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CIN: U74210TN1992PTC023645

GEOTECHNICAL SITE INVESTIGATION
BORING 1 AND 2
PROPOSED RESIDENTIAL APARTMENTS BUILDING SITE
P. NO. 30 AND 31, O. NO. 28 AND 29 N. NO. 51 AND 53
28TH CROSS STREET, INDIRA NAGAR
THIRUVANMIYUR, CHENNAI 600 020, TN.

Report to

M/s. Keyem Engineering Enterprises

N. No. 22, O. No. 38, 3rd East Street

Kamaraj Nagar

Thiruvanniyur, Chennai 600 041, TN.



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Report No. 064/GI/20-21.

March 5, 2021.

M/s. Keyem Engineering Enterprises

N. No. 22, O. No. 38, 3rd East Street

Kamaraj Nagar

Thiruvanniyur, Chennai 600 041, TN.

Geotechnical Site Investigation

Boring 1 and 2

Proposed Residential Apartments Building Site

P. No. 30 and 31, O. No. 28 and 29, N. No. 51 and 53

28th Cross Street, Indira Nagar

Thiruvanniyur, Chennai 600 0020, 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 letter dated February 24, 2021.

Estimated capacities of the recommended foundation 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,

PRASAD ARMSTRONG YEN GEC (P) Ltd.

B. Ram Prasad ME, PhD (Texas A&M)

Managing Director

CMDA Registration No. GTE/19/02/002

(064brpt)

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CHENNAI METROPOLITAN DEVELOPMENT AUTHORITY

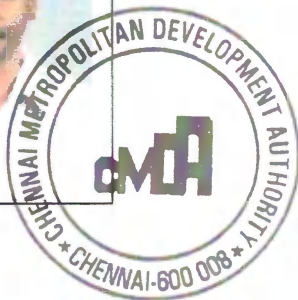
'Thalamuthu Natarajan Building', No.1, Gandhi Irwin Road,
Egmore, Chennai-600 008.

PROFESSIONAL REGISTRATION CERTIFICATE

This is to certify that the **Dr.B.RAM PRASAD** has enrolled as **Registered Geo-Technical Engineer (RGTE)** with Chennai Metropolitan Development Authority (CMDA) who has the qualification of **B.E.,(Civil Engg.), M.E.,(Geo-Tech.), Ph.D.**, and experience in the relevant field for **30 years**.

He has been given the Registration No.**GTE/19/02/002** on **19.02.2019**. He 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 **18.02.2024**.



Rthw 19/02/2019

(R.SHIVAKUMAR)

ASSISTANT PLANNER
CHENNAI METROPOLITAN DEVELOPMENT AUTHORITY
CHENNAI - 600 008

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SUMMARY

Prasad Armstrong Yen GEC (P) Ltd. performed a geotechnical site investigation at the **Proposed Residential Apartments Building Site, P. No. 30 and 31, O. No. 28 and 29, N. No. 51 and 53, 28th Cross Street, Indira Nagar, Thiruvanniyur, Chennai 600 020, TN.** The primary purpose of our investigation was to obtain data to select suitable foundation type and estimate load carrying capacity of the selected foundation for the proposed Stilt + 5 floors building. For the proposed building with planned column configuration typical maximum column load will be about 150 tons. This load detail was used only for estimating the preliminary foundation size and type of foundation.

The field investigation was performed on March 1 through 3, 2021. Number and location of the borings were selected to cover the proposed building area. Borings 1 and 2 were drilled 12-, and 14.5-M depth below the Existing Ground Level (EGL), respectively. Borings were drilled beyond 10-M due to presence of very weak soils in the 2- to 6-M. Borings were terminated after encountering hard stratum (SPT $N \geq 100$) in at least two successive tests and recovery of granite rock pieces. NX TC bit and Diamond bit core barrel was used for drilling through the rocky formation. 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. The proposed site was actually two adjacent plots. Each of the two plots had old G + 1 floor buildings during this investigation. Site had compound walls along all boundaries. Visual observation inferred EGL of the site to be about the Existing Ground Level (ERL) of road in front of the site. A few well grown trees were present in the site. Proposed construction will be the first major construction activity of this magnitude at this site. The soil stratigraphy at the borings is tabulated below:

Boring – 1:

<u>Stratum</u>	<u>Penetration, M</u>		<u>Description</u>
	<u>From</u>	<u>To</u>	
I	0	1.0	Red Brown Fine to Medium Sand with Silt, Brick and Stone Pieces
II	1.0	1.75	Brown Silty Fine to Medium Sand
III	1.75	4.0	Gray Very Soft to Stiff Clay
IV	4.0	10.0	Gray Fine to Medium Sand
V	10.0	12.0+	Brown and Gray Weathered Rock

Boring – 2:

<u>Stratum</u>	<u>Penetration, M</u>		<u>Description</u>
	<u>From</u>	<u>To</u>	
I	0	1.0	Red Brown Fine to Medium Sand with Brick and Stone Pieces
II	1.0	1.75	Brown Stiff Clay
III	1.75	4.0	Gray Very Soft to Soft Clay
IV	4.0	11.5	Gray Fine to Medium Sand
V	11.5	13.0	Brown Weathered Rock
VI	13.0	14.5+	Gray High Jointed Granite

Data from the borings indicate presence of variable soil profiles with very soft to soft clay between 2- and 5-M. For the expected column loads and encountered upper weak soil profiles it was **recommended** to provide **Tractor Mounted Direct Mud Circulation (DMC) Bored Cast In-Situ Pile foundation**. This type of pile installation work will have low construction vibrations otherwise it may affect the existing adjacent buildings foundations and also lead to objections from adjacent building owners. For this site it was recommended to provide a **minimum 11- and 10-M** total and effective length piles below EGL with top 1-M pile cutoff for pile caps and plinth beams. All piles should have **at least 1-M embedment into hard stratum** weathered rock. Ultimate and allowable pile capacities of various pile diameters were summarized below.

Pile Dia. M	Compressive Capacity		Uplift Capacity		Lateral Capacity	
	Ultimate Tons	Allowable Tons	Ultimate Tons	Allowable Tons	Ultimate Tons	Allowable Tons
0.45	114.55	38	39.64	13	8.10	2.70
0.50	150.68	50	44.32	15	10.00	3.33
0.60	234.93	78	53.85	18	14.40	4.80
0.75	354.99	118	68.54	23	22.50	7.50
0.90	501.24	167	83.74	28	32.40	10.80

It was recommended to provide at least a two-pile group using suitable pile diameter instead of single pile - single column by selecting appropriate pile diameter to provide better resistance to bending forces from column loads and seismic forces. For columns with low loads single pile per column can be provided. In case of columns for lift or staircase areas with close spacing single pile per column can be provided with a common pile cap. **Also, piles should be structurally designed for higher bending / flexural capacity for better resistance to lateral forces during seismic events.** All pile caps should be tied together in both directions through rigid plinth beams. In case of single pile and single column unit 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 at some locations may have to be drilled deeper than 11-M to 12.5-M (Boring 2) to achieve at least 1-M embedment into hard strata.**

In Boring 1 groundwater was at 2.1-M below EGL. In the combined site one 1.1-M diameter open well and a bore well of unknown depths were present. In the open well groundwater was at about 2.3-M below EGL. Bore well was located at about 15.4-m from Boring 2. High groundwater level could be due to recent rains in Chennai. Groundwater samples were collected for construction suitability purposes tests from Open well and bore well. Test results indicate that groundwater samples from open well and bore well were **not suitable** for construction purposes as per IS: 456 - 2000 code guidelines due to high alkalinity as inferred by the methyl orange titration test. Chemical tests on soil sample from 2-M depth of Boring 1 and 9-M depth of Boring 2 were performed to measure their pH, Cl, SO₃, and SO₄ ion concentration. Result inferred that there will be no adverse effects of soil chemical ions on foundations as their concentrations were lower than limiting concentration for groundwater as per IS: 456 - 2000. **Groundwater from the site wells can be used only after suitable treatment.** Groundwater quality should be checked regular intervals for construction suitability purposes from beginning of construction activities and adjust the treatment as required.

We do not expect construction problems at this site due to high groundwater conditions in non-rainy seasons. Visual observation inferred EGL of the site to be about ERL road in front of the site. It was recommended to raise FGL of the site by at least 0.6-M above ERL of road in front of the site.

