 m	88.6 m	85.5 m	82.5 m	80.6 m	80.0 m	79.5 m	79.0 m	78.6 m
Soil type		SaClay	SaClay	SiClay	CSiSand	CSiSand	SaClay	CSiSand	WShale	WShale	WR	WR
Field N value (N_{60})		9	11	20	7	26	30	100	200	200	300	300
Corrected SPT N		10	11	20	7	25	30	89	200	200	300	300
Bulk unit weight kN/m³		16.8	17.2	18.6	17.8	19.9	20.0	24.0	23.0	23.0	23.0	23.0
Undrained cohesion c_u kN/m²		62	66	120			150		1200	1200	1500	1500
Angle of friction deg					27.5°	33.0°		41.0°				
Adhesion factor		0.74	0.70	0.37	0.00	0.00	0.30	0.00	0.10	0.10	0.10	0.10
Earth pressure constant **		0.00	0.00	0.00	0.88	1.14	0.00	1.50	0.00	0.00	0.00	0.00
Friction between pile & soil deg					27.5°	33.0°		41.0°				
k tan δ					0.468	0.740		1.304				
Side Friction factor beta					0.368	0.686		0.503				
Selected friction factor-Beta					0.368	0.686		0.503				
Thickness		2.7 m	0.8 m	3.8 m	2.1 m	3.1 m	3.0 m	1.9 m	0.6 m	0.5 m	0.5 m	0.4 m
Mid depth		96.7 m	94.9 m	92.6 m	89.7 m	87.1 m	84.0 m	81.6 m	80.3 m	79.8 m	79.3 m	78.8 m
Effective overburden kN/m²		9.9	22.0	41.2	65.7	89.3	119.6	147.9	165.1	172.3	178.8	184.6
Ultimate unit side friction kN/m2		45.9	46.2	44.4	24.2	61.2	45.0	74.4	120.0	120.0	150.0	150.0

Pile tip level RL	80.0 m (18.1 m below GL)											
Pile diameter, mm	450 mm	500 mm	600 mm	750 mm								
Effective overburden pressure at 15-20 D kN/m²	77	86	103	128								
Ultimate end bearing resistance kN/m²	2900	2900	2900	2900								
Ultimate end bearing capacity, kN	461	569	820	1281								
Ultimate side firction capacity, kN	1033	1143	1360	1679								
Ultimate side firction capacity for full length, kN	1033	1143	1360	1679								
Total ultimate capacity, kN (for sett=5% D)	1494	1712	2180	2960								
Safe end bearing capacity, kN (for PFS)	168	207	298	466								
Safe side friction, kN (for PFS)	590	653	777	959								
Total safe capacity with common FS, kN	664	761	969	1316								
Total safe capacity with partial FS, kN	758	860	1075	1425								
Safe uplift capacity, kN	295	327	389	480								
Weight of pile, kN	38	47	67	105								
Safe compression capacity - structural, kN	994	1227	1767	2761								
Safe compression capacity kN (DL+LL)	664 kN	761 kN	969 kN	1316 kN								
Total drag kN												
Net safe compression capacity kN (for Drag)												
Total ultimate capacity, kN (for full length)	1494 kN	1712 kN	2180 kN	2960 kN								
FoS against full length friction	2.25	2.25	2.25	2.25								
Net safe uplift capacity kN	333 kN	374 kN	456 kN	585 kN								

Effective Grade of Concrete		M25
Percentage steel		0.40
Safe compressive strength, kN/m²		6250
Partial FS for end bearing	(Reese)	2.75
Partial FS for side friction	(Reese)	1.75
Common factor of safety	(Reese)	2.25
Factor of safety for uplift		3.50

Uplift is assumed roughly 2/3 of the positive friction +self weight

The design capacity under drag force is the least of (1) [Min of ultimate geotechnical capacity ÷ 1.5 & safe structural capacity]-Total drag and (2) Safe capacity with factor of safety.

ESTIMATION OF SAFE COMPRESSION AND TENSION CAPACITY OF BORED CAST-IN-SITU PILES

PROJECT

Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC

STRUCTURE

GROUND + FIVE RCC FRAME

Note: Pile capacities are estimated based on the procedure suggested in Appendix B of IS:2911 (Part1/Sec.2)-2010 with relevant amendments in IS2911 procedure OR O'Neill Reese (1988, 1999) procedure.

$Q_u = A_p q_o + \Sigma k_i P_{di} \tan\delta_i A_{si}$ (for sand layers) $+ \Sigma \alpha c_u A_{si}$ (for clay layers) A_p is cross section area of pile, q_o is end bearing resistance = $p_o N_q$ or $c_u \times N_c$ depending on type of soil; k_i is earth pressure constant 0.7 to 1.5; P_{di} is effective overburden

N_q is from IS 2911. Effective overburden perssure p_o at pile tip is limited to depth equal to 15 to 20 times pile diameter using submerged unit weight of the bearing stratum for the end bearing estimation. δ is interface friction angle equal to angle of shearing resistance ϕ. A_{si} is surface area of pile segment in consideration. Effective overburden perssure p_o at mid depth of the respective layer is used in the skin friction estimation. The term k_sTanδ is limited to β= 1.5-0.245vZ(m)in beta procedure (Ref Analysis and Design of Shallow and Deep Foundations, LC Reese, W.M. Isenhower and S.T Wang. Wiley, 2006, section 11.6.3). For Reese procedure, end bearing is 57.5 N kN/m² limited to 2900 kN/m² for sand, where N is corrected N_{60}.** is negative skin friction factor beta for -ve friction estimation

General details		Pile tip level RL	77.6 m					Tip level 1	Tip level 2	Tip level 3	Procedure ○ IS2911 ◉ Reese
Ground level RL	98.1 m	Soil at tip	wr			Depth of pile from GL		20.5 m			☐ CFA construction (Reese, adding 20%)
Scour / basement level, RL	98.1 m	SPT N	300			Reduced level pile tip		77.6 m			Skin friction limiting to critical depth NO
Pile cut-off level RL	97.0 m	side friction from, RL	94.4 m			Angle of friction, degrees		35.0°			Predominent soil profile CLAY
Design ground water table RL	98.1 m	Temporary casing depth, RL	94.4 m			Bearing capacity factor N_q (IS)		35.0			
Critical depth for end bearing 15 to 20D above tip		Bulk unit weight up to this depth	17.50	kN/m³	0.6	Undrained cohesion c_u kN/m²					Reference Test Data **BH/7**

Description	For drag force	For side friction												
From depth RL		98.0 m	95.3 m	94.4 m	91.8 m	90.1 m	88.6 m	85.5 m	82.9 m	79.6 m	77.8 m	77.6 m	77.1 m	76.9 m	76.6 m
To depth RL		95.3 m	94.4 m	91.8 m	90.1 m	88.6 m	85.5 m	82.9 m	79.6 m	77.8 m	77.6 m	77.1 m	76.9 m	76.6 m	75.9 m
Soil type		SaClay	SiClay	SiClay	SiClay	SaClay	SaClay	CSiSand	SaClay	CSiSand	WShale	WShale	WShale	WR	WR
Field N value (N_{60})		9	15	15	12	15	26	44	72	100	200	200	200	300	300
Corrected SPT N		9	15	15	12	15	27	39	72	82	200	200	200	300	300
Bulk unit weight kN/m³		16.8	17.8	17.8	18.4	18.7	19.4	21.6	23.2	24.0	23.0	23.0	23.0	23.0	23.0
Undrained cohesion c_u kN/m²		56	90	90	72	90	160		430		1200	1200	1200	1500	1500
Angle of friction deg								36.5°		40.5°					
Adhesion factor		0.81	0.51	0.51	0.64	0.51	0.28	0.00	0.17	0.00	0.10	0.10	0.10	0.10	0.10
Earth pressure constant **		0.00	0.00	0.00	0.00	0.00	0.00	1.31	0.00	1.50	0.00	0.00	0.00	0.00	
Friction between pile & soil deg								36.5°		40.5°					
k tan δ								0.969		1.281					
Side Friction factor beta								0.587		0.421					
Selected friction factor-Beta								0.587		0.421					
Thickness		2.7 m	0.9 m	2.6 m	1.7 m	1.5 m	3.1 m	2.6 m	3.3 m	1.8 m	0.2 m	0.5 m	0.2 m	0.3 m	0.7 m
Mid depth		96.7 m	94.9 m	93.1 m	91.0 m	89.4 m	87.1 m	84.2 m	81.3 m	78.7 m	77.7 m	77.4 m	77.0 m	76.8 m	76.3 m
Effective overburdan kN/m²		9.9	22.6	36.3	53.6	67.2	88.3	116.0	154.8	189.2	203.1	207.7	212.2	215.5	222.0
Ultimate unit side friction kN/m2		45.4	45.9	45.9	46.1	45.9	44.8	69.2	73.1	79.7	120.0	120.0	120.0	150.0	150.0

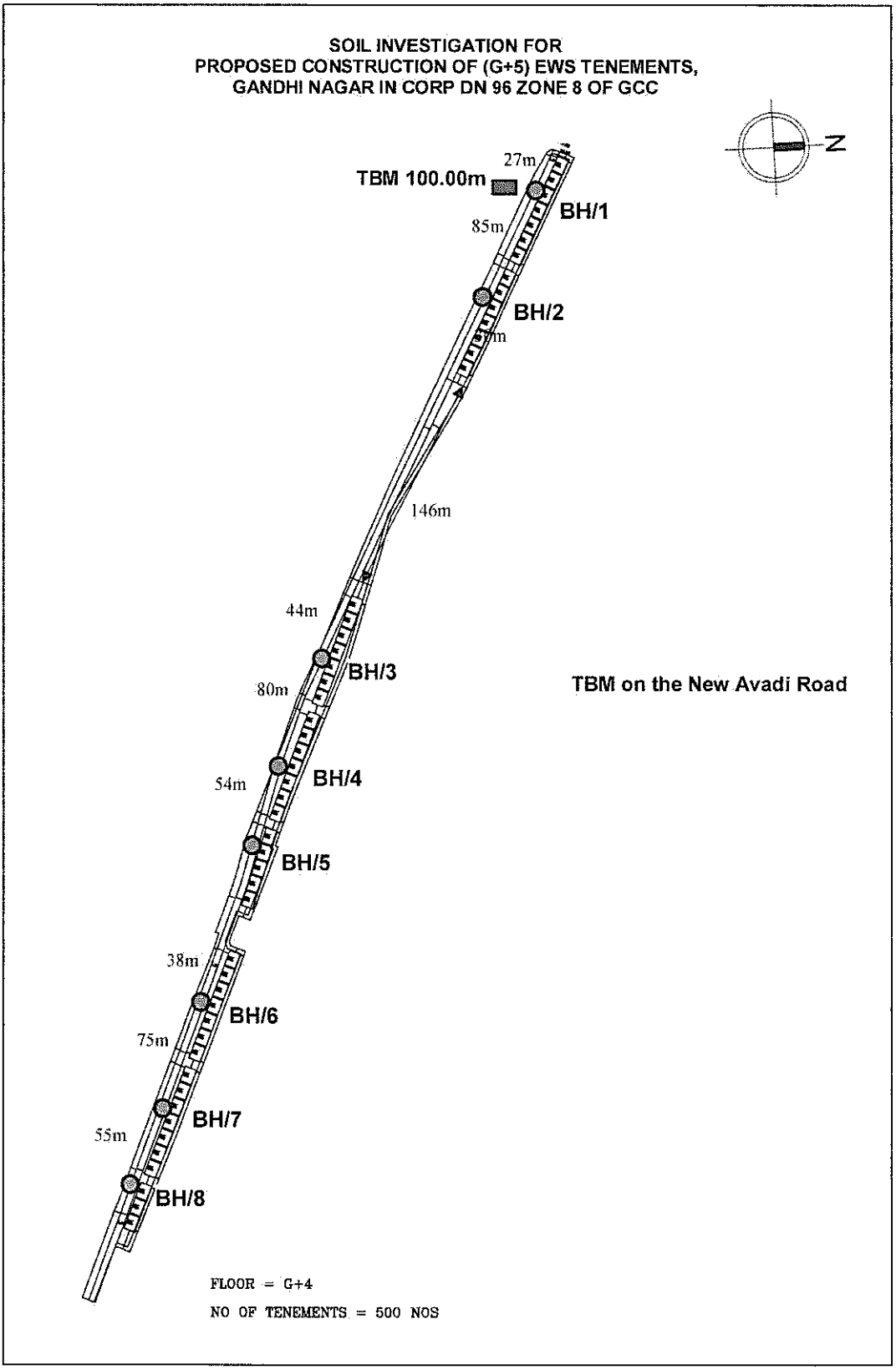
Pile tip level RL	77.6 m (20.5 m below GL)												Effective Grade of Concrete		M25
Pile diameter, mm	450 mm	500 mm	600 mm	750 mm									Percentage steel		0.40
Effective overburden pressure at 15-20 D kN/m²	77	86	103	128									Safe compressive strength, kN/m²		6250
Ultimate end bearing resistance kN/m²	2900	2900	2900	2900									Partial FS for end bearing	(Reese)	2.75
Ultimate end bearing capacity, kN	461	569	820	1281									Partial FS for side friction	(Reese)	1.75
Ultimate side firction capacity, kN	1367	1514	1806	2236									Common factor of safety	(Reese)	2.25
Ultimate side friction capacity for full length, kN	1367	1514	1806	2236											
Total ultimate capacity, kN (for sett=5% D)	1828	2083	2626	3517									Factor of safety for uplift		3.50
Safe end bearing capacity, kN (for PFS)	168	207	298	466									Uplift is assumed roughly 2/3 of the positive friction +self weight		
Safe side friction, kN (for PFS)	781	865	1032	1278									The design capacity under drag force is the least of (1) [Min of ultimate geotechnical capacity ÷ 1.5 & safe structural capacity]-Total drag and (2) Safe capacity with factor of safety.		
Total safe capacity with common FS, kN	812	926	1167	1563											
Total safe capacity with partial FS, kN	949	1072	1330	1744									**ESTIMATION OF SAFE COMPRESSION AND TENSION CAPACITY OF BORED CAST-IN-SITU PILES**		
Safe uplift capacity, kN	391	433	516	639											
Weight of pile, kN	43	53	77	120											
Safe compression capacity - structural, kN	994	1227	1767	2761									PROJECT		
Safe compression capacity kN (DL+LL)	812 kN	926 kN	1167 kN	1563 kN									**Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar In Corp DN 96 Zone 8 of GCC**		
Total drag kN															
Net safe compression capacity kN (for Drag)															
Total ultimate capacity, kN (for full length)	1828 kN	2083 kN	2626 kN	3517 kN									STRUCTURE		
FoS against full length friction	2.25	2.25	2.25	2.25									**GROUND + FIVE RCC FRAME**		
Net safe uplift capacity kN	434 kN	486 kN	593 kN	759 kN											

