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GEOTECHNICAL SITE INVESTIGATION

BORING 1 AND 2

PROPOSED COMMERCIAL BUILDING SITE

NO. 8, THEYAGARAYA ROAD

OPPOSITE TO GLOBUS

CORNER OF CHEVALIERS SIVAJI GANESAN ROAD

T NAGAR, CHENNAI 600 017, TN.

Report to

Mr. T S M Sadunnissa & Others
N. No. 16, O. No. 117, General Patters Road
Chennai 600 002, TN.

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

Report No. 074/GI/14-15.
July 21, 2014.

Mr. T S M Sadunnissa & Others
N. No. 16, O. No. 117, General Patters Road
Chennai 600 002, TN.

Geotechnical Site Investigation
Boring 1 and 2
Proposed Commercial Building Site
No. 8, Theyagaraya Road
Opposite to Globus
Corner of Chevaliers Sivaji Ganesan Road
T Nagar, Chennai 600 017, 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 letter dated July 2, 2014.

Estimated capacities of the foundations recommended for the proposed structure 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

(074brpt)
Copies Submitted: (3)

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SUMMARY

Prasad Armstrong Yen GEC (P) Ltd. performed a geotechnical site investigation at the Proposed Commercial Building Site, No. 8, Theyagaraya Road, Opposite to Globus, Corner of Chevaliers Sivaji Ganesan Road, T Nagar, Chennai 600 017, TN. The primary purpose of this investigation was to identify the soil stratification of the site, select the foundation type, and estimate load carrying capacity of the proposed foundation. The proposed building was expected to have B + G + 3 floors with nearly 9- by 10-M column grid. The expected maximum column load for the proposed type of building will be about 600 tons. These details were used only for estimating the preliminary foundation size and type of foundation.

The field investigation was performed July 9 through 13, 2014. Number and location of the borings was selected and provided by the architects through a site drawing. In total two borings were drilled at this site. Boring 1 and 2 were drilled to 20.5- and 22.5-M penetration respectively below the Existing Ground Level (EGL). Borings were drilled to confirmed hard stratum SPT N $\geq$ 75 to have data for pile foundation design due to expected heavy column loads. 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. Visual observation infers the site's EGL at about 0.45- to 0.6-M above the Existing Road Level (ERL) of road in front of the site. Many trees, bushes, and shrubs were preset in the site. Two buildings were present in the site. Proposed construction will be the first building of this magnitude at this site. Soil stratigraphy at the borings is tabulated below:

Boring – 1:

Stratum	Penetration, M From	To	Description
I	0	1.75	Brown Silty Fine Sand with Clay Binder
II	1.75	2.5	Brown Very Stiff Silty Clay
III	2.5	4.0	Brown Clayey and Sandy Silt
IV	4.0	4.75	Brown Very Stiff Clay with Sand Seams
V	4.75	11.5	Gray Soft to Very Stiff Clay
VI	11.5	16.0	Gray Fine to Coarse Sand with Silt
VII	16.0	19.0	Gray Green Brown Silty Fine Sand
VIII	19.0	20.5+	White Gray Yellow Brown Silty Fine Sand

Boring – 2:

Stratum	Penetration, M From	To	Description
I	0	3.75	Brown Silty Fine Sand
II	3.75	5.0	Brown Stiff Clay
III	5.0	6.0	Brown Gray Fine Sand
IV	6.0	7.0	Brown Gray Stiff Clay
V	7.0	7.75	Gray Brown Fine Sand with Silt
VI	7.75	9.0	Gray Soft Clay
VII	9.0	11.5	Gray Silty Fine Sand

VIII	11.5	19.0	Brown Gray Fine to Coarse Sand with Silt
IX	19.0	22.5+	Green Brown Yellow Gray Silty Fine to Medium Sand

Data from the borings indicate presence of similar soil profiles with some variations in the SPT N values. For the proposed building with a basement floor and large column spans it was recommended to provide "**Direct Mud Circulation (DMC) Bored Cast In-Situ**" piles. For the expected column loads piles of minimum 19.5-, and 16.5-M total and effective lengths with top 3-M pile cutoff for basement floor, and pile caps was considered in the analysis. Ultimate and allowable pile capacities of various pile diameters are summarized below.

	Compressive Capacity, Tons			
Pile Dia., M	**0.60**	**0.75**	**0.90**	**1.00**
Q_{ult}	323.42	522.16	775.87	930.74
Q_{all}	129	209	310	372

It is 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.

Groundwater was seen in the Boring 1 at 3.5-M below EGL about 48 hours after completion of the drilling of the boring and bailing out the bentonite solution to 4-M depth below EGL. A 1.2-M diameter open well and unknown depth was present in the site at a distance of about 6.4-M from Boring 2. Groundwater sample was collected from the open well for construction suitability tests. Test results indicate that groundwater from the bore well was **not suitable** for construction purposes as per IS: 456 – 2000 due to high alkalinity as inferred by the methyl orange titration test. Groundwater can be used for construction purposes after suitable treatment to maintain the acceptable groundwater quality as per IS: 456 – 2000 guidelines.

We do not expect construction problems at this site due to site's soil and groundwater conditions in non-rainy seasons. In rainy season or soon after rainy season groundwater can reach higher level that may be higher than the required basement floor bottom level. Site's EGL was at about 0.45- to 0.6-M above ERL of road in front of the site. In order to avoid future site flooding from rainwater it is recommended to raise the Finished Ground Level (**FGL**) of the site to at least 0.6-M above ERL of road in front of the site. Finished Floor Level (FFL) of the ground floor should be at least 0.6-M above FGL of the site. This will prevent rainwater flooding and dampness problems in the building from rainwater, and water from roads. The existing building in the site should be completely removed for the proposed building. Old building foundation should be completely removed.

Backfilling of the foundation excavations should be done with granular soil and it should be compacted properly to achieve proper densification to avoid settlements in flooring. Exposed bottom surface of the foundation excavation must be properly compacted with heavy duty mechanical vibrator to compact the exposed surface that gets loosened by mechanical excavation activities. This is to minimize settlements that can arise if the loosened soil in foundation excavation is not removed or compacted. Foundations should be placed on natural soil and not on old foundations or filled up soils. Excavated sand soil can be used for back filling and building basement filling purposes.

In view of presence of sandy soil in the top 3-M it was recommended to provide side slopes of **at least** 1.5 (H) : 1 (V) to prevent slope sliding. If not possible due to space constraint then it is recommended to provide designed earth retaining structure to prevent slope failure into the basement area. Sheet pile wall may be required in case of limited space between the building line and site boundary line.

There is potential for **pile necking / bulging** during pile installation due to groundwater and presence of sand layers. Proper care should be taken in pile installation to avoid pile structural integrity problems. **Pile load tests must be conducted as per relevant IS code to confirm the load carrying capacities recommended above and also to check the quality of pile installation**. Use of **Hydraulic Rotary Rig** is **not recommended** for this site due to groundwater and presence thick sand layers. Piles may be installed from EGL with pile cutoff of 3-M or at required basement floor bottom level. After completion of installation of pile, basement floor excavation can be made to minimize the duration of open excavation area.

All structures have to be designed for higher seismic forces (**Zone III**) due to increased seismic activity in peninsular India in the last decade. Seismic events of 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 Bay of Bengal and near Andaman Islands felt 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 **0.06g** the total estimated vertical settlement was 0.09 cms and total horizontal displacement was about 0 cms. Iwasaki liquefaction potential was 0.0 inferring "**No Liquefaction**." As per IS code for **Zone III** design horizontal acceleration was **0.04g** 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 **0.06g** was used.