Building's stilt floor's Finished Floor Level (FFL) should be at least 0.15-M above the Finished Ground Level (FGL) of the site. This will minimize rainwater runoff flooding into the site and building. Site filling should be done with granular fill soil with densification to achieve a total unit weight of at least 2 tons/M³. Old buildings present the site will have to be removed for the proposed construction. Proper care should be taken in pile installation to avoid **pile bulging / necking / improper concreting** during pile installation. For pile installation good quality bentonite and bentonite solution of suitable density should be used to minimize pile side wall collapse leading to necking problems as thick layers of clean sand were encountered in the borings. **Excess consumption of concrete can be expected at some depths in piles due to presence of very loose sand and very soft clay layers in the soil profiles of the borings.** Piles should be terminated in hard stratum weathered rock formation with a minimum 1-M of pile embedment. At pile termination depth bore should be properly washed and cleaned of all loosened material to prevent low end bearing capacity of the pile as the major pile load capacity will be developed by end bearing. **Pile load tests should be conducted as per relevant IS code to confirm the load carrying capacities recommended above and also to check quality of pile installation.**

For any reason hydraulic rotary rig has to be considered then it is necessary to reevaluate pile capacities based on the rig parameters based on input from piling contractor side, evaluate rig operations in the site, install test pile to check feasibility, check test pile for defects by Non-Destructive Tests (NDT), and **perform a few initial load test** to confirm the load carrying capacity of the pile installed by the hydraulic rotary rig. Also, NDTs should be performed on each and every pile of the planned building to confirm the pile integrity.

All structures have to be designed for higher seismic forces (**Zone III**) due to increased seismic activity in peninsular India in the past two decades. Seismic events of 5.4 magnitude on February 11, 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, 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 “Nil to Low” seismic susceptibility.** Under a seismic event of **6.5 Richter scale**, and peak ground acceleration of **0.07g** the total estimated vertical settlement was 1.83 cms and total horizontal displacement was about 0.28 cms. Iwasaki liquefaction potential was 0.0 inferring **“No Liquefaction.”** As per IS code for **Zone III** design horizontal acceleration was about **0.05g** only. However, when thick layer of very weak sediments are present the effect of seismic wave effects gets magnified. Hence, in the analysis peak ground acceleration of **0.07g** was used.

INTRODUCTION

Purpose and Scope

Prasad Armstrong Yen GEC (P) Ltd. performed a geotechnical site investigation at the **Proposed Residential Apartments Building Site, P. No. 30 and 31, O. No. 28 and 29, N. No. 51 and 53, 28th Cross Street, Indira Nagar, Thiruvanniyur, Chennai 600 020, TN.** The primary purpose of our investigation was to obtain data to select suitable foundation type and estimate load carrying capacity of the selected foundation for the proposed Stilt + 5 floors building. For the proposed building with planned column configuration typical maximum column load will be about 150 tons. This load detail was used only for estimating the preliminary foundation size and type of foundation. To accomplish these purposes, the following tasks were performed:

- (1) Borings 1 and 2 were drilled 12-, and 14.5-M depth to explore subsurface stratigraphy, and obtain soil and rock samples for laboratory testing;
- (2) 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 foundation.

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 calculations followed by a brief on construction considerations for this project.

FIELD AND LABORATORY INVESTIGATIONS

Exploratory Borings

Soil conditions at site for the proposed buildings were explored by two borings. Bore location details are presented on Plate 1. Number and location of the borings were selected to cover the proposed building area. Borings 1 and 2 were drilled 12-, and 14.5-M depth below EGL, respectively. Borings were drilled beyond 10-M due to presence of very weak soils in the 2- to 6-M. Borings were terminated after encountering hard stratum ($SPT\ N \geq 100$) in at least two successive tests and recovery of granite rock pieces. NX TC bit and Diamond bit core barrel was used for drilling through the rocky formation. 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 2.3-M below EGL in the site's open well. Log of Borings are presented on Plate 2 and 3.

Field and Laboratory Tests

Borings were drilled using Calyx drilling unit. In the borings SPT was performed at 1-M interval upto 10-M, and at 1.5-M interval beyond 10-M. SPT consists of driving a standard split spoon sampler, 51-mm outside diameter and 38-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 and rock samples were collected at 1-, and 1.5-M intervals either disturbed or undisturbed as the case may be. All soil and rock 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 are tabulated on the Summary of Test Results on Plate 4. Grain size distribution curves of tested soil are presented on Plate 5. Summary of Groundwater and Soil Chemical Test Results were presented on Plate 6.

GENERAL SOIL CONDITIONS

Topography

Natural topography of the site reflects a flat terrain. The proposed site was actually two adjacent plots. Each of the two plots had old G + 1 floor buildings during this investigation. Site had compound walls along all boundaries. Visual observation inferred EGL of the site to be about ERL of road in front of the site. A few well grown trees were present in the site. Proposed construction will be the first major construction activity of this magnitude at this site.

Soil Stratigraphy

The soil stratigraphy disclosed by our investigation is 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:

<u>Stratum</u>	<u>Penetration, M</u>		<u>Description</u>
	<u>From</u>	<u>To</u>	
I	0	1.0	Red Brown Fine to Medium Sand with Silt, Brick and Stone Pieces
II	1.0	1.75	Brown Silty Fine to Medium Sand
III	1.75	4.0	Gray Very Soft to Stiff Clay
IV	4.0	10.0	Gray Fine to Medium Sand
V	10.0	12.0+	Brown and Gray Weathered Rock

Boring – 2:

<u>Stratum</u>	<u>Penetration, M</u>		<u>Description</u>
	<u>From</u>	<u>To</u>	
I	0	1.0	Red Brown Fine to Medium Sand with Brick and Stone Pieces
II	1.0	1.75	Brown Stiff Clay
III	1.75	4.0	Gray Very Soft to Soft Clay
IV	4.0	11.5	Gray Fine to Medium Sand
V	11.5	13.0	Brown Weathered Rock
VI	13.0	14.5+	Gray High Jointed Granite

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 cohesion less soils were selected based on the SPT results, 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.)

Foundation calculations presented in this report were based on the lower bound soil proprieties of the Boring 1. A reevaluation of the recommendations in this report may be necessary if variations in the soil profile are encountered during the foundation excavation work. In addition, there may be a need to drill additional borings to investigate soil variability at that location. Based on the field and laboratory test results the following are the properties for soils encountered in the boring.

Boring – 1:

Stratum	Penetration, M		Properties
	From	To	
I	0	1.0	$\gamma_{sat} = 1.65 \text{ tons/M}^3$
II	1.0	1.75	$\phi = 32^\circ$; $\gamma_{sat} = 1.7 \text{ tons/M}^3$
IIIa	1.75	2.75	$C_u = 6 \text{ tons/M}^2$; $\gamma_{sat} = 1.6 \text{ tons/M}^3$
IIIb	2.75	4.0	$C_u = 1.25 \text{ tons/M}^2$; $\gamma_{sat} = 1.4 \text{ tons/M}^3$
IVa	4.0	6.0	$\phi = 26^\circ$; $\gamma_{sat} = 1.5 \text{ tons/M}^3$
IVb	6.0	7.0	$\phi = 31^\circ$; $\gamma_{sat} = 1.65 \text{ tons/M}^3$
IVc	7.0	8.0	$\phi = 32^\circ$; $\gamma_{sat} = 1.7 \text{ tons/M}^3$
IVd	8.0	10.0	$\phi = 34^\circ$; $\gamma_{sat} = 1.8 \text{ tons/M}^3$
Va	10.0	11.0	$\phi = 37^\circ$; $\gamma_{sat} = 2.1 \text{ tons/M}^3$
Vb	11.0	12.0+	$\phi = 39^\circ$; $\gamma_{sat} = 2.25 \text{ tons/M}^3$

Boring – 2:

Stratum	Penetration, M		Properties
	From	To	
I	0	1.0	$\gamma_{sat} = 1.6 \text{ tons/M}^3$
II	1.0	1.75	$C_u = 9 \text{ tons/M}^2$; $\gamma_{sat} = 1.65 \text{ tons/M}^3$
IIIa	1.75	2.75	$C_u = 2.5 \text{ tons/M}^2$; $\gamma_{sat} = 1.5 \text{ tons/M}^3$
IIIb	2.75	4.0	$C_u = 1.25 \text{ tons/M}^2$; $\gamma_{sat} = 1.4 \text{ tons/M}^3$
IVa	4.0	5.0	$\phi = 28^\circ$; $\gamma_{sat} = 1.6 \text{ tons/M}^3$
IVb	5.0	7.0	$\phi = 30^\circ$; $\gamma_{sat} = 1.65 \text{ tons/M}^3$
IVc	7.0	8.0	$\phi = 32^\circ$; $\gamma_{sat} = 1.7 \text{ tons/M}^3$
IVd	8.0	8.75	$\phi = 34^\circ$; $\gamma_{sat} = 1.8 \text{ tons/M}^3$
IVe	8.75	10.0	$\phi = 33^\circ$; $\gamma_{sat} = 1.75 \text{ tons/M}^3$
IVf	10.0	11.5	$\phi = 34^\circ$; $\gamma_{sat} = 1.8 \text{ tons/M}^3$
V	11.5	13.0+	$\phi = 38^\circ$; $\gamma_{sat} = 2.25 \text{ tons/M}^3$
VI	13.05	14.5+	$\phi = 39^\circ$; $\gamma_{sat} = 2.3 \text{ tons/M}^3$

DESIGN INFORMATION

Data from the borings indicate presence of variable soil profiles with very soft to soft clay between 2- and 5-M. For the expected column loads and encountered upper weak soil profiles it was **recommended** to provide **Tractor Mounted Direct Mud Circulation (DMC) Bored Cast In-Situ Pile foundation**. This type of pile installation work will have low construction vibrations otherwise it may affect the existing adjacent buildings foundations and also lead to objections from adjacent building owners. For this site it was recommended to provide a **minimum 11- and 10-M** total and effective length piles below EGL with top 1-M pile cutoff for pile caps and plinth beams. All piles should have **at least 1-M embedment into hard stratum** weathered rock. Pile capacity was estimated as per the IS: 2911 - 2010 (Part 1 / Section 2) Code guidelines. Ultimate and allowable pile compressive and uplift capacities of various pile diameters are summarized below.