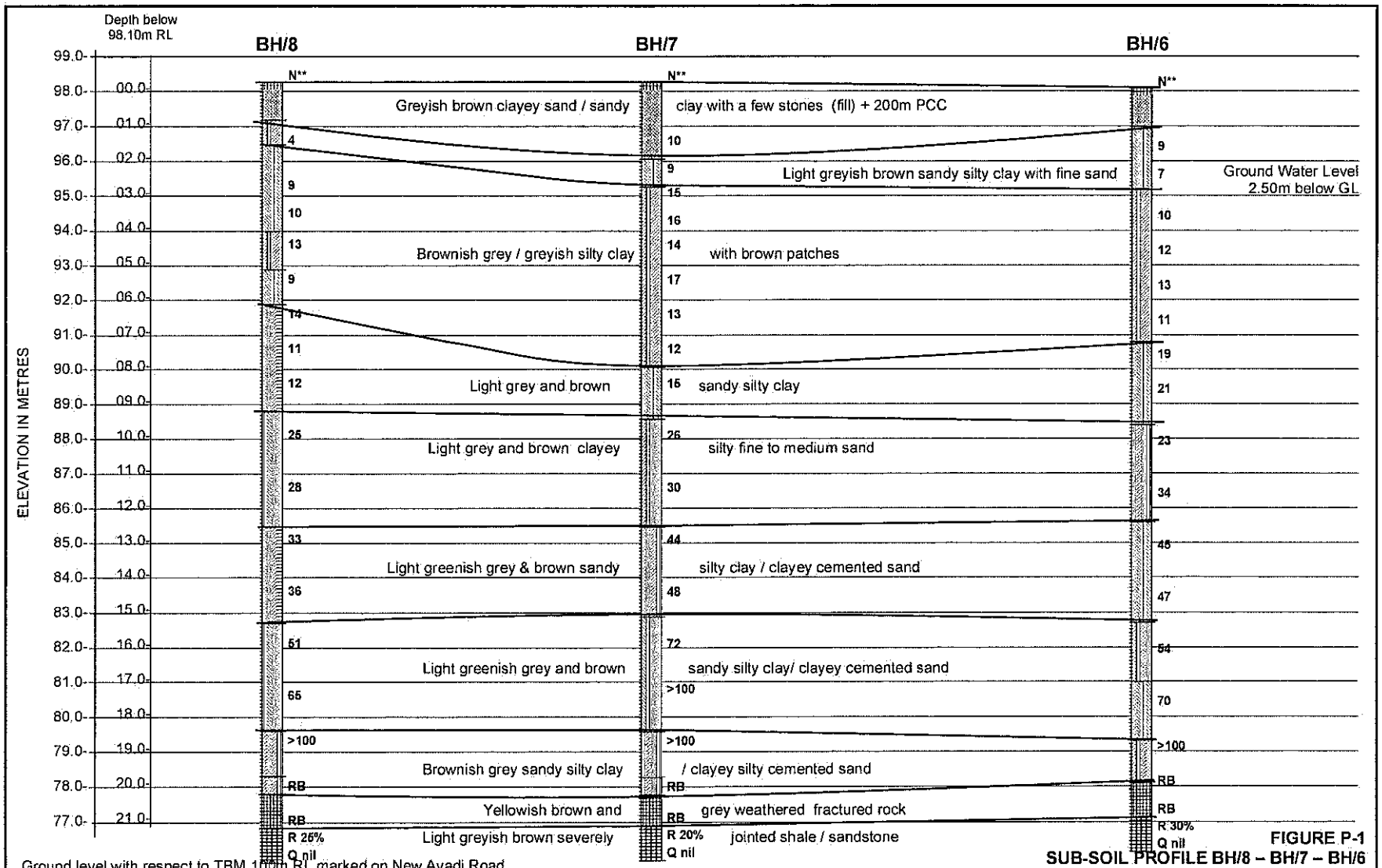
Note: Pile capacities are estimated based on the procedure suggested in Appendix B of IS:2911 (Part1/Sec.2)-2010 with relevant amendments in IS2911 procedure OR O'Neill Reese (1988, 1999) procedure.

$Q_u = A_p q_v + \Sigma k_i P_{di} \tan\delta_i A_{si}$ (for sand layers) $+ \Sigma \alpha c_u A_{si}$ (for clay layers) A_p is cross section area of pile, q_v is end bearing resistance = $p_0 N_q$ or $c_u \times N_c$ depending on type of soil; k_i is earth pressure constant 0.7 to 1.5; P_{di} is effective overburden

N_q is from IS 2911. Effective overburden perssure p_0 at pile tip is limited to depth equal to 15 to 20 times pile diameter using submerged unit weight of the bearing stratum for the end bearing estimation. δ is interface friction angle equal to angle of shearing resistance ϕ. A_{si} is surface area of pile segment in consideration. Effective overburden perssure p_0 at mid depth of the respective layer is used in the skin friction estimation. The term k_sTanδ is limited to β= 1.5-0.245√Z(m)in beta procedure (Ref Analysis and Design of Shallow and Deep Foundations, LC Reese, W.M. Isenhower and S.T Wang. Wiley, 2006, section 11.6.3). For Reese procedure, end bearing is 57.5 N kN/m² limited to 2900 kN/m² for sand, where N is corrected N_{60}.** is negative skin friction factor beta for -ve friction estimation

FIGURE 1
LOCATION OF BORE HOLES





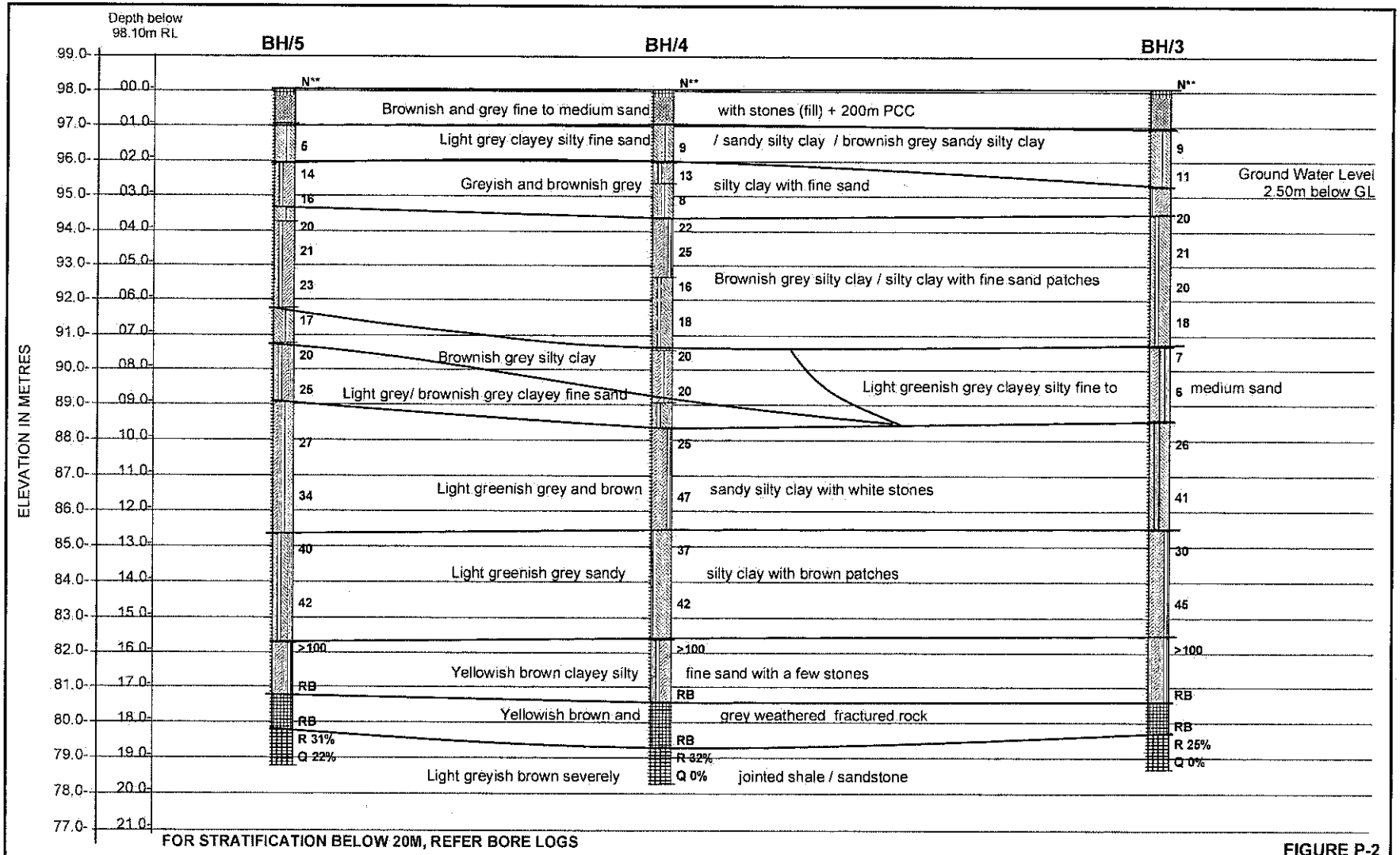
Ground level with respect to TBM 100m RL marked on New Avadi Road

Important note: The subsoil variations can be different from what is shown here as the boreholes are at large spacing

FIGURE P-1

SUB-SOIL PROFILE BH/8 – BH/7 – BH/6

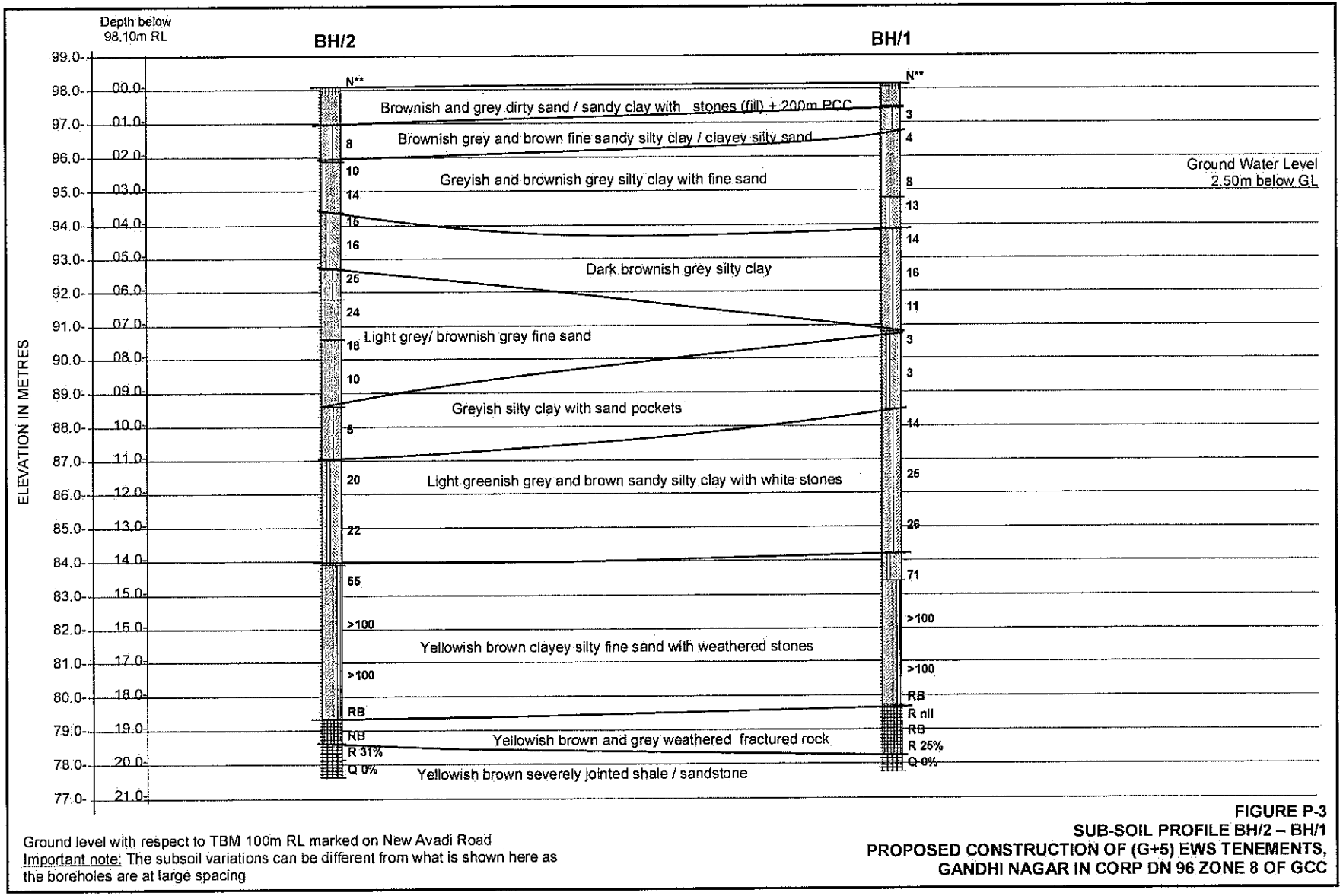
PROPOSED CONSTRUCTION OF (G+5) EWS TENEMENTS, GANDHI NAGAR IN CORP DN 96 ZONE 8 OF GCC



Ground level with respect to TBM 100m RL marked on New Avadi Road

Important note: The subsoil variations can be different from what is shown here as the boreholes are at large spacing

FIGURE P-2
SUB-SOIL PROFILE BH/5 – BH/4 – BH/3
PROPOSED CONSTRUCTION OF (G+5) EWS TENEMENTS, GANDHI NAGAR IN CORP DN 96 ZONE 8 OF GCC

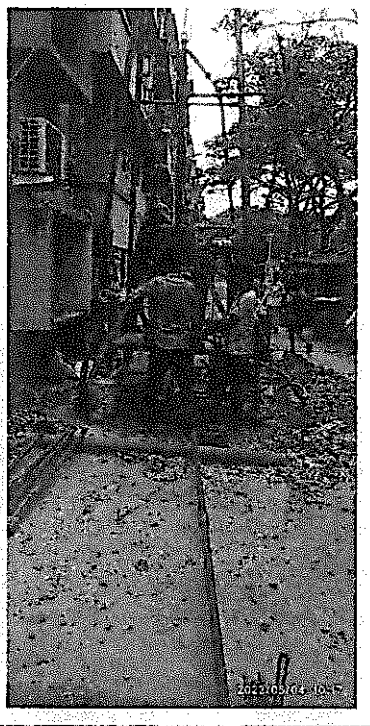


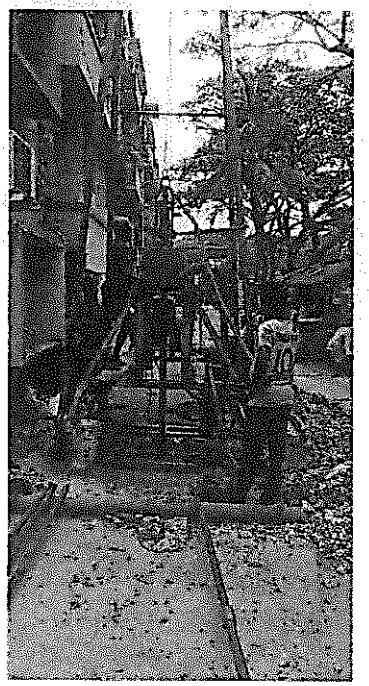
Ground level with respect to TBM 100m RL marked on New Avadi Road
Important note: The subsoil variations can be different from what is shown here as the boreholes are at large spacing

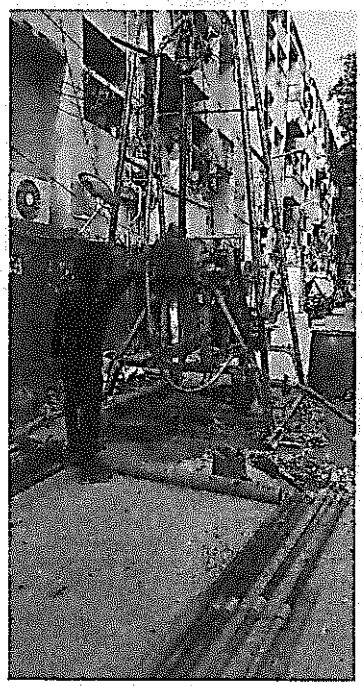
FIGURE P-3
SUB-SOIL PROFILE BH/2 – BH/1
PROPOSED CONSTRUCTION OF (G+5) EWS TENEMENTS, GANDHI NAGAR IN CORP DN 96 ZONE 8 OF GCC