INTRODUCTION

Purpose and Scope

Prasad Armstrong Yen GEC (P) Ltd. performed a geotechnical site investigation at the Proposed Commercial Building Site, No. 8, Theyagaraya Road, Opposite to Globus, Corner of Chevaliers Sivaji Ganesan Road, T Nagar, Chennai 600 017, TN. The primary purpose of this investigation was to identify the soil stratification of the site, select the foundation type, and estimate load carrying capacity of the proposed foundation. The proposed building was expected to have B + G + 3 floors with nearly 9- by 10-M column grid. The expected maximum column load for the proposed type of building will be about 600 tons. These details were used only for estimating the preliminary foundation size and type of foundation. To accomplish these purposes, the following tasks were performed:

(1) Boring 1 and 2 were drilled to 20.5- and 22.5-M respectively below the EGL to explore the subsurface stratigraphy and obtain soil samples for laboratory testing;

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

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

Report Format

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

FIELD AND LABORATORY INVESTIGATIONS

Exploratory Borings

Soil conditions at the site were explored by Boring 1 and 2. Number and location of the borings was selected and provided by the architects through a site drawing. Boring 1 and 2 were drilled to 20.5- and 22.5-M penetration respectively below EGL. Borings were drilled to confirmed hard stratum SPT N $\geq$ 75 to have data for pile foundation design due to expected heavy column loads. Groundwater was seen in the Boring 1 at about 3.5-M below EGL. Log of Boring are presented on Plate 2 and 3.

Field and Laboratory Tests

Boring was drilled using Calyx drilling unit. In the boring SPT was performed at 0.75-M interval upto 4-M, at 1-M interval upto 10-M, at 1.5-M interval upto 20-M, and at 2-M interval beyond 20-M. Soil samples for laboratory tests were collected from SPT split spoon sampler. SPT consists of driving a standard split spoon sampler, 50.8-mm outside diameter and 35-mm inside diameter into soil under the blows of a drop hammer of 63.5 kg falling weight freely through 75-cm. The number of blows required for 30-cm of penetration of sampler in soil is designated as N value and it is termed as the SPT blow count. Detailed information regarding SPT can be found in the IS: 2131 code of practice.

The soil-testing program was designed to evaluate pertinent index and engineering properties of the foundation soils. During the field operations soil samples were collected at 0.75-, 1-, 1.5-, and 2-M intervals either disturbed or undisturbed as the case may be. All soil samples were shipped to our Chennai laboratory where pertinent index properties - grain size analyses, natural water content Atterberg limit tests were performed on collected soil samples. All the test results 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 Water Test Results are presented on Plate 6.

GENERAL SOIL CONDITIONS

Topography

Natural topography of the site reflects a flat terrain. Visual observation infers the site's EGL at about 0.45- to 0.6-M above ERL of road in front of the site. Many trees, bushes, and shrubs were preset in the site. Two buildings were present in the site. Proposed construction will be the first building of this magnitude at this site.

Soil Stratigraphy

The soil stratigraphy disclosed by our field and laboratory investigations of the boring 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 From	To	Description
I	0	1.75	Brown Silty Fine Sand with Clay Binder
II	1.75	2.5	Brown Very Stiff Silty Clay
III	2.5	4.0	Brown Clayey and Sandy Silt
IV	4.0	4.75	Brown Very Stiff Clay with Sand Seams
V	4.75	11.5	Gray Soft to Very Stiff Clay
VI	11.5	16.0	Gray Fine to Coarse Sand with Silt
VII	16.0	19.0	Gray Green Brown Silty Fine Sand
VIII	19.0	20.5+	White Gray Yellow Brown Silty Fine Sand

Boring – 2:

Stratum	Penetration, M From	To	Description
I	0	3.75	Brown Silty Fine Sand
II	3.75	5.0	Brown Stiff Clay
III	5.0	6.0	Brown Gray Fine Sand
IV	6.0	7.0	Brown Gray Stiff Clay
V	7.0	7.75	Gray Brown Fine Sand with Silt
VI	7.75	9.0	Gray Soft Clay
VII	9.0	11.5	Gray Silty Fine Sand
VIII	11.5	19.0	Brown Gray Fine to Coarse Sand with Silt
IX	19.0	22.5+	Green Brown Yellow Gray Silty 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 cohesionless soils were selected based on the SPT, and grain size distribution analyses. Shear strength parameters for cohesive soils were selected based on the SPT results. The unit weight (soil density) profiles of the soils in the borings were developed from estimated values based on correlations of unit weight with particle size gradation and field test results (Bowles, 1982.)

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

Boring – 1:

Stratum	Penetration, M From	To	Properties
I	0	1.75	$\phi = 30^o$; $\gamma_{sat} = 1.7$ tons/M^3
II	1.75	2.5	$C_u = 11$ tons/M^2; $\gamma_{sat} = 1.7$ tons/M^3
III	2.5	4.0	$C_u = 6$ tons/M^2; $\gamma_{sat} = 1.65$ tons/M^3
IV	4.0	4.75	$C_u = 17$ tons/M^2; $\gamma_{sat} = 1.85$ tons/M^3
Va	4.75	6.5	$C_u = 9$ tons/M^2; $\gamma_{sat} = 1.7$ tons/M^3
Vb	6.5	7.5	$C_u = 6$ tons/M^2; $\gamma_{sat} = 1.6$ tons/M^3
Vc	7.5	10.0	$C_u = 2$ tons/M^2; $\gamma_{sat} = 1.4$ tons/M^3
Vd	10.0	11.5	$C_u = 6$ tons/M^2; $\gamma_{sat} = 1.65$ tons/M^3
VIa	11.5	13.0	$\phi = 32^o$; $\gamma_{sat} = 1.7$ tons/M^3
VIb	13.0	16.0	$\phi = 33^o$; $\gamma_{sat} = 1.75$ tons/M^3
VIIa	16.0	17.5	$\phi = 35^o$; $\gamma_{sat} = 2.0$ tons/M^3
VIIb	17.5	19.0	$\phi = 37^o$; $\gamma_{sat} = 2.1$ tons/M^3
VIIIa	19.0	20.5	$\phi = 37^o$; $\gamma_{sat} = 2.1$ tons/M^3
VIIIb	20.5+		$\phi = 38^o$; $\gamma_{sat} = 2.2$ tons/M^3

Boring – 2:

Stratum	Penetration, M From	To	Properties
I	0	3.75	$\phi = 31^o$; $\gamma_{sat} = 1.7$ tons/M^3
II	3.75	5.0	$C_u = 7.5$ tons/M^2; $\gamma_{sat} = 1.65$ tons/M^3
III	5.0	6.0	$\phi = 31^o$; $\gamma_{sat} = 1.65$ tons/M^3
IV	6.0	7.0	$C_u = 6$ tons/M^2; $\gamma_{sat} = 1.6$ tons/M^3
V	7.0	7.75	$\phi = 33^o$; $\gamma_{sat} = 1.75$ tons/M^3
VI	7.75	9.0	$C_u = 2$ tons/M^2; $\gamma_{sat} = 1.45$ tons/M^3
VII	9.0	11.5	$\phi = 27^o$; $\gamma_{sat} = 1.5$ tons/M^3
VIIIa	11.5	14.5	$\phi = 32^o$; $\gamma_{sat} = 1.7$ tons/M^3
VIIIb	14.5	17.5	$\phi = 34^o$; $\gamma_{sat} = 1.8$ tons/M^3
VIIIc	17.5	19.0	$\phi = 36^o$; $\gamma_{sat} = 2.0$ tons/M^3
IX	19.0	22.5+	$\phi = 37^o$; $\gamma_{sat} = 2.1$ tons/M^3

DESIGN INFORMATION

For the proposed building with a basement floor and heavy column loads "**Direct Mud Circulation (DMC) Bored Cast In-Situ**" piles were recommended. For the expected column loads piles of minimum 19.5-, and 16.5-M total and effective lengths with top 3-M pile cutoff for basement floor, and pile caps was considered. The piles **actual pile length at different parts of the site can vary** from the considered 19-M in case of lower N values soil at pile termination depth. Ultimate and allowable pile capacities of various pile diameters are summarized below.

Pile Dia., M	Compressive Capacity, Tons			
	0.60	0.75	0.90	1.00
Q_{ult}	323.42	522.16	775.87	930.74
Q_{all}	129	209	310	372

It is 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. Foundation capacity calculations were presented on Plate 7.

