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PRASAD ARMSTRONG YEN G E C (P) LTD.

821 (Old No. 439/4) Poonamallee High Road, Arumbakkam, Chennai 600 106.

Phone: 044 - 2363 7146; e-mail: paygec@yahoo.com

CIN: U74210TN1992PTC023645

GEOTECHNICAL SITE INVESTIGATION
BORING 1 AND 2
PROPOSED COMMERCIAL BUILDING SITE
NO. 38, BLOCK NO. 24, MAHATMA GANDHI ROAD
THIRUVANMIYUR, CHENNAI 600 041, TN.

Report to

M/s. Keyem Engineering Enterprises

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

Kamaraj Nagar

Thiruvanmiyur, Chennai 600 041, TN.

1245

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Report No. 153/GI/19-20.

August 25, 2019.

M/s. Keyem Engineering Enterprises

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

Kamaraj Nagar

Thiruvanniyur, Chennai 600 041, TN.

Attention: Mr. S. Rama Chandran
Proprietor

Geotechnical Site Investigation

Boring 1 and 2

Proposed Commercial Building Site

No. 38, Block No. 24, Mahatma Gandhi Road

Thiruvanniyur, Chennai 600 041, 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 ref. No. Nil received on August 17, 2019.

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

(153brpt)

Copies Submitted: (3)



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 Commercial Building Site, No. 38, Block No. 24, Mahathma Gandhi Road, Thiruvannamiyur, Chennai 600 041, 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 + 4 floors building. For the proposed building with planned column configuration typical maximum column load will be about 300 tons. This load detail was used only for estimating the preliminary foundation size and type of foundation.

The field investigation was performed on August 18 through 21, 2019. Number and location of the borings were selected to cover the proposed building area. Borings 1 and 2 were drilled 10-M depth below the Existing Ground Level (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. Proposed site was a corner plot with MG Road along northern boundary and RBI Colony 2nd Street along eastern boundary. Site had compound walls along all boundaries. Visual observation inferred EGL of the site to be about 0.25-M below ERL of MG Road, and 0.15-M below ERL of RBI Colony 2nd Street in front of the site. Old building present at this site was cleared before this investigation. Many trees, bushes, plants were present in the site near compound walls during this work. 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	Brown Silty Fine Sand with Clay Binder
II	1.0	3.0	Brown Stiff to Hard Clay
III	3.0	10.0+	Brown Fine to Medium Sand

Boring – 2:

<u>Stratum</u>	<u>Penetration, M</u>		<u>Description</u>
	<u>From</u>	<u>To</u>	
I	0	1.0	Brown Fine to Medium Sand with Silt, Brick and Stone Pieces
II	1.0	2.0	Brown Silty fine Sand
III	2.0	7.0	Brown Fine to Medium Sand
IV	7.0	10.0+	Brown Gray Fine to Medium Sand

Data from the borings indicate presence of similar soil profiles with sandy soil upto 10-M with some variations in soil type in the top 3-M. For the expected high column loads and encountered 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 **9- and 8-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 4-M embedment into hard stratum sand. 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	139.95	56	49.10	20	10.63	4.25
0.50	167.29	67	54.78	22	11.94	4.77
0.60	229.29	92	66.26	27	15.47	6.19
0.75	340.91	136	83.82	34	20.14	8.06
0.90	475.40	190	101.77	41	24.49	9.80

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 the column loads. 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.

Groundwater was not clearly seen in the borings. There is a bore well of about 30.5-M depth located at about 17-M from Boring 1. This bore well developed just a few days before this investigation field work. Ground water was seen at about 10.6-M below EGL in the bore well. Groundwater sample was collected for construction suitability purposes tests from this bore well. Test results indicate that groundwater sample from the bore well was suitable for construction purposes as per IS: 456 - 2000 code guidelines. Chemical tests on soil samples from 2-M depth in Boring 1 and 8-M depth in 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.

We do expect construction problems at this site due to site soil and groundwater conditions. Visual observation inferred EGL of the site to be about 0.25-M below ERL of MG Road, and 0.15-M below ERL of RBI Colony 2nd Street in front of the site. It was recommended to raise FGL of the site by at least 0.6-M above ERL of roads in front of the site. Building's stilt floor's FFL should be at least 0.2-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.

Proper care should be taken in pile installation to avoid **pile necking / improper concreting** during pile installation due to presence of all sand soil profile. 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. Piles should be terminated in hard stratum formation with at least 4-M of pile embedment. At pile termination depth bore should be properly washed and cleaned of all loosened sand 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 the quality of pile installation.

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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 "No" seismic susceptibility. Under a seismic event of **6.5 Richter scale**, and peak ground acceleration of **0.08g** the total estimated vertical settlement was 0.0 cms and total horizontal displacement was about 0.0 cms. Iwasaki liquefaction potential was 0.0 inferring "**No Liquefaction.**" As per IS code for **Zone III** design horizontal acceleration was **0.08g** 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 **0.08g** was used.

INTRODUCTION

Purpose and Scope

Prasad Armstrong Yen GEC (P) Ltd. performed a geotechnical site investigation at the Proposed Commercial Building Site, No. 38, Block No. 24, Mahathma Gandhi Road, Thiruvanniyur, Chennai 600 041, 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 + 4 floors building. For the proposed building with planned column configuration typical maximum column load will be about 300 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 10-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 10-M depth 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 not clearly seen in the borings. 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. 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 samples were collected at 1-M interval 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 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. Proposed site was a corner plot with MG Road along northern boundary and RBI Colony 2nd Street along eastern boundary. Site had compound walls along all boundaries. Visual observation inferred EGL of the site to be about 0.25-M below ERL of MG Road, and 0.15-M below ERL of RBI Colony 2nd Street in front of the site. Old building present at this site was cleared before this investigation. Many trees, bushes, plants were present in the site near compound walls during this work. 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:

Stratum	Penetration, M		Description
	From	To	
I	0	1.0	Brown Silty Fine Sand with Clay Binder
II	1.0	3.0	Brown Stiff to Hard Clay
III	3.0	10.0+	Brown Fine to Medium Sand

Boring - 2:

Stratum	Penetration, M		Description
	From	To	
I	0	1.0	Brown Fine to Medium Sand with Silt, Brick and Stone Pieces
II	1.0	2.0	Brown Silty fine Sand
III	2.0	7.0	Brown Fine to Medium Sand
IV	7.0	10.0+	Brown Gray Fine to Medium Sand