Pile Dia. M	Compressive Capacity		Tran. Uplift Capacity		Lateral Capacity	
	Ultimate Tons	Allowable Tons	Ultimate Tons	Allowable Tons	Ultimate Tons	Allowable Tons
0.45	114.55	38	39.64	13	8.10	2.70
0.50	150.68	50	44.32	15	10.00	3.33
0.60	234.93	78	53.85	18	14.40	4.80
0.75	354.99	118	68.54	23	22.50	7.50
0.90	501.24	167	83.74	28	32.40	10.80

It was recommended to provide at least a two-pile group using suitable pile diameter instead of single pile - single column by selecting appropriate pile diameter to provide better resistance to bending forces from column loads and seismic forces. For columns with low loads single pile per column can be provided. In case of columns for lift or staircase areas with close spacing single pile per column can be provided with a common pile cap. **Also, piles should be structurally designed for higher bending / flexural capacity for better resistance to lateral forces during seismic events.** All pile caps should be tied together in both directions through rigid plinth beams. In case of single pile and single column unit 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 at some locations may have to be drilled deeper than 11-M to 12.5-M (Boring 2) to achieve at least 1-M embedment into hard strata.** Sample calculations are presented on Plate 7.

GROUNDWATER AND SOIL CHECMIAL ANALYSIS

In Boring 1 groundwater was at 2.1-M below EGL. In the combined site one 1.1-M diameter open well and a bore well of unknown depths were present. In the open well groundwater was at about 2.3-M below EGL. Bore well was located at about 15.4-m from Boring 2. High groundwater level could be due to recent rains in Chennai. Groundwater samples were collected for construction suitability purposes tests from Open well and bore well. Test results indicate that groundwater samples from open well and bore well were **not suitable** for construction purposes as per IS: 456 - 2000 code guidelines due to high alkalinity as inferred by the methyl orange titration test. Chemical tests on soil sample from 2-M depth of Boring 1 and 9-M depth of Boring 2 were performed to measure their pH, Cl, SO₃, and SO₄ ion concentration. Result inferred that there will be no adverse effects of soil chemical ions on foundations as their concentrations were lower than limiting concentration for groundwater as per IS: 456 - 2000. **Groundwater from the site wells can be used only after suitable**

treatment. Groundwater quality should be checked regular intervals for construction suitability purposes from beginning of construction activities and adjust the treatment as required. Summary of groundwater and soil chemical test results were presented on Plate 6.

CONSTRUCTION CONSIDERATIONS

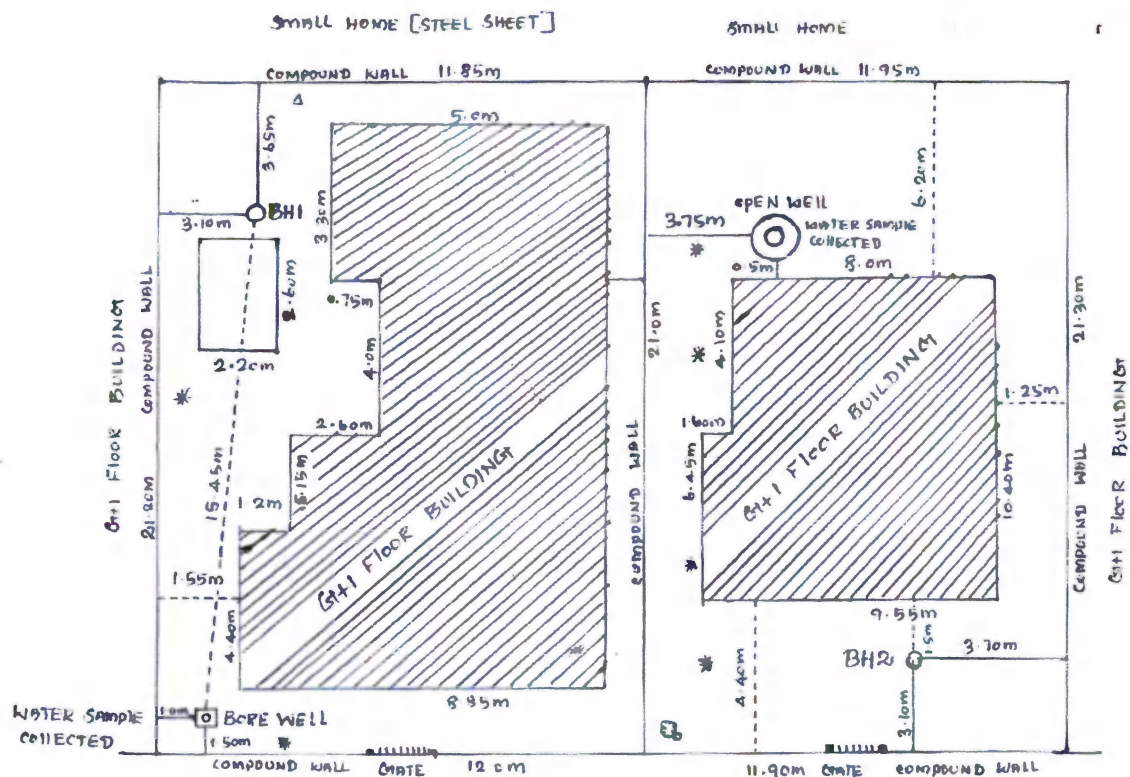
We do not expect construction problems at this site due to high groundwater conditions in non-rainy seasons. Visual observation inferred EGL of the site to be about ERL road in front of the site. It was recommended to raise FGL of the site by at least 0.6-M above ERL of road in front of the site. Building's stilt floor's FFL should be at least 0.15-M above FGL of the site. This will minimize rainwater runoff flooding into the site and building. Site filling should be done with granular fill soil with densification to achieve a total unit weight of at least 2 tons/M³. Old buildings present the site will have to be removed for the proposed construction. Proper care should be taken in pile installation to avoid **pile bulging / necking / improper concreting** during pile installation. For pile installation good quality bentonite and bentonite solution of suitable density should be used to minimize pile side wall collapse leading to necking problems as thick layers of clean sand were encountered in the borings. **Excess consumption of concrete can be expected at some depths in piles due to presence of very loose sand and very soft clay layers in the soil profiles of the borings.** Piles should be terminated in hard stratum weathered rock formation with a minimum 1-M of pile embedment. At pile termination depth bore should be properly washed and cleaned of all loosened material to prevent low end bearing capacity of the pile as the major pile load capacity will be developed by end bearing. **Pile load tests should be conducted as per relevant IS code to confirm the load carrying capacities recommended above and also to check quality of pile installation.**

For any reason hydraulic rotary rig has to be considered then it is necessary to reevaluate pile capacities based on the rig parameters based on input from piling contractor side, evaluate rig operations in the site, install test pile to check feasibility, check test pile for defects by Non-Destructive Tests (NDT), and **perform a few initial load test** to confirm the load carrying capacity of the pile installed by the hydraulic rotary rig. Also, NDTs should be performed on each and every pile of the planned building to confirm the pile integrity.

All structures have to be designed for higher seismic forces (**Zone III**) due to increased seismic activity in peninsular India in the past two decades. Seismic events of 5.4 magnitude on February 11, 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, 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 "Nil to Low" seismic susceptibility.** Under a seismic event of **6.5 Richter scale**, and peak ground acceleration of **0.07g** the total estimated vertical settlement was 1.83 cms and total horizontal displacement was about 0.28 cms. Iwasaki liquefaction potential was 0.0 inferring **"No Liquefaction."** As per IS code for **Zone III** design horizontal acceleration was about **0.05g** only. However, when thick layer of very weak sediments are present the effect of seismic wave effects gets magnified. Hence, in the analysis peak ground acceleration of **0.07g** was used. Liquefaction analysis results are presented on Plate 8.