GROUND WATER

Groundwater was seen in the Boring 1 at 3.5-M below EGL about 48 hours after completion of the drilling of the boring and bailing out the bentonite solution to 4-M depth below EGL. A 1.2-M diameter open well and unknown depth was present in the site at a distance of about 6.4-M from Boring 2. Groundwater sample was collected from the open well for construction suitability tests. Test results indicate that groundwater from the bore well was **not suitable** for construction purposes as per IS: 456 – 2000 due to high alkalinity as inferred by the methyl orange titration test. Groundwater can be used for construction purposes after suitable treatment to maintain the acceptable groundwater quality per IS: 456 – 2000 guidelines. Summary of ground water test results are presented on Plate 6.

CONSTRUCTION CONSIDERATIONS

We do not expect construction problems at this site due to site's soil and groundwater conditions in non-rainy seasons. In rainy season or soon after rainy season groundwater can reach higher level that may be higher than the required basement floor bottom level. Site's EGL was at about 0.45- to 0.6-M above ERL of road in front of the site. In order to avoid future site flooding from rainwater it is recommended to raise **FGL** of the site to at least 0.6-M above ERL of road in front of the site. FFL of the ground floor should be at least 0.6-M above FGL of the site. This will prevent rainwater flooding and dampness problems in the building from rainwater, and water from roads. The existing building in the site should be completely removed for the proposed building. Old building foundation should be completely removed.

Backfilling of the foundation excavations should be done with granular soil and it should be compacted properly to achieve proper densification to avoid settlements in flooring. Exposed bottom surface of the foundation excavation must be properly compacted with heavy duty mechanical vibrator to compact the exposed surface that gets loosened by mechanical excavation activities. This is to minimize settlements that can arise if the loosened soil in foundation excavation is not removed or

compacted. Foundations should be placed on natural soil and not on old foundations or filled up soils. Excavated sand soil can be used for back filling and building basement filling purposes.

In view of presence of sandy soil in the top 3-M it was recommended to provide side slopes of **at least** 1.5 (H) : 1 (V) to prevent slope sliding. If not possible due to space constraint then it is recommended to provide designed earth retaining structure to prevent slope failure into the basement area. Sheet pile wall may be required in case of limited space between the building line and site boundary line.

There is potential for **pile necking / bulging** during pile installation due to groundwater and presence of sand layers. Proper care should be taken in pile installation to avoid pile structural integrity problems. **Pile load tests must be conducted as per relevant IS code to confirm the load carrying capacities recommended above and also to check the quality of pile installation**. Use of **Hydraulic Rotary Rig** is **not recommended** for this site due to groundwater and presence thick sand layers. Piles may be installed from EGL with pile cutoff of 3-M or at required basement floor bottom level. After completion of installation of pile, basement floor excavation can be made to minimize the duration of open excavation area.

All structures have to be designed for higher seismic forces (**Zone III**) due to increased seismic activity in peninsular India in the last decade. Seismic events of 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 Bay of Bengal and near Andaman Islands felt 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 **0.06g** the total estimated vertical settlement was 0.09 cms and total horizontal displacement was about 0 cms. Iwasaki liquefaction potential was 0.0 inferring "**No Liquefaction**." As per IS code for **Zone III** design horizontal acceleration was **0.04g** 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 **0.06g** was used. Liquefaction Analysis results are presented on Plate 8.

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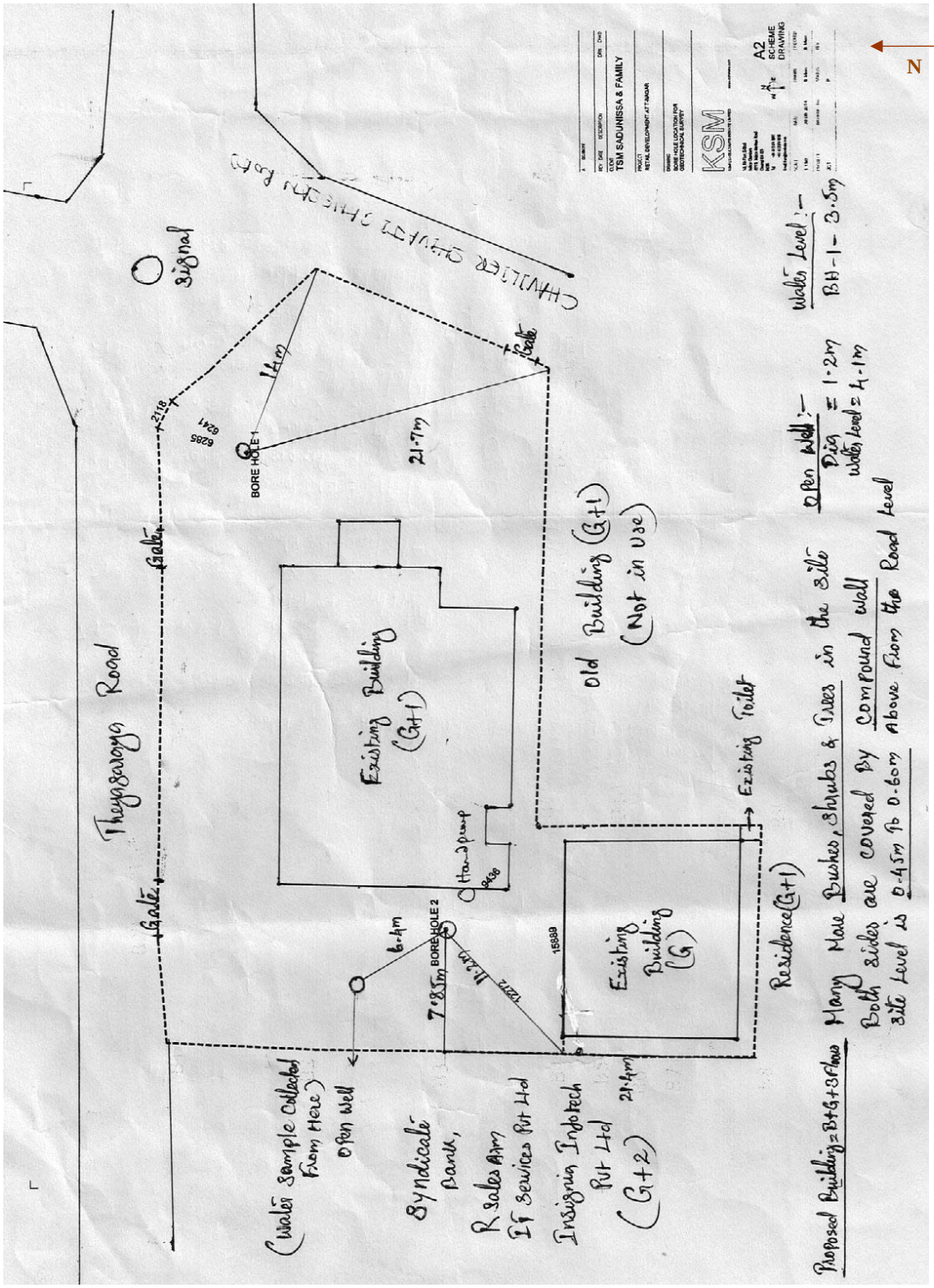
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(Not To Scale)

Site EGL = 0.3- to 0.45-M Above ERL of Road Near Site.

SITE PLAN WITH BORE LOCATION DETAILS.