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 properties 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	$\gamma_{sat} = 1.6 \text{ tons/M}^3$
IIa	1.0	1.75	$C_u = 20 \text{ tons/M}^2$; $\gamma_{sat} = 1.85 \text{ tons/M}^3$
IIb	1.75	3.0	$C_u = 9 \text{ tons/M}^2$; $\gamma_{sat} = 1.65 \text{ tons/M}^3$
IIIa	3.0	3.75	$\phi = 37^\circ$; $\gamma_{sat} = 2.1 \text{ tons/M}^3$
IIIb	3.75	5.0	$\phi = 36^\circ$; $\gamma_{sat} = 2.0 \text{ tons/M}^3$
IIIc	5.0	10.0	$\phi = 37^\circ$; $\gamma_{sat} = 2.1 \text{ tons/M}^3$
IIId	10.0+		$\phi = 38^\circ$; $\gamma_{sat} = 2.2 \text{ tons/M}^3$

Boring - 2:

Stratum	Penetration, M		Properties
	From	To	
I	0	1.0	$\gamma_{sat} = 1.65 \text{ tons/M}^3$
II	1.0	2.0	$\phi = 33^\circ$; $\gamma_{sat} = 1.75 \text{ tons/M}^3$
III	2.0	7.0	$\phi = 37^\circ$; $\gamma_{sat} = 2.1 \text{ tons/M}^3$
IVa	7.0	8.5	$\phi = 38^\circ$; $\gamma_{sat} = 2.2 \text{ tons/M}^3$
IVb	8.5	10.0	$\phi = 37^\circ$; $\gamma_{sat} = 2.1 \text{ tons/M}^3$
IVc	10.0+		$\phi = 38^\circ$; $\gamma_{sat} = 2.2 \text{ tons/M}^3$

DESIGN INFORMATION

Data from the borings indicate presence of similar soil profiles with sandy soil upto 10-M with some variations in soil type in the top 3-M. For the expected high column loads and encountered 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 **9- and 8-M** total and effective length piles below EGL 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 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	139.95	56	49.10	20	10.63	4.25
0.50	167.29	67	54.78	22	11.94	4.77
0.60	229.29	92	66.26	27	15.47	6.19
0.75	340.91	136	83.82	34	20.14	8.06
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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 the column loads. 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. Sample calculations are presented on Plate 7.

GROUNDWATER AND SOIL CHEMICAL ANALYSIS

Groundwater was not clearly seen in the borings. There is a bore well of about 30.5-M depth located at about 17-M from Boring 1. This bore well developed just a few days before this investigation field work. Ground water was seen at about 10.6-M below EGL in the bore well. Groundwater sample was collected for construction suitability purposes tests from this bore well. Test results indicate that groundwater sample from the bore well was **suitable** for construction purposes as per IS: 456 - 2000 code guidelines. Chemical tests on soil samples from 2-M depth in Boring 1 and 8-M depth in 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. Summary of groundwater and soil chemical test results were presented on Plate 6.

CONSTRUCTION CONSIDERATIONS

We do expect construction problems at this site due to site soil and groundwater conditions. Visual observation inferred EGL of the site to be about 0.25-M below ERL of MG Road, and 0.15-M below ERL of RBI Colony 2nd Street in front of the site. It was recommended to raise FGL of the site by at least 0.6-M above ERL of roads in front of the site. Building's stilt floor's FFL should be at least 0.2-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.

Proper care should be taken in pile installation to avoid **pile necking / improper concreting** during pile installation due to presence of all sand soil profile. 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. Piles should be terminated in hard stratum formation with at least 4-M of pile embedment. At pile termination depth bore should be properly washed and cleaned of all loosened sand 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 the quality of pile installation.

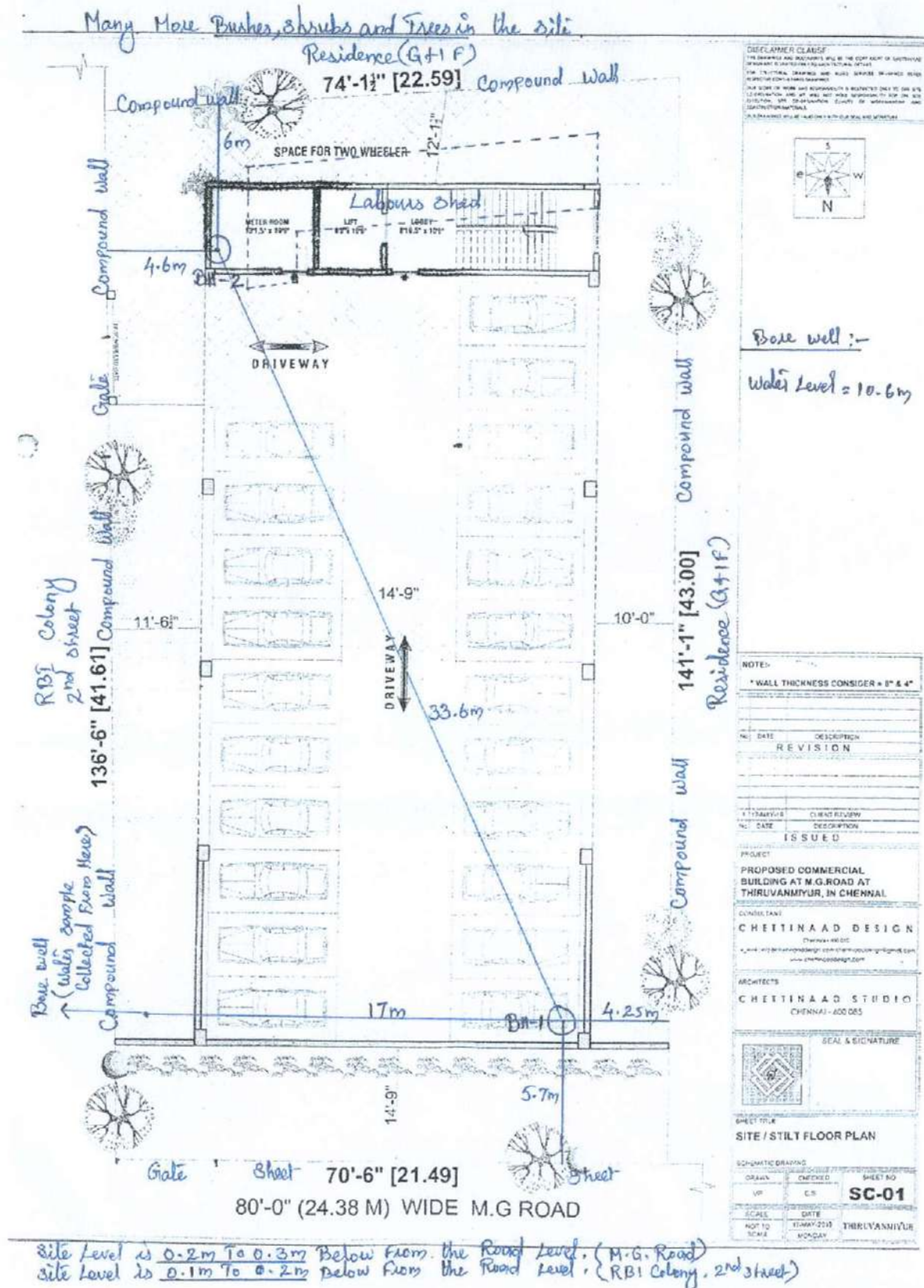
All structures have to be designed for higher seismic forces (**Zone III**) due to increased seismic activity in peninsular India in the past two decades. Seismic events of 5.4 magnitude on February 11, 2019, 7.9 magnitude on April 25, 2015, 6.0 magnitude on May 21, 2014, 8.4 magnitude on April 11, 2012, 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 "No" seismic susceptibility. Under a seismic event of **6.5 Richter scale**, and peak ground acceleration of **0.08g** the total estimated vertical settlement was 0.0 cms and total horizontal displacement was about 0.0 cms. Iwasaki liquefaction potential was 0.0 inferring "**No Liquefaction**." As per IS code for **Zone III** design horizontal acceleration was **0.08g** 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 **0.08g** was used. Liquefaction analysis results are presented on Plate 8.

