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GEOTECHNICAL SITE INVESTIGATION

BORING 1 AND 2

PROPOSED RESIDENTIAL APARTMENTS BUILDING SITE

"KURINJI ELITE"

NO. 174 AND 175, KURINJI COLONY, 4TH AVENUE

SHANTHI COLONY, ANNA NAGAR, CHENNAI 600 040, TN.

Report to

M/s. India Builders (Chennai) Ltd.
No. AA – 36, 3rd Main Road, 3rd Street
Anna Nagar, Chennai 600 040, TN.

Dr. B. Ram Prasad ME, Ph D (Texas A&M)
N. No. 821, O. No. 439/4 Poonamallee High Road
Arumbakkam, Chennai 600 106.
Phone: 9384752246; E-Mail: paygec@gmail.com

Report No. 006/BRP/24-25.
May 30, 2024.

M/s. India Builders (Chennai) Ltd.
No. AA – 36, 3rd Main Road, 3rd Street
Anna Nagar, Chennai 600 040, TN.

Attention: Mr. R. Surya
Asst. Structural Engineer

Geotechnical Site Investigation
Boring 1 and 2
Proposed Residential Apartments Building Site
"Kurinji Elite"
No. 174 and 175, Kurinji Colony, 4th Avenue
Shathi Colony, Anna Nagar, Chennai 600 040, TN.

The Prasad Armstrong Yen GEC (P) Ltd., Chennai is pleased to submit this report on our geotechnical site investigation conducted at the above location. This work was authorized by your confirmation e-mail dated April 26, 2024.

Estimated capacities of the foundations recommended for the proposed building are presented here in final form together with a summary of laboratory and field data.

We appreciate the opportunity to be of service to you on this project. Please call us if you have any questions or when we can be of further assistance.

Sincerely,



B. Ram Prasad ME, PhD (Texas A&M)
CMDA Registration No. GTE/2024/2/0055

Copies Submitted: (3)

CHENNAI METROPOLITAN DEVELOPMENT AUTHORITY
Thalamuthu Natarajan Building, No.1, Gandhi Irwin Road, Egmore,
Chennai - 600 008
Phone : 28414855 Fax: 91-044-28548416
E-mail: mscmda@tn.gov.in
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PROFESSIONAL REGISTRATION CERTIFICATE

This is to certify that the Thiru / Tmt. / M/s. **Dr. B. Ram Prasad** has enrolled as **Registered Geo Tech Engineer** with Chennai Metropolitan Development Authority (CMDA) who has the qualification of **Equivalent degree** and experience in the relevant field for **35** years.

He/She has been given the Registration No. **GTE/2024/2/0055** on **29-Feb-2024** He/She shall be required to comply with the duties and responsibilities prescribed by the Government of Tamil Nadu in Part V, "Registration of Professionals", Tamil Nadu Combined Development and Building Rules, 2019 approved vide G.O.(ms) No.18 MAWS (MA1) Dept. Dated. 04.02.2019.

This Registration is valid upto **27-Feb-2029**.

Signature valid
Name :A Meganathan
Designation :Superintendent
Date :02/29/2024 3:07:28 PM



A Meganathan

Superintendent

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SUMMARY

Prasad Armstrong Yen GEC (P) Ltd. performed a geotechnical site investigation at the Proposed Residential Apartments Building Site, "**Kurinji Elite**", No. 174 and 175, Kurinji Colony, 4th Avenue, Shanthi Colony, Anna Nagar, Chennai 600 040, TN. The primary purpose of our investigation was to obtain data to identify foundation type and estimate load carrying capacity of the selected foundation for the proposed Stilt + 4 floors building. For the proposed building type typical maximum column load will be about 175 tons. These load details were used only for estimating the preliminary foundation size and type of foundation.

The field investigation was performed May 20 through 23, 2024. Number and location of the borings was selected to cover the proposed building area. Boring 1 and 2 were drilled to 28-, and 28.5-M below the Existing Ground Level (EGL), respectively. Both borings were terminated with at least 4-M drilling through the hard strata sand and shale with SPT "N_{avg}" $\geq$ 75. Borings were drilled beyond 10-M due to presence of very loose sand, soft clay soils and potentially liquefiable soils between 9- and 16-M below EGL. Tests were conducted to determine the pertinent index and engineering properties of the soils encountered. We then performed engineering analyses to develop the required design data.

Natural topography of the site reflects a flat terrain. Site was a corner plot with 4th Avenue along the southern boundary, and 6th Cross Street along the eastern boundary. Visual observation infers site's EGL was at about the Existing Road Level (ERL) of 4th Avenue, and 0.15-M above ERL of 6th Cross Street in front of the site. Compound wall was present along three boundaries of the site except western boundary that was open with adjacent construction site. No significant vegetation was present in the site. Proposed construction will be the first major construction activity of this magnitude to cover the site. Soil stratigraphy at the borings is tabulated below:

Boring – 1:

Stratum	Penetration, M From	To	Description
I	0	2.0	Brown Silty Fine to Coarse Sand with Brick and Stone Pieces – Filled Up Soil
II	2.0	2.75	Brown Very Stiff Clay
III	2.75	6.0	Brown Gray Stiff to Very Stiff Clay
IV	6.0	8.75	Brown Fine to Medium Sand with Silt
V	8.75	9.75	Gray Fine to Medium Sand with Silt
VI	9.75	11.5	Gray Soft Clay
VII	11.5	16.0	Gray Green Fine to Medium Sand with Silt
VIII	16.0	20.75	Brown Gray Red Yellow Hard Clay
IX	20.75	24.5	Brown Fine to Medium Sand with Silt
X	24.5	26.5	Brown Gray Yellow Silty Fine to Medium Sand
XI	26.5	28.0+	Brown Gray Very Hard Clay - Shale

Boring – 2:

Stratum	Penetration, M From	To	Description
I	0	2.0	Brown Silty Fine to Coarse Sand with Brick and Stone Pieces – Filled Up Soil
II	2.0	6.0	Brown Gray Stiff to Very Stiff Clay
III	6.0	7.75	Brown Fine to Medium Sand with Silt
IV	7.75	8.75	Gray Silty Fine Sand
V	8.75	13.0	Gray Fine to Medium Sand with Silt
VI	13.0	16.0	Red Brown Gray Green Fine to Medium Sand
VII	16.0	20.5	Brown Gray Red Green Hard Clay
VIII	20.5	26.5	Brown Gray Red Yellow Fine to Medium Sand with Silt
IX	26.5	28.5+	Brown Gray Very Hard Clay - Shale

Data from borings infer presence of soil profiles with weak soils between 9- and 16-M below EGL for the expected column loads. Also, liquefaction analysis inferred potential for liquefaction settlements in the top 16-M for encountered soil profiles. Therefore, for the encountered soil profiles and expected column loads shallow foundation was not recommended as foundation can undergo significant settlements due to static and seismic conditions. For the proposed building it was **recommended** to provide "**Tractor Mounted Direct Mud Circulation (DMC) Cast In-Situ Pile**" foundation. Recommended type of pile installation work will have low construction vibrations otherwise it may affect the existing building foundations and also lead to objections from adjacent building owners. It was recommended to provide a minimum **25- and 24-M total and effective length piles** with top 1-M pile cutoff for pile caps and plinth beams. Ultimate and allowable pile capacities of various pile diameters were summarized below:

Pile Dia. M	Compressive Capacity		Uplift Capacity		Lateral Capacity @ 5 mm Defl.
	Ultimate Tons	Allowable Tons	Ultimate Tons	Allowable Tons	Allowable Tons
0.45	237.70	**86**	163.70	**55**	**3.66**
0.50	274.29	**100**	182.55	**61**	**4.13**
0.60	353.86	**129**	220.65	**74**	**5.09**
0.75	489.51	**178**	278.78	**93**	**6.52**
0.90	645.27	**235**	338.10	**113**	**7.96**

It was recommended to provide at least a two-pile group using suitable pile diameter instead of single pile - single column for better resistance to bending forces from column loads and seismic forces. In case of columns for lift or staircase area or places with close column spacing, and low column loads single pile per column can be provided with a common pile cap. Also, **piles should be structurally designed as cantilever columns from non-liquefiable layer with higher bending / flexural capacity for better resistance to lateral forces during seismic events due to potential for liquefaction and lateral movement of liquefied soil in saturated conditions**. All the pile caps should be tied together through rigid plinth beams. In case single pile and single column unit is considered then extreme care should be taken to match center line of pile and column to minimize eccentricity to avoid additional bending moments in the pile. **Piles should be terminated in the hard strata with at least 1-M embedment.**

A 1.2-M diameter open well of unknown depth was present NW corner of the site at about 21.9-M from Boring 1. In the open well groundwater was at about 3.8-M below EGL. Groundwater sample was collected from the open well for construction suitability tests. Test results indicate that tested groundwater from the open well was **suitable** for construction purposes as per IS: 456-2000. Chemical tests were performed on soil samples from 2-, and 24.5-M of Boring 1, and 3- and 22.5-M of Boring 2. Soil samples were tested for pH, Chlorides, and Sulphates. A 5% soil solution was initially prepared by mixing with distilled water. This solution was allowed to soak and settle for 24 hours. After that soil solution was filtered pH test was performed on the derived solution. Test results infer presence of **less than limiting concentrations** adverse chemicals in the tested soil samples as per IS: 456 – 2000 code guidelines for construction water. It was recommended to check site's groundwater quality at regular intervals from beginning of construction activities. If necessary, suitable groundwater treatment should be adopted to make groundwater acceptable for construction purposes.

We not expect construction problems at this site due to site soil and groundwater conditions during non-rainy season. Site's EGL was at about ERL of 4th Avenue in front of the site. In order to minimize future site flooding from road runoff it was recommended to raise site's FGL by **at least 0.6-M above ERL** of road in front of the site, and the Finished Floor Level (FFL) of stilt floor should be 0.25-M above FGL of the site. Foundation excavation, site, and building basement fillings should be done with granular soils with proper compaction to achieve a minimum unit weight of 2.0 tons/M^3.

Proper care should be taken in pile installation to avoid **pile necking / bulging / improper concreting** during pile installation due to presence of clean and layers of loose sand soils in the soil profiles. Pile bulging can be expected between 9- and 16-M below EGL. Piles should be terminated in hard strata only. At pile termination depth bore should be properly washed and cleaned of all loosened material to prevent low end bearing capacity of the pile. In the initial piles SPT may be performed at pile termination depth after wasting to confirm the proper cleaning of bore, and generate the site specific correlation of the drilling rate of the specific rig and SPT values of the hard strata. Extreme care should be taken during pile installation including use of good quality bentonite and bentonite solution of suitable specific gravity to minimize and prevent pile side wall collapse in thick layers of sand soils. **Hydraulic rigs were not recommended for this site soil conditions.** Pile load tests should be conducted as per relevant IS code to confirm the load carrying capacities recommended above and also to check the quality of pile installation.