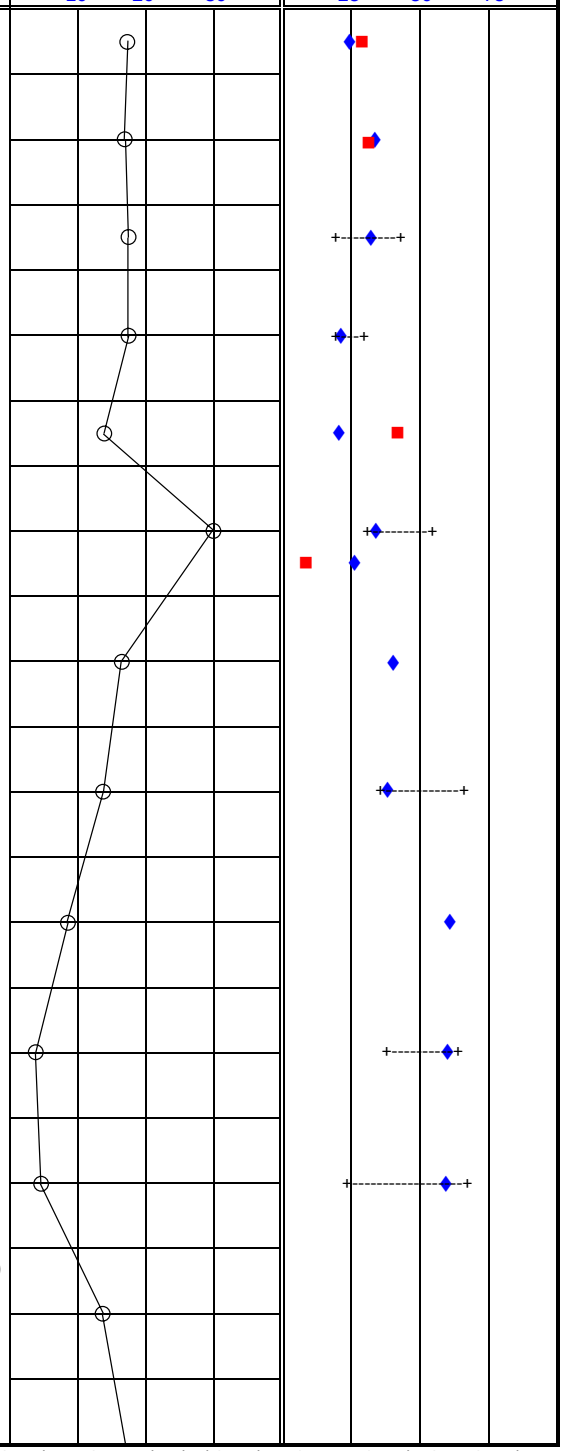
PLATE 1

LOG OF BORING

Project: Proposed Commercial Building Site, No. 8, Thyagaraya Road, Corner of Chaveliers Sivaji Ganesan Road, T Nagar, Chennai 600 017, TN.

Bore Hole No.: 1 **Type of Boring:** Calyx Drill **Dia. of Hole:** 150 mm
Started on: 09-07-'14 **Ended on:** 11-07-'14 **Field Work In Charge:** M Munivel
Final Depth: 20.5-M **Depth to G W S:** 3.5-M **Remarks:** Bore Hole Level 0.45-M above ERL.

DEPTH, M	SOIL DESCRIPTION	SPT / VANE & SAMPLE TYPE
	BROWN SILTY FINE SAND with clay binder (To 1.75-M)	SPT @ 0.25 M 3/6/12 = 18 Blows
1.0	0.0- to 1.75-m – $\phi = 30^o$; $\gamma_t = 1.7$ tons/M^3 ($N_{avg} = 17$)	SPT @ 1 M 2/6/11 = 17 Blows
		SPT @ 1.75 M 4/8/10 = 18 Blows
2.0	BROWN VERY STIFF SILTY CLAY (To 2.5-M)	
	1.75- to 2.5-m – $C_u = 11$ tons/M^2; $\gamma_t = 1.7$ tons/M^3 ($N_{avg} = 18$)	SPT @ 2.5 M 3/6/12 = 18 Blows
3.0	BROWN CLAYEY AND SANDY SILT (To 4.0-M)	SPT @ 3.25 M
	2.5- to 4.0-m – $C_u = 6$ tons/M^2; $\gamma_t = 1.65$ tons/M^3 ($N_{avg} = 13$)	5/6/7 = 13 Blows
4.0		SPT @ 4 M 2/13/17 = 30 Blows
	BROWN VERY STIFF CLAY with sand seams (To 4.75-M) ($N_{avg} = 30$)	
	4.0- to 4.75-m – $C_u = 17$ tons/M^2; $\gamma_t = 1.85$ tons/M^3	SPT @ 5 M
5.0	GRAY SOFT TO VERY STIFF CLAY (To 11.5-M)	5/7/10 = 17 Blows
GWL 6.0	4.75- to 6.5-m – $C_u = 9$ tons/M^2; $\gamma_t = 1.7$ tons/M^3 ($N_{avg} = 15$)	SPT @ 6 M 3/5/8 = 13 Blows
7.0	6.5- to 7.5-m – $C_u = 6$ tons/M^2; $\gamma_t = 1.6$ tons/M^3 ($N_{avg} = 9$)	SPT @ 7 M 1/5/4 = 9 Blows
8.0		SPT @ 8 M 1/1/2 = 3 Blows
9.0	7.5- to 10.0-m – $C_u = 2$ tons/M^2; $\gamma_t = 1.4$ tons/M^3 ($N_{avg} = 3$) -with shell fragments at 9-m	SPT @ 9 M 2/2/2 = 4 Blows
10.0		SPT @ 10 M (SNR) 3/5/8 = 13 Blows
	10.- to 11.5-m – $C_u = 6$ tons/M^2; $\gamma_t = 1.65$ tons/M^3 ($N_{avg} = 13$)	
11.0		



CONTINUED ON PLATE 2b

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

PLATE 2a

LOG OF BORING

Project: Proposed Commercial Building Site, No. 8, Thyagaraya Road, Corner of Chaveliers Sivaji Ganesan Road, T Nagar, Chennai 600 017, TN.

Bore Hole No.: 1 **Type of Boring:** Calyx Drill **Dia. of Hole:** 150 mm
Started on: 09-07-'14 **Ended on:** 11-07-'14 **Field Work In Charge:** M Munivel
Final Depth: 20.5-M **Depth to G W S:** 3.5-M **Remarks:** Continued from Plate 2a.

DEPTH, M	SOIL DESCRIPTION	SPT / VANE & SAMPLE TYPE
	GRAY SOFT TO VERY STIFF CLAY (To 11.5-M)	SPT @ 11.5 M 7/8/12 = 20 Blows
12.0	GRAY FINE TO COARSE SAND with silt (To 16.0-M)	
	-with shell fragments at 11.5-m	
	11.5- to 13.0-m – $\phi = 32^o$; $\gamma_t = 1.7$ tons/M^3	
	($N_{avg} = 20$)	SPT @ 13 M 6/11/13 = 24 Blows
13.0		
14.0		
	13.0- to 16.0-m – $\phi = 33^o$; $\gamma_t = 1.75$ tons/M^3	SPT @ 14.5 M 7/11/15 = 26 Blows
	($N_{avg} = 25$)	
15.0		
16.0	-silty fine to coarse sand at 16-m	SPT @ 16 M 7/11/34 = 45 Blows
	GRAY GREEN BROWN SILTY FINE SAND (To 19.0-M)	
	16.0- to 17.5-m – $\phi = 35^o$; $\gamma_t = 2.0$ tons/M^3	
17.0	($N_{avg} = 45$)	
	-with shell fragments at 17.5-m	SPT @ 17.5 M 24/ 4.5 cms for 10 Blows
18.0		2 cms for 10 Blows (Hammer Rebound)
	17.5- to 19.0-m – $\phi = 37^o$; $\gamma_t = 2.1$ tons/M^3	
	($N_{avg} > 100$)	
19.0		SPT @ 19 M 24/32/ 5 cms for 10 Blows
	WHITE GRAY YELLOW BROWN SILTY FINE SAND (Below 19.0-M)	3 cms for 10 Blows (Hammer Rebound)
	19.0- to 20.5-m – $\phi = 37^o$; $\gamma_t = 2.1$ tons/M^3	
20.0	($N_{avg} \sim 75$)	
	-gray brown fine to medium sand at 20.5-m	SPT @ 20.5 M 8 cms for 20 Blows
	20.5-m+ – $\phi = 38^o$; $\gamma_t = 2.2$ tons/M^3	2 cms for 10 Blows
21.0	($N_{avg} > 100$)	(Hammer Rebound)
22.0		

SPT "N" PROFILE: 10 20 30 — INDEX TEST DATA: 25 50 75

BORE HOLE TERMINATED AT 20.5-M

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

PLATE 2b

LOG OF BORING

Project: Proposed Commercial Building Site, No. 8, Thyagaraya Road, Corner of Chaveliers Sivaji Ganesan Road, T Nagar, Chennai 600 017, TN.