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Site EGL = 0.25-M Below ERL of MG Road In Front of Site.
Site EGL = 0.15-M Below ERL of RBI Colony 2nd Street In Front of Site.

SITE PLAN WITH BORE LOCATION DETAILS.

(Not To Scale)

PLATE 1

LOG OF BORING

Project: Proposed Commercial Building Site, No. 38, Block No. 24, Mahatma Gandhi Road, Thiruvannamipur, Chennai 600 041, TN.

Bore Hole No.: 1
Started on: 19-08-'19
Final Depth: 10.0-M

Type of Boring: Calyx Drill
Ended on: 20-08-'19
Depth to G W S: 10.6-M

Dia. of Hole: 150 mm
Field Work In Charge: M Munivel
Remarks: From Site Bore Well.

DEPTH, M	SOIL DESCRIPTION	SPT / VANE & SAMPLE TYPE	SPT "N" PROFILE			INDEX TEST DATA		
			25	50	75	25	50	75
	BROWN SILTY FINE SAND with clay binder (To 1.0-M)	SPT @ 0.25 M 3/6/7 = 13 Blows						
1.0	0.0- to 1.0-m - $\gamma_t = 1.6 \text{ tons/M}^3$ ($N_{avg} \sim 8$)	SPT @ 1 M 7/16/16 = 32 Blows						
	BROWN STIFF TO HARD CLAY (To 3.0-M)							
2.0	1.0- to 1.75-m - $C_u = 20 \text{ tons/M}^2$; $\gamma_t = 1.85 \text{ tons/M}^3$ ($N_{avg} = 32$)	SPT @ 2 M 4/6/8 = 14 Blows						
	grayish brown color at 2-m							
3.0	1.75- to 3.0-m - $C_u = 9 \text{ tons/M}^2$; $\gamma_t = 1.65 \text{ tons/M}^3$ ($N_{avg} = 14$)	SPT @ 3 M 22/ 4 cms for 10 Blows						
	BROWN FINE TO MEDIUM SAND (Below 3.0-M)	4 cms for 10 Blows						
4.0	3.0- to 3.75-m - $\phi = 37^\circ$; $\gamma_t = 2.1 \text{ tons/M}^3$ ($N_{avg} = 75$)	SPT @ 4 M 12/19/24 = 43 Blows						
	3.75- to 5.0-m - $\phi = 36^\circ$; $\gamma_t = 2.0 \text{ tons/M}^3$ ($N_{avg} = 43$)	SPT @ 5 M 24/ 8 cms for 20 Blows						
5.0								
6.0		SPT @ 6 M 18/24/ 8 cms for 20 Blows						
7.0		SPT @ 7 M 26/ 8 cms for 20 Blows						
8.0	5.0- to 10.0-m - $\phi = 37^\circ$; $\gamma_t = 2.1 \text{ tons/M}^3$ ($N_{avg} \sim 75$)	SPT @ 8 M 24/ 8 cms for 20 Blows						
9.0	-brownish gray color at 9-m	SPT @ 9 M 28/ 4 cms for 10 Blows 3 cms for 10 Blows (Hammer Rebound)						
10.0	-gray color at 10-m	SPT @ 10 M 31/ 3 cms for 10 Blows						
	10.0-m+ - $\phi = 38^\circ$; $\gamma_t = 2.2 \text{ tons/M}^3$ ($N_{avg} > 100$)	2 cms for 10 Blows (Hammer Rebound)						
GWL								
11.0								

BORE HOLE TERMINATED AT 10.0-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 2

LOG OF BORING

Project: Proposed Commercial Building Site, No. 38, Block No. 24, Mahatma Gandhi Road, Thiruvannamipur, Chennai 600 041, TN.

Bore Hole No.: 2
Started on: 20-08-'19
Final Depth: 10.0-M

Type of Boring: Calyx Drill
Ended on: 21-08-'19
Depth to G W S: 10.6-M

Dia. of Hole: 150 mm
Field Work In Charge: M Munivel
Remarks: From Site Bore Well.