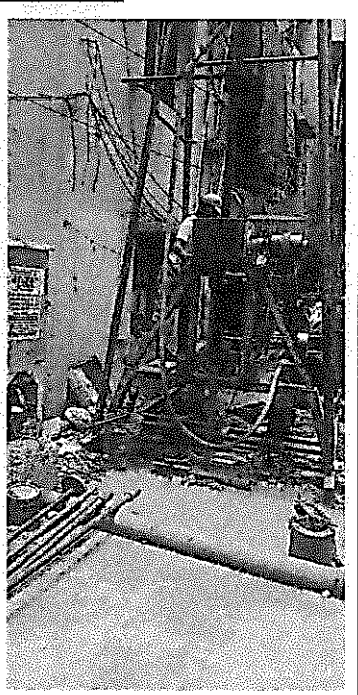
**PROPOSED CONSTRUCTION OF (G+5) EWS TENEMENTS,
GANDHI NAGAR IN CORP DN 96 ZONE 8 OF GCC
PHOTOGRAPHS OF GEOTECHNICAL INVESTIGATION**











ROCK CORE SAMPLES FROM BH/1 TO BH/8

PROPOSED CONSTRUCTION OF (G+5) EWS TENEMENTS,
GANDHI NAGAR IN CORP DN 96 ZONE 8 OF GCC



GEOTECHNICAL SOLUTIONS[A1]

SUMMARY OF LABORATORY TEST RESULTS

Project: **Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC** **TABLE 1**

Borehole Nos: **BH/1, BH/2, BH/3, BH/4, BH/5, BH/6, BH/7, and BH/8** SHEET 1 OF 7

Type of Boring and dia of bore hole: 150mm diameter rotary boring with mud circulation Ground Water Table: 2.5m to 3.0m in borehole (May 2022)

Sample Depth m	Sample Type	Visual Identification of Soil	SPT "N"	Classification	Natural Moisture content %	Liquid Limit %	Plastic Limit %	Plasticity Index %	Liquidity Index	Differential Free Swell Index %	Specific Gravity	Gravel %	Coarse Sand %	Medium Sand %	Fine Sand %	Silt %	Clay %
Depth (1)	Type (2)	Description (3)	(4)	CLASS (5)	NMC (6)	LL (7)	PL (8)	PI (9)	LI (10)	DFSI (11)	SG (12)	G (13)	CS (14)	MS (15)	FS (16)	Silt (17)	Clay (18)
		BOREHOLE BH/1															
0.50	DS	Greyish sandy silty clay/clayey silty fine to medium sand with brown patches			18.1												
0.75	SPT	Light greyish brown sandy silty clay with stones	3	SC	25.9							12.5	5.2	8.9	28.1	45.3	
1.50	SPT	Brownish grey silty clay with fine sand	4		21.0												
2.25	UDS	Brownish grey silty clay with fine sand		SC-CH	33.6	52.2	24.7	27.5	0.324	30.8							
2.75	SPT	Brownish grey silty clay with fine sand	8		32.6												
3.50	SPT	Brownish grey silty clay	13	CH	35.4	66.8	29.9	36.9	0.149	100.0							
4.50	SPT	Dark brownish grey silty clay	14		38.2												
5.50	SPT	Dark brownish grey silty clay	16	CH	39.6	63.5	33.9	29.6	0.193	33.3							
6.50	SPT	Dark brownish grey silty clay	11		44.9												
7.50	SPT	Greyish silty clay with fine sand	3	CH	37.4	61.7	33.1	28.6	0.150								
8.50	SPT	Greyish silty clay	3		56.5												
10.00	SPT	Light greenish grey and brown sandy silty clay	14	SC-CL	15.5	31.9	LSL-5.7%										
11.50	SPT	Light greenish grey and brown sandy silty clay	25		25.3												
13.00	SPT	Light greenish grey and brown sandy silty clay	26	SC-CH	29.4	76.5	26.0	50.5	0.067								
14.50	SPT	TOP: Light greyish and brown sandy silty clay	71	SC-CI	24.5	48.4	17.6	30.8	0.224								
		BOT: Light yellowish brown clayey silty fine sand			14.3												

TABLE 1

Project: **Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC**

Depth (1)	Type (2)	Description (3)	"N" (4)	CLASS (5)	NMC (6)	LL (7)	PL (8)	PI (9)	LI (10)	DFSI (11)	SG (12)	G (13)	CS (14)	MS (15)	FS (16)	Silt (17)	Clay (18)
16.00	SPT	Light yellowish brown clayey silty fine sand	>100	SC-SM	14.1								0.6	12.4	67.1	19.9	
17.50	SPT	Light yellowish brown clayey silty fine sand	>100	SC-SM	15.6								1.8	7.3	63.6	27.3	
19.50-20.50		Light yellowish brown & grey severely jointed weathered rock (shale)															
		BOREHOLE BH/2															
0.50-0.75	DS	Brownish and light grey sandy silty clay			17.0												
1.50	SPT	Brownish and light grey sandy silty clay/clayey silty sand	8	SC-CI	23.0	37.3	16.7	20.6	0.306	21.4							
2.25	SPT	Brownish and light grey sandy silty clay	10		21.8												
3.00	SPT	Brownish and light grey sandy silty clay	14	SC-CI	25.7	44.3	20.0	24.3	0.235	36.3							
3.75	SPT	Brownish grey silty clay with fine sand patches	15		35.5												
4.50	SPT	Brownish grey silty clay with fine sand patches	16	SC-CH	40.2	61.0	31.0	30.0	0.307								
5.50	SPT	Light grey silty fine sand with traces of clay	25	SM-SP	25.9								0.3	5.2	67.9	26.6	
6.50	SPT	Light grey fine sand	24	SP	28.3									0.6	88.6	10.8	
7.50	SPT	Light brownish grey fine sand	18	SP	25.5									1.0	89.3	9.7	
8.50	SPT	Light brownish grey fine sand	10	SP	35.4									1.5	87.9	10.6	
10.00	SPT	Greyish silty clay with sand patches	5	SC-CI	31.2	44.7	16.3	28.4	0.525								
11.50	SPT	Light greenish grey sandy silty clay with brown patches	20		17.9												
13.00	SPT	Light greenish grey sandy silty clay with brown patches	22	SC-CI	17.6	40.7	15.6	25.1	0.080								
14.50	SPT	Light yellowish brown clayey silty fine sand	55	SC-SM	15.8							2.6	2.5	6.8	57.5	30.6	
16.00	SPT	Light yellowish brown clayey silty fine sand	>100	SC-SM	14.2									5.6	68.1	26.3	
17.50	SPT	Light yellowish brown clayey silty fine sand	>100		14.1												
19.50-20.50		Light greyish brown severely jointed weathered shale															

TABLE 1

Project: **Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC** SHEET 3 OF 7

Depth (1)	Type (2)	Description (3)	"N" (4)	CLASS (5)	NMC (6)	LL (7)	PL (8)	PI (9)	LI (10)	DFSI (11)	SG (12)	G (13)	CS (14)	MS (15)	FS (16)	Silt (17)	Clay (18)
		BOREHOLE BH/3															
0.50-0.75	DS	Brownish grey fine to medium sand with stones			10.2												
1.50	SPT	Brownish grey fine sandy silty clay	9	SC	16.9							6.3	3.1	7.6	43.7	39.3	
2.25	SPT	Brownish grey fine sandy silty clay	11	SC-Cl	32.3	39.4	22.3	17.1	0.585	15.4							
3.00	UDS	Brownish grey silty clay with fine sand		SC-CH	33.0	69.9	32.1	37.8	0.024	28.6							
3.75	SPT	Brownish grey silty clay	20		33.7												
4.50	SPT	Brownish grey silty clay	21	CH	33.4	66.4	31.4	35.0	0.057	35.7							
5.50	SPT	Brownish grey silty clay	20		35.6												
6.50	SPT	Greyish brown silty clay	18	CH	36.6	67.5	32.1	35.4	0.127	109.0							
7.50	SPT	Light greenish grey clayey silty fine to medium sand	7	SC-SP	19.0									34.8	45.8	19.4	
8.50	SPT	Light greenish grey clayey silty fine to medium sand	6	SC-SP	23.6									35.8	45.0	19.2	
10.00	SPT	Light grey and brown clayey silty cemented fine to medium sand	26	SC-SW	12.3	18.5	LSL-6.9%						0.7	43.2	29.5	26.6	
11.50	SPT	Light grey and brown clayey silty cemented fine to medium sand with stones	41	SC-SW	13.2	22.8	LSL-3.7%					12.2	4.6	35.9	24.5	22.8	
13.00	SPT	Light greenish grey sandy silty clay	30		23.2												
14.50	SPT	Light greenish grey sandy silty clay	45	SC-Cl	24.2	44.7	19.3	25.4	0.193								
16.00	SPT	Yellowish brown clayey silty fine sand	>100	SC-SM	14.5							4.8	3.3	7.7	54.0	30.2	
18.40-19.40		Lt grey & brown severely jointed weathered rock with black patches															
		BOREHOLE BH/4															
0.50-0.75	DS	Brownish grey fine to medium sand with stones			9.5												
1.50	SPT	Greyish brown sandy silty clay	9	SC-CL	27.1	33.7	18.0	15.7	0.580	18.2							
2.25	SPT	TOP: Greyish brown clayey silty fine sand	13		25.5												
		BOT: Brownish grey silty clay with fine sand		SC-Cl	28.5	47.9	23.8	24.1	0.195	7.1							
3.00	SPT	Brownish grey silty clay with fine sand	8	SC-Cl	27.0	40.7	18.2	22.5	0.391								
3.75	SPT	Brownish grey clayey silty fine sand with sandy clay pockets	22	SC-CL	31.6	26.9	LSL-2.9%			20.0							

TABLE 1

Project: **Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC**

Depth (1)	Type (2)	Description (3)	"N" (4)	CLASS (5)	NMC (6)	LL (7)	PL (8)	PI (9)	LI (10)	DFSI (11)	SG (12)	G (13)	CS (14)	MS (15)	FS (16)	Silt (17)	Clay (18)
4.00	SPT	Greyish brown clayey silty fine sand	25	SC-SM	26.7									0.3	76.7	23.0	
5.50	SPT	Brownish grey silty clay with fine sand patches	16	SC-CH	32.8	66.6	21.5	45.1	0.251	58.3							
6.50	SPT	Brownish grey silty clay	18		34.3												
7.50	SPT	Light grey and brown sandy silty clay	20		12.7												
8.50	SPT	TOP: Light grey and brown sandy silty clay	20		12.7												
		BOT: Grey and brown clayey silty fine sand															
10.00	SPT	Light grey and brown sandy silty clay/ clayey cemented sand	25	SC-SW	12.9								0.2	34.4	32.6	32.8	
11.50	SPT	Light greenish grey sandy silty clay with brown patches / cemented	47	SC-SW	11.1								0.3	44.4	31.6	23.7	
13.00	SPT	Light greenish grey sandy silty clay with brown patches	37	SC-Cl	19.0	40.4	18.2	22.2	0.036								
14.50	SPT	Light greenish grey sandy silty clay with brown patches	42		17.3												
16.00	SPT	Yellowish brown clayey silty sand with weathered stones	>100	SC-SP	14.4							0.6	1.5	6.7	63.4	27.8	
18.80-19.80		Light greyish brown severely jointed weathered rock (sandstone)															
		BOREHOLE BH/5															
0.50-0.75 DS		Brownish grey fine to medium sand with stones			11.4												
1.50	SPT	Light grey clayey silty fine sand / sandy silty clay	5	SC-CL	25.1	27.8	LSL-7.6%			9.1							
2.25	SPT	Brownish grey silty clay	14		24.1												
3.00	SPT	TOP: Brownish grey silty clay with brown patches	16	SC-Cl	27.7	37.0	17.4	19.6	0.526	8.3							
		BOT: Brownish grey sandy silty clay			27.8												
3.75	SPT	Brownish grey silty clay	20		33.1												
4.50	SPT	Brownish grey silty clay	21	CH	36.1	68.2	30.9	37.3	0.139	100.0							
5.50	SPT	Brownish grey silty clay	23		35.7												
6.50	SPT	Brownish grey silty clay with red patches	17	CH	48.2	97.4	35.8	61.6	0.201	116.7							
7.50	SPT	Ligth grey clayey silty fine to medium sand	20	SC-SP	14.8								0.3	33.5	42.0	24.2	
8.50	SPT	TOP: Ligth grey clayey silty fine to medium sand		SC-SP	0.0									34.7	42.6	22.7	
		BOT: Ligth grey and brown clayey silty fine to medium sand	25	SC-SW	12.6								0.2	43.9	30.2	25.7	

TABLE 1

Project: **Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC**

Depth (1)	Type (2)	Description (3)	"N" (4)	CLASS (5)	NMC (6)	LL (7)	PL (8)	PI (9)	LI (10)	DFSI (11)	SG (12)	G (13)	CS (14)	MS (15)	FS (16)	Silt (17)	Clay (18)
10.00	SPT	Light grey and brown clayey silty cemented fine to medium sand	27	SC-SP	12.4									44.2	30.6	25.2	
11.50	SPT	Light grey and brown clayey silty cemented fine to medium sand	34	SC-SP	12.4									42.8	31.9	25.3	
13.00	SPT	Light greenish grey sandy silty clay with brown patches	40	SC-CI	21.0	40.4	18.2	22.2	0.036								
14.50	SPT	Light greenish grey and brown sandy silty clay	42	SC-CI	21.2	43.8	17.0	26.8	0.157								
16.00	SPT	Yellowish brown clayey silty fine sand	>100	SC-SM	16.0								1.0	6.3	63.2	29.5	
18.30-19.30		Light greyish brown jointed weathered rock (shale & sandstone)															
		BOREHOLE BH/6															
0.50-0.75	DS	Light greyish brown fine sand			12.4												
1.50	SPT	Light greyish brown silty clay with fine sand	9	SC-CI	26.3	34.7	17.1	17.6	0.523	9.0							
2.25	SPT	Light brownish grey silty clay with fine sand	7		28.5												
3.00	UDS	Greyish silty clay with brown patches		CH	28.6	65.0	26.4	38.6	0.057	25.6							
3.50	SPT	Greyish silty clay	10		36.2												
4.50	SPT	Greyish silty clay with brown patches	12		27.9												
5.50	SPT	Greyish silty clay	13		36.6	75.4	34.2	41.2	0.058	18.2							
6.50	SPT	Greyish silty clay	11	CH	37.7	87.0	35.0	52.0	0.052	7.1							
7.50	SPT	Light grey and brown sandy silty clay	19		14.5												
8.50	SPT	Light grey and brown sandy silty clay	21	SC-CH	12.9	50.6	20.7	29.9	<0.00					36.9	33.4	29.7	
10.00	SPT	Light greyish brown clayey silty fine sand with medium sand	23	SC-SP	14.9							2.9	2.0	14.4	53.3	27.4	
11.50	SPT	Light greenish grey clayey silty fine to medium sand with brown patches	34	SC-SW	13.0							0.3	0.4	48.8	30.6	19.9	
13.00	SPT	Light greenish grey and brown sandy silty clay	45	SC-CI	21.0	39.0	19.0	20.0	0.100								
14.50	SPT	Light greenish grey and brown sandy silty clay	47		19.6												
16.00	SPT	Light greenish grey and brown clayey silty cemented fine to medium sand	54	SC-SW	11.8								0.6	40.5	31.4	27.5	
17.50	SPT	Light grey and brown sandy silty clay	70		10.8												
19.00	SPT	Brownish grey sandy silty clay	>100	SC	21.1								2.9	38.2	17.3	41.6	
21.00-22.00		Light grey and brown severely jointed weathered rock (shale /sandstone)															