All structures have to be designed for higher seismic forces (**Zone III**) due to increased seismic activity in peninsular India in the last decade and half. Seismic events of 5.1 magnitude on August 24, 2021, 5.1 magnitude on February 12, 2019, 7.9 magnitude on April 25, 2015, 6.0 magnitude on May 21, 2014, 8.4 magnitude on April 11, 2012, 7.2 magnitude on June 13, 2010, and 7.6 magnitude on August 11, 2009 with epicenters in Himalayas, Bay of Bengal, and near Andaman Islands were felt at Chennai. It is recommended to provide rigid plinth beams in ground level, columns designed for shear forces or shear walls in the structure, and continuous lintels in each floor. Lintels must be integrated into columns of the structure. Plinth beams must be designed to be rigid to allow redistribution of loads in case of differential settlements. The site soil profile infers **"Medium to High"** seismic susceptibility. Under IS code **Zone III** design seismic event of **6.0 Richter scale**, and peak ground acceleration of **0.16g** the total estimated vertical settlement was 34.54 cms and total horizontal displacement was about 379.62 cms. Iwasaki liquefaction potential was 10.44 inferring "**Liquefaction Probable**."

INTRODUCTION

Purpose and Scope

Prasad Armstrong Yen GEC (P) Ltd. performed a geotechnical site investigation at the Proposed Residential Apartments Building Site, "**Kurinji Elite**", No. 174 and 175, Kurinji Colony, 4th Avenue, Shanthi Colony, Anna Nagar, Chennai 600 040, TN. The primary purpose of our investigation was to obtain data to identify foundation type and estimate load carrying capacity of the selected foundation for the proposed Stilt + 4 floors building. For the proposed building type typical maximum column load will be about 175 tons. These load details were used only for estimating the preliminary foundation size and type of foundation. To accomplish these purposes, the following tasks were performed:

(1) Boring 1, and 2 were drilled to 28-, and 28.5-M below EGL, respectively to explore the subsurface stratigraphy and obtain soil samples for laboratory testing;

(2) Field and laboratory tests were conducted to evaluate the pertinent index and engineering properties of the foundation materials; and

(3) Engineering analyses were performed to develop foundation design information for the proposed building.

Report Format

The initial sections of this report contain brief descriptions of the field and laboratory phases of our study. A general soils description is then presented, followed by discussions of foundation design recommendations followed by a brief on construction considerations for this project.

FIELD AND LABORATORY INVESTIGATIONS

Exploratory Borings

Soil conditions at the site were explored by Boring 1 and 2. Bore location details were presented on Plate 1. Number and location of the borings was selected to cover the proposed building area. Boring 1 and 2 were drilled to 28-, and 28.5-M below EGL, respectively. Both borings were terminated with at least 4-M drilling through the hard strata sand and shale with SPT "N_{avg}" $\geq$ 75. Borings were drilled beyond 10-M due to presence of very loose sand, soft clay soils and potentially liquefiable soils between 9- and 16-M below EGL. Tests were conducted to determine the pertinent index and engineering properties of the soils encountered. We then performed engineering analyses to develop the required design data. Groundwater was at about 3.8-M below EGL in the site's open well. Log of Boring were presented on Plate 2 and 3.

Field and Laboratory Tests

Boring was drilled using Calyx drilling unit. In the boring SPT was performed at 1-M interval up to 10-M, at 1.5-M interval up to 20.5-M, and at 2-M beyond 20.5-M. Soil samples for laboratory tests were collected from SPT split spoon sampler. SPT consists of driving a standard split spoon sampler, 50.8-mm outside diameter and 35-mm inside diameter into soil under the blows of a drop hammer of

63.5 kg falling weight freely through 75-cm. The number of blows required for 30-cm of penetration of sampler in soil is designated as N value and it is termed as the SPT blow count. Detailed information regarding SPT can be found in the IS: 2131 code of practice.

The soil-testing program was designed to evaluate pertinent index and engineering properties of the foundation soils. During the field operations soil samples were collected at 1-, 1.5-, and 2-M intervals either disturbed or undisturbed as the case may be. All soil samples were shipped to our Chennai laboratory where pertinent index properties – grain size analyses, natural water content Atterberg limit tests were performed on collected soil samples. All the test results were tabulated on the Summary of Test Results on Plate 4. Grain size distribution curves of tested soil are presented on Plate 5. Summary of Water and Soil Chemical Test Results are presented on Plate 6.

GENERAL SOIL CONDITIONS

Topography

Natural topography of the site reflects a flat terrain. Site was a corner plot with 4th Avenue along the southern boundary, and 6th Cross Street along the eastern boundary. Visual observation infers site's EGL was at about ERL of 4th Avenue, and 0.15-M above ERL of 6th Cross Street in front of the site. Compound wall was present along three boundaries of the site except western boundary that was open with adjacent construction site. No significant vegetation was present in the site. Proposed construction will be the first major construction activity of this magnitude to cover the site.

Soil Stratigraphy

The soil stratigraphy disclosed by our field and laboratory investigations of the boring was presented on the log of boring on Plate 2 and 3. The soil stratigraphy is based on classification of soil samples recovered from the boring, and our observations during drilling operations. A generalized summary of the major soil strata is tabulated below:

Boring – 1:

Stratum	Penetration, M From	To	Description
I	0	2.0	Brown Silty Fine to Coarse Sand with Brick and Stone Pieces – Filled Up Soil
II	2.0	2.75	Brown Very Stiff Clay
III	2.75	6.0	Brown Gray Stiff to Very Stiff Clay
IV	6.0	8.75	Brown Fine to Medium Sand with Silt
V	8.75	9.75	Gray Fine to Medium Sand with Silt
VI	9.75	11.5	Gray Soft Clay
VII	11.5	16.0	Gray Green Fine to Medium Sand with Silt
VIII	16.0	20.75	Brown Gray Red Yellow Hard Clay
IX	20.75	24.5	Brown Fine to Medium Sand with Silt
X	24.5	26.5	Brown Gray Yellow Silty Fine to Medium Sand
XI	26.5	28.0+	Brown Gray Very Hard Clay - Shale

Boring – 2:

Stratum	Penetration, M From	To	Description
I	0	2.0	Brown Silty Fine to Coarse Sand with Brick and Stone Pieces – Filled Up Soil
II	2.0	6.0	Brown Gray Stiff to Very Stiff Clay
III	6.0	7.75	Brown Fine to Medium Sand with Silt
IV	7.75	8.75	Gray Silty Fine Sand
V	8.75	13.0	Gray Fine to Medium Sand with Silt
VI	13.0	16.0	Red Brown Gray Green Fine to Medium Sand
VII	16.0	20.5	Brown Gray Red Green Hard Clay
VIII	20.5	26.5	Brown Gray Red Yellow Fine to Medium Sand with Silt
IX	26.5	28.5+	Brown Gray Very Hard Clay - Shale

Detailed soil descriptions that include textural variations and inclusions are noted on the log of boring presented on Plate 2 and 3.

Interpretation of Soil Properties

Shear strength parameters for cohesionless soils were selected based on the SPT, and grain size distribution analyses. Shear strength parameters for cohesive soils were selected based on the SPT results. The unit weight (soil density) profiles of the soils in the borings were developed from estimated values based on correlations of unit weight with particle size gradation and field test results (Bowles, 1982.)

Recommendations presented herein are based on the soil properties encountered in the Boring 1 and 2. There may be a need to drill additional borings to investigate soil variability if encountered during the foundation work. Based on the field and laboratory test results the following are the properties for soils encountered in the boring.

Boring – 1:

Stratum	Penetration, M From	To	Properties
I	0	2.0	$\phi = 34^o$; $\gamma_{sat} = 1.85$ tons/M^3
II	2.0	2.75	$C_u = 18$ tons/M^2; $\gamma_{sat} = 1.85$ tons/M^3
IIIa	2.75	4.0	$C_u = 7$ tons/M^2; $\gamma_{sat} = 1.65$ tons/M^3
IIIb	4.0	6.0	$C_u = 9$ tons/M^2; $\gamma_{sat} = 1.7$ tons/M^3
IVa	6.0	7.75	$\phi = 35^o$; $\gamma_{sat} = 1.95$ tons/M^3
IVb	7.75	8.75	$\phi = 34^o$; $\gamma_{sat} = 1.85$ tons/M^3
V	8.75	9.75	$\phi = 25^o$; $\gamma_{sat} = 1.5$ tons/M^3
VI	9.75	11.5	$C_u = 2$ tons/M^2; $\gamma_{sat} = 1.4$ tons/M^3
VII	11.5	16.0	$\phi = 24^o$; $\gamma_{sat} = 1.45$ tons/M^3
VIIIa	16.0	18.75	$C_u = 24$ tons/M^2; $\gamma_{sat} = 2.0$ tons/M^3
VIIIb	18.75	20.75	$C_u = 19$ tons/M^2; $\gamma_{sat} = 1.9$ tons/M^3
IXa	20.75	22.5	$\phi = 36^o$; $\gamma_{sat} = 2.0$ tons/M^3
IXb	22.5	24.5	$\phi = 38^o$; $\gamma_{sat} = 2.2$ tons/M^3
X	24.5	26.5	$\phi = 39^o$; $\gamma_{sat} = 2.25$ tons/M^3

XIa	26.5	28.0	C_u = 40 tons/M^2; γ_{sat} = 2.2 tons/M^3
XIb	28.0		C_u = 50 tons/M^2; γ_{sat} = 2.25 tons/M^3

Boring – 2:

	Penetration, M		
Stratum	From	To	Properties
I	0	2.0	$\phi = 25^o$; γ_{sat} = 1.5 tons/M^3
IIa	2.0	4.75	C_u = 11 tons/M^o; γ_{sat} = 1.7 tons/M^3
IIb	4.75	6.0	C_u = 7.5 tons/M^o; γ_{sat} = 1.65 tons/M^3
III	6.0	7.75	$\phi = 35^o$; γ_{sat} = 1.9 tons/M^3
IV	7.75	8.75	$\phi = 32^o$; γ_{sat} = 1.7 tons/M^3
V	8.75	13.0	$\phi = 24^o$; γ_{sat} = 1.4 tons/M^3
VIa	13.0	14.0	$\phi = 34^o$; γ_{sat} = 1.85 tons/M^3
VIb	14.0	16.0	$\phi = 31^o$; γ_{sat} = 1.65 tons/M^3
VIIa	16.0	18.5	C_u = 25 tons/M^o; γ_{sat} = 2.0 tons/M^3
VIIb	18.5	20.5	C_u = 19 tons/M^o; γ_{sat} = 1.85 tons/M^3
VIIIa	20.5	22.5	$\phi = 35^o$; γ_{sat} = 1.9 tons/M^3
VIIIb	22.5	24.5	$\phi = 36^o$; γ_{sat} = 2.0 tons/M^3
VIIIc	24.5	26.5	$\phi = 38^o$; γ_{sat} = 2.2 tons/M^3
IX	26.5	28.5+	C_u = 50 tons/M^o; γ_{sat} = 2.25 tons/M^3

DESIGN INFORMATION

Data from borings infer presence of soil profiles with weak soils between 9- and 16-M below EGL for the expected column loads. Also, liquefaction analysis inferred potential for liquefaction settlements in the top 16-M for encountered soil profiles. Therefore, for the encountered soil profiles and expected column loads shallow foundation was not recommended as foundation can undergo significant settlements due to static and seismic conditions. For the proposed building it was **recommended** to provide "**Tractor Mounted Direct Mud Circulation (DMC) Cast In-Situ Pile**" foundation. Recommended type of pile installation work will have low construction vibrations otherwise it may affect the existing building foundations and also lead to objections from adjacent building owners. It was recommended to provide a minimum **25- and 24-M total and effective length piles** with top 1-M pile cutoff for pile caps and plinth beams. Pile capacity was estimated as per the IS: 2911 - 2010 (Part 1 / Section 2) Code guidelines. Ultimate and allowable pile capacities of various pile diameters are summarized below:

Pile Dia. M	Compressive Capacity		Uplift Capacity		Lateral Capacity @ 4 mm Defl.
	Ultimate Tons	Allowable Tons	Ultimate Tons	Allowable Tons	Allowable Tons
0.45	237.70	**86**	163.70	**55**	**3.66**
0.50	274.29	**100**	182.55	**61**	**4.13**
0.60	353.86	**129**	220.65	**74**	**5.09**
0.75	489.51	**178**	278.78	**93**	**6.52**
0.90	645.27	**235**	338.10	**113**	**7.96**

It was recommended to provide at least a two-pile group using suitable pile diameter instead of single pile - single column for better resistance to bending forces from column loads and seismic forces. In case of columns for lift or staircase area or places with close column spacing, and low column loads single pile per column can be provided with a common pile cap. Also, **piles should be**

structurally designed as cantilever columns from non-liquefiable layer with higher bending / flexural capacity for better resistance to lateral forces during seismic events due to potential for liquefaction and lateral movement of liquefied soil in saturated conditions. All the pile caps should be tied together through rigid plinth beams. In case single pile and single column unit is considered then extreme care should be taken to match center line of pile and column to minimize eccentricity to avoid additional bending moments in the pile. **Piles should be terminated in the hard strata with at least 1-M embedment**. Foundation capacity calculations were presented on Plate 7.

GROUNDWATER AND SOIL CHEMICAL ANALYSIS

A 1.2-M diameter open well of unknown depth was present NW corner of the site at about 21.9-M from Boring 1. In the open well groundwater was at about 3.8-M below EGL. Groundwater sample was collected from the open well for construction suitability tests. Test results indicate that tested groundwater from the open well was **suitable** for construction purposes as per IS: 456-2000. Chemical tests were performed on soil samples from 2-, and 24.5-M of Boring 1, and 3- and 22.5-M of Boring 2. Soil samples were tested for pH, Chlorides, and Sulphates. A 5% soil solution was initially prepared by mixing with distilled water. This solution was allowed to soak and settle for 24 hours. After that soil solution was filtered pH test was performed on the derived solution. Test results infer presence of **less than limiting concentrations** adverse chemicals in the tested soil samples as per IS: 456 – 2000 code guidelines for construction water. It was recommended to check site's groundwater quality at regular intervals from beginning of construction activities. If necessary, suitable groundwater treatment should be adopted to make groundwater acceptable for construction purposes. Summary of groundwater and soil chemical test results are presented on Plate 6.

CONSTRUCTION CONSIDERATIONS

We not expect construction problems at this site due to site soil and groundwater conditions during non-rainy season. Site's EGL was at about ERL of 4th Avenue in front of the site. In order to minimize future site flooding from road runoff it was recommended to raise site's FGL by **at least 0.6-M above ERL** of road in front of the site, and FFL of stilt floor should be 0.25-M above FGL of the site. Foundation excavation, site, and building basement fillings should be done with granular soils with proper compaction to achieve a minimum unit weight of 2.0 tons/M^3.

Proper care should be taken in pile installation to avoid **pile necking / bulging / improper concreting** during pile installation due to presence of clean and layers of loose sand soils in the soil profiles. Pile bulging can be expected between 9- and 16-M below EGL. Piles should be terminated in hard strata only. At pile termination depth bore should be properly washed and cleaned of all loosened material to prevent low end bearing capacity of the pile. In the initial piles SPT may be performed at pile termination depth after wasting to confirm the proper cleaning of bore, and generate the site specific correlation of the drilling rate of the specific rig and SPT values of the hard strata. Extreme care should be taken during pile installation including use of good quality bentonite and bentonite solution of suitable specific gravity to minimize and prevent pile side wall collapse in thick layers of sand soils. **Hydraulic rigs were not recommended for this site soil conditions.** Pile load tests should be conducted as per relevant IS code to confirm the load carrying capacities recommended above and also to check the quality of pile installation.

All structures have to be designed for higher seismic forces (**Zone III**) due to increased seismic activity in peninsular India in the last decade and half. Seismic events of 5.1 magnitude on August 24, 2021, 5.1 magnitude on February 12, 2019, 7.9 magnitude on April 25, 2015, 6.0 magnitude on May 21, 2014, 8.4 magnitude on April 11, 2012, 7.2 magnitude on June 13, 2010, and 7.6 magnitude on August 11, 2009 with epicenters in Himalayas, Bay of Bengal, and near Andaman Islands were felt at Chennai. It is recommended to provide rigid plinth beams in ground level, columns designed for shear forces or shear walls in the structure, and continuous lintels in each floor. Lintels must be integrated into columns of the structure. Plinth beams must be designed to be rigid to allow redistribution of loads in case of differential settlements. The site soil profile infers **"Medium to High"** seismic susceptibility. Under IS code **Zone III** design seismic event of **6.0 Richter scale**, and peak ground acceleration of **0.16g** the total estimated vertical settlement was 34.54 cms and total horizontal displacement was about 379.62 cms. Iwasaki liquefaction potential was 10.44 inferring "**Liquefaction Probable**." Liquefaction Analysis results are presented on Plate 8.

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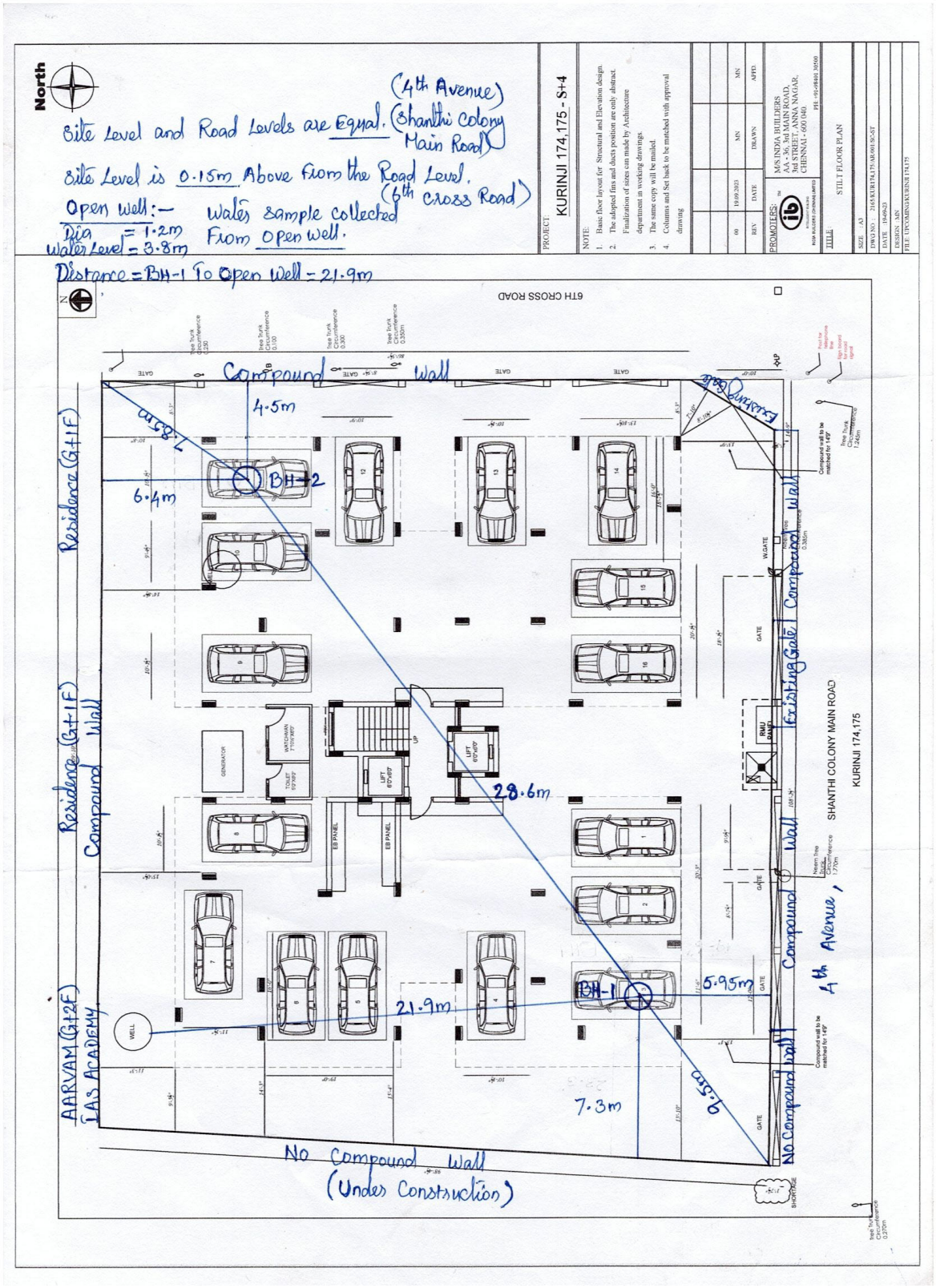
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N



(Not To Scale)

Site EGL = ERL of 4th Avenue In-Front of the Site.