DEPTH, M	SOIL DESCRIPTION	SPT / VANE & SAMPLE TYPE	SPT "N" PROFILE			INDEX TEST DATA		
			25	50	75	25	50	75
	BROWN FINE TO MEDIUM SAND with silt, brick and stone pieces (To 1.0-M)	DS @ 0.25 M						
1.0	0.0- to 1.0-m - $\gamma_t = 1.65 \text{ tons/M}^3$ ($N_{avg} \sim 14$)	SPT @ 1 M 7/10/15 = 25 Blows						
	BROWN SILTY FINE SAND (To 2.0-M)							
2.0	1.0- to 2.0-m - $\phi = 33^\circ$; $\gamma_t = 1.75 \text{ tons/M}^3$ ($N_{avg} = 25$)	SPT @ 2 M 26/ 8 cms for 20 Blows						
	BROWN FINE TO MEDIUM SAND (To 7.0-M)							
3.0		SPT @ 3 M 30/ 8 cms for 20 Blows						
4.0		SPT @ 4 M 30/ 6 cms for 15 Blows 1.5 cms for 5 Blows (Hammer Rebound)						
5.0	2.0- to 7.0-m - $\phi = 37^\circ$; $\gamma_t = 2.1 \text{ tons/M}^3$ ($N_{avg} > 75$)	SPT @ 5 M 4 cms for 10 Blows 3 cms for 10 Blows (Hammer Rebound)						
6.0		SPT @ 6 M 3.5 cms for 10 Blows 3 cms for 10 Blows (Hammer Rebound)						
7.0		SPT @ 7 M 31/ 4 cms for 20 Blows						
	BROWN GRAY FINE TO MEDIUM SAND (Below 7.0-M)							
8.0	7.0- to 8.5-m - $\phi = 38^\circ$; $\gamma_t = 2.2 \text{ tons/M}^3$ ($N_{avg} > 100$)	SPT @ 8 M 28/ 3 cms for 10 Blows 2 cms for 10 Blows (Hammer Rebound)						
9.0		SPT @ 9 M 27/ 4 cms for 10 Blows 3 cms for 10 Blows						
	8.5- to 10.0-m - $\phi = 37^\circ$; $\gamma_t = 2.1 \text{ tons/M}^3$ ($N_{avg} > 75$)							
10.0		SPT @ 10 M 31/ 3 cms for 10 Blows						
	10.0-m+ - $\phi = 38^\circ$; $\gamma_t = 2.2 \text{ tons/M}^3$ ($N_{avg} > 100$)	2 cms for 10 Blows						
GWL								
11.0								

BORE HOLE TERMINATED AT 10.0-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 3

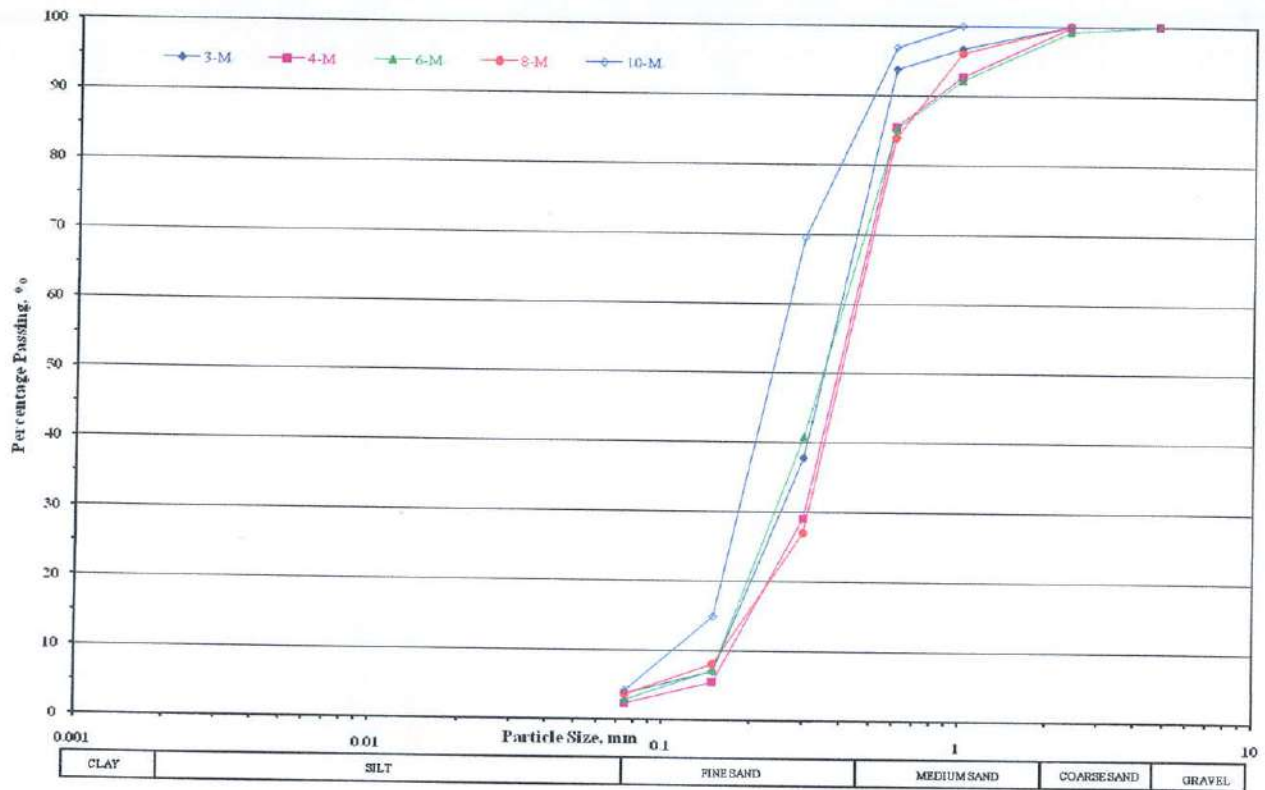
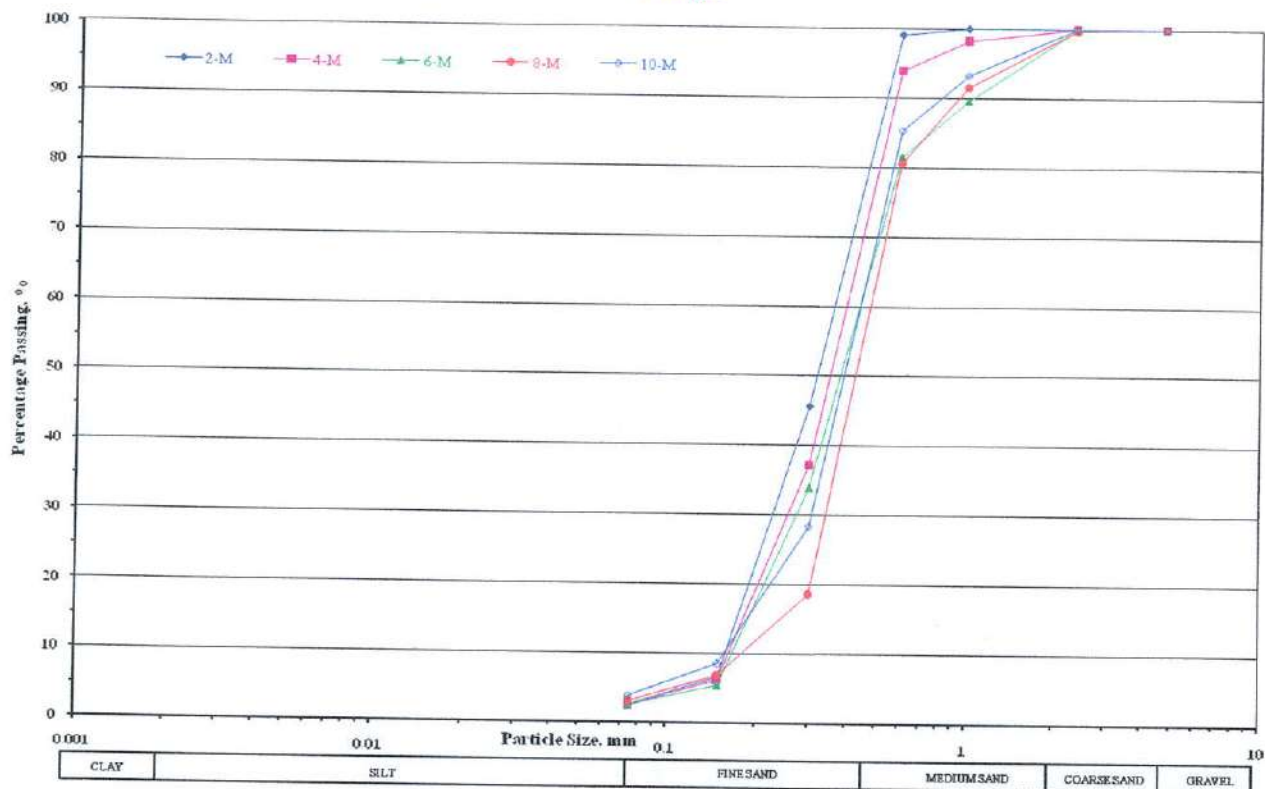
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SUMMARY OF TEST RESULTS