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- Bureau of Indian Standards (2010), Code of Practice for Design and Construction of Pile Foundations, Part – I Concrete Piles; Section 2 – Bored Cast In-Situ Piles, IS: 2911 (Part I / Sec 2) - 2010, New Delhi.
- Bureau of Indian Standards (2010), Code of Practice for Design and Construction of Bored Cast-In-Situ Pile Founded on Rocks - Guidelines, IS: 14593 - 1998, New Delhi.
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- Bureau of Indian Standards (2002), Criteria for Earthquake Resistant Design of Structures, Part – 1: General Provision and Buildings, IS: 1893-2002 (Part 1), New Delhi.
- Bureau of Indian Standards (1980), Recommended Procedure for Standard Penetration Test, IS:2131 - 1980, New Delhi.
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30'-0" IDE INDRA NAGAR 28th CROSS STREET.

- SITE 1 FOUND LEVEL IS EVEN THE ROAD LEVEL
- BH1 TO BORE WELL DISTANCE - 15.45m, WATER SAMPLE COLLECTED
- BH2 TO OPEN WELL DISTANCE Ap- 20.0m,
OPEN WELL - DIA-1.10m, DEPTH-UNKNOWN, WATER LEVEL - 2.30m (WATER SAMPLE COLLECTED)
- * COCONUT TREES.
- ② MANGRO TREES.
- WATER LEVELS : BH1 - 2.10m, BH2 - NOT MEASURED.

Site EGL = ERL of Road In Front of Site.

(Not To Scale)

SITE PLAN WITH BORE LOCATION DETAILS.

PLATE 1

LOG OF BORING

Project: Proposed Residential Apartments Building Site, P. No. 30 and 31, O. No. 28 and 29, N. no. 51 and 53, 28th Cross Street, Indira Nagar, Thiruvannamipur, Chennai 600 020, TN.

Bore Hole No.: 1
Started on: 1-03-'21
Final Depth: 12.0-M

Type of Boring: Calyx Drill
Ended on: 1-03-'21
Depth to G W S: 2.1-M

Dia. of Hole: 150 mm
Field Work In Charge: R Murugesan
Remarks: None.

DEPTH, M	SOIL DESCRIPTION	SPT / VANE & SAMPLE TYPE	SPT "N" PROFILE			INDEX TEST DATA		
			10	20	30	25	50	75
1.0	RED BROWN FINE TO MEDIUM SAND with silt, brick and stone pieces (To 1.0-M) 0.0- to 1.0-m - $\gamma_t = 1.65 \text{ tons/M}^3$ ($N_{avg} \sim 14$)	DS @ 0.5 M SPT @ 1 M 7/8/8 = 16 Blows						
2.0	BROWN SILTY FINE TO MEDIUM SAND (To 1.75-M) 1.0- to 1.75-m - $\phi = 32^\circ$, $\gamma_t = 1.7 \text{ tons/M}^3$ ($N_{avg} = 16$)	SPT @ 2 M 4/4/6 = 10 Blows						
3.0	GRAY VERY SOFT TO STIFF CLAY (To 4.0-M) 1.75- to 2.75-m - $C_u = 6 \text{ tons/M}^2$, $\gamma_t = 1.6 \text{ tons/M}^3$ ($N_{avg} = 10$)	SPT @ 3 M 1/1/1 = 2 Blows						
4.0	2.75- to 4.0-m - $C_u = 1.25 \text{ tons/M}^2$, $\gamma_t = 1.4 \text{ tons/M}^3$ ($N_{avg} = 2$)	SPT @ 4 M 1/2/3 = 5 Blows						
5.0	GRAY FINE TO MEDIUM SAND (To 10.0-M) 4.0- to 6.0-m - $\phi = 26^\circ$, $\gamma_t = 1.5 \text{ tons/M}^3$ ($N_{avg} \sim 5.5$)	SPT @ 5 M 2/2/4 = 6 Blows						
6.0	6.0- to 7.0-m - $\phi = 31^\circ$, $\gamma_t = 1.65 \text{ tons/M}^3$ ($N_{avg} = 14$)	SPT @ 6 M 6/6/8 = 14 Blows						
7.0	7.0- to 8.0-m - $\phi = 32^\circ$, $\gamma_t = 1.7 \text{ tons/M}^3$ ($N_{avg} = 18$)	SPT @ 7 M 6/8/10 = 18 Blows						
8.0	8.0- to 10.0-m - $\phi = 34^\circ$, $\gamma_t = 1.8 \text{ tons/M}^3$ ($N_{avg} = 26$)	SPT @ 8 M 7/12/13 = 25 Blows						
9.0		SPT @ 9 M 9/12/15 = 27 Blows						
10.0	NX TC bit drilling from 10-m	SPT @ 10 M 5 cms for 10 Blows						
11.0	BROWN AND GRAY WEATHERED ROCK (Below 10.0-M) 10.0- to 11.0-m - $\phi = 37^\circ$, $\gamma_t = 2.1 \text{ tons/M}^3$ ($N_{avg} = 100$)	3 cms for 10 Blows (Hammer Rebound)						
	drilled from 10- to 10.5-m in 30 minutes							

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; ■ = % -75 μ Size

PLATE 2a

LOG OF BORING

Project: Proposed Residential Apartments Building Site, P. No. 30 and 31, O. No. 28 and 29, N. no. 51 and 53, 28th Cross Street, Indira Nagar, Thiruvananthapuram, Chennai 600 020, TN.

Bore Hole No.: 1
Started on: 1-03-'21
Final Depth: 12.0-M

Type of Boring: Calyx Drill
Ended on: 1-03-'21
Depth to G W S: 2.1-M

Dia. of Hole: 150 mm
Field Work In Charge: R Murugesan
Remarks: Continued from Plate 2b.

DEPTH, M	SOIL DESCRIPTION	SPT / VANE & SAMPLE TYPE	SPT "N" PROFILE			INDEX TEST DATA		
			10	20	30	25	50	75
	BROWN AND GRAY WEATHERED ROCK (Below 10.0-M)	SPT @ 11.5M (SNR)						
	NX Diamond bit drilling from 10.5-m	0 cms for 10 Blows						
12.0	11.0- to 12.0-m - $\phi = 39^\circ$; $\gamma_t = 2.25 \text{ tons/M}^3$ ($N_{avg} >> 100$)	(Hammer Rebound) SPT @ 12 M (SNR)						
	drilled from 10.5- to 11.5-m in 60 minutes	0 cms for 10 Blows						
	13 cms core recovered drilling to 11.5-m	(Hammer Rebound)						
13.0	drilled from 11.5- to 12-m in 30 minutes							
	8 cms core recovered drilling to 12-m							
14.0								
15.0								
16.0								
17.0								
18.0								
19.0								
20.0								
21.0								
22.0								

BORE HOLE TERMINATED AT 17.5-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; ■ = % -75 μ Size

PLATE 2b

LOG OF BORING

Project: Proposed Residential Apartments Building Site, P. No. 30 and 31, O. No. 28 and 29, N. no. 51 and 53, 28th Cross Street, Indira Nagar, Thiruvananthapuram, Chennai 600 020, TN.

Bore Hole No.: 2
Started on: 2-03-'21
Final Depth: 14.5-M

Type of Boring: Calyx Drill
Ended on: 3-03-'21
Depth to G W S: 2.3-M

Dia. of Hole: 150 mm
Field Work In Charge: R Murugesan
Remarks: GWL from Site Open Well.