SITE PLAN WITH BORE LOCATION DETAILS.

PLATE 1

LOG OF BORING

Project: Proposed Residential Apartments Building Site, "**Kurinji Elite**", No. 174 & 175, Kurinji Colony, 4th Avenue, Shanthi Colony, Anna Nagar, Chennai 600 040, TN.

Bore Hole No.: 1 **Type of Boring:** Calyx Drill **Dia. of Hole:** 150 mm
Started on: 20-05-'24 **Ended on:** 21-05-'24 **Field Work In Charge:** R Murugesan
Final Depth: 28.0-M **Depth to G W S:** 3.8-M **Remarks:** GWL from Site Open Well.

DEPTH, M	SOIL DESCRIPTION	SPT / VANE & SAMPLE TYPE	SPT "N" PROFILE 25 50 75	INDEX TEST DATA 25 50 75
	BROWN SILTY FINE TO COARSE SAND with brick and stone pieces – Filled Up Soil (To 2.0-M)	DS @ 0.25 M		
1.0	0.0- to 2.0-m – $\phi = 34^o$; $\gamma_t = 1.85$ tons/M^3 ($N_{avg} = 28$)	SPT @ 1 M 12/14/14 = 28 Blows		
2.0		SPT @ 2 M 7/14/17 = 31 Blows		
	BROWN VERY STIFF CLAY (To 2.75-M) 2.0- to 2.75-m – $C_u = 18$ tons/M^2; $\gamma_t = 1.85$ tons/M^3 ($N_{avg} = 31$)			
3.0	**BROWN GRAY STIFF TO VERY STIFF CLAY (To 6.0-M)** 2.75- to 4.0-m – $C_u = 7$ tons/M^2; $\gamma_t = 1.65$ tons/M^3 ($N_{avg} = 12$)	SPT @ 3 M 5/6/6 = 12 Blows		
GWL 4.0		SPT @ 4 M 5/8/9 = 17 Blows		
5.0	4.0- to 6.0-m – $C_u = 9$ tons/M^2; $\gamma_t = 1.7$ tons/M^3 ($N_{avg} = 17$)	SPT @ 5 M 4/7/10 = 17 Blows		
6.0		SPT @ 6 M 12/17/20 = 37 Blows		
	BROWN FINE TO MEDIUM SAND with silt (To 8.75-M)			
7.0	6.0- to 7.75-m – $\phi = 35^o$; $\gamma_t = 1.95$ tons/M^3 ($N_{avg} = 37$)	SPT @ 7 M 12/18/20 = 38 Blows		
8.0	7.75- to 8.75-m – $\phi = 34^o$; $\gamma_t = 1.85$ tons/M^3 ($N_{avg} = 32$)	SPT @ 8 M 11/16/16 = 32 Blows		
9.0	**GRAY FINE TO MEDIUM SAND with silt (To 9.75-M)** 8.75- to 9.75-m – $\phi = 25^o$; $\gamma_t = 1.5$ tons/M^3 ($N_{avg} = 5$)	SPT@ 9 M 1/2/3 = 5 Blows		
10.0	**GRAY SOFT CLAY (To 11.5-M)** 9.75- to 11.5-m – $C_u = 2$ tons/M^2; $\gamma_t = 1.4$ tons/M^3 ($N_{avg} = 3$)	SPT @ 10 M 0/1/2 = 3 Blows		
11.0				

CONTINUED ON PLATE 2b.

SPT=Standard Penetration Test; DS=Disturbed Sample; UDS = UnDisturbed Sample; WS=Water Sample; SNR=Sample Not Recovered; LS = Liner Sample; +----+ = Plastic and Liquid Limits; ♦ = N M C; ■ = % -75μ Size

LOG OF BORING

Project: Proposed Residential Apartments Building Site, "**Kurinji Elite**", No. 174 & 175, Kurinji Colony, 4th Avenue, Shanthi Colony, Anna Nagar, Chennai 600 040, TN.

Bore Hole No.: 1 **Type of Boring:** Calyx Drill **Dia. of Hole:** 150 mm
Started on: 20-05-'24 **Ended on:** 21-05-'24 **Field Work In Charge:** R Murugesan
Final Depth: 28.0-M **Depth to G W S:** 3.8-M **Remarks:** Continued from Plate 2a.

DEPTH, M	SOIL DESCRIPTION	SPT / VANE & SAMPLE TYPE	SPT "N" PROFILE 25 50 75	INDEX TEST DATA 25 50 75
	GRAY SOFT CLAY (To 11.5-M)	SPT @ 11.5 M 0/0/1 = 1 Blows		
12.0	GRAY GREEN FINE TO MEDIUM SAND with silt (To 16.0-M)			
13.0		SPT @ 13 M 1/1/2 = 3 Blows		
	11.5- to 16.0-m – $\phi = 24^o$; $\gamma_t = 1.45$ tons/M^3 ($N_{avg} = 2$)			
14.0				
		SPT @ 14.5 M 1/1/1 = 2 Blows		
15.0				
16.0	-with limestone nodules at 16-m	SPT @ 16 M 14/20/22 = 42 Blows		
	BROWN GRAY RED YELLOW GREEN HARD CLAY (To 20.75-M)			
17.0				
	16.0- to 18.75-m – $C_u = 24$ tons/M^2; $\gamma_t = 2.0$ tons/M^3 ($N_{avg} = 43$)	SPT @ 17.5 M 15/20/24 = 44 Blows		
18.0				
19.0		SPT @ 19 M 13/14/21 = 35 Blows		
	18.75- to 20.75-m – $C_u = 19$ tons/M^2; $\gamma_t = 1.9$ tons/M^3 ($N_{avg} = 35$)			
20.0				
		SPT @ 20.5 M 14/17/27 = 44 Blows		
21.0	BROWN FINE TO MEDIUM SAND with silt (To 24.5-M)			
	20.75- to 22.5-m – $\phi = 36^o$; $\gamma_t = 2.0$ tons/M^3 ($N_{avg} = 44$)			
22.0				

CONTINUED ON PLATE 2c.

SPT=Standard Penetration Test; DS=Disturbed Sample; UDS = UnDisturbed Sample; WS=Water Sample; SNR=Sample Not Recovered; LS = Liner Sample; +----+ = Plastic and Liquid Limits; ♦ = N M C; ■ = % -75μ Size

LOG OF BORING

Project: Proposed Residential Apartments Building Site, "**Kurinji Elite**", No. 174 & 175, Kurinji Colony, 4th Avenue, Shanthi Colony, Anna Nagar, Chennai 600 040, TN.

Bore Hole No.: 1 **Type of Boring:** Calyx Drill **Dia. of Hole:** 150 mm
Started on: 20-05-'24 **Ended on:** 21-05-'24 **Field Work In Charge:** R Murugesan
Final Depth: 28.0-M **Depth to G W S:** 3.8-M **Remarks:** Continued from Plate 2b.

DEPTH, M	SOIL DESCRIPTION	SPT / VANE & SAMPLE TYPE	SPT "N" PROFILE 25 50 75	INDEX TEST DATA 25 50 75
	BROWN FINE TO MEDIUM SAND with silt (To 24.5-M)	SPT @ 22.5 M 31/ 3 cms for 10 Blows		■ ♦
23.0		2 cms for 10 Blows (Hammer Rebound)		
	22.5- to 24.5-m – $\phi = 38^{o}$; $\gamma_t = 2.2$ tons/M^3			
24.0	($N_{avg} > 100$)			
		SPT @ 24.5 M 33/ 2 cms for 10 Blows		♦ ■
25.0	BROWN GRAY YELLOW SILTY FINE TO MEDIUM SAND (To 26.5-M)	1 cm for 10 Blows (Hammer Rebound)		
	24.5- to 26.5-m – $\phi = 39^{o}$; $\gamma_t = 2.25$ tons/M^3			
26.0	($N_{avg} >> 100$)			
		SPT @ 26.5 M 3 cms for 10 Blows		♦
27.0	BROWN GRAY VERY HARD CLAY - SHALE (Below 26.5-M)	2 cms for 10 Blows (Hammer Rebound)		
	26.5- to 28.0-m – $C_u = 40$ tons/M^2; $\gamma_t = 2.2$ tons/M^3			
28.0	($N_{avg} > 100$) -drilled from 26.5- to 28-m in 85 minutes	SPT @ 28 M (SNR) 2 cms for 20 Blows		
	28.0-m+ – $C_u = 50$ tons/M^2; $\gamma_t = 2.25$ tons/M^3	(Hammer Rebound)		
29.0	($N_{avg} >> 100$)			
30.0				
31.0				
32.0				
33.0				

BORE HOLE TERMINATED AT 28.0-M

SPT=Standard Penetration Test; DS=Disturbed Sample; UDS = UnDisturbed Sample; WS=Water Sample; SNR=Sample Not Recovered; LS = Liner Sample; +----+ = Plastic and Liquid Limits; ♦ = N M C; ■ = % -75μ Size

PLATE 2c

LOG OF BORING

Project: Proposed Residential Apartments Building Site, "**Kurinji Elite**", No. 174 & 175, Kurinji Colony, 4th Avenue, Shanthi Colony, Anna Nagar, Chennai 600 040, TN.

Bore Hole No.: 2 **Type of Boring:** Calyx Drill **Dia. of Hole:** 150 mm
Started on: 22-05-'24 **Ended on:** 23-05-'24 **Field Work In Charge:** R Murugesan
Final Depth: 28.5-M **Depth to G W S:** 3.8-M **Remarks:** GWL from Site Open Well.