Boring No.	Depth, M	w %	PL	LL	-75 μ %	SAND			GRAVEL	IS CLASS.
						Fine%	Medium%	Coarse%	%	
1	0.25	19			24					
	1.0	17	19	50						CH
	2.0	29	19	59						CH
	3.0	16			4	66	30	0	0	SP
	4.0	12			2	59	37	2	0	SP
	5.0	18			3					
	6.0	15			3	63	32	2	0	SP
	7.0	16			2					
	8.0	18			4	56	40	0	0	SP
	9.0	21			2					
	10.0	21			4	81	15	0	0	SP
2	0.25	11			8					
	1.0	11			15					
	2.0	10			2	74	24	0	0	SP
	3.0	16			2					
	4.0	16			3	67	30	0	0	SP
	5.0	16			3					
	6.0	18			3	58	37	2	0	SP
	7.0	16			3					
	8.0	18			3	51	44	2	0	SP
	9.0	18			3					
	10.0	18			4	57	38	1	0	SP

FREE SWELL INDEX TEST RESULTS

BORING	DEPTH, M	FREE SWELL INDEX, %
1	1.0	115
	2.0	164

Grain Size Distribution Curves
Boring 1Grain Size Distribution Curves
Boring 2

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SUMMARY OF WATER TEST RESULTS**SITE'S NEW BORE WELL; DEPTH = 30.5-M; WATER LEVEL = 10.6-M.****DISTANCE FROM BORING 1 ~ 17-M.**

S. No.	Description	Results Obtained	As per IS:456 – 2000
1	To neutralize 100 cc of water using phenolphthalein as indicator	1.0 ml	Not more than 5 ml of 0.02N NaOH
2	To neutralize 100 cc of water using methyl orange as indicator	24.0 ml	Not more than 25 ml of 0.02N H ₂ SO ₄
3	a Organic Solids, mg/liter	30	200 Max.
	b Inorganic Solids, mg/liter	830	3,000 Max.
	c Sulphates as SO ₃ , mg/liter	48	400 Max.
	d Chlorides as Cl, mg/liter	160	2,000 Max. - Plain Concrete
	e Suspended Solids, mg/liter	0	500 Max. RCC
	f pH	6.82	2,000 Max. 6 Min.

Remarks: The sample meets the requirements of clauses.
Hence water can 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	7.24	80	32	26
2	8.0	7.15	86	30	25

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 RECOMMENDED FOUNDATION

Bearing capacity was estimated using lower bound soil properties of **Boring 1**. Following is a list of design assumptions:

Type of Foundation	= Isolated Column Footing Foundation;
Foundation Depth below EGL	= 2-M;
Worst Case Ground Water Level	= At EGL;
Minimum Footing Width	= 1.5-M;
Expected Max. Comp. Column Load	= 175 Tons.

Bearing Capacity Calculations:

Ultimate Bearing Pressure $q_{ult} = C_u * N_c * S_c * D_c + q' (N_q - 1) * S_q * d_q + 0.5 * B * \gamma' * N_\gamma * S_\gamma * d_\gamma$	
ϕ (avg)	= 36°
C_u (Undrained Shear Strength)	= 0 tons/M ²
N_c (Bearing Capacity Factor)	= N/A
N_q (Bearing Capacity Factor)	= 39.48
N_γ (Bearing Capacity Factor)	= 60.31
S_c (Shape Factor)	= $1 + 0.2 * (B/L) = 1.0 + 0.2 * (1.5/1.5) = 1.20$
D_c (Depth Factor)	= $1 + 0.2 * D_f/B * \tan(45 + \phi/2) = 1.39$
S_q (Shape Factor)	= $1 + 0.2 * (B/L) = 1.0 + 0.2 * (1.5/1.5) = 1.20$
d_q (Depth Factor)	= $1 + 0.1 * D_f/B * \tan(45 + \phi/2) = 1.19$
S_γ (Shape Factor)	= $1 - 0.4 * (B/L) = 1 - 0.4 * (1.5/1.5) = 0.60$;
d_γ (Depth Factor)	= $1 + 0.1 * D_f/B * \tan(45 + \phi/2) = 1.19$
q' (O B @ Footing)	= $1.0 * (1.6-1) + 1.0 * (1.65-1) = 1.25 \text{ tons/M}^2$.