Bore Hole No.: 2 **Type of Boring:** Calyx Drill **Dia. of Hole:** 150 mm
Started on: 11-07-'14 **Ended on:** 13-07-'14 **Field Work In Charge:** M Munivel
Final Depth: 22.5-M **Depth to G W S:** Not Measured **Remarks:** Bore Hole Level 0.6-M above ERL.

DEPTH, M	SOIL DESCRIPTION	SPT / VANE & SAMPLE TYPE
	BROWN SILTY FINE SAND (To 3.75-M)	SPT @ 0.25 M
	-with brick and stone pieces at 0.25-m	6/11/14 = 25 Blows
1.0		SPT @ 1 M
		6/10/14 = 24 Blows
		SPT @ 1.75 M
		5/6/11 = 17 Blows
2.0	0.0- to 3.75-m – $\phi = 31^o$; $\gamma_t = 1.7$ tons/M^3	
	($N_{avg} = 23$)	SPT @ 2.5 M
		7/12/14 = 26 Blows
3.0		SPT @ 3.25 M
		6/9/12 = 21 Blows
		SPT @ 4 M
4.0	**BROWN STIFF CLAY (To 5.0-M)**	2/5/7 = 12 Blows
	3.75- to 5.0-m – $C_u = 7.5$ tons/M^2; $\gamma_t = 1.65$ tons/M^3	
	($N_{avg} = 12$)	
5.0		SPT @ 5 M
		3/6/6 = 12 Blows
	BROWN GRAY FINE SAND (To 6.0-M)	
	5.0- to 6.0-m – $\phi = 31^o$; $\gamma_t = 1.65$ tons/M^3	
	($N_{avg} = 12$)	SPT @ 6 M
6.0		3/5/5 = 10 Blows
	BROWN GRAY STIFF CLAY (To 7.0-M)	
	6.0- to 7.0-m – $C_u = 6$ tons/M^2; $\gamma_t = 1.6$ tons/M^3	
	($N_{avg} = 10$)	SPT @ 7 M
7.0		2/10/14 = 24 Blows
	GRAY BROWN FINE SAND with silt (To 7.75-M)	
	7.0- to 7.75-m – $\phi = 33^o$; $\gamma_t = 1.75$ tons/M^3	
	($N_{avg} = 24$)	SPT @ 8 M
8.0	**GRAY SOFT CLAY (To 9.0-M)**	1/1/2 = 3 Blows
	7.75- to 9.0-m – $C_u = 2$ tons/M^2; $\gamma_t = 1.45$ tons/M^3	
	($N_{avg} = 3$)	
9.0		SPT @ 9 M
		2/2/4 = 6 Blows
	GRAY SILTY FINE SAND (To 11.5-M)	
		SPT @ 10 M
10.0	9.0- to 11.5-m – $\phi = 27^o$; $\gamma_t = 1.5$ tons/M^3	0/2/3 = 5 Blows
	($N_{avg} = 5$)	
11.0		

SPT "N" PROFILE: 10 20 30

INDEX TEST DATA: 25 50 75

CONTINUED ON PLATE 3b

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

PLATE 3a

LOG OF BORING

Project: Proposed Commercial Building Site, No. 8, Thyagaraya Road, Corner of Chaveliers Sivaji Ganesan Road, T Nagar, Chennai 600 017, TN.

Bore Hole No.: 2 **Type of Boring:** Calyx Drill **Dia. of Hole:** 150 mm
Started on: 11-07-'14 **Ended on:** 13-07-'14 **Field Work In Charge:** M Munivel
Final Depth: 22.5-M **Depth to G W S:** Not Measured **Remarks:** Continued from Plate 3a.

DEPTH, M	SOIL DESCRIPTION	SPT / VANE & SAMPLE TYPE
	GRAY SILTY FINE SAND (To 11.5-M)	SPT @ 11.5 M 4/9/11 = 20 Blows
12.0	BROWN GRAY FINE TO COARSE SAND with silt (To 19.0-M)	
13.0	11.5- to 14.5-m – $\phi = 32^{o}$; $\gamma_t = 1.7$ tons/M^3 ($N_{avg} = 20$)	SPT @ 13 M 8/10/11 = 21 Blows
14.0		
	-green gray color at 14.5-m	SPT @ 14.5 M 9/14/16 = 30 Blows
15.0		
16.0	14.5- to 17.5-m – $\phi = 34^{o}$; $\gamma_t = 1.8$ tons/M^3 ($N_{avg} = 27$)	SPT @ 16 M 6/10/14 = 24 Blows
17.0		
		SPT @ 17.5 M 10/19/32 = 51 Blows
18.0	17.5- to 19.0-m – $\phi = 36^{o}$; $\gamma_t = 2.0$ tons/M^3 ($N_{avg} = 51$)	
19.0		SPT @ 19 M 33/ 3 cms for 10 Blows
	GREEN BROWN YELLOW GRAY SILTY FINE TO MEDIUM SAND (Below 19.0-M)	2 cms for 10 Blows (Hammer Rebound)
20.0		
	19.0- to 22.5-m – $\phi = 37^{o}$; $\gamma_t = 2.1$ tons/M^3 ($N_{avg} > 75$)	SPT @ 20.5 M 23/ 4 cms for 10 Blows
21.0		4 cms for 10 Blows
		SPT @ 22.5 M 4 cms for 10 Blows
22.5		2 cms for 10 Blows (Hammer Rebound)

SPT @ 11.5 M 4/9/11 = 20 Blows
SPT @ 13 M 8/10/11 = 21 Blows
SPT @ 14.5 M 9/14/16 = 30 Blows
SPT @ 16 M 6/10/14 = 24 Blows
SPT @ 17.5 M 10/19/32 = 51 Blows
SPT @ 19 M 33/ 3 cms for 10 Blows
2 cms for 10 Blows (Hammer Rebound)
SPT @ 20.5 M 23/ 4 cms for 10 Blows
4 cms for 10 Blows
SPT @ 22.5 M 4 cms for 10 Blows
2 cms for 10 Blows (Hammer Rebound)

SPT "N" PROFILE: 10 20 30

INDEX TEST DATA: 25 50 75

BORE HOLE TERMINATED AT 22.5-M.