DEPTH, M	SOIL DESCRIPTION	SPT / VANE & SAMPLE TYPE
	BROWN SILTY FINE TO COARSE SAND with brick and stone pieces – Filled Up Soil (To 2.0-M)	DS @ 0.25 M
1.0	0.0- to 2.0-m – $\phi = 25^o$; $\gamma_t = 1.5$ tons/M^3 ($N_{avg} = 5$)	SPT @ 1 M 2/2/3 = 5 Blows
2.0		SPT @ 2 M 7/7/12 = 19 Blows
	BROWN GRAY STIFF TO VERY STIFF CLAY (To 6.0-M)	
3.0		SPT @ 3 M 6/6/11 = 17 Blows
	2.0- to 4.75-m – $C_u = 11$ tons/M^2; $\gamma_t = 1.7$ tons/M^3 ($N_{avg} = 18$)	
GWL 4.0		SPT @ 4 M 4/6/12 = 18 Blows
5.0		SPT @ 5 M 3/5/7 = 12 Blows
	4.75- to 6.0-m – $C_u = 7.5$ tons/M^2; $\gamma_t = 1.65$ tons/M^3 ($N_{avg} = 12$)	
6.0		SPT @ 6 M 14/15/17 = 32 Blows
	BROWN FINE TO MEDIUM SAND with silt (To 7.75-M)	
7.0	6.0- to 7.75-m – $\phi = 35^o$; $\gamma_t = 1.9$ tons/M^3 ($N_{avg} = 35$)	SPT @ 7 M 14/20/17 = 37 Blows
8.0	**GRAY SILTY FINE SAND (To 8.75-M)** 7.75- to 8.75-m – $\phi = 32^o$; $\gamma_t = 1.7$ tons/M^3 ($N_{avg} = 16$)	SPT @ 8 M 6/7/9 = 16 Blows
9.0	**GRAY FINE TO MEDIUM SAND with silt (To 13.0-M)**	SPT @ 9 M 0/1/1 = 2 Blows
10.0	8.75- to 13.0-m – $\phi = 24^o$; $\gamma_t = 1.4$ tons/M^3 ($N_{avg} \sim 2$)	SPT @ 10 M 0/1/1 = 2 Blows
11.0		

SPT "N" PROFILE: 25 50 75

INDEX TEST DATA: 25 50 75

CONTINUED ON PLATE 3b.

SPT=Standard Penetration Test; DS=Disturbed Sample; UDS = UnDisturbed Sample; WS=Water Sample; SNR=Sample Not Recovered; LS = Liner Sample; +----+ = Plastic and Liquid Limits; ♦ = N M C; ■ = % -75μ Size

LOG OF BORING

Project: Proposed Residential Apartments Building Site, "**Kurinji Elite**", No. 174 & 175, Kurinji Colony, 4th Avenue, Shanthi Colony, Anna Nagar, Chennai 600 040, TN.

Bore Hole No.: 2 **Type of Boring:** Calyx Drill **Dia. of Hole:** 150 mm
Started on: 22-05-'24 **Ended on:** 23-05-'24 **Field Work In Charge:** R Murugesan
Final Depth: 28.5-M **Depth to G W S:** 3.8-M **Remarks:** Continued from Plate 3a.

DEPTH, M	SOIL DESCRIPTION	SPT / VANE & SAMPLE TYPE	SPT "N" PROFILE 25 50 75	INDEX TEST DATA 25 50 75
	GRAY FINE TO MEDIUM SAND with silt (To 13.0-M)	SPT @ 11.5 M 0/0/1 = 1 Blows		
12.0	8.75- to 13.0-m – $\phi = 24^o$; $\gamma_t = 1.4$ tons/M^3 ($N_{avg} \sim 2$)			
13.0		SPT @ 13 M 7/12/18 = 30 Blows		
	RED BROWN GRAY GREEN FINE TO MEDIUM SAND with silt (To 16.0-M)			
14.0	13.0- to 14.0-m – $\phi = 34^o$; $\gamma_t = 1.85$ tons/M^3 ($N_{avg} = 30$)			
		SPT @ 14.5 M 6/6/7 = 13 Blows		
15.0	14.0- to 16.0-m – $\phi = 31^o$; $\gamma_t = 1.65$ tons/M^3 ($N_{avg} = 13$)			
16.0		SPT @ 16 M 11/17/25 = 42 Blows		
	BROWN GRAY RED GREEN HARD CLAY (To 20.5-M)			
17.0				
	16.0- to 18.5-m – $C_u = 25$ tons/M^2; $\gamma_t = 2.0$ tons/M^3 ($N_{avg} = 45$)	SPT @ 17.5 M 15/21/28 = 49 Blows		
18.0				
19.0		SPT @ 19 M 12/15/19 = 34 Blows		
	18.5- to 20.5-m – $C_u = 19$ tons/M^2; $\gamma_t = 1.85$ tons/M^3 ($N_{avg} = 34$)			
20.0				
		SPT @ 20.5 M 14/16/22 = 38 Blows		
21.0	BROWN GRAY RED YELLOW FINE TO MEDIUM SAND with silt (To 26.5-M)			
	20.5- to 22.5-m – $\phi = 35^o$; $\gamma_t = 1.9$ tons/M^3 ($N_{avg} = 38$)			
22.0				

CONTINUED ON PLATE 3c.

SPT=Standard Penetration Test; DS=Disturbed Sample; UDS = UnDisturbed Sample; WS=Water Sample; SNR=Sample Not Recovered; LS = Liner Sample; +----+ = Plastic and Liquid Limits; ♦ = N M C; ■ = % -75μ Size

LOG OF BORING

Project: Proposed Residential Apartments Building Site, "**Kurinji Elite**", No. 174 & 175, Kurinji Colony, 4th Avenue, Shanthi Colony, Anna Nagar, Chennai 600 040, TN.

Bore Hole No.: 2 **Type of Boring:** Calyx Drill **Dia. of Hole:** 150 mm
Started on: 22-05-'24 **Ended on:** 23-05-'24 **Field Work In Charge:** R Murugesan
Final Depth: 28.5-M **Depth to G W S:** 3.8-M **Remarks:** Continued from Plate 3b.

DEPTH, M	SOIL DESCRIPTION	SPT / VANE & SAMPLE TYPE	SPT "N" PROFILE 25 50 75	INDEX TEST DATA 25 50 75
	BROWN GRAY RED YELLOW FINE TO MEDIUM SAND with silt (To 26.5-M)	SPT @ 22.5 M 32/ 19/25/28 = 53 Blows		
23.0				
	22.5- to 24.5-m – $\phi = 36^o$; $\gamma_t = 2.0$ tons/M^3			
24.0	($N_{avg} = 53$)			
		SPT @ 24.5 M 32/ 3 cms for 10 Blows		
25.0		2 cms for 10 Blows (Hammer Rebound)		
	24.5- to 26.5-m – $\phi = 38^o$; $\gamma_t = 2.2$ tons/M^3			
26.0	($N_{avg} > 100$)			
		SPT @ 26.5 M 2 cms for 10 Blows		
27.0	BROWN GRAY VERY HARD CLAY - SHALE (Below 26.5-M)	1 cm for 10 Blows (Hammer Rebound)		
	26.5- to 28.5-m – $C_u = 50$ tons/M^2; $\gamma_t = 2.25$ tons/M^3			
28.0	($N_{avg} >> 100$)			
	-drilled from 26.5- to 28.5-m in 75 minutes	SPT @ 28.5 M 1.5 cms for 10 Blows		
29.0		1 cm for 10 Blows (Hammer Rebound)		
30.0				
31.0				
32.0				
33.0				

BORE HOLE TERMINATED AT 28.5-M

SPT=Standard Penetration Test; DS=Disturbed Sample; UDS = UnDisturbed Sample; WS=Water Sample; SNR=Sample Not Recovered; LS = Liner Sample; +----+ = Plastic and Liquid Limits; ♦ = N M C; ■ = % -75μ Size

PLATE 3c

SUMMARY OF TEST RESULTS

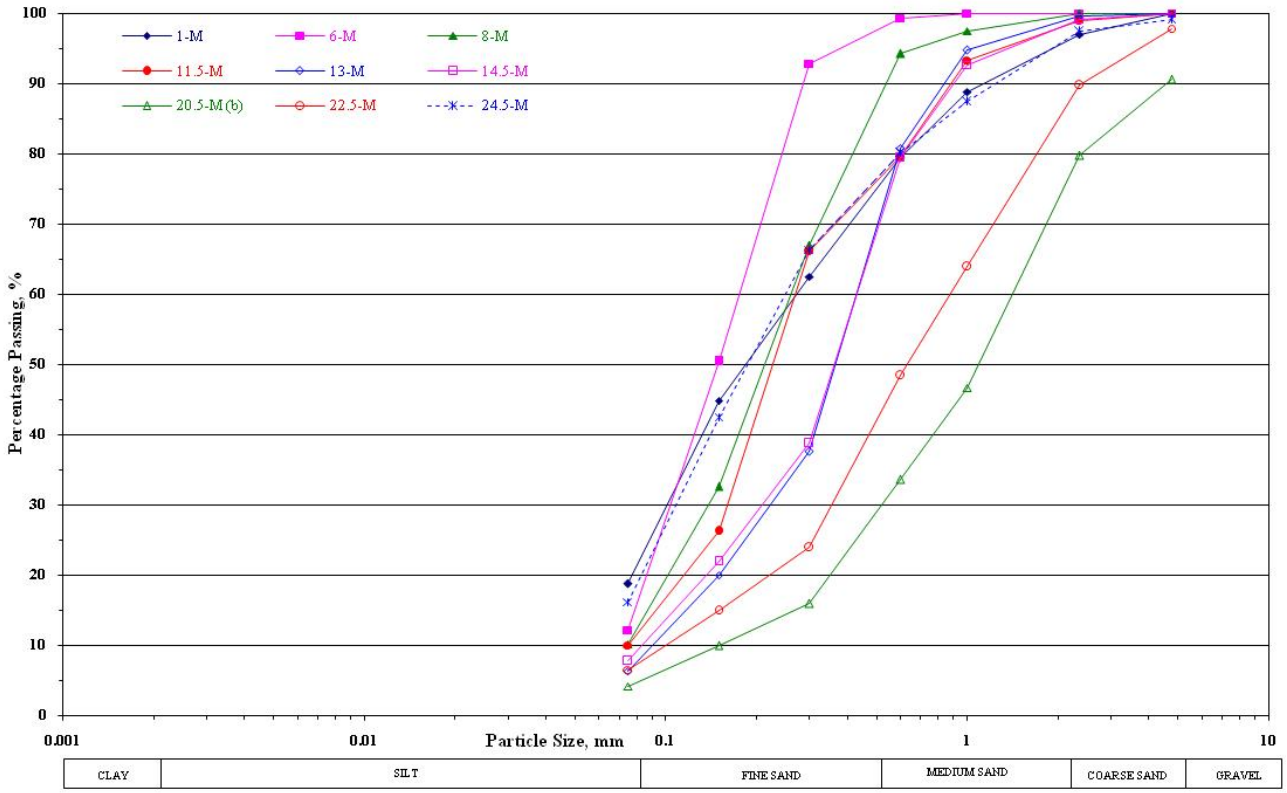
Boring No.	Depth, M	w %	PL	LL	-75μ%	SAND			GRAVEL %	IS CLASS.
						Fine%	Medium%	Coarse%		
1	0.25	8			1					
	1.0	12			19	53	23	5	0	SM
	2.0	27	24	66						CH
	3.0	30								
	4.0	31	23	65						CH
	5.0	30	26	67						CH
	6.0	22			12	84	4	0	0	SM
	7.0	17			5					
	8.0	23			10	72	17	1	0	SP-SM
	9.0	21			5					
	10.0	36	25	54						CH
	11.5	27			10	64	24	2	0	SP-SM
	13.0	15			6	56	37	1	0	SP
	14.5	19			8	54	36	2	0	SP
	16.0	24	29	73						CH
	17.5	37								
	19.0	37	40	98						CH
	20.5a	36	40	100						CH
	20.5b	11			4	22	47	18	9	SP
	22.5	11			7	31	47	13	2	SP
	24.5	13			16	58	21	4	1	SM
	26.5	17	shale							
	28.0	SNR								
2	0.25	2			1					
	1.0	13			14	49	32	4	1	SM
	2.0	20	21	59						CH
	3.0	26								
	4.0	25	24	51						CH
	5.0	29	32	66						CH
	6.0	18			11	62	27	0	0	SP-SM
	7.0	15			6					
	8.0	28			20	75	5	0	0	SM
	9.0	21			6					
	10.0	22			6	60	34	1	0	SP
	11.5	17			3					
	13.0	14			9	48	42	1	0	SP-SM
	14.5	15			7	43	44	6	0	SP
	16.0	26	36	76						CH
	17.5	40								
	19.0	43	49	113						CH
	20.5	14			10	43	45	2	0	SP-SM
	22.5	10			8	33	48	10	1	SP
	24.5	13			11	50	33	4	2	SP-SM
	26.5	20	shale							
	28.5	18	shale							