Note: Ground water is assumed to rise to FGL of the site.

$$q_{ult} = 0 + 1.25 * (39.48 - 1.0) * 1.20 * 1.19 + 0.5 * 1.0 * 1.5 * 60.31 * 0.6 * 1.19 = 100.98 \sim 101 \text{ tons/M}^2$$

$$q_{all} = q_{ult} / 2.5 = 101 / 2.5 = 40.4 \text{ tons/M}^2 \quad \text{Use } q_{all} = 25 \text{ tons/M}^2$$

Footing Size Required for 175 tons Load = $175/25 = 7\text{-M}^2$ or $L = B = 2.64\text{-M}$ Say 2.65-M.

Settlement Calculations:

In case of rectangular footings the "Zone of Influence" will extend to "2B" depth below footing, i.e., $2 * 2.65 = 5.3\text{-M}$ below footing or upto hard stratum level. There will be only elastic (immediate) settlement and no consolidation (long term) settlement as soil profile had only sand soil in the zone of influence.

Elastic or Immediate Settlement:-

- 2.0- to 3.0-M = $H_1 = 1.0\text{-M}$; SPT "N" = 47 (Sand); $E_s = 5,000 \text{ tons/M}^2$
 - 3.0- to 4.0-M = $H_2 = 1.0\text{-M}$; SPT "N" = 75 (Sand); $E_s = 7,500 \text{ tons/M}^2$
 - 4.0- to 6.75-M = $H_3 = 2.75\text{-M}$; SPT "N" > 100 (Sand); $E_s = 9,000 \text{ tons/M}^2$
 - 6.75- to 7.3-M = $H_4 = 0.55\text{-M}$; SPT "N" ~ 100 (Sand); $E_s = 7,500 \text{ tons/M}^2$
- $$E_{savg} = (1.0 * 5000 + 1.0 * 7500 + 2.75 * 9000 + 0.55 * 7500) / 5.30 = 7,806.60 \sim 7,800 \text{ tons/M}^2$$
- $$q_0 = 25 \text{ tons/M}^2; H/B' = 5.3/1.325 = 4; L/B = 2.65/2.65 = 1.0; \mu = 0.2; E_s = 7,800 \text{ tons/M}^2$$
- $$I_f = 0.8; I_1 = 0.408; I_2 = 0.037; I_s = 0.436;$$
- $$\Delta H_E = 4 * 25.0 * 1.325 * (1 - 0.2^2) / 7800 * 0.80 * 0.436 * 1000 = 5.69 \text{ mm}$$
- Total Elastic Settlement $\Delta H_E = 5.69 \text{ mm}$.

Consolidation Settlement: None.

Total Consolidation Settlement $\Delta H_C = 0.00$ mm.

Total Combined Settlement $\Delta H = \Delta H_E + \Delta H_C = 5.69 + 0.00 = 5.69 \sim 6$ mm.

The estimated total settlement for a 2.65- by 2.65-M isolated column footing foundation **at 2-M below EGL** was about 6 mm for a bearing pressure of 25 tons/M², less than 60 mm – allowable limits for the total settlements for isolated column footing foundations for framed structure with panel walls as per IS: 1904 - 2006 code. Hence, isolated column footing foundation can be used for the proposed building at this site.

SAMPLE CALCULATIONS FOR DMC BORED CAST IN SITU PILES.**PILE CAPACITY CALCULATIONS - By IS : 2911 (Part I / Sec. 2) - 2010 Method.****PROPOSED COMMERCIAL BUILDING SITE****No. 38, Block No. 24, Mahatma Gandhi Road, Thiruvanniyur, Chennai 600 041, TN.****Bored Cast In-Situ Pile Details:**

Total Pile Length = 9.00 M below EGL
 Top Pile Cutoff Length = 1.00 M Top pile cutoff length for pilecaps
 Pile Effective Concreting Length = 8.00 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	Brown Silty F to M Sand with Clay ..	0.00	1.00	~ 8			1.60
2a	Brown Stiff to Hard Clay	1.00	1.75	32	20.00		1.85
2b	Brown Stiff to Hard Clay	1.75	3.00	14	9.00		1.65
3a	Brown Fine to Medium Sand	3.00	3.75	75		37	2.10
3b	Brown Fine to Medium Sand	3.75	5.00	43		36	2.00
3c	Brown Fine to Medium Sand	5.00	10.00	~ 75		37	2.10
3d	Brown Fine to Medium Sand	10.00	10.00	> 100		38	2.20

For Cohesive Soils :-

C _u	α
9.00	0.50
20.00	0.28

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

Unit Skin Friction in Clay Soils, $f_s = \alpha C_u$ $K_o = 1.00$
 Unit Skin Friction in Sand Soils, $f_s = \sigma' K_o \tan \delta$
 Skin Friction of the Each Strata, $Q_{si} = f_s * \pi D L_i$
 Total Ult. Skin Friction, $Q_{s,ult} = \sum Q_{si}$
 Unit End Bearing in Clay Soils, $q_{ult} = 9 C_u$
 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 Ultimate Pile Capacity, $Q_{ult} = Q_{s,ult} + Q_{p,ult}$
 Allowable Pile Capacity, $Q_{all} = Q_{ult} / FS$ FS = Factor of Safety = 2.50