TABLE 1

Project: **Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC** SHEET 6 OF 7

Depth (1)	Type (2)	Description (3)	"N" (4)	CLASS (5)	NMC (6)	LL (7)	PL (8)	PI (9)	LI (10)	DFSI (11)	SG (12)	G (13)	CS (14)	MS (15)	FS (16)	Silt (17)	Clay (18)
		BOREHOLE BH/7															
0.50-0.75	DS	Greyish brown sandy silty clay			22.1												
1.50	SPT	Greyish brown sandy silty clay	10	SC	17.5							3.7	2.2	22.0	36.2	35.9	
2.25	SPT	Light grey sandy silty clay	9		25.2												
3.00	SPT	Greyish silty clay	15	CH	34.1	66.1	28.9	37.2	0.140	58.3							
3.75	SPT	Greyish silty clay	16		34.2												
4.50	SPT	Greyish silty clay	14	CH	33.1	65.4	28.9	36.5	0.115								
5.50	SPT	Greyish silty clay	17		33.9												
6.50	SPT	Greyish silty clay	13	CH	46.0	100.7	38.2	62.5	0.125								
7.50	SPT	Greyish silty clay	12		51.2												
8.50	SPT	Light grey sandy silty clay	15	SC	14.7									34.1	35.1	30.8	
10.00	SPT	Light grey and yell brown sandy silty clay / clayey cemented sand	26		11.8												
11.50	SPT	Light grey and yell brown sandy silty clay / clayey cemented sand	30	SC	10.3							0.6	0.4	37.9	31.3	29.8	
13.00	SPT	Light greenish grey clayey silty fine sand	44	SC-SM	17.3							0.5	2.8	11.4	41.1	44.2	
16.00	SPT	Light grey and brown sandy silty clay / clayey cemented sand	72	SC	12.6							6.3	1.3	22.4	34.7	35.3	
17.50	SPT	Light grey and brown sandy silty clay / clayey cemented sand	>100		16.4												
19.00	SPT	Light yellowish brown clayey silty fine sand	>100	SC-SM	12.5							0.4	1.5	8.0	64.4	25.7	
21.40-22.40		Light grey and brown severely jointed / fracturedweathered rock															
		BOREHOLE BH/8															
0.50-0.75	DS	Brownish grey sandy silty clay			20.0												
1.50	SPT	TOP: Greyish brown silty clay with fine sand	4	SC-CL	22.5	34.4	16.5	17.9	0.335	7.6							
		BOT: Brownish grey silty clay			24.3												
2.25	UDS	Brownish grey silty clay		CH	27.8	48.6	21.1	27.5	0.244	23.0							
2.75	SPT	Brownish grey silty clay	9		26.2												

TABLE 1

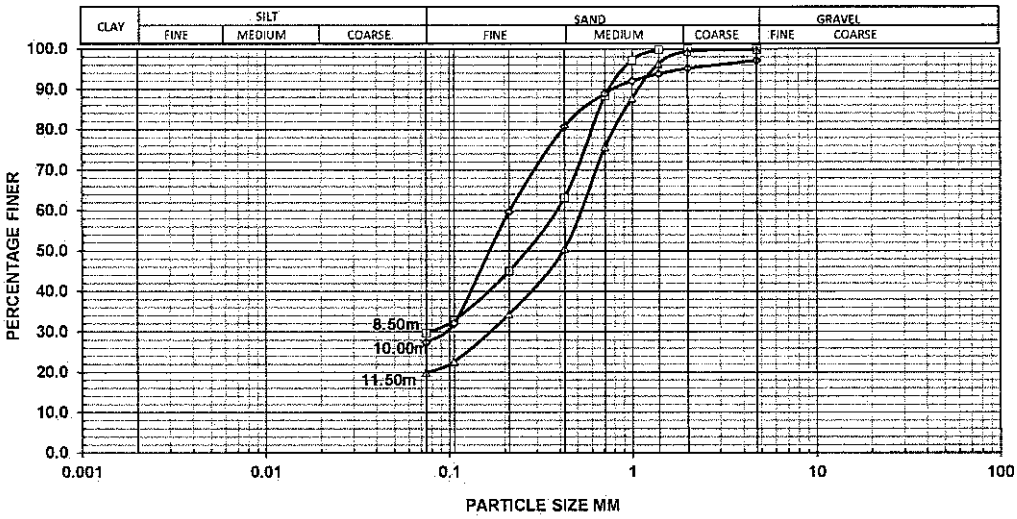
Project: **Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC** SHEET 7 OF 7

Depth (1)	Type (2)	Description (3)	"N" (4)	CLASS (5)	NMC (6)	LL (7)	PL (8)	PI (9)	LI (10)	DFSI (11)	SG (12)	G (13)	CS (14)	MS (15)	FS (16)	Silt (17)	Clay (18)
3.50	SPT	Brownish grey silty clay	10	CH	34.4	59.3	25.8	33.5	0.257	81.8							
4.50	SPT	Greyish silty clay	13		36.9												
5.50	SPT	Light grey silty clay with brown patches	9	CH	47.7	82.1	38.9	43.2	0.204								
6.50	SPT	Light greenish grey and brown clayey silty fine to medium sand	14		14.2												
7.50	SPT	Light greenish grey and brown clayey silty fine to medium sand	11	SC-SP	15.0									36.3	39.1	24.6	
8.50	SPT	Light greenish grey and brown clayey silty fine to medium sand	12		15.7												
10.00	SPT	Light grey and brown clayey silty fine to medium sand	25	SC-SP	13.4							0.8	0.7	48.0	28.8	21.7	
11.50	SPT	Light grey and brown clayey silty fine to medium sand	28		12.3												
13.00	SPT	Light greenish grey clayey silty cemented fine to medium sand	33	SC-SP	17.8								0.8	41.6	34.4	23.2	
14.50	SPT	Light greenish grey clayey silty cemented fine to medium sand with stones	36	SC-CI	20.1	45.2	21.0	24.2	<0.00								
16.00	SPT	Light greenish grey and brown sandy silty clay/ clayey cemented sand	51		15.5												
17.50	SPT	Light greenish grey and brown sandy silty clay/ clayey cemented sand	65	SC	11.5							2.2	8.8	30.3	27.2	31.5	
19.00	SPT	Brownish grey sandy silty clay	>100	SC	20.8							0.8	4.1	43.4	18.0	33.7	
21.50-22.50		Light grey and brown severely jointed weathered rock (shale /sandstone)															

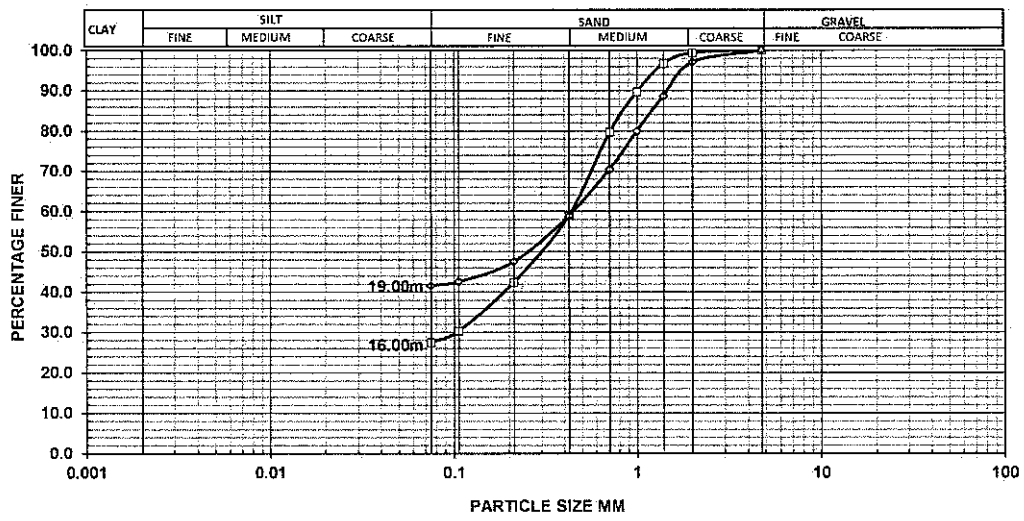
ANNEXURE G-6

GRAIN SIZE DISTRIBUTION CURVES

PROJECT: **Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC**



BH NO	DEPTH	PERCENTAGE FINER (Sieve size in mm)							Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay	Classification	D50 mm	cu (sand)	cc (sand)
	M	80.0	20.0	4.75	2.00	0.425	0.075	0.002	G	CS	MS	FS	Si	C	CLASS			
BH/6	8.50m		100.0	100.0	100.0	63.1	29.7		0.0	0.0	36.9	33.4	29.7		SC	0.257	3.850	1.045
BH/6	10.00m		100.0	97.1	95.1	80.7	27.4		2.9	2.0	14.4	53.3	27.4		SC-SP	0.166	2.724	0.762
BH/6	11.50m		100.0	99.7	99.3	50.5	19.9		0.3	0.4	48.8	30.6	19.9		SC-SW	0.416	4.203	1.170

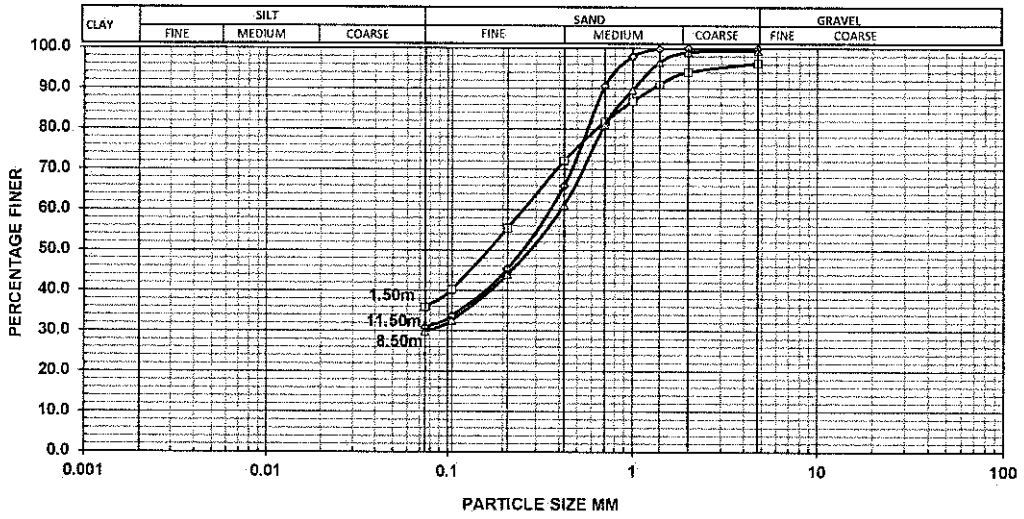


BH NO	DEPTH	PERCENTAGE FINER (Sieve size in mm)							Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay	Classification	D50 mm	cu (sand)	cc (sand)
	M	80.0	20.0	4.75	2.00	0.425	0.075	0.002	G	CS	MS	FS	Si	C	CLASS			
BH/6	16.00m		100.0	100.0	99.4	58.9	27.5		0.0	0.6	40.5	31.4	27.5		SC-SW	0.292	4.187	1.022
BH/6	19.00m		100.0	100.0	97.1	58.9	41.6		0.0	2.9	38.2	17.3	41.6		SC	0.247	4.215	0.989

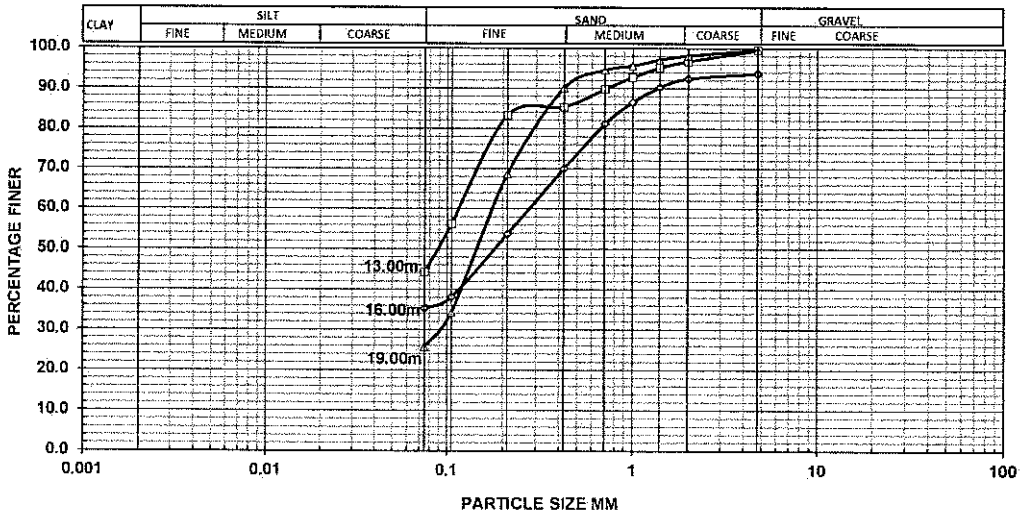
ANNEXURE G-7

GRAIN SIZE DISTRIBUTION CURVES

PROJECT: **Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC**



BH NO	DEPTH	PERCENTAGE FINER (Sieve size in mm)							Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay	Classification	D50 mm	cu (sand)	cc (sand)
	M	80.0	20.0	4.75	2.00	0.425	0.075	0.002	G	CS	MS	FS	SI	C	CLASS			
BH/7	1.50m		100.0	96.3	94.1	72.1	35.9		3.7	2.2	22.0	36.2	35.9		SC	0.166	4.105	0.784
BH/7	8.50m		100.0	100.0	100.0	65.9	30.8		0.0	0.0	34.1	35.1	30.8		SC	0.249	3.602	1.048
BH/7	11.50m		100.0	99.4	99.0	61.1	29.8		0.6	0.4	37.9	31.3	29.8		SC	0.271	4.092	1.023

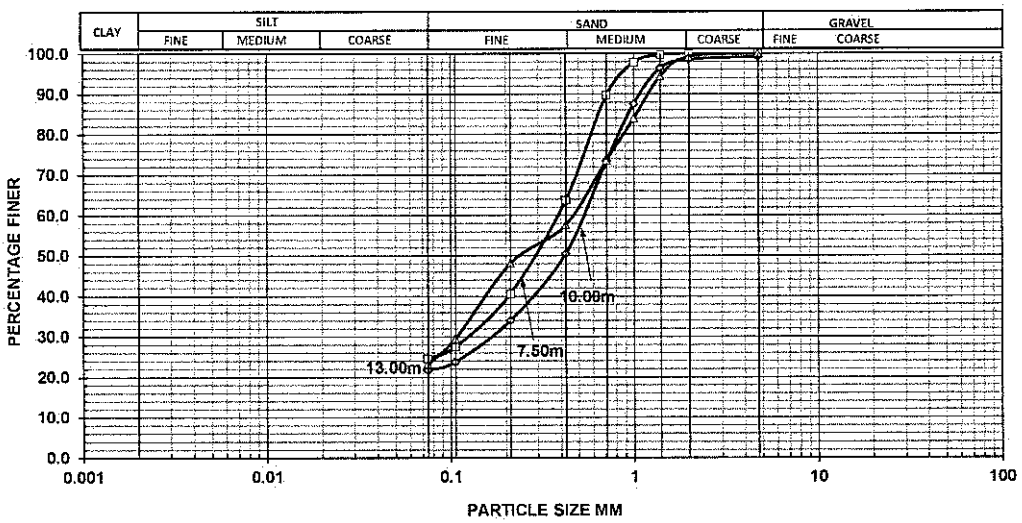


BH NO	DEPTH	PERCENTAGE FINER (Sieve size in mm)							Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay	Classification	D50 mm	cu (sand)	cc (sand)
	M	80.0	20.0	4.75	2.00	0.425	0.075	0.002	G	CS	MS	FS	SI	C	CLASS			
BH/7	13.00m		100.0	99.5	96.7	85.3	44.2		0.5	2.8	11.4	41.1	44.2		SC-SM	0.089	2.089	0.884
BH/7	16.00m		100.0	93.7	92.4	70.0	35.3		6.3	1.3	22.4	34.7	35.3		SC	0.180	4.107	0.761
BH/7	19.00m		100.0	99.6	98.1	90.1	25.7		0.4	1.5	8.0	64.4	25.7		SC-SM	0.146	2.205	0.863