FREE SWELL INDEX TEST RESULTS

BORE NO.	DEPTH, M	FREE SWELL INDEX, %
1	**2.0**	**111**
	3.0	**121**
2	**2.0**	**107**
	3.0	**119**

PLATE 4

Grain Size Distribution Curves
Boring 1



Grain Size Distribution Curves
Boring 2

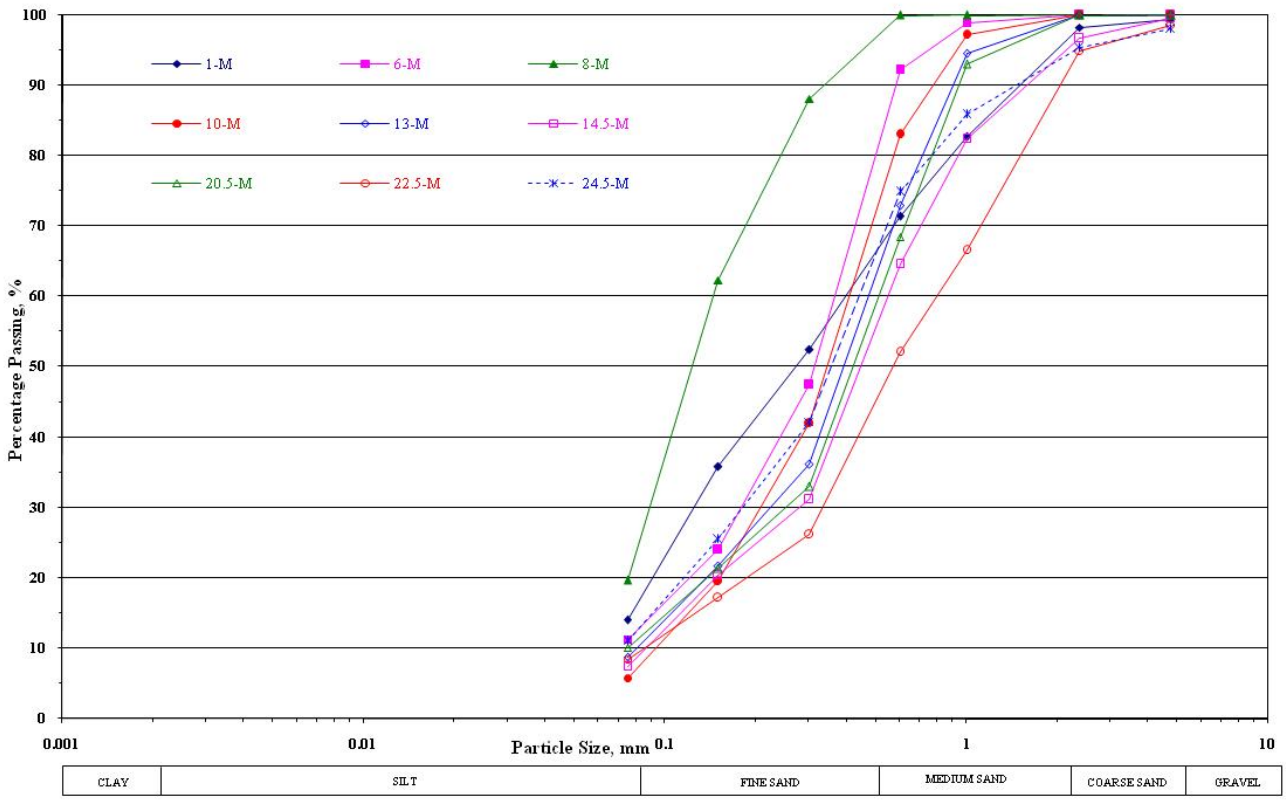


PLATE 5

SUMMARY OF WATER TEST RESULTS

OPEN WELL; DEPTH = UNKNOWN; DISTANCE = 21.9-M FROM BOERING 1

WATER LEVEL = 3.8-M IN SITE OPEN WELL.

S. No.		Description	Results Obtained	As per IS:456 – 2000
1		To neutralize 100 cc of water using phenolphthalein as indicator	0.30 ml	Not more than 5 ml of 0.02N NaOH
2		To neutralize 100 cc of water using methyl orange as indicator	24.4 ml	Not more than 25 ml of 0.02N H_2SO_4
3	a	Organic Solids, mg/liter	28	200 Max.
	b	Inorganic Solids, mg/liter	910	3,000 Max.
	c	Sulphates as SO_3, mg/liter	96	400 Max.
	d	Chlorides as Cl, mg/liter	170	2,000 Max. - Plain Concrete 500 Max. RCC
	e	Suspended Solids, mg/liter	0	2,000 Max.
	f	pH	7.20	6 Min.

Remarks: The sample meets the requirements of above clauses.
Hence water can be used for construction purposes as per IS 456 - 2000.

SUMMARY OF SOIL CHEMICAL TEST RESULTS

Boring	Depth, M	pH	Chlorides	Sulphates, ppm	
			ppm	SO_4	SO_3
1	2.0	7.97	180	98	82
	24.50	7.58	112	68	57
2	3.0	7.35	108	54	45
	22.5	7.36	112	66	55

Remarks:

pH tests on soil samples were performed on soil solution prepared with 5% soil. Soil solution was soaked in water for 24 hours, and the solution was filtered. Tests were performed on the filtered water.

Sulphates and chlorides content were for total soil weight.

Test results infer tested site soils had low adverse chemical ions.

SAMPLE CALCULATIONS FOR DMC BORED CAST IN SITU PILES.

PILE CAPACITY CALCULATIONS - By IS : 2911 (Part I / Sec. 2) - 2010 Method.

PROPOSED RESIDENTIAL APARTMENTS BUILDING SITE

"Kurinji Elite", No. 174 & 175, Kurinji Colony, 4th Avenue, Shanthi Colony, Anna Nagar, Chennai 600 040, TN.

Bored Cast In-Situ Pile Details:

Total Pile Length = **25.00 M** below EGL

Top Pile Cutoff Length = 1.00 M Top pile cutoff length for pilecaps

Pile Effective Concreting Length = 24.00 M

Pile Diameters Considered: **0.45 0.50 0.60 0.75 0.90 -M.**

Design Soil Profile Used in the Pile Capacity Calculations (Boring 1 and 2 Data)

S.No.	Soil Description	From	To	N_{avg}	C_u, T/M^2	ϕ^0	γ_T, T/M^3	
1a	Brown Silty F to M Sand with ….	0.00	1.00	28		34	1.85	
1b	Brown Silty F to M Sand with ….	1.00	2.00	28		34	1.85	
2	Brown Stiff Clay	2.00	2.75	31	18.00		1.85	
3a	Brown Gray Stiff to Very Stiff Clay	2.75	4.00	12	7.00		1.65	
3b	Brown Gray Stiff to Very Stiff Clay	4.00	6.00	17	9.00		1.70	
4a	Brown Fine to Medium Sand with Silt	6.00	7.75	37		35	1.95	
4b	Brown Fine to Medium Sand with Silt	7.75	8.75	32		34	1.85	
5	Gray F to M Sand with Silt	8.75	9.75	5		25	1.50	
6	Gray Soft Clay	9.75	11.50	3	2.00		1.40	
7	Gray Green F to M Sand with Silt	11.50	16.00	2		24	1.45	
8a	Brown Gray Red Yellow Green Hard Cla	16.00	18.75	43	24.00		2.00	Boring 2 Profile
8b	Brown Gray Red Yellow Green Hard Cla	18.75	20.75	35	19.00		1.90	Boring 2 Profile
9a	Br. Gray Red Yellow F to M Sand with S	20.75	22.50	38		35	1.90	Boring 2 Profile
9b	Br. Gray Red Yellow F to M Sand with S	22.50	24.50	53		36	2.00	Boring 2 Profile
9c	Br. Gray Red Yellow F to M Sand with S	24.50	26.50	> 100		38	2.20	Boring 2 Profile
10	Brown Gray Very Hard Clay	26.50	28.50	>> 100	50.00		2.25	Boring 2 Profile

For Cohesive Soils :-

C_u	α
2.00	1.00
7.00	0.60
9.00	0.50
18.00	0.31
19.00	0.30
24.00	0.28
50.00	0.28

Pile Capacity Calculations by IS : 2911 (Part I / Sec. 2) Method.