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

PLATE 3b

SUMMARY OF TEST RESULTS

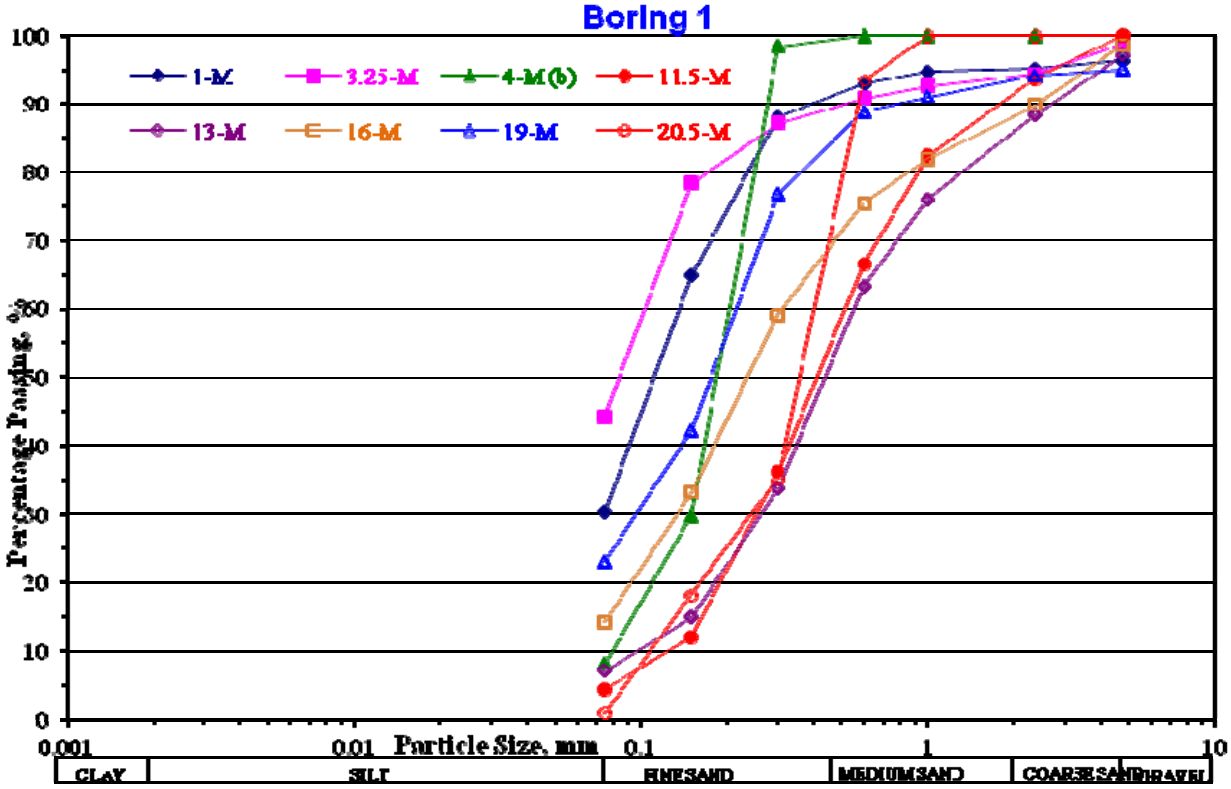
Boring	Depth,	w %	PL	LL	-75μ%	SAND			GRAVEL	IS
No.	M					Fine%	Medium%	Coarse%	%	CLASS.
1	0.25	25			28					
	1.0	33			30	61	4	1	4	SM
	1.75	31	20	41						CL
	2.5	23	21	30						ML
	3.25	23			44	45	5	5	1	SM
	4.0a	33	30	54						CH
	4.0b	26			8	91	1	0	0	SP
	5.0	42								
	6.0	39	37	67						CH
	7.0	60								
	8.0	58	39	65						CH
	9.0	57	25	67						CH
	10.0	SNR								
	11.5	13			4	49	38	9	0	SP
	13.0	21			7	44	35	11	3	SP
	14.5	13			4					
	16.0	15			14	54	20	10	2	SM
	17.5	13			7					
	19.0	20			23	61	10	1	5	SM
	20.5	17			1	68	31	0	0	SP
2	0.25	22			20					
	1.0	31			39	52	5	0	4	SM
	1.75	29			39					
	2.5	22			27	66	4	1	2	SM
	3.25	20			44	54	2	0	0	SM
	4.0	38	36	59						CH
	5.0	31			0	97	3	0	0	SP
	6.0	35	28	65						CH
	7.0	26			8	89	3	0	0	SP
	8.0	50	34	78						CH
	9.0	44			13	75	12	0	0	SM
\	10.0	24			9	53	31	7	0	SP-SM
	11.5	14			4					
	13.0	11			4	40	45	10	1	SP
	14.5	12			5					
	16.0	15			9	57	25	9	0	SP-SM
	17.5	12			7					
	19.0	10			11	41	32	12	4	SP-SM
	20.5	11			18					
	22.5	12			14	61	20	4	1	SM

FREE SWELL INDEX TEST RESULTS

BORE NO.	DEPTH, M	FREE SWELL INDEX, %
1	**1.75**	**30**
	2.5	**117**
	4.0	**125**
2	**4.0**	**79**

PLATE 4

Grain Size Distribution Curves
Boring 1



Grain Size Distribution Curves
Boring 2

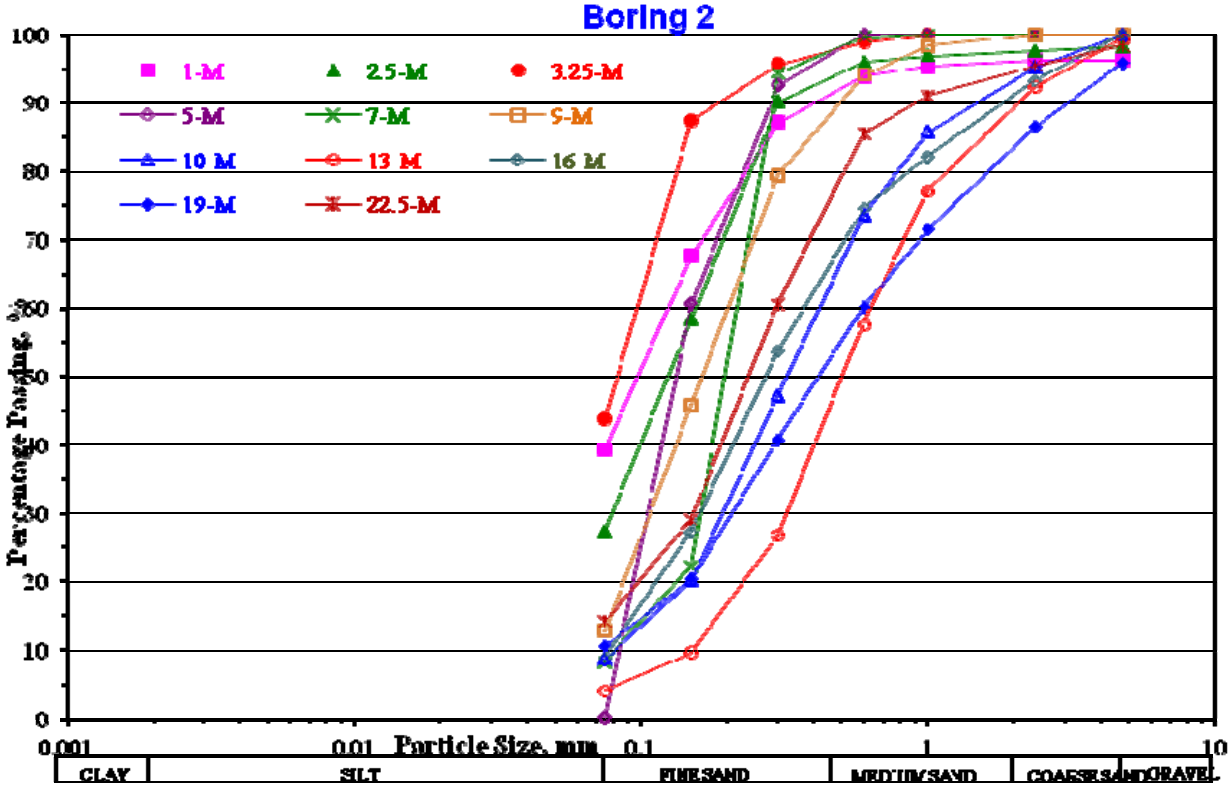


PLATE 5

SUMMARY OF WATER TEST RESULTS

PLOT'S OPEN WELL; WELL DIAMETER = 1.2-M

DISTANCE FROM BORING 2 = 6.4-M; WATER LEVEL IN OPEN WELL = 4.1-M.

S. No.		Description	Results Obtained	As per IS:456 – 2000
1		To neutralize 100 cc of water using phenolphthalein as indicator	0.5 ml	Not more than 5 ml of 0.02N NaOH
2		To neutralize 100 cc of water using methyl orange as indicator	55.0 ml	Not more than 25 ml of 0.02N H_2SO_4
3	a	Organic Solids, mg/liter	40	200 Max.
	b	Inorganic Solids, mg/liter	1100	3,000 Max.
	c	Sulphates as SO_3, mg/liter	60	400 Max.
	d	Chlorides as Cl, mg/liter	177	2,000 Max. - Plain Concrete 500 Max. RCC
	e	Suspended Solids, mg/liter	0	2,000 Max.
	f	Ph	7.62	6 Min.

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

SAMPLE CALCULATIONS FOR DMC RIG BORED CAST IN SITU PILES.

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

PROPOSED COMMERCIAL BUILDING SITE

No. 8, Theyagaraya Road, T Nagar, Chennai 600 017, TN.