DEPTH, M	SOIL DESCRIPTION	SPT / VANE & SAMPLE TYPE	SPT "N" PROFILE			INDEX TEST DATA		
			10	20	30	25	50	75
1.0	RED BROWN FINE TO MEDIUM SAND with brick and stone pieces (To 1.0-M) 0.0- to 1.0-m - $\gamma_t = 1.6 \text{ tons/M}^3$ ($N_{avg} = 8$)	DS @ 0.5 M SPT @ 1 M 4/6/9 = 15 Blows						
2.0	BROWN STIFF CLAY (To 1.75-M) 1.0- to 1.75-m - $C_u = 9 \text{ tons/M}^2$; $\gamma_t = 1.65 \text{ tons/M}^3$ ($N_{avg} = 15$)	SPT @ 2 M 1/2/2 = 4 Blows						
GWL	GRAY VERY SOFT TO SOFT CLAY (To 4.0-M) 1.75- to 2.75-m - $C_u = 2.5 \text{ tons/M}^2$; $\gamma_t = 1.5 \text{ tons/M}^3$ ($N_{avg} = 4$)	SPT @ 3 M 0/1/1 = 2 Blows						
3.0	with shell fragments at 3-m 2.75- to 4.0-m - $C_u = 1.25 \text{ tons/M}^2$; $\gamma_t = 1.4 \text{ tons/M}^3$ ($N_{avg} = 2$)	SPT @ 4 M 2/3/5 = 8 Blows						
4.0	GRAY FINE TO MEDIUM SAND (To 11.5-M) 4.0- to 5.0-m - $\phi = 28^\circ$; $\gamma_t = 1.6 \text{ tons/M}^3$ ($N_{avg} = 8$)	SPT @ 5 M 2/4/6 = 10 Blows						
5.0		SPT @ 6 M 3/5/7 = 12 Blows						
6.0	5.0- to 7.0-m - $\phi = 30^\circ$; $\gamma_t = 1.65 \text{ tons/M}^3$ ($N_{avg} = 11$)	SPT @ 7 M 4/6/10 = 16 Blows						
7.0		SPT @ 8 M 7/12/15 = 27 Blows						
8.0	7.0- to 8.0-m - $\phi = 32^\circ$; $\gamma_t = 1.7 \text{ tons/M}^3$ ($N_{avg} = 16$)	SPT @ 9 M 8/10/12 = 22 Blows						
9.0	8.0- to 8.75-m - $\phi = 34^\circ$; $\gamma_t = 1.8 \text{ tons/M}^3$ ($N_{avg} = 27$)	SPT @ 10 M 11/12/15 = 27 Blows						
10.0	8.75- to 10.0-m - $\phi = 33^\circ$; $\gamma_t = 1.75 \text{ tons/M}^3$ ($N_{avg} = 22$)							
	with silt at 10-m							
11.0	10.0- to 11.5-m - $\phi = 34^\circ$; $\gamma_t = 1.8 \text{ tons/M}^3$ ($N_{avg} = 27$)							

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; ■ = % -75 μ Size

PLATE 3a

LOG OF BORING

Project: Proposed Residential Apartments Building Site, P. No. 30 and 31, O. No. 28 and 29, N. no. 51 and 53, 28th Cross Street, Indira Nagar, Thiruvannamiyur, Chennai 600 020, TN.

Bore Hole No.: 2
Started on: 2-03-'21
Final Depth: 14.5-M

Type of Boring: Calyx Drill
Ended on: 3-03-'21
Depth to G W S: 2.3-M

Dia. of Hole: 150 mm
Field Work In Charge: R Murugesan
Remarks: Continued from Plate 3b.

DEPTH. M	SOIL DESCRIPTION	SPT / VANE & SAMPLE TYPE	SPT "N" PROFILE			INDEX TEST DATA		
			10	20	30	25	50	75
	GRAY FINE TO MEDIUM SAND (To 11.5-M) NX TC bit drilling from 11.5-m	SPT @ 11.5 M 3 cms for 10 Blows						
12.0	BROWN WEATHERED RED ROCK (To 13.0-M) 11.5- to 13.0-m - $\phi = 38^\circ$; $\gamma_t = 2.2 \text{ tons/M}^3$ ($N_{avg} > 100$)	2 cms for 10 Blows (Hammer Rebound)						
13.0	drilled from 11.5- to 13-m in 35 min NX Diamond bit drilling from 13-m	SPT @ 13M (SNR) 2 cms for 10 Blows						
	GRAY HIGHLY JOINTED GRANITE (Below 13.0-M) 13.0- to 14.5-m - $\phi = 39^\circ$; $\gamma_t = 2.25 \text{ tons/M}^3$ ($N_{avg} >> 100$)	1 cm for 10 Blows (Hammer Rebound)						
14.0	drilled from 13- to 14.5-m in 50 min.	SPT @ 14.5M (SNR) 0 cms for 10 Blows						
15.0	14.5-m+ - $\phi = 40^\circ$; $\gamma_t = 2.3 \text{ tons/M}^3$ ($N_{avg} >> 100$) 52 cms core recovered drilling to 14.5-m 35% CR & 26% RQD	(Hammer Rebound)						
16.0								
17.0								
18.0								
19.0								
20.0								
21.0								
22.0								

BORE HOLE TERMINATED AT 16.0-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; ■ = % -75 μ Size

PLATE 3b

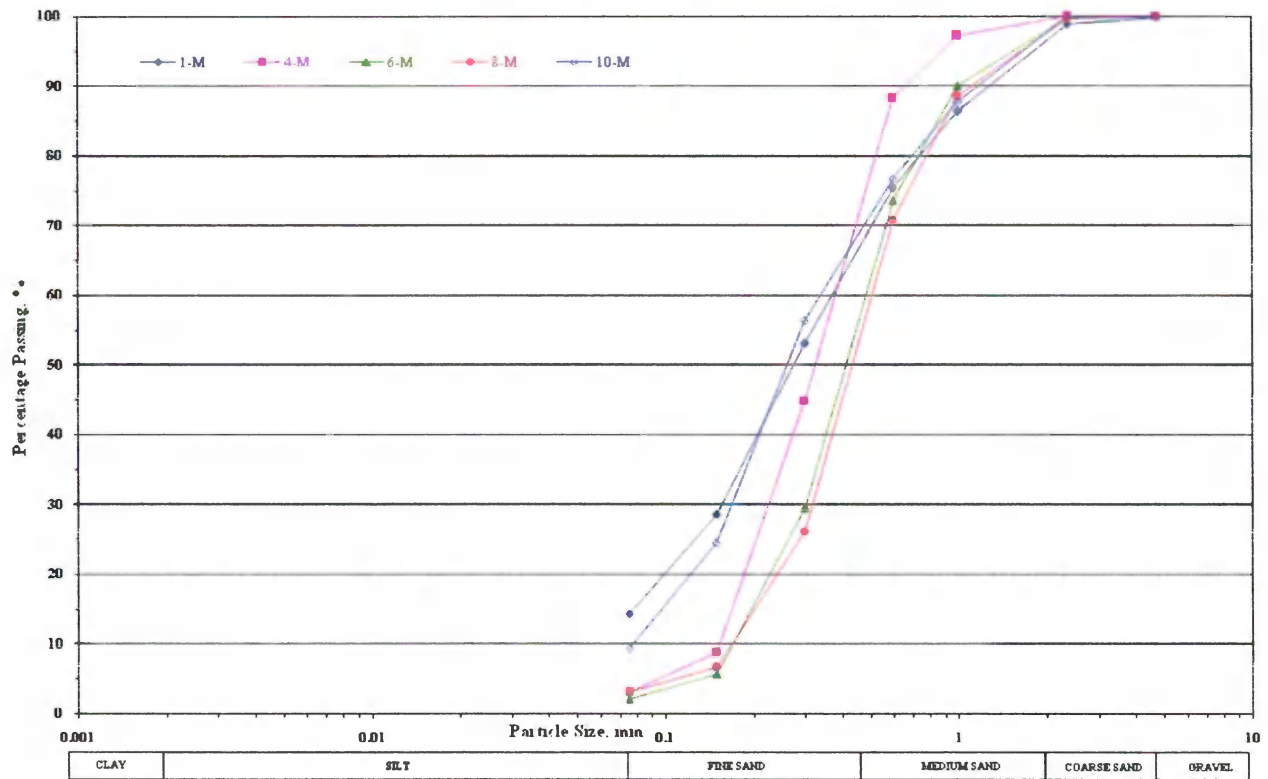
SUMMARY OF TEST RESULTS

Boring No	Depth, M	w %	PL	LL	-75 μ %	SAND			GRAVEL %	IS CLASS.
						Fine%	Medium%	Coarse%		
1	0.5	6			6					
	1.0	15			14	52	30	4	0	SM
	2.0	44	32	77						CH
	3.0	65	33	81						CH
	4.0	20			3	67	30	0	0	SP
	5.0	19			2					
	6.0	18			2	53	43	2	0	SP
	7.0	17			2					
	8.0	17			3	48	46	3	0	SP
	9.0	18			2					
	10.0	10			9	59	29	3	0	SP-SM
	11.5	SNR	rock	core	pieces					
	12.0	SNR	rock	core	pieces					
2	0.5	5			4					
	1.0	22	20	57						CH
	2.0	53	29	72						CH
	3.0	70	28	81						CH
	4.0	19			3	60	35	2	0	SP
	5.0	19			2					
	6.0	17			3	49	45	3	0	SP
	7.0	15			2					
	8.0	15			2	46	48	4	0	SP
	9.0	17			2					
	10.0	15			3	48	44	5	0	SP
	11.5	10			8	28	25	16	23	SW
	13.0	SNR								
	14.5	SNR	rock	core	pieces					