Unit Skin Friction in Clay Soils, f_s = αC_u

Unit Skin Friction in Sand Soils, f_s = $\sigma' K_o \tan\delta$ K_o = 1.00

Skin Friction of the Each Strata, Q_{si} = $f_s * \pi D L_i$

Total Ult. Skin Friction, $Q_{s\ ult}$ = ΣQ_{si}

Unit End Bearing in Clay Soils, q_{ult} = $9C_u$

Unit End bearing in Sand Soils, q_{ult} = $\sigma' N_q + 0.5 D \gamma N_\gamma$

Ultimate End Bearing, $Q_{p\ ult}$ = $q_{ult} * \pi D^2/4$

Total Ultmate Pile Capacity, Q_{ult} = $Q_{s\ ult} + Q_{p\ ult}$

Allowable Pile Capacity, Q_{all} = Q_{ult}/FS FS = Factor of Safety = **2.75**

COMPRESSIVE PILE CAPACITY CALCULATIONS

Skin Friction Calculations

S.No.	Soil Description	From	To	ϕ^0 / C_u	$\delta = \phi$	γ'_s, T/M^3	σ'_{Mid},T/M^2	f_s,T/M^2	Pile Dia 0.45 Q_s, T	0.50 Q_s, T	0.60 Q_s, T	0.75 Q_s, T	0.90 Q_s, T	-M.
1a	Brown Silty F to M Sand with ….	0.00	1.00	34	34	0.85	0.43	0.00	0.00	0.00	0.00	0.00	0.00	Cutoff
1b	Brown Silty F to M Sand with ….	1.00	2.00	34	34	0.85	1.28	0.86	1.22	1.35	1.62	2.03	2.43	
2	Brown Stiff Clay	2.00	2.75	18.00		0.85	2.02	5.58	5.92	6.58	7.89	9.86	11.84	
3a	Brown Gray Stiff to Very Stiff Clay	2.75	4.00	7.00		0.65	2.74	4.20	7.43	8.25	9.90	12.38	14.85	
3b	Brown Gray Stiff to Very Stiff Clay	4.00	6.00	9.00		0.70	3.84	4.50	12.73	14.14	16.97	21.21	25.46	
4a	Brown Fine to Medium Sand with Silt	6.00	7.75	35	35	0.95	5.38	3.76	9.31	10.35	12.42	15.52	18.63	
4b	Brown Fine to Medium Sand with Silt	7.75	8.75	34	34	0.85	6.63	4.47	6.33	7.03	8.43	10.54	12.65	
5	Gray F to M Sand with Silt	8.75	9.75	25	25	0.50	7.31	0.00	0.00	0.00	0.00	0.00	0.00	
6	Gray Soft Clay	9.75	11.50	2.00	2	0.40	7.91	0.00	0.00	0.00	0.00	0.00	0.00	
7	Gray Green F to M Sand with Silt	11.50	16.00	24	24	0.45	9.27	0.00	0.00	0.00	0.00	0.00	0.00	
8a	Brown Gray Red Yellow Green Hard Cla	16.00	18.75	24.00		1.00	11.66	6.72	26.14	29.04	34.85	43.56	52.27	
8b	Brown Gray Red Yellow Green Hard Cla	18.75	20.75	19.00		0.90	13.93	5.70	16.12	17.91	21.50	26.87	32.25	
9a	Br. Gray Red Yellow F to M Sand with S	20.75	22.50	35	35	0.90	15.62	10.94	27.07	30.07	36.09	45.11	54.13	
9b	Br. Gray Red Yellow F to M Sand with S	22.50	24.50	36	36	1.00	17.41	12.65	35.77	39.74	47.69	59.62	71.54	
9c	Br. Gray Red Yellow F to M Sand with S	24.50	25.00	38	38	1.20	18.71	14.61	10.33	11.48	13.78	17.22	20.67	
								Net Total Ultimate Skin Friction, $Q_{s\,ult}$=	158.36	175.95	211.14	263.93	316.72	

@ 25-M below EGL Soil
Formation - Very Dense Sand
L/D of Pile = 25.0/0.45 > 20
L/D of Pile = 25.0/0.50 > 20
L/D of Pile = 25.0/0.60 > 20
L/D of Pile = 25.0/0.75 > 20
L/D of Pile = 25.0/0.90 > 20
Use Lim. Value or Actual σ'_{base}

N = > 100
N_q = 67 **(Lower Value)**
N_γ = 65 **(Lower Value)**

Limited to as per IRC 78 - 2014: (Page 80, Note-2)

	0.45	0.50	0.60	0.75	0.90	
Base A=	0.1591	0.1964	0.2829	0.4420	0.6364	-M^2
σ'_{base} =	7.18	7.66	8.48	9.83	11.03	T/M^2
$q_{b\,ult}$ =	498.69	500.64	504.54	510.39	516.24	T/M^2
$q_{b\,ult}$ =	**550.00**	**550.00**	**550.00**	**550.00**	**550.00**	**T/M^2**
$Q_{b\,ult}$ =	79.35	98.34	142.71	225.58	328.55	Tons
$Q_{s\,ult}$ =	158.36	175.95	211.14	263.93	316.72	Tons
$Q_{tot\,ult}$=	**237.70**	**274.29**	**353.86**	**489.51**	**645.27**	Tons
F.S. =	2.75	2.75	2.75	2.75	2.75	
Allowable Compressive Capacity = **Q_{All} =**	**86.44**	**99.74**	**128.68**	**178.00**	**234.64**	Tons
Use Q_{All} =	**86**	**100**	**129**	**178**	**235**	**Tons**

Note:-

1 Pile Load Test must be conducted as per relavant IS Code to confirm the above estimated pile capacities before completion of installtion of all piles.
2 Pile installation must be done with extreme care to prevent "Necking" and "Buldging" problems due to presence of thick layers of sand soils;
3 Ground water level was assumed to rise to ground level in worst case conditions.
4 Limiting All. End Bearing Pressure in "**Hard Rock**" as per IRC code was 500 tons/M^2. Hence, q_b (all) is limited to 200 tons/M^2 for Very Dense Sand.
5 Higher Factor of Safety (2.75) was used instead of BIS code recommended value of 2.50 to account for presence of thick layers of very loose sand and weak clay layer which can settle suddenly during design seismic conditions.

UPLIFT PILE CAPACITY CALCULATIONS

Skin Friction Calculations

S.No.	Soil Description	From	To	ϕ^0 / C_u	$\delta = \phi$	γ'_s, T/M^3	σ'_{Mid},T/M^2	f_s,T/M^2	Pile Dia 0.45 Q_s, T	0.50 Q_s, T	0.60 Q_s, T	0.75 Q_s, T	0.90 Q_s, T	-M.
1a	Brown Silty F to M Sand with ….	0.00	1.00	34	34	0.85	0.43	0.00	0.00	0.00	0.00	0.00	0.00	Cutoff
1b	Brown Silty F to M Sand with ….	1.00	2.00	34	34	0.85	1.28	0.86	1.22	1.35	1.62	2.03	2.43	
2	Brown Stiff Clay	2.00	2.75	18.00		0.85	2.02	5.58	5.92	6.58	7.89	9.86	11.84	
3a	Brown Gray Stiff to Very Stiff Clay	2.75	4.00	7.00		0.65	2.74	4.20	7.43	8.25	9.90	12.38	14.85	
3b	Brown Gray Stiff to Very Stiff Clay	4.00	6.00	9.00		0.70	3.84	4.50	12.73	14.14	16.97	21.21	25.46	
4a	Brown Fine to Medium Sand with Silt	6.00	7.75	35	35	0.95	5.38	3.76	9.31	10.35	12.42	15.52	18.63	
4b	Brown Fine to Medium Sand with Silt	7.75	8.75	34	34	0.85	6.63	4.47	6.33	7.03	8.43	10.54	12.65	
5	Gray F to M Sand with Silt	8.75	9.75	25	25	0.50	7.31	0.00	0.00	0.00	0.00	0.00	0.00	
6	Gray Soft Clay	9.75	11.50	2.00	2	0.40	7.91	0.00	0.00	0.00	0.00	0.00	0.00	
7	Gray Green F to M Sand with Silt	11.50	16.00	24	24	0.45	9.27	0.00	0.00	0.00	0.00	0.00	0.00	
8a	Brown Gray Red Yellow Green Hard Cla	16.00	18.75	24.00		1.00	11.66	6.72	26.14	29.04	34.85	43.56	52.27	
8b	Brown Gray Red Yellow Green Hard Cla	18.75	20.75	19.00		0.90	13.93	5.70	16.12	17.91	21.50	26.87	32.25	
9a	Br. Gray Red Yellow F to M Sand with S	20.75	22.50	35	35	0.90	15.62	10.94	27.07	30.07	36.09	45.11	54.13	
9b	Br. Gray Red Yellow F to M Sand with S	22.50	24.50	36	36	1.00	17.41	12.65	35.77	39.74	47.69	59.62	71.54	
9c	Br. Gray Red Yellow F to M Sand with S	24.50	25.00	38	38	1.20	18.71	14.61	10.33	11.48	13.78	17.22	20.67	
								Net Total Ultimate Skin Friction, $Q_{s\,ult}$=	158.36	175.95	211.14	263.93	316.72	

Unit Weight of Pile RCC = γ_{conc} 2.40 T/M^3

	0.45	0.50	0.60	0.75	0.90	
Base A=	0.1591	0.1964	0.2829	0.4420	0.6364	-M^2
Pile Length, L =	24.00	24.00	24.00	24.00	24.00	-M
Pile Volume, V =	3.82	4.71	6.79	10.61	15.27	-M^3
Submerged Pile Weight W =	5.35	6.60	9.50	14.85	21.38	Tons
$Q_{s\,ult}$ =	158.36	175.95	211.14	263.93	316.72	Tons
$Q_{tot\,ult}$=	**163.70**	**182.55**	**220.65**	**278.78**	**338.10**	Tons
F.S. =	3.00	3.00	3.00	3.00	3.00	
Allowable Uplift Capacity = Q_{All} =	**54.57**	**60.85**	**73.55**	**92.93**	**112.70**	Tons
Use Q_{All} =	**55**	**61**	**74**	**93**	**113**	**Tons**

Note:-

1 Pile Load Test must be conducted as per relavant IS Code to confirm the above estimated pile capacities before completion of installtion of all piles.

2 Pile installation must be done with extreme care to prevent "Necking" and "Buldging" problems due to presence of thick layers of sand soils;

3 Ground water level was assumed to rise to ground level in worst case conditions.

4 **Negative skin friction was not considred in the uplift capacity calculations as the uplift forces will likely to be trancient in nature.**

SAMPLE CALCULATIONS FOR DMC BORED CAST IN SITU PILES.