Bored Cast In-Situ Pile Details:

Pile Driven Length = 19.50 M below EGL
Top Pile Cutoff Length = 3.00 M Top pile cutoff length for basement floor and pilecaps
Pile Effective Concreting Length = 16.50 M
Pile Diameters Considered: **0.60 0.75 0.90 1.00 -M.**

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

S.No.	Soil Description	From	To	N_{avg}	C_u, T/M^2	ϕ^0	γ_T, T/M^3
1a	Brown Silty Fine Sand	0.00	3.00	23		31	1.70
1b	Brown Silty Fine Sand	3.00	3.75	23		31	1.70
2	Brown Stiff Clay	3.75	5.00	12	7.50		1.65
3	Brown Gray Silty Fine Sand	5.00	6.00	12		31	1.65
4	Brown Gray Stiff Clay	6.00	7.00	10	6.00		1.60
5	Gray Brown Fine Sand with Silt	7.00	7.75	24		33	1.75
6	Gray Soft Clay	7.75	9.00	3	2.00		1.45
7	Gray Silty Fine Sand	9.00	11.50	5		27	1.50
8a	Brown Gray F to C Sand with Silt	11.50	14.50	20		32	1.70
8b	Brown Gray F to C Sand with Silt	14.50	17.50	27		34	1.80
8c	Brown Gray F to C Sand with Silt	17.50	19.00	51		36	2.00
9	Gre. Br. Yel. Gray Silty F to M Sand	19.00	22.50	> 75		37	2.10

For Cohesive Soils :-

SPT "N"	α
< 4	1.0
4 to 8	0.5
8 to 15	0.4
> 15	0.3

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

Unit Skin Friction in Clay Soils, f_s = αC_u
Unit Skin Friction in Sand Soils, f_s = $\sigma' K_o \tan\delta$ K_o = 1.5
Skin Friction of the Each Strata, Q_{si} = $f_s * \pi D L_i$
Total Ult. Skin Frition, $Q_{s\,ult}$ = ΣQ_{si}

Unit End Bearing in Clay Soils, q_{ult} = $9C_u$
Unit End bearing in Sand Soils, q_{ult} = $\sigma' N_q + 0.5 D \gamma N_\gamma$
Ultimate End Bearing, $Q_{p\,ult}$ = $q_{ult} * \pi D^2/4$

Total Ultmate Pile Capacity, Q_{ult} = $Q_{s\,ult} + Q_{p\,ult}$
Allowable Pile Capacity, Q_{all} = Q_{ult}/FS FS = Factor of Safety = **2.50**

Skin Friction Calculations

S.No.	Soil Description	From	To	ϕ^0 / C_u	$\delta = \phi$	γ'_s, T/M^3	σ'_{Mid},T/M^2	f_s,T/M^2	Pile Dia 0.60 Q_s, T	0.75 Q_s, T	0.90 Q_s, T	1.00 Q_s, T	-M.
1a	Brown Silty Fine Sand	0.00	3.00	31	31	0.70	0.00	0.00	0.00	0.00	0.00	0.00	Pile Caps Cutoff
1b	Brown Silty Fine Sand	3.00	3.75	31	31	0.70	0.26	0.24	0.33	0.42	0.50	0.56	
2	Brown Stiff Clay	3.75	5.00	7.50		0.65	0.93	3.00	7.07	8.84	10.61	11.79	
3	Brown Gray Silty Fine Sand	5.00	6.00	31	31	0.65	1.66	1.50	2.83	3.53	4.24	4.71	
4	Brown Gray Stiff Clay	6.00	7.00	6.00		0.60	2.29	2.40	4.53	5.66	6.79	7.54	
5	Gray Brown Fine Sand with Silt	7.00	7.75	33	33	0.75	2.87	2.79	3.95	4.94	5.93	6.59	
6	Gray Soft Clay	7.75	9.00	2.00		0.45	3.43	2.00	4.71	5.89	7.07	7.86	
7	Gray Silty Fine Sand	9.00	11.50	27	27	0.50	4.34	3.31	15.63	19.53	23.44	26.05	
8a	Brown Gray F to C Sand with Silt	11.50	14.50	32	32	0.70	6.01	5.64	31.88	39.85	47.82	53.13	
8b	Brown Gray F to C Sand with Silt	14.50	17.50	34	34	0.80	8.26	8.36	47.29	59.11	70.94	78.82	
8c	Brown Gray F to C Sand with Silt	17.50	19.00	36	36	1.00	10.21	11.13	31.48	39.35	47.22	52.47	
9	Gre. Br. Yel. Gray Silty F to M Sand	19.00	19.50	37	37	1.10	11.24	12.70	11.98	14.97	17.96	19.96	
								Net Total Ultimate Skin Friction, $Q_{s\,ult}$=	161.68	202.10	242.52	269.46	

			0.60	0.75	0.90	1.00	
@ 19.5-M below Existing G. L. Soil	N =	> 75					
Fine to Medium Sand	N_q =	70					
L/D of Pile = 19.5/0.60 > 20	N_γ =	65	Base A=	0.2829	0.4420	0.6364	0.7857 -M^2
L/D of Pile = 19.5/0.75 > 20			σ'_{base} =	7.86	9.96	11.51	11.51 T/M^2
L/D of Pile = 19.5/0.90 > 20			$q_{b\,ult}$ =	571.83	724.19	838.05	841.63 T/M^2
L/D of Pile = 19.5/1.00 > 20			**Limited to** $q_{b\,ult}$ =	**900.00**	**900.00**	**900.00**	**900.00 T/M^2**
Use Actual or Lim. Value σ'_{base}			$Q_{b\,ult}$ =	161.74	320.07	533.36	661.28 Tons
			$Q_{s\,ult}$ =	161.68	202.10	242.52	269.46 Tons
			$Q_{tot\,ult}$=	**323.42**	**522.16**	**775.87**	**930.74** Tons
			F.S. =	2.5	2.5	2.5	2.5
		Allowable Compressive Capacity =	Q_{All} =	**129.37**	**208.86**	**310.35**	**372.30** Tons
			Use Q_{All} =	**129**	**209**	**310**	**372 Tons**

Note:-

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

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

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 330 tons/M^2. Therefore, q_b (all) is limited to 300 tons/M^2 in the weathered rock.