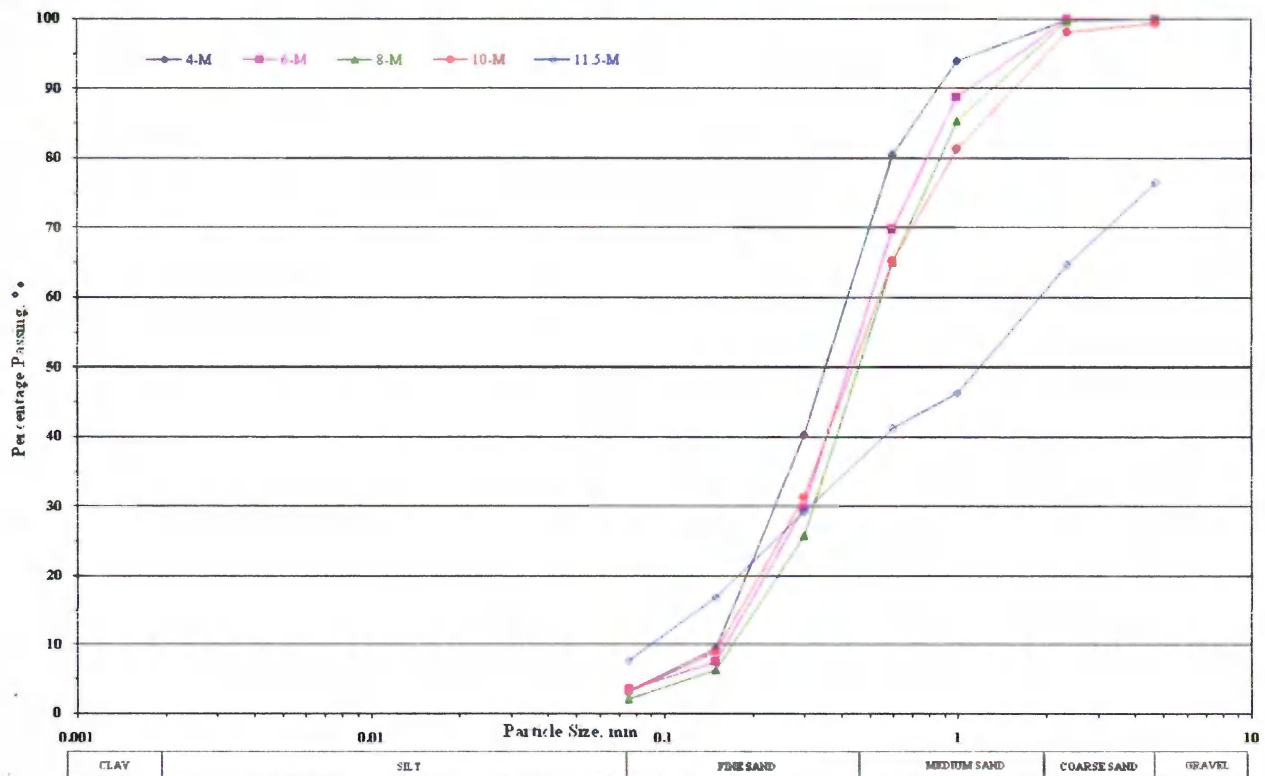
FREE SWELL INDEX TEST RESULTS

BORE NO.	DEPTH, M	FREE SWELL INDEX, %
1	2.0	177
	3.0	173
2	1.0	87
	2.0	158
	3.0	164

Grain Size Distribution Curves Boring 1



Grain Size Distribution Curves Boring 2



SUMMARY OF WATER TEST RESULTS**OPEN WELL; DIAMETER = 1.1-M; DEPTH = UNKNOWN; WATER LEVEL = 2.3-M.**

S. No.	Description	Results Obtained	As per IS:456 – 2000
1	To neutralize 100 cc of water using phenolphthalein as indicator	0.40 ml	Not more than 5 ml of 0.02N NaOH
2	To neutralize 100 cc of water using methyl orange as indicator	40.0 ml	Not more than 25 ml of 0.02N H ₂ SO ₄
3	a Organic Solids, mg/liter	40	200 Max.
	b Inorganic Solids, mg/liter	986	3,000 Max.
	c Sulphates as SO ₃ , mg/liter	142	400 Max.
	d Chlorides as Cl, mg/liter	255	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 does not meet the requirements of above clause 2.
Hence water cannot be used for construction purposes as per IS 456 - 2000.

BORE WELL; DEPTH = UNKNOWN; WATER LEVEL = COULD NOT SEE
DISTANCE = 15.4-M FROM BORING 2.

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	41.0 ml	Not more than 25 ml of 0.02N H ₂ SO ₄
3	a Organic Solids, mg/liter	48	200 Max.
	b Inorganic Solids, mg/liter	1,168	3,000 Max.
	c Sulphates as SO ₃ , mg/liter	160	400 Max.
	d Chlorides as Cl, mg/liter	276	2,000 Max. - Plain Concrete 500 Max. RCC
	e Suspended Solids, mg/liter	0	2,000 Max.
	f pH	7.60	6 Min.

Remarks: The sample does not meet the requirements of above clause 2.
Hence water cannot be used for construction purposes as per IS 456 - 2000.

SUMMARY OF SOIL CHEMICAL TEST RESULTS

Bore No.	Depth M	pH	Chlorides PPM	Sulphates SO ₄ , PPM	Sulphates SO ₃ , PPM
1	2.0	7.00	68	0	0
2	9.0	7.60	80	0	0

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****P. No. 30 & 31, O. No. 28 & 29, N. No. 51 & 53, 28th Cross Street, Indira Nagar, Thiruvanniyur, Chennai 600 020, TN.****Bored Cast In-Situ Pile Details:**

Total Pile Length = 11.00 M below EGL
 Top Pile Cutoff Length = 1.00 M Top pile cutoff length for pilecaps
 Pile Effective Concreting Length = 10.00 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 Data)**

S.No.	Soil Description	From	To	N _{avg}	C _u , T/M ²	φ ⁰	γ _T , T/M ³
1	Red Brown F to M Sand with ...	0.00	1.00	14			1.65
2	Brown Silty Fine to Medium Sand	1.00	1.75	16		32	1.70
3a	Gray Very Soft to Stiff Clay	1.75	2.75	10	6.00		1.60
3b	Gray Very Soft to Stiff Clay	2.75	4.00	2	1.25		1.40
4a	Gray Fine to Medium Sand	4.00	6.00	5.5		26	1.50
4b	Gray Fine to Medium Sand	6.00	7.00	14		31	1.65
4c	Gray Fine to Medium Sand	7.00	8.00	18		32	1.70
4d	Gray Fine to Medium Sand	8.00	10.00	26		34	1.80
5a	Brown & Gray Weathered Rock	10.00	11.00	100		37	2.10
5b	Brown & Gray Weathered Rock	11.00	12.00	>> 100		39	2.30

For Cohesive Soils :-

C _u	α
1.25	1.00
6.00	0.75

Pile Capacity Calculations by IS : 2911 (Part I / Sec. 2) Method.Unit Skin Friction in Clay Soils, $f_s = \alpha C_u$ 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, $Q_{s\text{ ult}} = \sum Q_{si}$ 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, $Q_{p\text{ ult}} = q_{ult} * \pi D^2 / 4$ Total Ultimate Pile Capacity, $Q_{ult} =$ Allowable Pile Capacity, $Q_{all} = Q_{ult} / FS$ $Q_{s\text{ ult}} + Q_{p\text{ ult}}$

FS = Factor of Safety = 3.00

COMPRESSIVE PILE CAPACITY CALCULATIONS**Skin Friction Calculations**

S.No.	Soil Description	From	To	ϕ^0 / C_u	$\delta = \phi$	$\gamma'_s, T/M^3$	$\sigma'_{Mid}, T/M^2$	Pile Dia $f_s, T/M^2$	0.45	0.50	0.60	0.75	0.90	-M.
									Q_s, T	Q_s, T	Q_s, T	Q_s, T	Q_s, T	Q_s, T
1	Red Brown F to M Sand with	0.00	1.00	0	0	0.65	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00 Cutoff
2	Brown Silty Fine to Medium Sand	1.00	1.75	32	32	0.70	0.91	0.57	0.60	0.67	0.81	1.01	1.21	
3a	Gray Very Soft to Stiff Clay	1.75	2.75	6.00	6	0.60	1.48	4.50	6.36	7.07	8.49	10.61	12.73	
3b	Gray Very Soft to Stiff Clay	2.75	4.00	1.25	1	0.40	2.03	1.25	2.21	2.46	2.95	3.68	4.42	
4a	Gray Fine to Medium Sand	4.00	6.00	26	26	0.50	2.78	1.35	3.83	4.25	5.10	6.38	7.66	
4b	Gray Fine to Medium Sand	6.00	7.00	31	31	0.65	3.60	2.16	3.06	3.40	4.08	5.10	6.12	
4c	Gray Fine to Medium Sand	7.00	8.00	32	32	0.70	4.28	2.67	3.78	4.20	5.04	6.30	7.56	
4d	Gray Fine to Medium Sand	8.00	10.00	34	34	0.80	5.43	3.66	10.35	11.50	13.80	17.25	20.70	
5a	Brown & Gray Weathered Rock	10.00	11.00	37	37	1.10	6.78	5.11	7.22	8.02	9.63	12.03	14.44	
5b	Brown & Gray Weathered Rock	11.00	11.00	39	39	1.30	7.33	5.93	0.00	0.00	0.00	0.00	0.00	