PILE CAPACITY CALCULATIONS - By IS : 2911 (Part I / Sec. 2) - 2010 Method.

PROPOSED RESIDENTIAL APARTMENTS BUILDING SITE

"Kurinji Elite", No. 174 & 175, Kurinji Colony, 4th Avenue, Shanthi Colony, Anna Nagar, Chennai 600 040, TN.

Treat Soil Profile from 1- to 6.75-M = Stiff to Very Stiff Clay
Average "N" Value = 20
Undrained Shear Strength, C_u = 200.00 kN/M^2

$$\text{Deflec., } y = \frac{H(e+Z_f)^3*1000}{12EI} \text{ mm}$$

As per IS : 2911 (Part 1 / Sec 2) : 2010, Annex C, Table 3, Page 14
For Soft Clay with Estimated N_{avg} , Subgrade Modulus, k_1 = 20000 $kN/M^2/M$ (Lower Value due to Weak Soils Below 9-M)
(For Soft Clay with with Some Increase in Value due to to sand soil layers)
As per IS : 2911 (Part 1 / Sec 2) : 2010, Annex C, Page 14, Section C. 2.3.1

$$\text{Lateral Load } H = \frac{y*12EI}{(e+Z_f)^3*1000} \text{ kN}$$

Stiffness Factor R, in M = $\sqrt[4]{\frac{EI}{KB}}$ $K = \frac{k_1*0.3}{1.5*Dia.}$

Concrete Grade = M30 Max. Comp. Stress in Bending 3000 $Tons/M^2$ $E_c = 5000\ Sqrt(f_{ck})$ N/mm^2
Min. % of Reinforcement Content = 0.40% f_c = 300 Kg/cm^2 30 N/mm^2 **E_c = 27386.1 N/mm^2**
Modulus of Pile, E_c = 273861 Kg/cm^2 = 2.74E+07 kN/M^2

Dia., D M	(I) Mom. of Inertia, M^4	EI	K	R M	L_1 M	L_1/R	L_e/R	L_e M	y mm	L_1+L_e (Z_f) M	H Tons
0.45	0.00201	55124	8888.9	1.93	0.25	0.130	2.20	4.24	5.00	4.49	**3.66**
0.50	0.00307	84017	8000.0	2.14	0.25	0.117	2.20	4.71	5.00	4.96	**4.13**
0.60	0.00636	174218	6666.7	2.57	0.25	0.097	2.20	5.65	5.00	5.90	**5.09**
0.75	0.01553	425337	5333.3	3.21	0.25	0.078	2.20	7.06	5.00	7.31	**6.52**
0.90	0.03221	881978	4444.4	3.85	0.25	0.065	2.20	8.48	5.00	8.73	**7.96**

For the present vaiable soil profile, depth of pile fixity varies from 4.25- to 8.25-M for various pile dia. in clayey soil profiles.

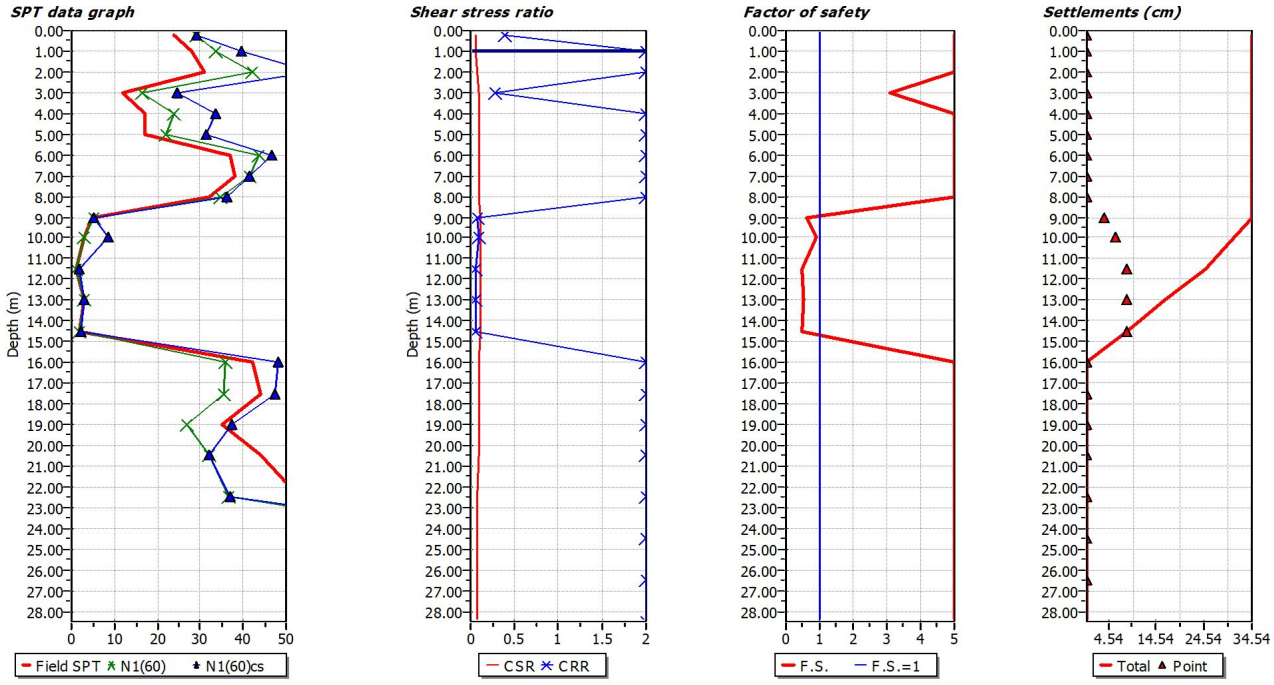
LIQUEFACTION ANALYSIS REPORT

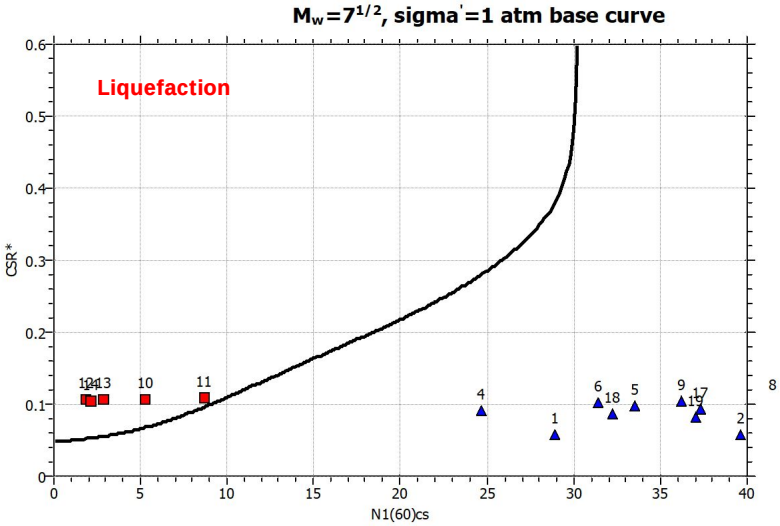
Project title : No. 174 & 175, Kurinji Colony, 4th Avenue, Shanthi Colony, Anna Nagar, Chennai 600 040, TN.

Project subtitle : Boring 1 Soil Profile

Input parameters and analysis data

In-situ data type:	Standard Penetration Test	Depth to water table:	1.00 m
Analysis type:	Deterministic	Earthquake magnitude M_w:	6.00
Analysis method:	NCEER 1998	Peak ground accelaration:	0.16 g
Fines correction method:	Idriss & Seed	User defined F.S.:	1.00





Horizontal Acceleration, A_h = 0.16g

This software is licensed to : TRIAL VERSION

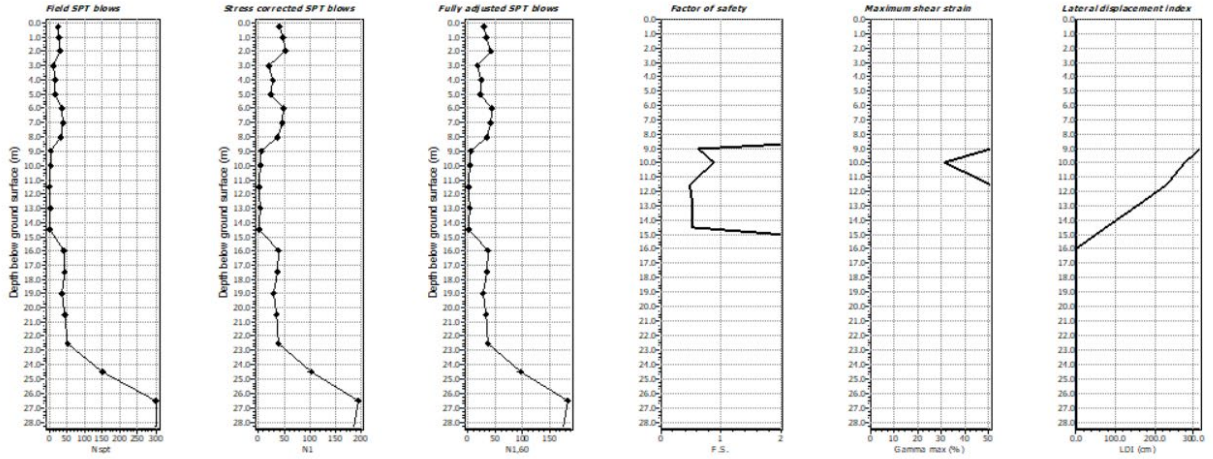
GEOLOGISMIKI Geotechnical Software

GeoLogismiki - Merarhias 56, 621 25 Serres, Greece
Url : http://www.geologismiki.gr - Email : info@geologismiki.gr

LiqIT software v.4.6
Assessment of soil liquefaction potential from SPT, CPT or Vs data

LATERAL DISPLACEMENTS ESTIMATION DUE TO SOIL LIQUEFACTION[1]

Geometric parameters: Gently sloping ground without free face
Total lateral displacement estimation: 379.62 cm



N_{spt}: Measured SPT blows
N_1: Stress adjusted SPT blows
$N_{1,60}$: Fully adjusted SPT blows

F.S.: Factor of safety
Gamma max: Maximum cyclic shear strain
LDI: Lateral displacement index

[1] This method was developed using the NCEER methods (SPT and CPT) and other methods will produce slightly different results

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