Skin Friction Calculations

COMPRESSIVE PILE CAPACITY CALCULATIONS

S.No.	Soil Description	From	To	ϕ^0 / C_u	$\delta = \phi$	γ'_{fs}	T/M^3	σ'_{Mid}	T/M^2	f_{fs}	Pile Dia	$Q_{s, T}$	$Q_{s, T}$	$Q_{s, T}$	$Q_{s, T}$	$Q_{s, T}$	Cutoff
1	Brown Silty F to M Sand with Clay ..	0.00	1.00	0		0	0.60		0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
2a	Brown Stiff to Hard Clay	1.00	1.75	20.00			0.85		0.92	5.60	5.94	6.60	7.92	9.90	11.88		
2b	Brown Stiff to Hard Clay	1.75	3.00	9.00			0.65		1.64	4.50	7.96	8.84	10.61	13.26	15.91		
3a	Brown Fine to Medium Sand	3.00	3.75	37	37		1.10		2.46	1.86	1.97	2.19	2.62	3.28	3.94		
3b	Brown Fine to Medium Sand	3.75	5.00	36	36		1.00		3.50	2.54	4.50	4.99	5.99	7.49	8.99		
3c	Brown Fine to Medium Sand	5.00	9.00	37	37		1.10		6.33	4.77	26.96	29.96	35.95	44.94	53.92		

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

47.32	52.58	63.09	78.87	94.64
-------	-------	-------	-------	-------

@ 9-M below Existing G. L. Soil

Formation - Very Dense Sand

L/D of Pile = 9.0/0.45 = 20

L/D of Pile = 9.0/0.50 < 20

L/D of Pile = 9.0/0.60 < 20

L/D of Pile = 9.0/0.75 < 20

L/D of Pile = 9.0/0.90 < 20

Use Lim. Value or Actual σ'_{base}

N = ~75

N_q = 68N_y = 65Base A = 0.1591 0.1964 0.2829 0.4420 0.6364 -M² $\sigma'_{base} = 8.33$ 8.33 8.33 8.33 8.33 T/M² $q_{b, ult} = 582.19$ 583.98 587.55 592.91 598.28 T/M² $q_{b, ult} = 750.00$ 750.00 750.00 750.00 750.00 T/M² $Q_{b, ult} = 92.63$ 114.71 166.19 262.05 380.76 Tons $Q_{s, ult} = 47.32$ 52.58 63.09 78.87 94.64 Tons $Q_{tot, ult} = 139.95$ 167.29 229.29 340.91 475.40 Tons

F.S. = 2.50 2.50 2.50 2.50 2.50

 $Q_{All} = 55.98$ 66.92 91.71 136.37 190.16 Tons $Q_{All} = 56$ 67 92 136 190 Tons

Allowable Compressive Capacity =

Use

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 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 IS code was 500 tons/M². Therefore, q_b (all) is limited to 300 tons/M².

5 Hydraulic Rotary Rig is not suitable for encountered sand profile. If used piles may have to reach deeper level.

Skin Friction Calculations

S.No.	Soil Description	From	To	ϕ^0 / C_u	$\delta = \phi$	$\gamma_s, T/M^3$	$\sigma'_{Mid}, T/M^2$	$f_s, T/M^2$	Pile Dia	0.45	0.50	0.60	0.75	0.90	-M.
1	Brown Silty F to M Sand with Clay ..	0.00	1.00	0	0	0.60	0.30	0.00		$Q_{s, T}$	$Q_{s, T}$	$Q_{s, T}$	$Q_{s, T}$	$Q_{s, T}$	Cutoff
2a	Brown Stiff to Hard Clay	1.00	1.75	20.00		0.85	0.92	5.60		0.00	6.60	7.92	9.90	11.88	
2b	Brown Stiff to Hard Clay	1.75	3.00	9.00		0.65	1.64	4.50		0.00	8.84	10.61	13.26	15.91	
3a	Brown Fine to Medium Sand	3.00	3.75	37	37	1.10	2.46	1.86		0.00	2.19	2.62	3.28	3.94	
3b	Brown Fine to Medium Sand	3.75	5.00	36	36	1.00	3.50	2.54		4.50	4.99	5.99	7.49	8.99	
3c	Brown Fine to Medium Sand	5.00	9.00	37	37	1.10	6.33	4.77		26.96	29.96	35.95	44.94	53.92	

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

47.32	52.58	63.09	78.87	94.64
-------	-------	-------	-------	-------

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 =	8.00	8.00	8.00	8.00	8.00	-M
Pile Volume, V =	1.27	1.57	2.26	3.54	5.09	-M ³
Submerged Pile Weight W =	1.78	2.20	3.17	4.95	7.13	Tons
$Q_{s, ult} =$	47.32	52.58	63.09	78.87	94.64	Tons
$Q_{tot, ult} =$	49.10	54.78	66.26	83.82	101.77	Tons
F.S. =	2.50	2.50	2.50	2.50	2.50	
Allowable Transient Uplift Capacity = $Q_{All} =$	19.64	21.91	26.51	33.53	40.71	Tons
Use $Q_{All} =$	20	22	27	34	41	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 COMMERCIAL BUILDING SITE

No. 38, Block No. 24, Mahatma Gandhi Road, Thiruvanniyur, Chennai 600 041, TN.

BORING 1 SOIL PROFILE

Pile Dia.	0.45	0.50	0.60	0.75	0.90 -M
Pile Type	Bored Cast In-Situ Concrete Piles				
Concrete Grade =	M30	Max. Comp. Stress in Bending		$f_c =$	
Min. % of Reinforcement Content =	0.40%			700 Tons/M ² 70 Kg/cm ²	

Modulus of Pile, $E_c = 200000 \text{ Kg/cm}^2 = 2000000 \text{ Tons/M}^2$

Soil's $\phi = 34^\circ$ Lower Bound Value from 3- and 10-M
 Soil's $\gamma' = 0.90 \text{ Tons/M}^3$
 $K_p = 3.54$ Passive Co-Efficient of Earth Pressure

Factor of Safety = 2.50

Dia., D M	(I) Mom. of Inertia, M ⁴	y = D/2 M	f_c Tons/M ²	M_{yield} Tons-M	$\frac{M_{yield}}{D^4 \gamma' K_p}$	Broms Factor	P_{ult} Tons	P_{all} Tons
				$f_c * I$		$\frac{P_{ult}}{K_p \gamma' D^3}$		
0.45	0.00201	0.23	700	6.26	47.98	16.50	10.63	4.25
0.50	0.00307	0.25	700	8.59	43.18	15.00	11.94	4.77
0.60	0.00636	0.30	700	14.84	35.98	13.50	15.47	6.19
0.75	0.01553	0.38	700	28.99	28.79	11.25	20.14	8.06
0.90	0.03221	0.45	700	50.10	23.99	9.50	24.49	9.80

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 100 tons axial pile load with pile caps and tie beams.