Net Total Ultimate Skin Friction, $Q_{s \text{ ult}}$

37.41	41.57	49.89	62.36	74.83
-------	-------	-------	-------	-------

@ 11-M below EGL Soil - Very
Hard Weathered Rock

L/D of Pile = $11.0/0.45 > 20$ L/D of Pile = $11.0/0.50 > 20$ L/D of Pile = $11.0/0.60 > 20$ L/D of Pile = $11.0/0.75 > 20$ L/D of Pile = $11.0/0.90 < 20$ Use Lim. Value or Actual σ'_{base} $N = >> 100$ $N_q = 85$ $N_y = 81$

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

Allowable Compressive Capacity =

Use

	0.45	0.50	0.60	0.75	0.90 -M
Base A=	0.1591	0.1964	0.2829	0.4420	0.6364 -M ²
$\sigma'_{base} =$	5.43	6.23	7.33	7.33	7.33 T/M ²
$q_{b \text{ ult}} =$	484.82	555.45	654.22	662.11	670.01 T/M ²
$q_{b \text{ ult}} =$	900.00	900.00	900.00	900.00	900.00 T/M ²
$Q_{b \text{ ult}} =$	77.14	109.11	185.05	292.63	426.41 Tons
$Q_{s \text{ ult}} =$	37.41	41.57	49.89	62.36	74.83 Tons
$Q_{\text{tot ult}} =$	114.55	150.68	234.93	354.99	501.24 Tons
F.S. =	3.00	3.00	3.00	3.00	3.00
$Q_{All} =$	38.18	50.23	78.31	118.33	167.08 Tons
$Q_{All} =$	38	50	78	118	167 Tons

Note:-

- 1 Pile Load Test must be conducted as per relevant IS Code to confirm the above estimated pile capacities before completion of installation of all piles.
- 2 Pile installation must be done with extreme care to prevent "Necking" and "Bulging" problems due to presence of Very Loose Sand / Very Soft Clay Strata;
- 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 IS code was 500 tons/M². Therefore, q_b (all) is limited to 300 tons/M².
- 5 Factor of Safety 3.0 was used instead of IS code standard value of 2.50 due to encountered weak soil in top 5-M that can contribute -ve Skin Friction.

UPLIFT PILE CAPACITY CALCULATIONS**Skin Friction Calculations**

S.No.	Soil Description	From	To	ϕ^0 / C_u	$\delta = \phi$	$\gamma'_s, T/M^3$	$\sigma'_{Mid}, T/M^2$	Pile Dia $f_s, T/M^2$	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.
1	Red Brown F to M Sand with	0.00	1.00	0	0	0.65	0.33	0.00	0.00	0.00	0.00	0.00	0.00	Cutoff
2	Brown Silty Fine to Medium Sand	1.00	1.75	32	32	0.70	0.91	0.57	0.60	0.67	0.81	1.01	1.21	
3a	Gray Very Soft to Stiff Clay	1.75	2.75	6.00	6	0.60	1.48	4.50	6.36	7.07	8.49	10.61	12.73	
3b	Gray Very Soft to Stiff Clay	2.75	4.00	1.25	1	0.40	2.03	1.25	2.21	2.46	2.95	3.68	4.42	
4a	Gray Fine to Medium Sand	4.00	6.00	26	26	0.50	2.78	1.35	3.83	4.25	5.10	6.38	7.66	
4b	Gray Fine to Medium Sand	6.00	7.00	31	31	0.65	3.60	2.16	3.06	3.40	4.08	5.10	6.12	
4c	Gray Fine to Medium Sand	7.00	8.00	32	32	0.70	4.28	2.67	3.78	4.20	5.04	6.30	7.56	
4d	Gray Fine to Medium Sand	8.00	10.00	34	34	0.80	5.43	3.66	10.35	11.50	13.80	17.25	20.70	
5a	Brown & Gray Weathered Rock	10.00	11.00	37	37	1.10	6.78	5.11	7.22	8.02	9.63	12.03	14.44	
5b	Brown & Gray Weathered Rock	11.00	11.00	39	39	1.30	7.33	5.93	0.00	0.00	0.00	0.00	0.00	

Net Total Ultimate Skin Friction, $Q_{s\text{ ult}}$

37.41 41.57 49.89 62.36 74.83

Unit Weight of Pile RCC = γ_{conc} 2.40 T/M³

	0.45	0.50	0.60	0.75	0.90 -M
Base A=	0.1591	0.1964	0.2829	0.4420	0.6364 -M ²
Pile Length, L =	10.00	10.00	10.00	10.00	10.00 -M
Pile Volume, V =	1.59	1.96	2.83	4.42	6.36 -M ³
Submerged Pile Weight W =	2.23	2.75	3.96	6.19	8.91 Tons
$Q_{s\text{ ult}}$ =	37.41	41.57	49.89	62.36	74.83 Tons
$Q_{\text{tot ult}}$ =	39.64	44.32	53.85	68.54	83.74 Tons
F.S. =	3.00	3.00	3.00	3.00	3.00
Allowable Transient Uplift Capacity =	13.21	14.77	17.95	22.85	27.91 Tons
Use	13	15	18	23	28 Tons

Note:-

- 1 Pile Load Test must be conducted as per relevant IS Code to confirm the above estimated pile capacities before completion of installation of all piles.
- 2 Pile installation must be done with extreme care to prevent "Necking" and "Bulging" problems due to presence of Very Loose Sand / Very Soft Clay Strata;
- 3 Ground water level was assumed to rise to ground level in worst case conditions.

SAMPLE CALCULATIONS FOR LATERAL LOAD CAPACITY OF PILES.**BY BROMS (1964) METHOD.****PROPOSED RESIDENTIAL APARTMENTS BUILDING SITE****P. No. 30 & 31, O. No. 28 & 29, N. No. 51 & 53, 28th Cross Street, Indira Nagar, Thiruvanimiyur, Chennai 600 020, TN.****BORING 1 SOIL PROFILE**

Pile Dia.	0.45	0.50	0.60	0.75	0.90 -M
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Pile Type Bored Cast In-Situ Concrete Piles

Concrete Grade =	M30	Max. Comp. Stress in Bending	$f_c = \begin{cases} 700 \text{ Tons/M}^2 \\ 70 \text{ Kg/cm}^2 \end{cases}$
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Min. % of Reinforcement Content = 0.40%

Modulus of Pile, $E_c =$	200000 Kg/cm ²	=	2000000 Tons/M ²
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Soil's $C_u =$ 4.00 Tons/M² Wt. Avg. from 1- to 4-M of Boring 1Soil's $\gamma' =$ 0.60 Tons/M³

Factor of Safety = 3.00

Dia., D M	(I) Mom. of Inertia, M ⁴	y = D/2 M	f_c Tons/M ²	M_{yield} Tons-M	$\frac{M_{yield}}{D^3 C_u}$	Broms Factor	P_{ult} Tons	P_{all} Tons
				$\frac{f_c * I}{y}$		$\frac{P_{ult}}{C_u D^2}$		
0.45	0.00201	0.23	700	6.26	17.18	10.00	8.10	2.70
0.50	0.00307	0.25	700	8.59	17.18	10.00	10.00	3.33
0.60	0.00636	0.30	700	14.84	17.18	10.00	14.40	4.80
0.75	0.01553	0.38	700	28.99	17.18	10.00	22.50	7.50
0.90	0.03221	0.45	700	50.10	17.18	10.00	32.40	10.80

Note:-

- 1.) Pile Load Test must be conducted as per relevant IS Code to confirm the above estimated pile capacities before completion of installation of all piles.
- 2.) Pile is assumed to be "Fixed Head" type than "Free Head" due to provision of pile cap with a minimum 20 tons axial pile load with pile caps and tie beams.