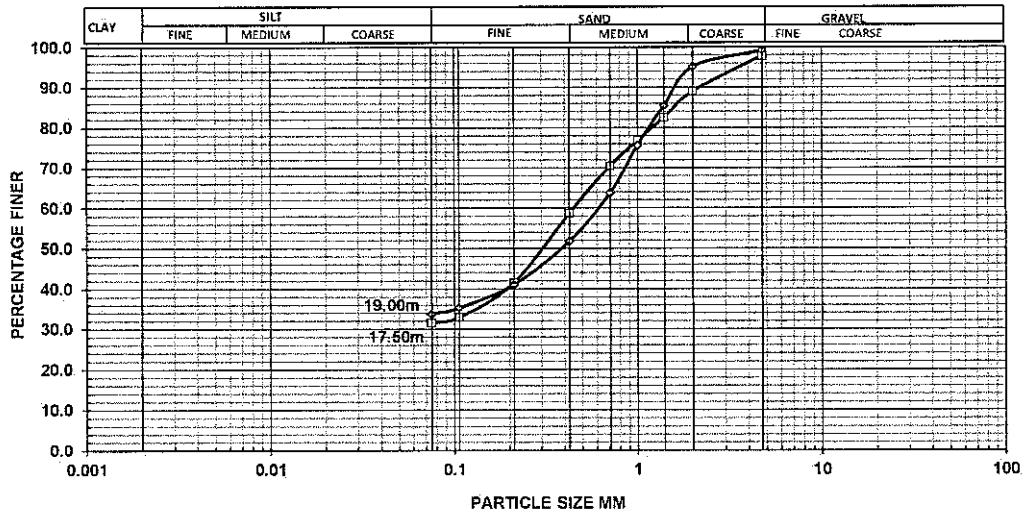
ANNEXURE G-8

GRAIN SIZE DISTRIBUTION CURVES

PROJECT: **Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC**



BH NO	DEPTH	PERCENTAGE FINER (Sieve size in mm)							Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay	Classification	D50 mm	cu (sand)	cc (sand)
	M	80.0	20.0	4.75	2.00	0.425	0.075	0.002	G	CS	MS	FS	Si	C	CLASS			
BH/8	7.50m		100.0	100.0	100.0	63.7	24.6		0.0	0.0	36.3	39.1	24.6		SC-SP	0.281	3.541	1.030
BH/8	10.00m		100.0	99.2	98.5	50.5	21.7		0.8	0.7	48.0	28.8	21.7		SC-SP	0.416	4.081	1.155
BH/8	13.00m		100.0	100.0	99.2	57.6	23.2		0.0	0.8	41.6	34.4	23.2		SC-SP	0.244	5.539	0.567

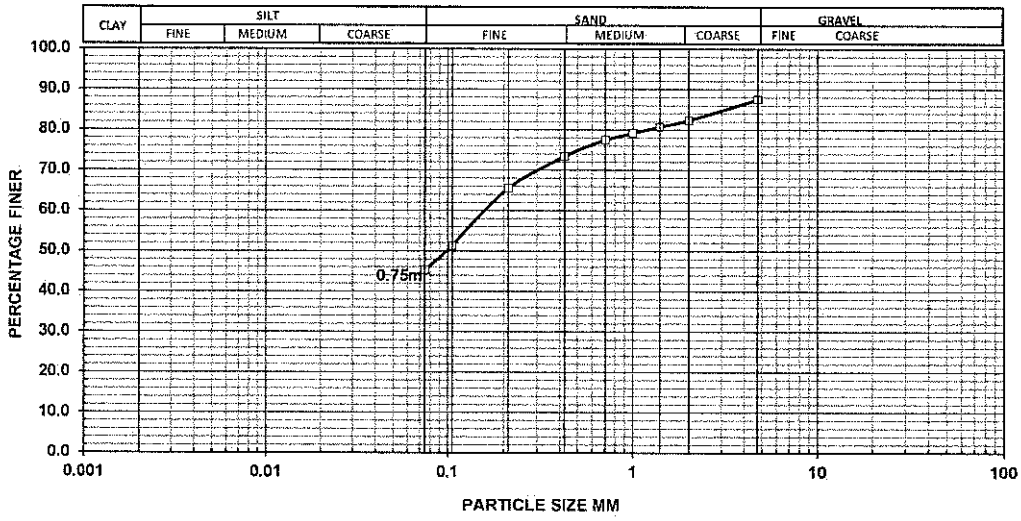


BH NO	DEPTH	PERCENTAGE FINER (Sieve size in mm)							Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay	Classification	D50 mm	cu (sand)	cc (sand)
	M	80.0	20.0	4.75	2.00	0.425	0.075	0.002	G	CS	MS	FS	Si	C	CLASS			
BH/8	17.50m		100.0	97.8	89.0	58.7	31.5		2.2	8.8	30.3	27.2	31.5		SC	0.299	4.838	0.806
BH/8	19.00m		100.0	99.2	95.1	51.7	33.7		0.8	4.1	43.4	18.0	33.7		SC	0.381	4.815	1.155

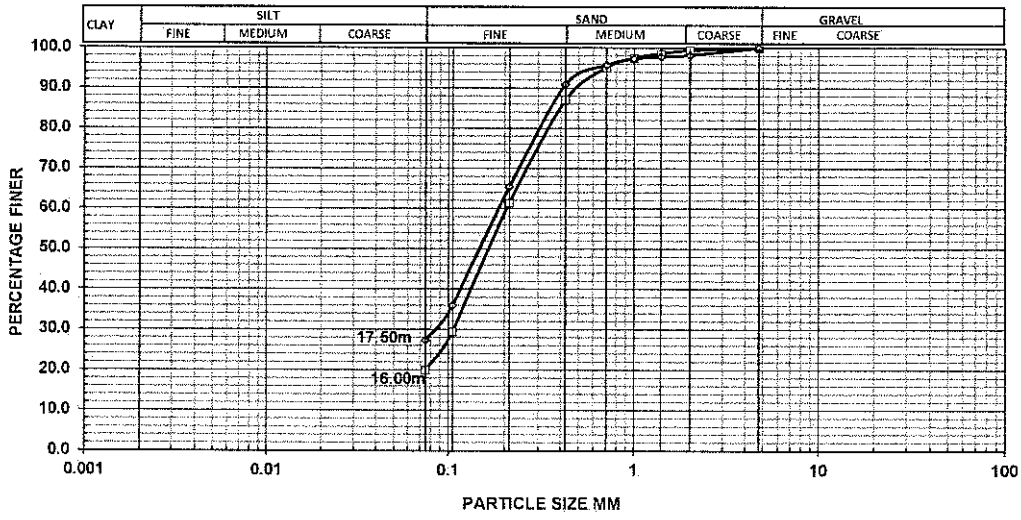
ANNEXURE G-1

GRAIN SIZE DISTRIBUTION CURVES

PROJECT: **Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC**



BH NO	DEPTH	PERCENTAGE FINER (Sieve size in mm)							Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay	Classification	D50 mm	cu (sand)	cc (sand)
	M	80.0	20.0	4.75	2.00	0.425	0.075	0.002	G	CS	MS	FS	Si	C	CLASS			
BH/1	0.75m		100.0	87.5	82.3	73.4	45.3		12.5	5.2	8.9	28.1	45.3		SC	0.098	7.984	0.368

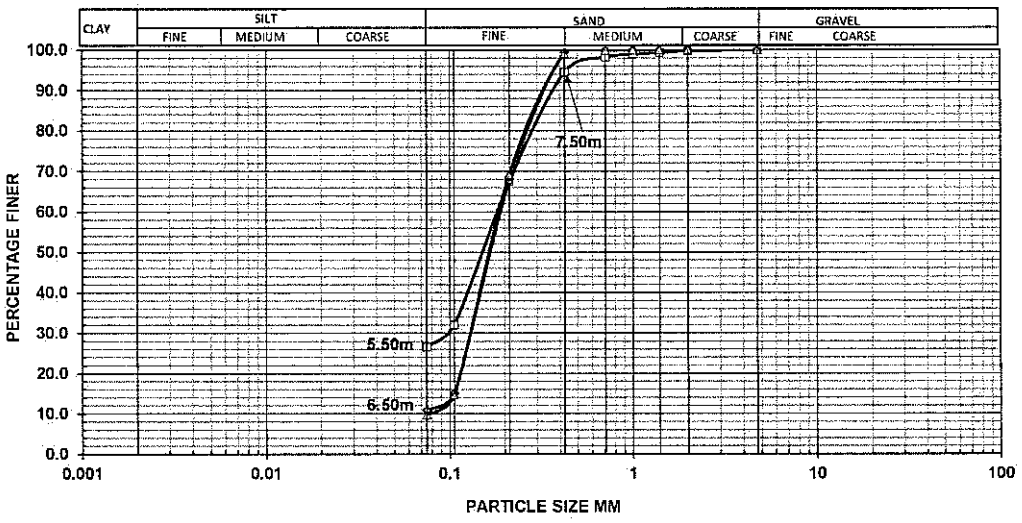


BH NO	DEPTH	PERCENTAGE FINER (Sieve size in mm)							Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay	Classification	D50 mm	cu (sand)	cc (sand)
	M	80.0	20.0	4.75	2.00	0.425	0.075	0.002	G	CS	MS	FS	Si	C	CLASS			
BH/1	16.00m		100.0	100.0	99.4	87.0	19.9		0.0	0.6	12.4	67.1	19.9		SC-SM	0.166	2.524	0.829
BH/1	17.50m		100.0	100.0	98.2	90.9	27.3		0.0	1.8	7.3	63.6	27.3		SC-SM	0.148	2.452	0.844

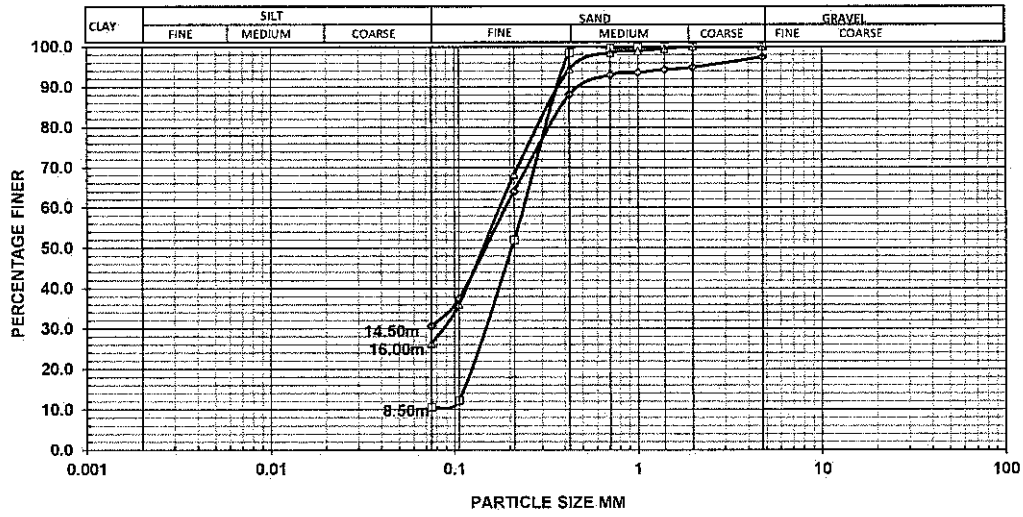
ANNEXURE G-2

GRAIN SIZE DISTRIBUTION CURVES

PROJECT: **Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC**



BH NO	DEPTH	PERCENTAGE FINER (Sieve size in mm)							Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay	Classification	D50 mm	cu (sand)	cc (sand)
	M	80.0	20.0	4.75	2.00	0.425	0.075	0.002	G	CS	MS	FS	Si	C	CLASS			
BH/2	5.50m		100.0	100.0	99.7	94.5	26.6		0.0	0.3	5.2	67.9	26.6		SM-SP	0.151	2.093	0.850
BH/2	6.50m		100.0	100.0	100.0	99.4	10.8		0.0	0.0	0.6	88.6	10.8		SP	0.168	1.804	0.889
BH/2	7.50m		100.0	100.0	100.0	99.0	9.7		0.0	0.0	1.0	89.3	9.7		SP	0.166	1.774	0.892

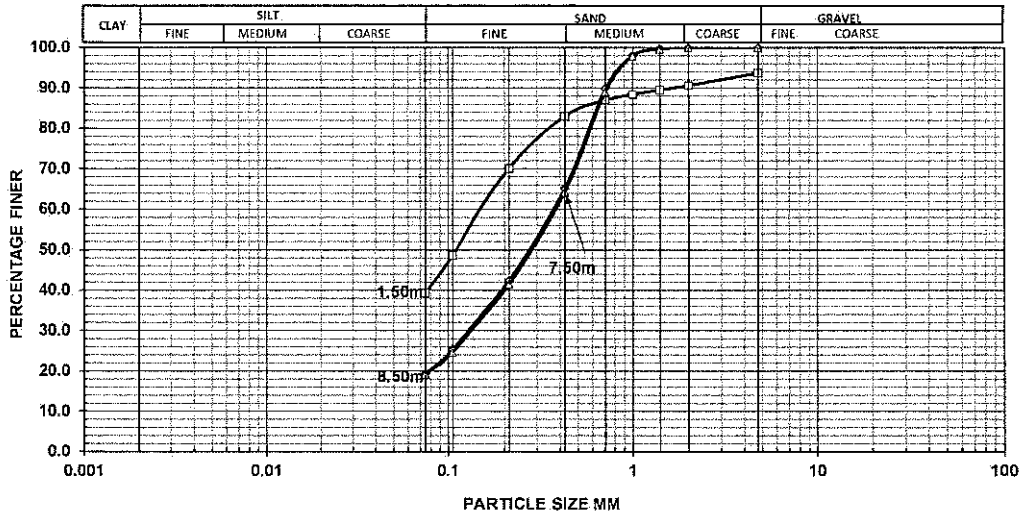


BH NO	DEPTH	PERCENTAGE FINER (Sieve size in mm)							Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay	Classification	D50 mm	cu (sand)	cc (sand)
	M	80.0	20.0	4.75	2.00	0.425	0.075	0.002	G	CS	MS	FS	Si	C	CLASS			
BH/2	8.50m		100.0	100.0	100.0	98.5	10.6		0.0	0.0	1.5	87.9	10.6		SP	0.205	2.113	0.882
BH/2	14.50m		100.0	97.4	94.9	88.1	30.6		2.6	2.5	6.8	57.5	30.6		SC-SM	0.147	2.527	0.815
BH/2	16.00m		100.0	100.0	100.0	94.4	26.3		0.0	0.0	5.6	68.1	26.3		SC-SM	0.143	2.313	0.872