5 **"ROTARY HYDRAULIC RIG" was not recommended for this site.**

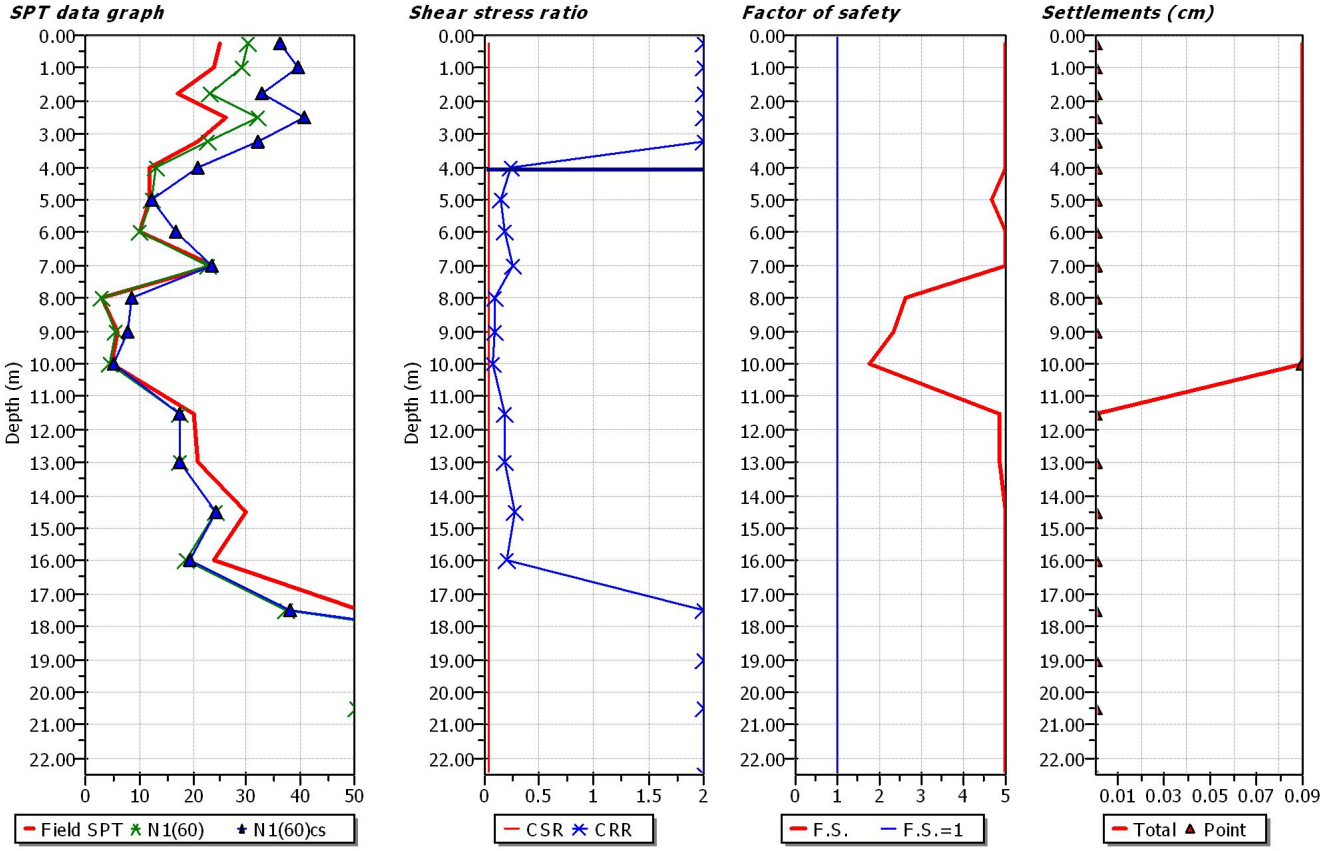
LIQUEFACTION ANALYSIS REPORT

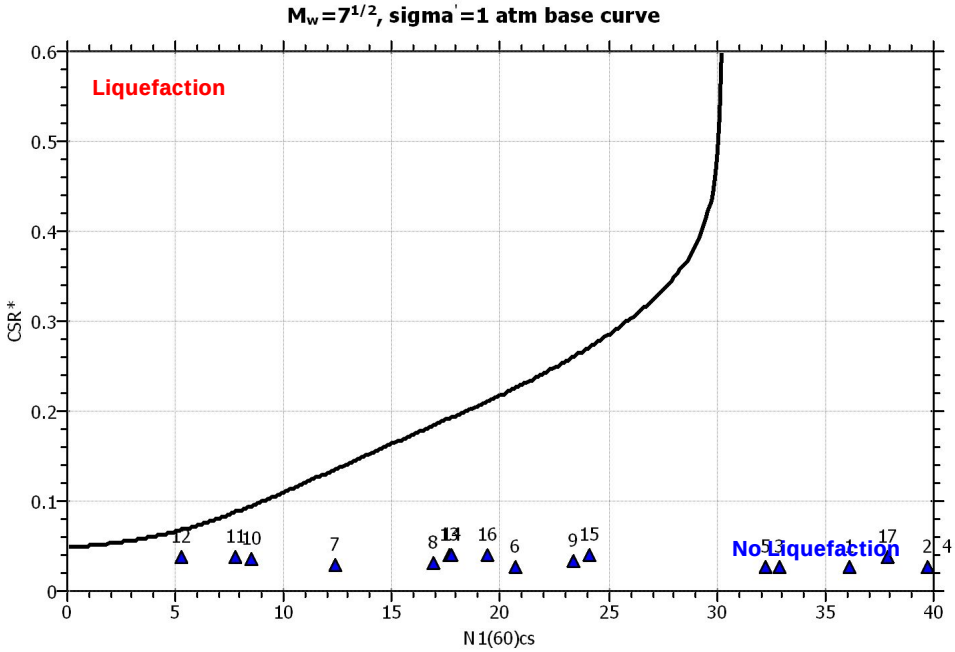
Project title : TSM Sadunissa & Others, No. 8, Theyagaraya Road, T Nagar, Chennai 600 017.

Project subtitle : Boring 2 Soil Profile

Input parameters and analysis data

In-situ data type:	Standard Penetration Test	Depth to water table:	4.10 m
Analysis type:	Deterministic	Earthquake magnitude M_w:	6.50
Analysis method:	NCEER 1998	Peak ground accelaration:	0.06 g
Fines correction method:	Idriss & Seed	User defined F.S.:	1.00





Horizontal Acceleration, α_h = 0.06g

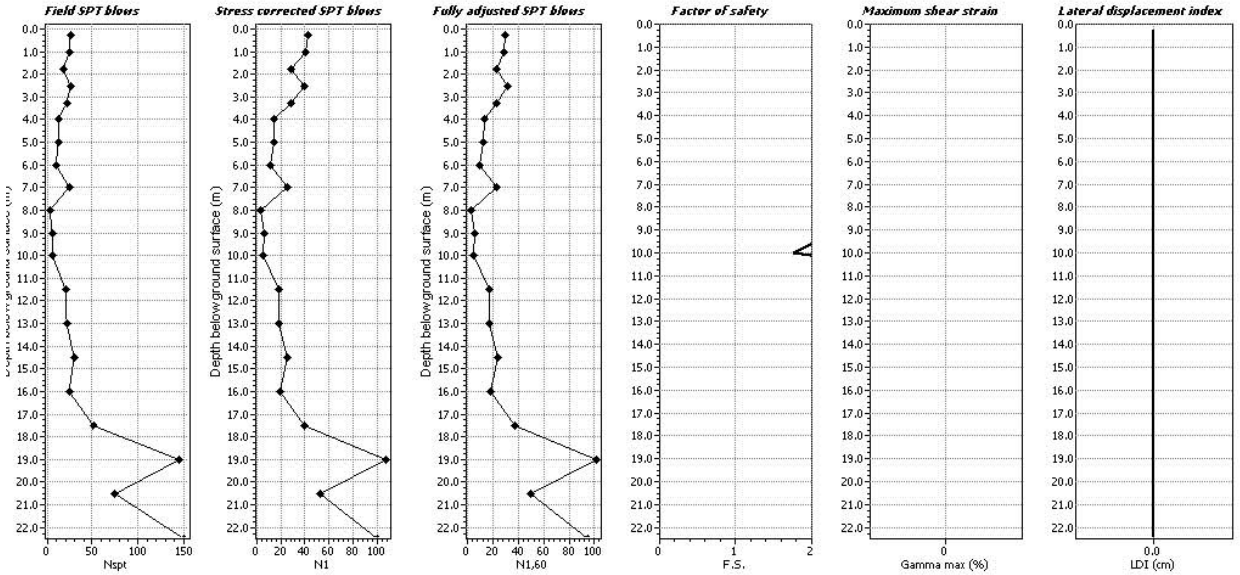
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Url : http://www.geologismiki.gr - Email : info@geologismiki.gr

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

LATERAL DISPLACEMENTS ESTIMATION DUE TO SOIL LIQUEFACTION[1]

ometric parameters: Gently sloping ground without free face
:al lateral displacement estimation: 0.00 cm



: Measured SPT blows
: Stress adjusted SPT blows
: Fully adjusted SPT blows

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

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

PLATE 8b

PRASAD ARMSTRONG YEN G E C (P) LTD.
821 (Old # 439/4) Poonamallee High Road
Arumbakkam, Chennai 600 106.
Phone: 044 - 2363 7146; e-mail: paygec@yahoo.com



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Ownership, Compliance & Legal Verification

Encumbrance Certificate (EC) Search, Find Your SRO, Temple Property Check, WAQF Property Check, View Patta/Chitta, View FMB, Patta Analyzer, EC Analyzer

Zoning & Land Use Analysis

Land Use Zone Finder, CRZ Zone Check, Aquifer Zone Check, CBA Check, EWS Check, Road Width Check, Proposed Road Widening Check, FSI Calculator

Property Documentation & Workflow Tools

Forms & Templates, Document Generator, Document Translation, Dictionary

Vastu & Property Management Tools

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