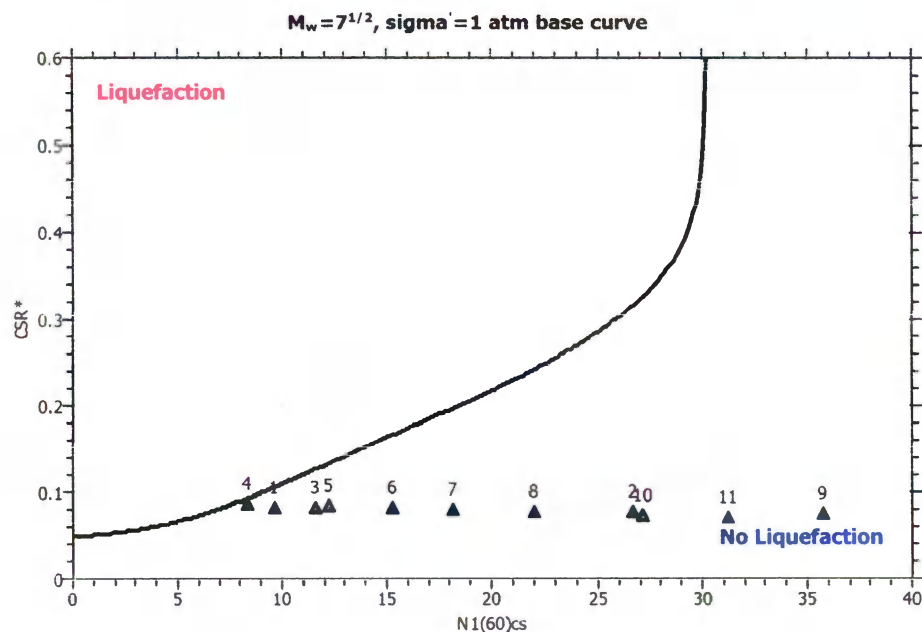
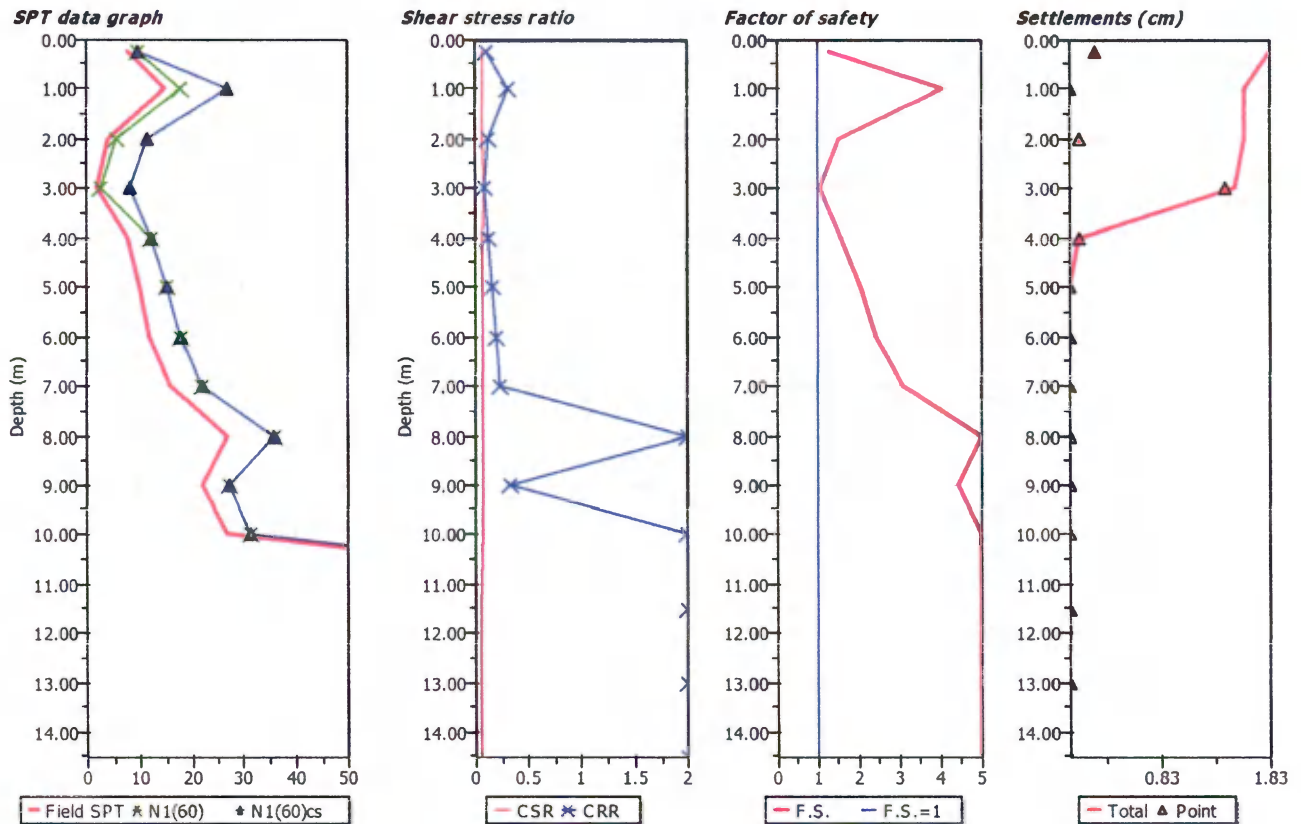
LIQUEFACTION ANALYSIS REPORT

Project title : O. No. 29, 28th Cross Street, Indira Nagar, Adyar, Chennai 600 020, TN.

Project subtitle : Boring 2 Soil Profile

Input parameters and analysis data

In-situ data type:	Standard Penetration Test	Depth to water table:	0.00 m
Analysis type:	Deterministic	Earthquake magnitude M_w :	6.50
Analysis method:	NCEER 1998	Peak ground acceleration:	0.07 g
Fines correction method:	Idriss & Seed	User defined F.S.:	1.00



Horizontal Acceleration, $A_h = 0.07g$

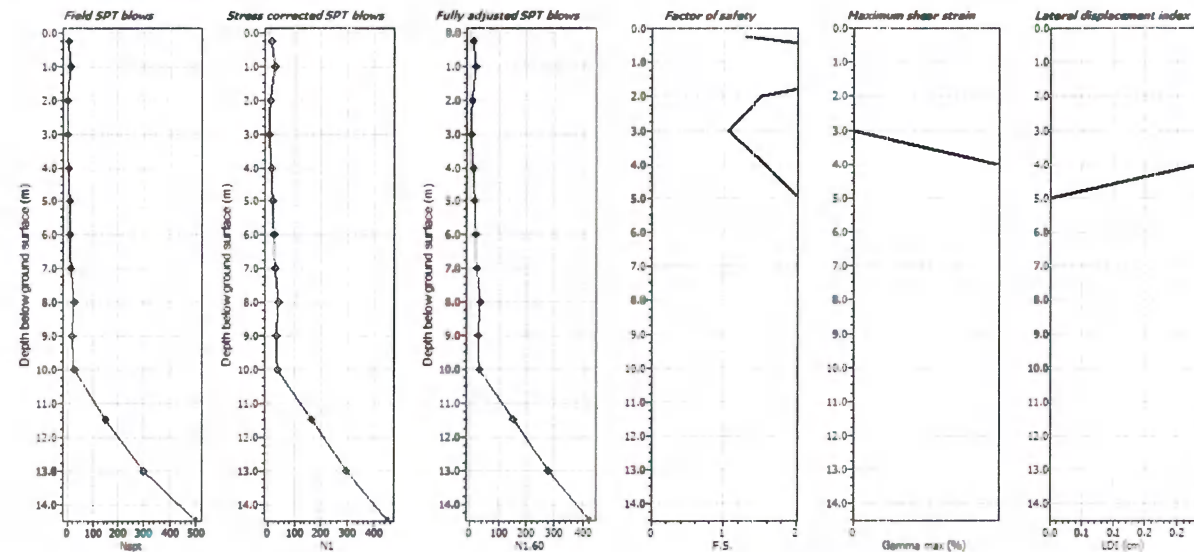
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 LqTT Software v.4.6
 Assessment of soil liquefaction potential from SPT, CPT or Vb data

LATERAL DISPLACEMENTS ESTIMATION DUE TO SOIL LIQUEFACTION¹

Geometric parameters: Gently sloping ground without free face
 Total lateral displacement estimation: 0.28 cm

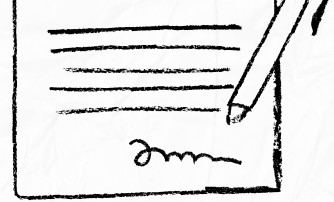


N₆₀: Measured SPT blows
 N₆₀: Stress corrected SPT blows
 N₆₀: Fully adjusted SPT blows

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

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

LqTT v.4.6 - Soil Liquefaction Assessment Software



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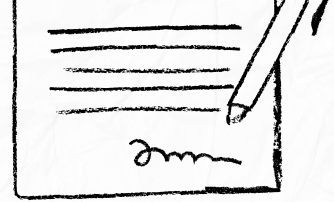
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