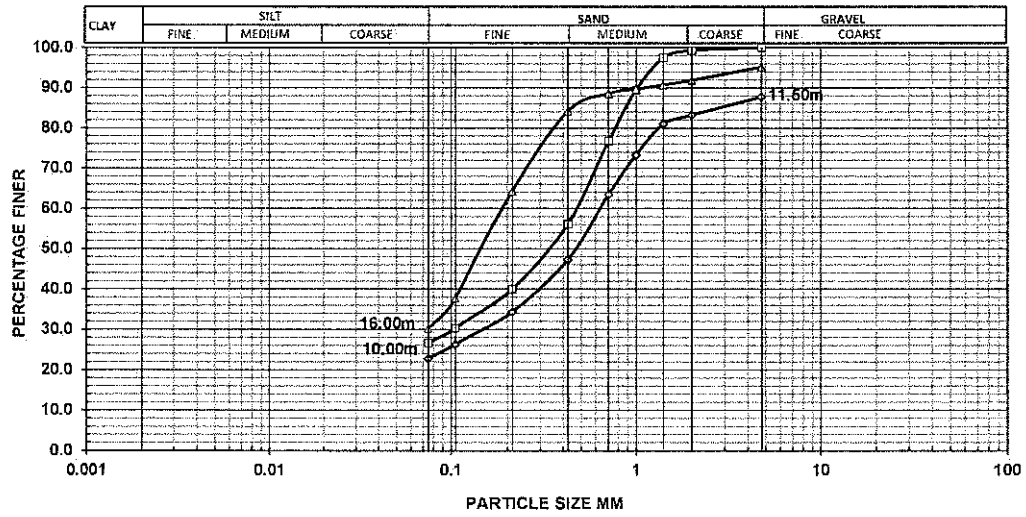
ANNEXURE G-3

GRAIN SIZE DISTRIBUTION CURVES

PROJECT: **Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC**



BH NO	DEPTH	PERCENTAGE FINER (Sieve size in mm)							Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay	Classification	D50 mm	cu (sand)	cc (sand)
	M	80.0	20.0	4.75	2.00	0.425	0.075	0.002	G	CS	MS	FS	Si	C	CLASS			
BH/3	1.50m		100.0	93.7	90.6	83.0	39.3		6.3	3.1	7.6	43.7	39.3		SC	0.111	3.053	0.740
BH/3	7.50m		100.0	100.0	100.0	65.2	19.4		0.0	0.0	34.8	45.8	19.4		SC-SP	0.267	3.875	0.931
BH/3	8.50m		100.0	100.0	100.0	64.2	19.2		0.0	0.0	35.8	45.0	19.2		SC-SP	0.276	3.857	0.941

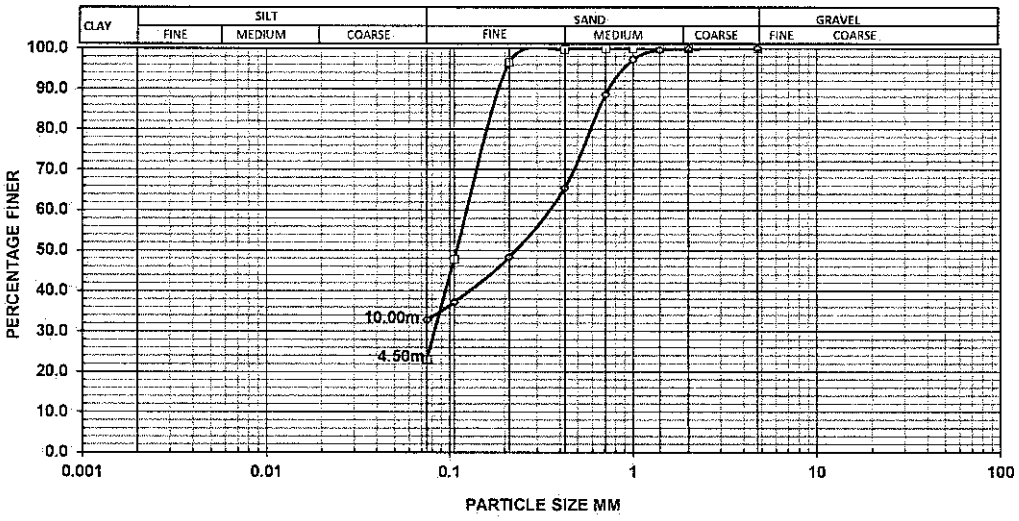


BH NO	DEPTH	PERCENTAGE FINER (Sieve size in mm)							Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay	Classification	D50 mm	cu (sand)	cc (sand)
	M	80.0	20.0	4.75	2.00	0.425	0.075	0.002	G	CS	MS	FS	Si	C	CLASS			
BH/3	10.00m		100.0	100.0	99.3	56.1	26.6		0.0	0.7	43.2	29.5	26.6		SC-SW	0.327	4.432	1.129
BH/3	11.50m		100.0	87.8	83.2	47.3	22.8		12.2	4.6	35.9	24.5	22.8		SC-SW	0.463	5.655	1.185
BH/3	16.00m		100.0	95.2	91.9	84.2	30.2		4.8	3.3	7.7	54.0	30.2		SC-SM	0.146	2.688	0.787

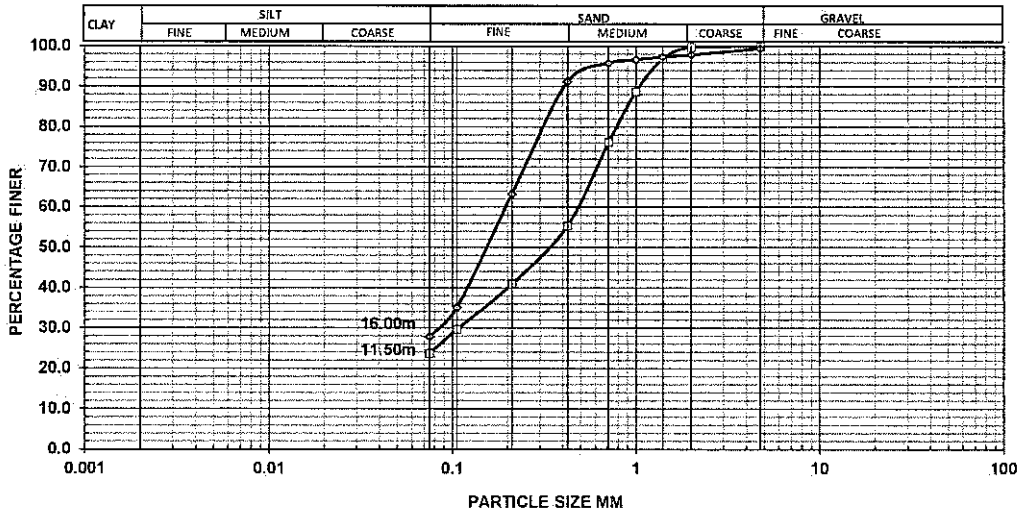
ANNEXURE G-4

GRAIN SIZE DISTRIBUTION CURVES

PROJECT: **Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC**



BH NO	DEPTH	PERCENTAGE FINER (Sieve size in mm)							Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay	Classification	D50 mm	cu (sand)	cc (sand)
	M	80.0	20.0	4.75	2.00	0.425	0.075	0.002	G	CS	MS	FS	Si	C	CLASS			
BH/4	4.50m		100.0	100.0	100.0	99.7	23.0		0.0	0.0	0.3	76.7	23.0		SC-SM	0.109	1.721	0.893
BH/4	10.00m		100.0	100.0	99.8	65.4	32.8		0.0	0.2	34.4	32.6	32.8		SC-SW	0.227	4.115	1.063

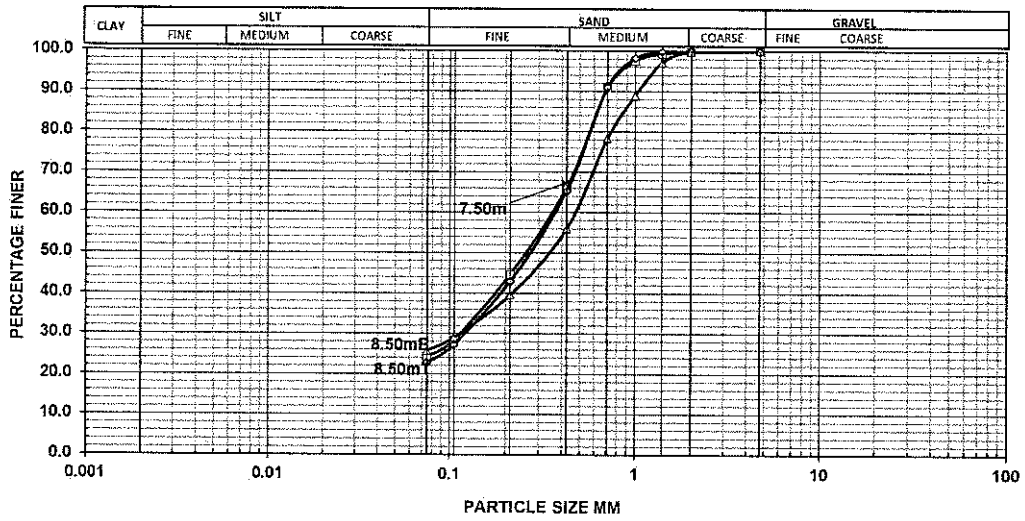


BH NO	DEPTH	PERCENTAGE FINER (Sieve size in mm)							Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay	Classification	D50 mm	cu (sand)	cc (sand)
	M	80.0	20.0	4.75	2.00	0.425	0.075	0.002	G	CS	MS	FS	Si	C	CLASS			
BH/4	11.50m		100.0	100.0	99.7	55.3	23.7		0.0	0.3	44.4	31.6	23.7		SC-SW	0.329	5.115	1.096
BH/4	16.00m		100.0	99.4	97.9	91.2	27.8		0.6	1.5	6.7	63.4	27.8		SC-SP	0.105	2.444	0.838

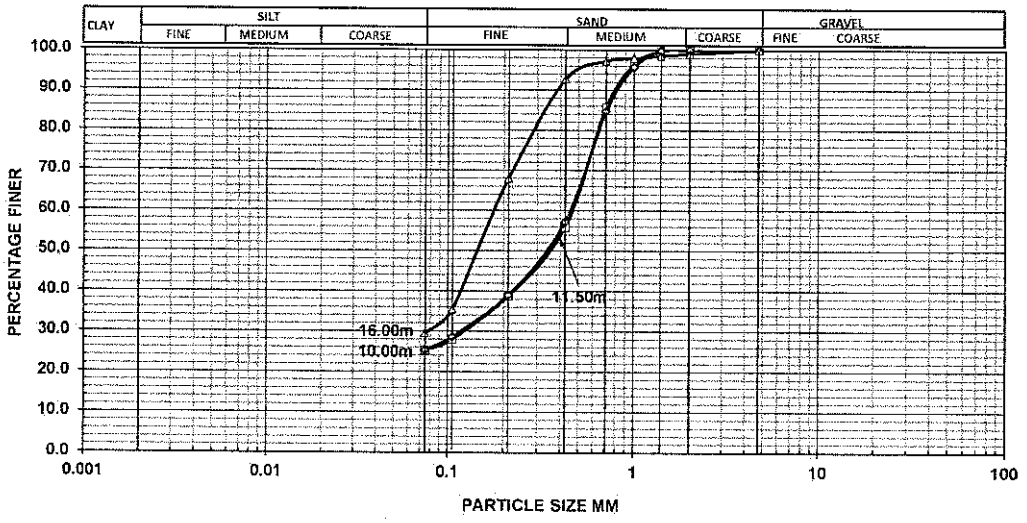
ANNEXURE G-5

GRAIN SIZE DISTRIBUTION CURVES

PROJECT: **Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC**



BH NO	DEPTH	PERCENTAGE FINER (Sieve size in mm)							Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay	Classification	D50 mm	cu (sand)	cc (sand)
	M	80.0	20.0	4.75	2.00	0.425	0.075	0.002	G	CS	MS	FS	Si	C	CLASS			
BH/5	7.50m		100.0	100.0	99.7	66.2	24.2		0.0	0.3	33.5	42.0	24.2		SC-SP	0.252	3.718	0.931
BH/5	8.50mT		100.0	100.0	100.0	65.3	22.7		0.0	0.0	34.7	42.6	22.7		SC-SP	0.264	3.750	0.966
BH/5	8.50mB		100.0	100.0	99.8	55.9	25.7		0.0	0.2	43.9	30.2	25.7		SC-SW	0.331	4.244	1.123



BH NO	DEPTH	PERCENTAGE FINER (Sieve size in mm)							Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay	Classification	D50 mm	cu (sand)	cc (sand)
	M	80.0	20.0	4.75	2.00	0.425	0.075	0.002	G	CS	MS	FS	Si	C	CLASS			
BH/5	10.00m		100.0	100.0	100.0	55.8	25.2		0.0	0.0	44.2	30.6	25.2		SC-SP	0.336	3.768	1.189
BH/5	11.50m		100.0	100.0	100.0	57.2	25.3		0.0	0.0	42.8	31.9	25.3		SC-SP	0.323	3.855	1.157
BH/5	16.00m		100.0	100.0	99.0	92.7	29.5		0.0	1.0	6.3	63.2	29.5		SC-SM	0.145	2.178	0.838

ONE DIMENSIONAL CONSOLIDATION TEST RESULTS

ANNEXURE C-1

strain - log p curve

SHEET 1 of 2

Test Data

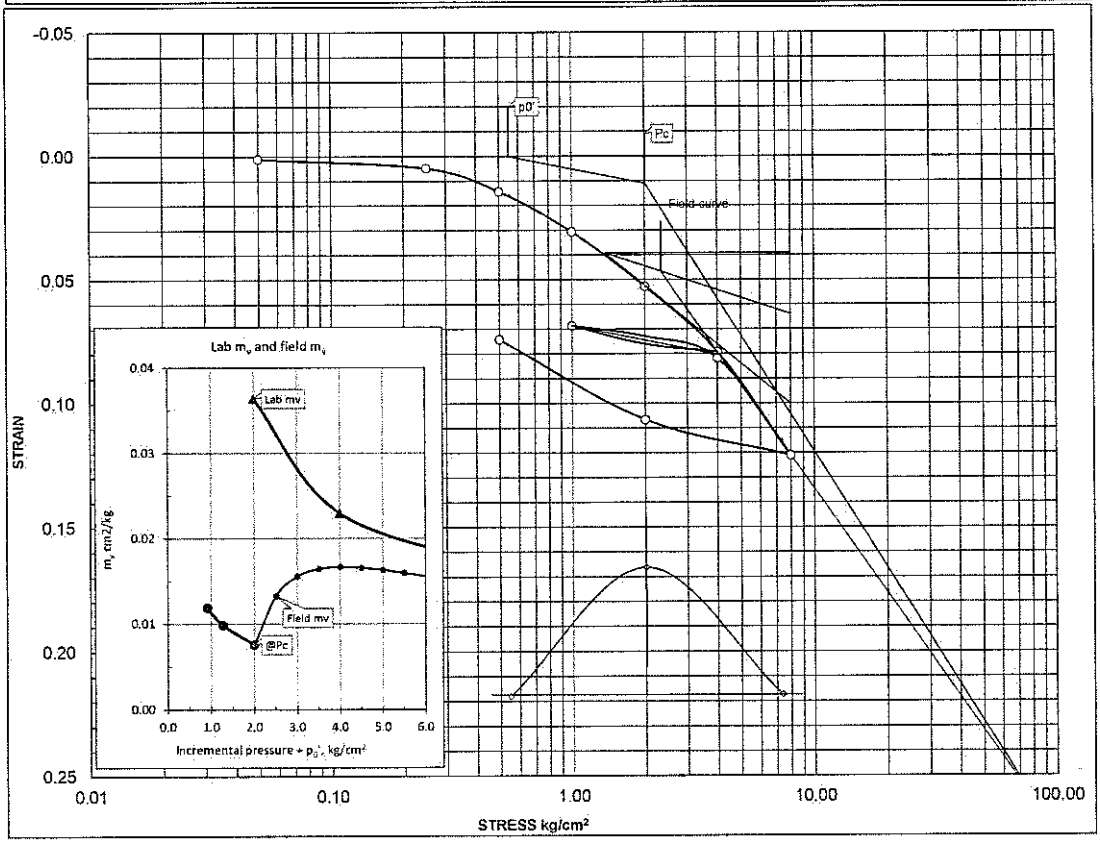
Wt of Consolidation Ring gm :	188.73	Diameter of ring mm :	59.85
Wt of Ring + wet Soil gm :	292.08	Height of ring mm :	19.45
Wt of Wet Soil gm :	103.35	Volume of Ring :	54.74
Wt of Wet Soil after test gm :	102.85	Specific Gravity :	2.600
Wt of ring + Dry Soil gm :	266.92	Initial Void Ratio :	0.82
Wt of Dry soil gm :	78.19	Moisture Content % :	32.18
Wet Density gm/cc :	1.888	Moisture after Test %:	31.54
Dry Density gm/cc :	1.428	Height of Solids mm :	10.685
Liquid Limit %	52.20	Saturated Moisture %:	31.55
Plastic Limit %	24.70	Per cent Saturation :	101.99
Plasticity Index	27.50		
Liquidity Index	0.272		