LIQUEFACTION ANALYSIS REPORT

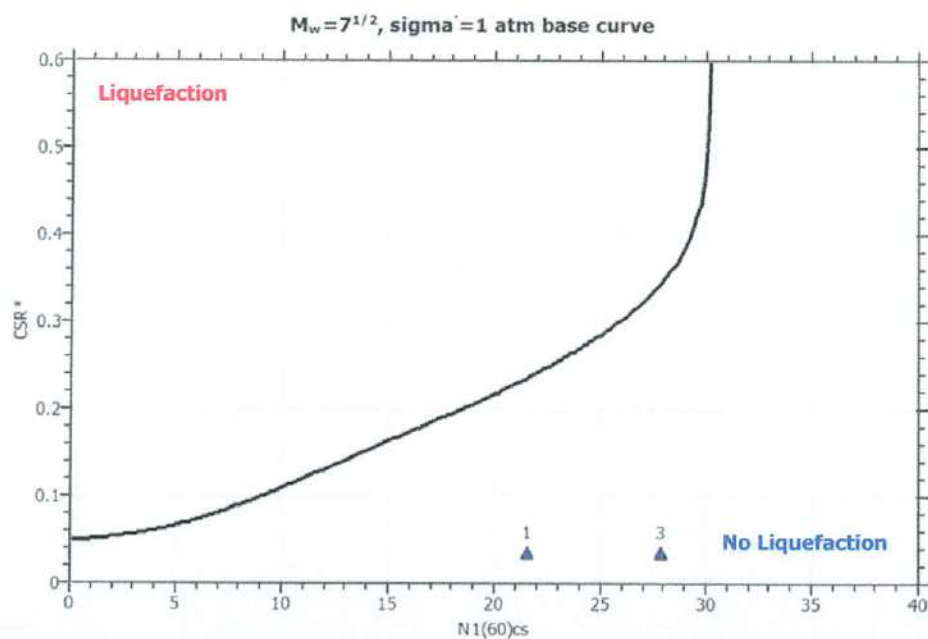
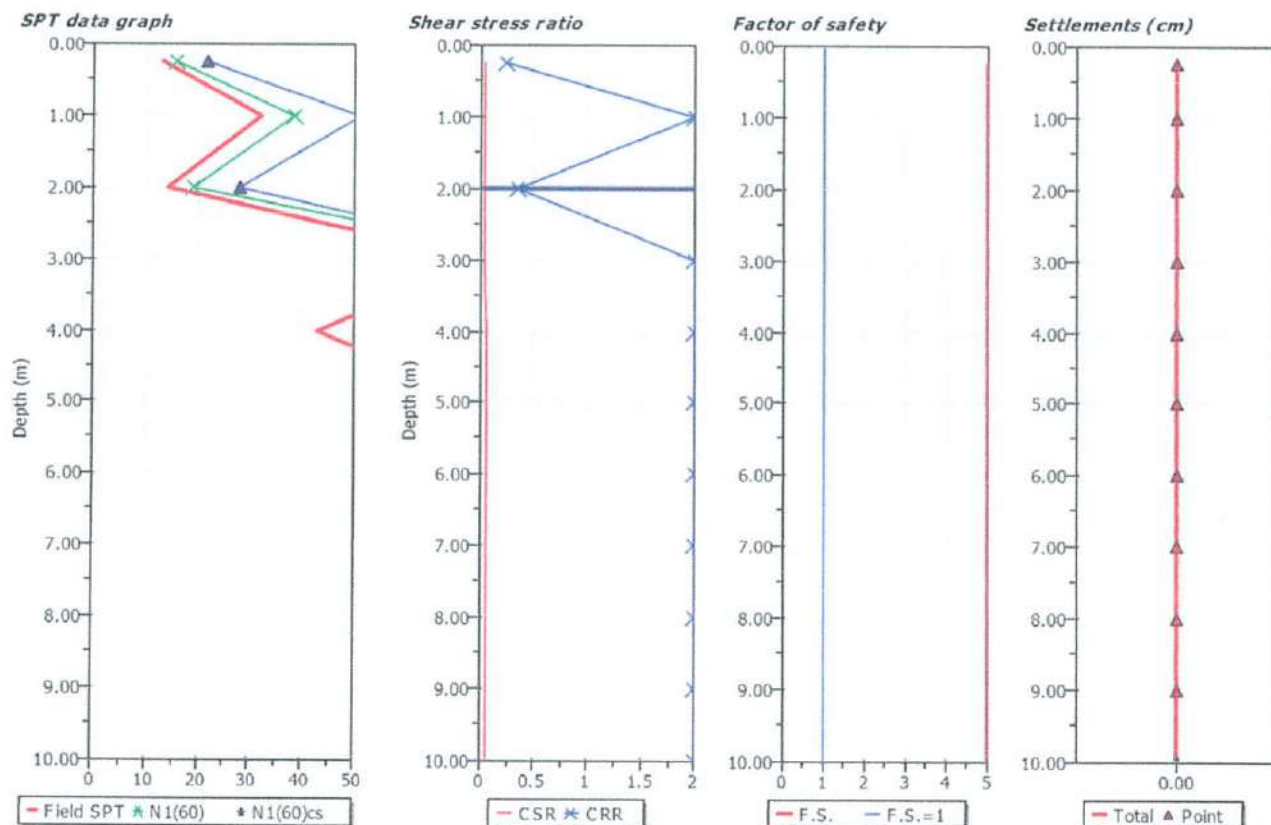
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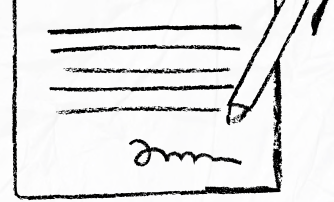
Project subtitle : Boring 1 Soil Profile

Input parameters and analysis data

In-situ data type: Standard Penetration Test
 Analysis type: Deterministic
 Analysis method: NCEER 1998
 Fines correction method: Idriss & Seed

Depth to water table: 2.00 m
 Earthquake magnitude M_w : 6.50
 Peak ground acceleration: 0.08 g
 User defined F.S.: 1.00





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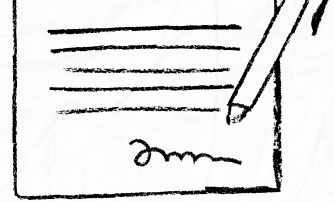
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