PROJECT: **Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in**

BH NO: **BH/1** DEPTH **2.25m**

SOIL: **Brownish grey silty clay with fine sand**

Stress kg/cm²	Dial div	Incr div	Comp mm	Strain	Height mm	Void ratio	T_{90} min	$C_{v(90)}$ m²/yr	T_{50} min	$C_{v(50)}$ m²/yr	Δ_p kg/cm²	m_v cm²/kg	E_c kg/cm²
0.00	4472	0	0.000	0.0000	19.45	0.820	–	–	–	–	–		
0.05	4462	10	0.020	0.0010	19.43	0.818	–	–	–	–	–		
0.25	4425	47	0.094	0.0048	19.36	0.811	–	–	–	–	–		
0.50	4332	140	0.280	0.0144	19.17	0.794	–	–	–	–	–		
1.00	4174	298	0.596	0.0306	18.85	0.764	71.2	0.57	18.0	0.52	0.45	0.0681	14.7
2.00	3959	513	1.026	0.0528	18.42	0.724	91.4	0.42	18.9	0.48	1.45	0.0364	27.5
4.00	3702	770	1.540	0.0792	17.91	0.678	79.6	0.46	16.2	0.53	3.45	0.0229	43.6
1.00	3804	668	1.336	0.0687	18.11	0.695	–	–	–	–	–	–	–
4.00	3677	795	1.590	0.0817	17.86	0.671	338.6	0.11	–	–	3.00	0.0044	229.7
8.00	3295	1177	2.354	0.1210	17.10	0.600	103.4	0.33	30.0	0.26	7.45	0.0162	61.6
2.00	3435	1037	2.074	0.1066	17.38	0.626	–	–	–	–	–		
0.50	3750	722	1.444	0.0742	18.01	0.685	–	–	–	–	–		
0.00	3953	519	1.038	0.0534	18.41	0.723	–	–	–	–	–		



Compression Ratio CR [= cc/(1+e0)]		0.1556*	0.1134^	
Re-compression ratio RR [= cr/(1+e0)]		0.0196	0.0196	
Effective overburden presure			0.550	kg/cm²
Pre-consolidation Pressure P_c	(Schmertmann)		2.012	kg/cm²
Pre-consolidation Pressure P_c	(Casagrande)		2.334	kg/cm²
Coefficient of secondary consolidation $C_{\alpha\varepsilon}$			2.86E-03 up to 200 kN/m²	3.99E-03 up to 800 kN/m²

OCR	3.95	* Schmertmann, ^ Casagrande	
CR/RR	5.79	from	to
Lab m_v	(cm^2 /kg)	0.0162	0.0681
Field m_v	(cm^2 /kg)	0.0075	0.0167
Note: for settlement estimations, use field m_v			

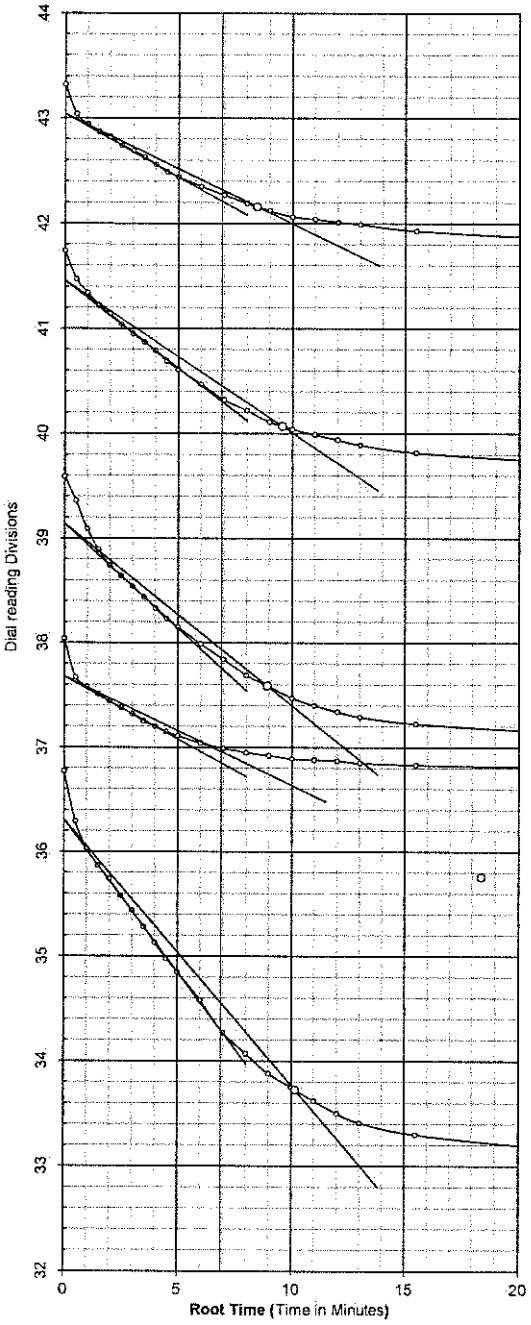
Note: mv values are from effective overburden pressure only

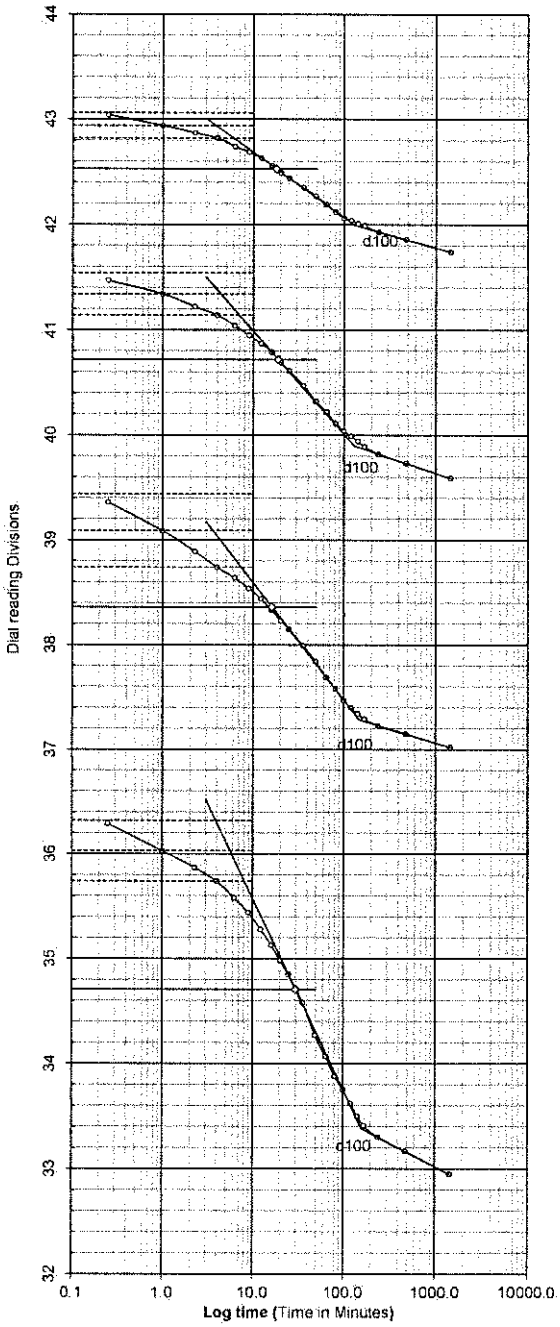
Date May 3, 2022

GEOTECHNICAL Solutions, Chennai

ONE DIMENSIONAL CONSOLIDATION TEST RESULTS

Project: Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC
Bore hole: BH/1 Depth 2.25m
Soil: Brownish grey silty clay with fine sand





Range kg/cm^2	t_{90} min	Coefficient of cons c_{v1} m^2/year
0.50 to 1.00	71.20	0.566
1.00 to 2.00	91.40	0.424
2.00 to 4.00	79.60	0.462
1.00 to 4.00	338.60	0.106
4.00 to 8.00	103.40	0.329

Range kg/cm^2	t_{50} min	c_{v2} m^2/year	Coefficient of sec. consolidation $C_{\alpha c}$
0.50 to 1.00	17.95	0.521	2.58E-03
1.00 to 2.00	18.87	0.477	3.15E-03
2.00 to 4.00	16.16	0.529	2.90E-03
-	-	-	-
4.00 to 8.00	29.97	0.264	5.09E-03

ONE DIMENSIONAL CONSOLIDATION TEST RESULTS

ANNEXURE C-2

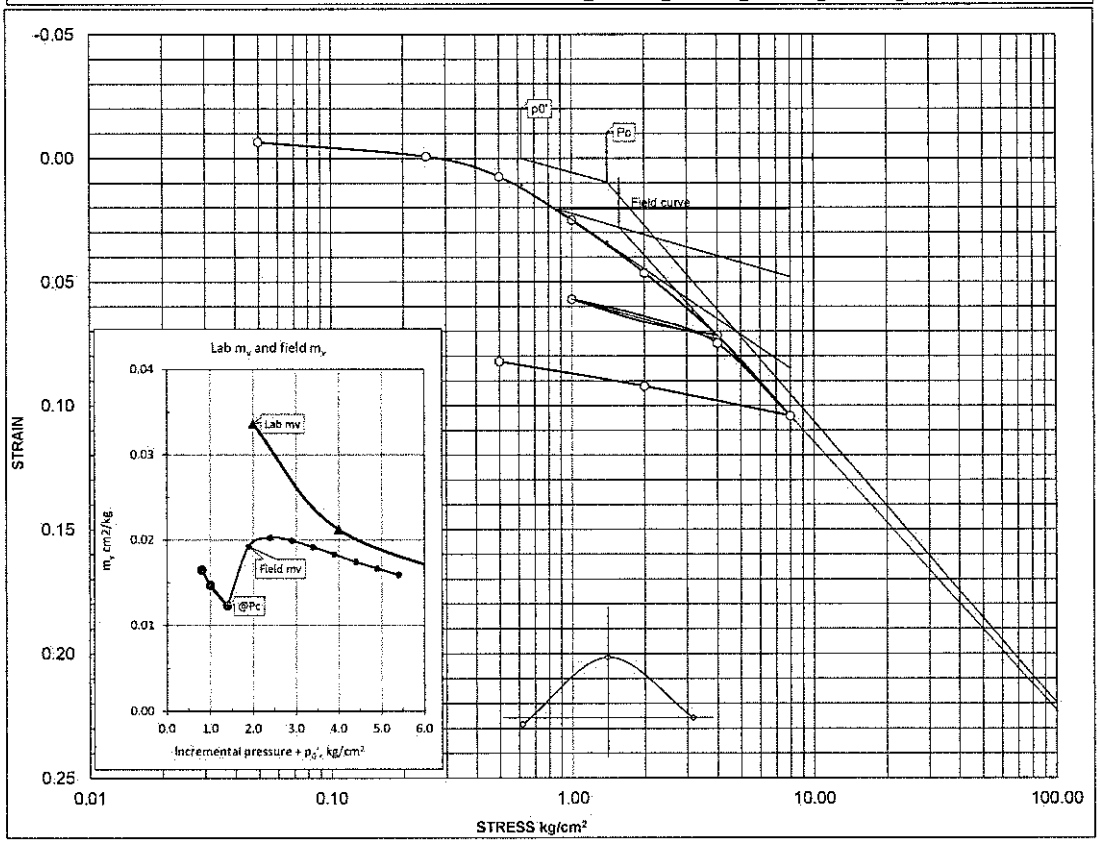
strain - log p curve

Test Data

Wt of Consolidation Ring gm :	254.63	Diameter of ring mm :	70.00
Wt of Ring + wet Soil gm :	394.80	Height of ring mm :	20.00
Wt of Wet Soil gm :	140.17	Volume of Ring :	77.00
Wt of Wet Soil after test gm :	140.37	Specific Gravity :	2.591
Wt of ring + Dry Soil gm :	358.09	Initial Void Ratio :	0.93
Wt of Dry soil gm :	103.46	Moisture Content % :	35.48
Wet Density gm/cc :	1.820	Moisture after Test %:	35.68
Dry Density gm/cc :	1.344	Height of Solids mm :	10.372
Liquid Limit %	66.40	Saturated Moisture %:	35.83
Plastic Limit %	31.40	Per cent Saturation :	99.03
Plasticity Index	35.00		
Liquidity Index	0.117		

PROJECT:	Geotechnical Investigation for Proposed Construction of (G+5)	
BH NO:	BH/3	DEPTH 3.00m bot
SOIL:	Brownish grey silty clay	

Stress kg/cm²	Dial div	Incr div	Comp mm	Strain	Height mm	Void ratio	T_{50} min	$C_{v(50)}$ m^2/yr	T_{50} min	$C_{v(50)}$ m^2/yr	Δ_p kg/cm²	m_v cm^2/kg	E_C kg/cm²
0.00	4532	0	0.000	0.0000	20.00	0.928	–	–	–	–	–		
0.05	4598	-66	-0.132	-0.0066	20.13	0.941	–	–	–	–	–		
0.25	4540	-8	-0.016	-0.0008	20.02	0.930	–	–	–	–	–		
0.50	4458	74	0.148	0.0074	19.85	0.914	–	–	–	–	–	–	–
1.00	4281	251	0.502	0.0251	19.50	0.880	37.3	1.16	6.4	1.57	0.38	0.0661	15.1
2.00	4068	464	0.928	0.0464	19.07	0.839	59.1	0.70	16.2	0.60	1.38	0.0336	29.7
4.00	3815	717	1.434	0.0717	18.57	0.790	69.9	0.56	15.3	0.60	3.38	0.0212	47.1
1.00	3962	570	1.140	0.0570	18.86	0.818	–	–	–	–	–	–	–
4.00	3783	749	1.498	0.0749	18.50	0.784	49.0	0.79	–	–	3.00	0.0060	167.6
8.00	3490	1042	2.084	0.1042	17.92	0.727	93.3	0.40	26.7	0.32	7.38	0.0141	70.8
2.00	3610	922	1.844	0.0922	18.16	0.751	–	–	–	–	–		
0.50	3710	822	1.644	0.0822	18.36	0.770	–	–	–	–	–		
0.00	3905	627	1.254	0.0627	18.75	0.807	–	–	–	–	–		



Compression Ratio CR [= cc/(1+e0)]		0.1134*	0.0960^		OCR	2.40	* Schmertmann, ^ Casagrande
Re-compression ratio RR [= cr/(1+e0)]		0.0271	0.0271		CR/RR	3.54	from / to
Effective overburden presure			0.620	kg/cm²	Lab m_v	(cm^2 /kg)	0.0141 / 0.0661
Pre-consolidation Pressure P_c	(Schmertmann)		1.400	kg/cm²	Field m_v	(cm^2 /kg)	0.0123 / 0.0203
Pre-consolidation Pressure P_c	(Casagrande)		1.574	kg/cm²	Note: for settlement estimations, use field m_v		
Coefficient of secondary consolidation $C_{\alpha\varepsilon}$			2.06E-03 up to 200 kN/m²			3.58E-03 up to 800 kN/m²	

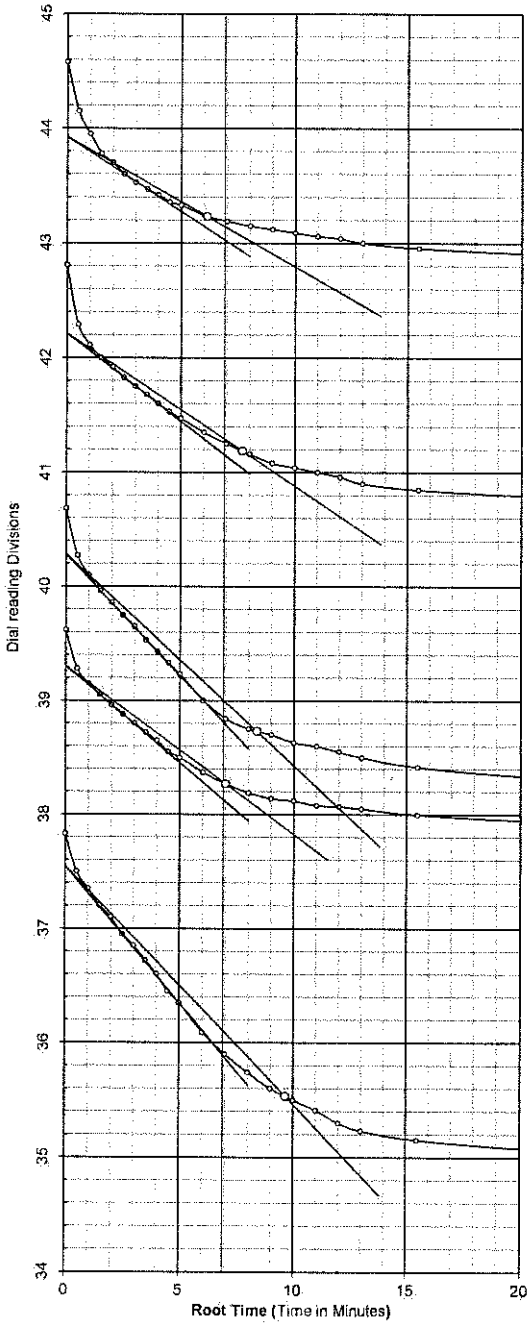
Note: mv values are from effective overburden pressure only

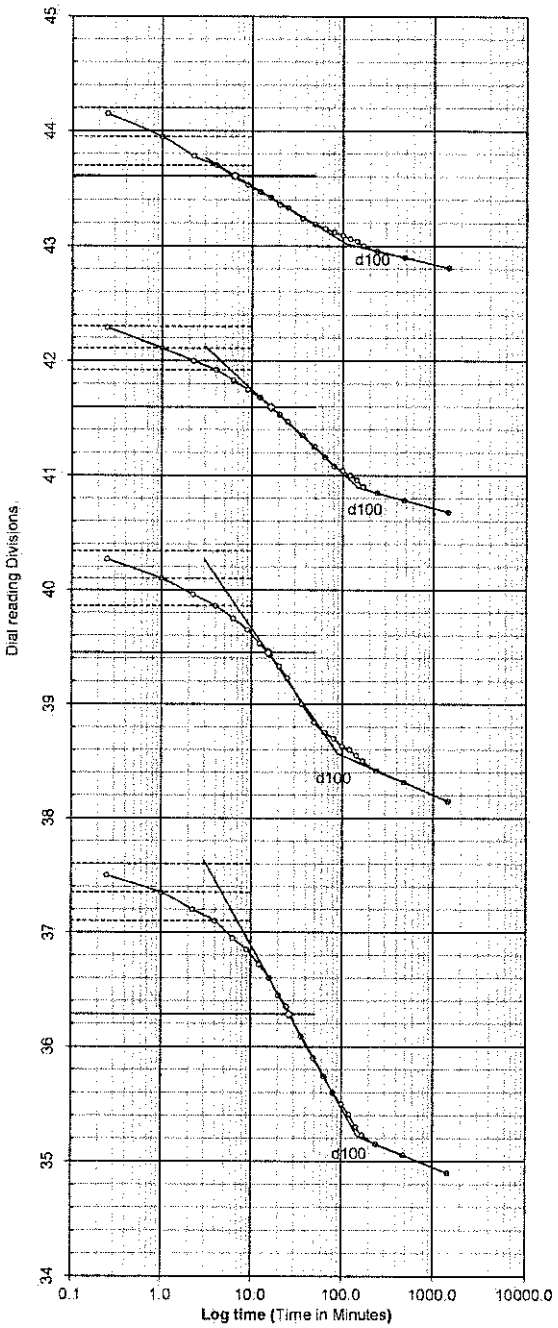
Date May 6, 2022

GEOTECHNICAL Solutions, Chennai

ONE DIMENSIONAL CONSOLIDATION TEST RESULTS

Project: Geotechnical Investigation for Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC
Bore hole: BH/3 Depth 3.00m bgl
Soil: Brownish grey silty clay





Range kg/cm^2	t_{90} min	Coefficient of cons c_{vt} m^2/year
0.50 to 1.00	37.30	1.156
1.00 to 2.00	59.10	0.701
2.00 to 4.00	69.90	0.565
1.00 to 4.00	49.00	0.794
4.00 to 8.00	93.30	0.396

Range kg/cm^2	t_{50} min	c_{v2} m^2/year	Coefficient of sec. consolidation $C_{\alpha c}$
0.50 to 1.00	6.40	1.566	1.90E-03
1.00 to 2.00	16.16	0.596	2.23E-03
2.00 to 4.00	15.27	0.600	3.63E-03
	-	-	-
4.00 to 8.00	26.66	0.322	3.53E-03

ANNEXURE U-1

Unconfined Compression Strength Test UCC on soil sample

Project:

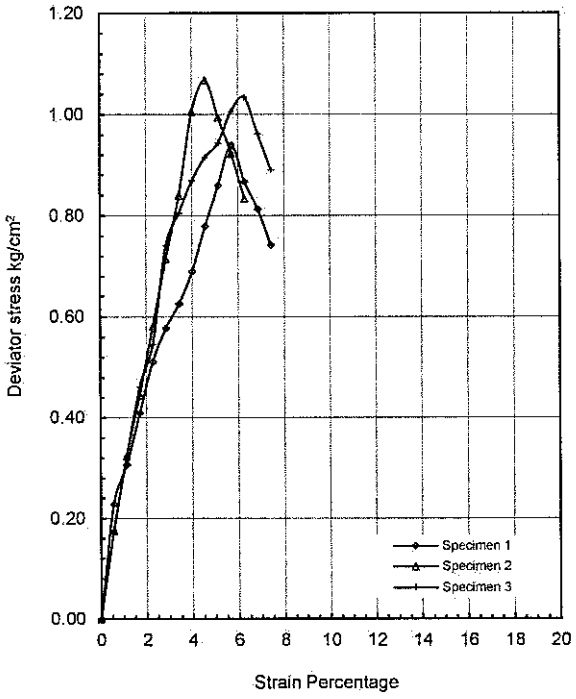
Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC

Date of Test	**06-May-22**
Borehole	**BH/1**
Depth	**2.25m**

Soil

Brownish grey silty clay with fine sand

Insitu bulk density	1.867 gm/cc
Insitu Dry Density	1.404 gm/cc
Water Content	32.98 %
Liquid Limit %	52.20
Plastic Limit %	24.70
Plasticity Index %	27.50
Liquidity Index	0.30

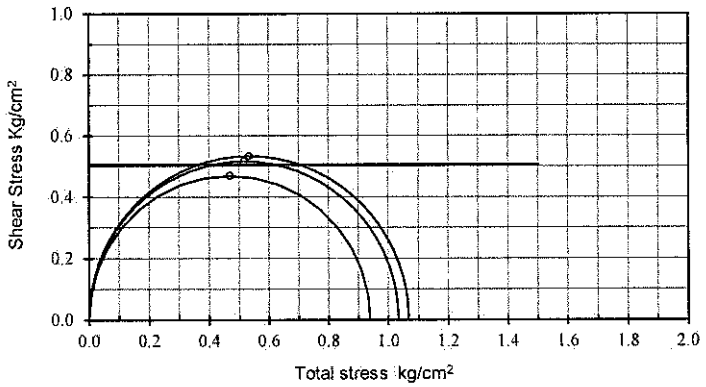


Maximum Shear Stress

Specimen No:	Deviator stress	Shear stress kg/cm²
Specimen 1	0.939	0.470
Specimen 2	1.068	0.534
Specimen 3	1.034	0.517

Results

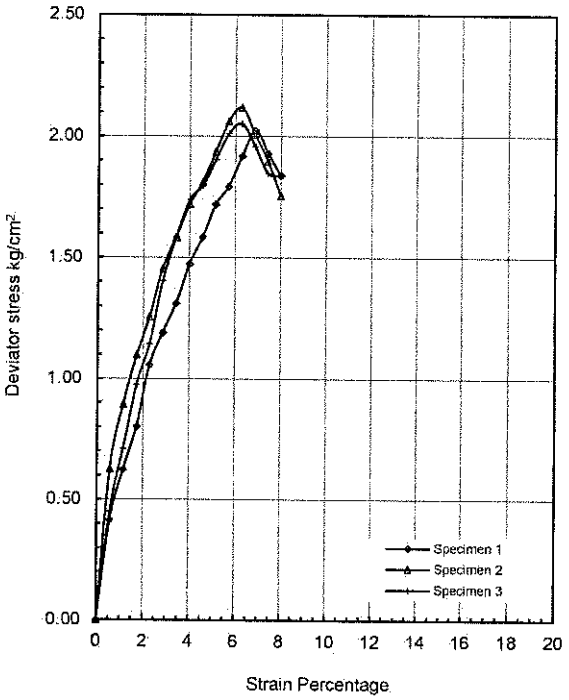
Unconfined compression strength q_u	1.014	kg/cm²
Undrained Cohesion c_u	0.507	kg/cm²
Secant Modulus (undrained)	25.59	kg/cm²



Unconfined Compression Strength Test UCC on soil sample

Project:

Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC



Date of Test	**08-May-22**
Borehole	**BH/3**
Depth	**3.00m**

Soil

Brownish grey silty clay

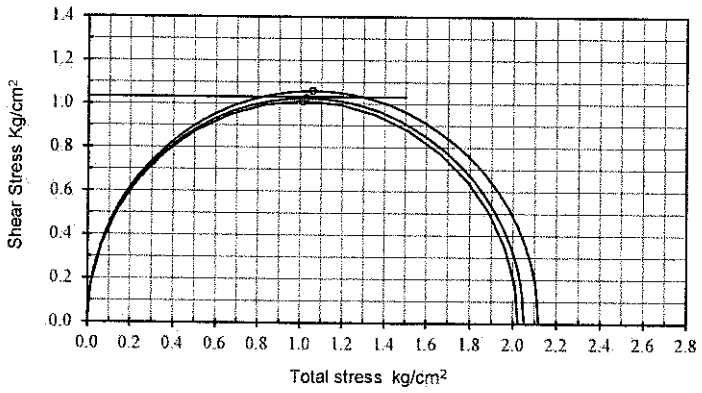
Insitu bulk density	1.870 gm/cc
Insitu Dry Density	1.404 gm/cc
Water Content	33.14 %
Liquid Limit %	69.90
Plastic Limit %	32.10
Plasticity Index %	37.80
Liquidity Index	0.03

Maximum Shear Stress

Specimen No:	Deviator stress	Shear stress kg/cm²
Specimen 1	2.024	1.012
Specimen 2	2.118	1.059
Specimen 3	2.052	1.026

Results

Unconfined compression strength q_u	2.065	kg/cm²
Undrained Cohesion c_u	1.032	kg/cm²
Secant Modulus (undrained)	58.44	kg/cm²

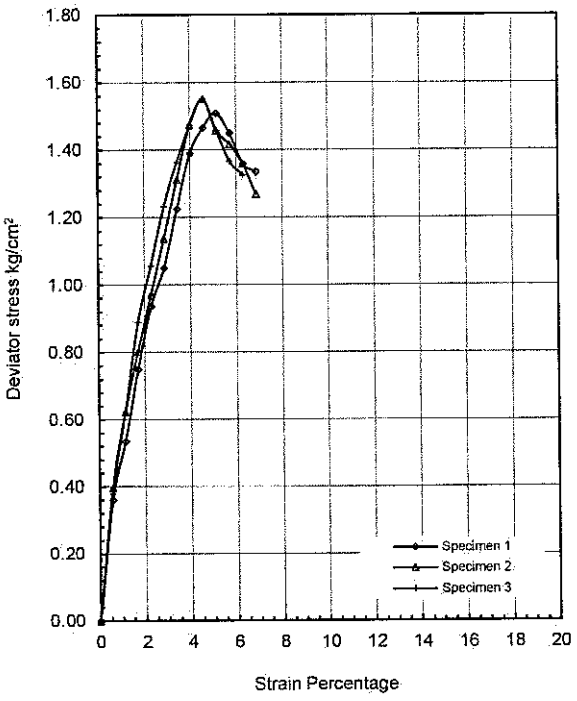


ANNEXURE U-3

Unconfined Compression Strength Test UCC on soil sample

Project:

Proposed Construction of (G+5) EWS Tenements at Gandhi Nagar in Corp DN 96 Zone 8 of GCC



Date of Test	**14-May-22**
Borehole	**BH/6**
Depth	**3.00m**

Soil

Greyish silty clay with brown patches

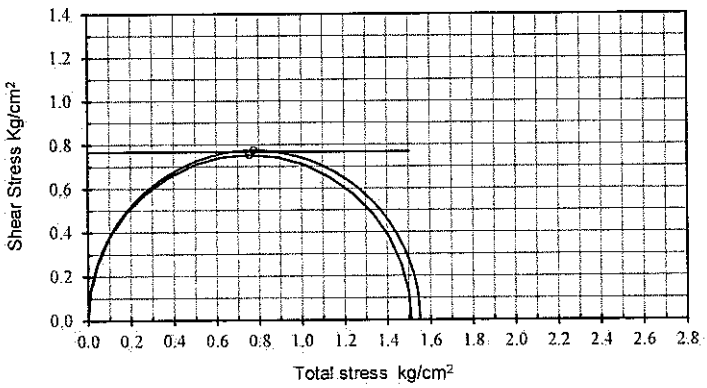
Insitu bulk density	1.918 gm/cc
Insitu Dry Density	1.462 gm/cc
Water Content	31.19 %
Liquid Limit %	65.00
Plastic Limit %	24.40
Plasticity Index %	40.60
Liquidity Index	0.17

Maximum Shear Stress

Specimen No:	Deviator stress	Shear stress kg/cm²
Specimen 1	1.509	0.755
Specimen 2	1.551	0.776
Specimen 3	1.551	0.776

Results

Unconfined compression strength q_u	1.537 kg/cm²
Undrained Cohesion c_u	0.769 kg/cm²
Secant Modulus (undrained)	49.85 kg/cm²



CUBE/BLDG/TNUHDB/151/2022-23 06 Sep 2022

Er. S. Sudalai Muthukumar,
Executive Engineer (I/C),
Division III,
Tamil Nadu Urban Habitat Development Board,
Vyasarpadi,
Chennai-600039.

GEOTECHNICAL INVESTIGATION REPORT SUBMISSION FOR RECONSTRUCTION OF 500 (G+5) TENEMENTS AT GANDHI NAGAR SCHEME IN CORPORATION DIVISION 96, ZONE 8 OF GCC, CHENNAI.

Sir,

1. Please refer to:

   (a) Your Work Order Letter No. /JE(P)/2022 dated 06 April 2022.
   (b) CUBE's Proposal for the said assessment CUBE/BLDG/TNUHDB/016A/2022-23 dated 02 May 2022.

2. Geotechnical Investigation report for the Gandhi Nagar scheme is enclosed herewith.

3. Request Acknowledgement.

B. John Joseph
Senior Manager – Projects
Building & Constructions
CUBE.

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