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CIN: U74210TN1992PTC023645

# GEOTECHNICAL SITE INVESTIGATION
## BORING 1 THROUGH 3
## PROPOSED RESIDENTIAL APARTMENTS BUILDING SITE
## S. NO. 206 / 1A PART (AS PER PATTA NO. 2592 – S. NO. 260/246)
## PORUR VILLAGE, CHENNAI 600 116
## MADURAVOYAL TALUK, CHENNAI DISTRICT, TN.

For PRASAD ARMSTRONG YEN
GEOTECH ENGINEERING CONSULTANTS (P) LTD.

Dr. B. Ramprasad
ME, PhD (Texas A&M)
Reg. No. GTE/2024/2/0055
Managing Director

Report to

**M/s. Kaizen Shelters**
Flat No. G1, A Block, Navaratna Apartments
Plot No. 17, 18 & 19, Dhanalakshmi Nagar, Manapakkam, Chennai 600 125, TN.

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Report No. 111/GI/23-24.
September 25, 2023.

M/s. Kaizen Shelters
Flat No. G1, A Block, Navaratna Apartments
Plot No. 17, 18 & 19, Dhanalakshmi Nagar
Manapakkam, Chennai 600 125, TN.

Attention: Mr. Guru
Site Engineer

**Geotechnical Site Investigation**
**Boring 1 through 3**
**Proposed Residential Apartments Building Site**
**S. No. 260 / 1A Part (As per Patta No. 2592 – S. No. 260/246)**
**Porur Village, Chennai 600 116**
**Maduravoyal Taluk, Chennai District, 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 Work Order No. Nil dated September 11, 2023.

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

(111brpt)
Copies Submitted: (3)

For PRASAD ARMSTRONG YEN
GEOTECH ENGINEERING CONSULTANTS (P) LTD.

Dr. B. Ramprasad
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Managing Director

**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**.



CHENNAI METROPOLITAN DEVELOPMENT AUTHORITY * CHENNAI-600 008 *

19/02/2019

**(R.SHIVAKUMAR)**

ASSISTANT PLANNER
CHENNAI METROPOLITAN DEVELOPMENT AUTHORITY
CHENNAI - 600 008

For PRASAD ARMSTRONG YEN
GEOTECH ENGINEERING CONSULTANTS (P) LTD.

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**CHENNAI METROPOLITAN DEVELOPMENT AUTHORITY**
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## PROFESSIONAL REGISTRATION CERTIFICATE

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

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

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



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

A Meganathan

Superintendent

For PRASAD ARMSTRONG YEN
GEOTECH ENGINEERING CONSULTANTS (P) LTD.

Dr. B. Ramprasad
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# SUMMARY

Prasad Armstrong Yen G E C (P) Ltd. performed a geotechnical site investigation at the Proposed Residential Apartments Building Site, S. No. 260 / 1A Part (As per Patta No. 2592 – S. No. 260/246), Porur Village, Chennai 600 116, Maduravoyal Taluk, Chennai District, 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. Expected typical maximum column load was about 150 tons due to expected large column span and spacing. These details were used only for estimating the preliminary foundation size and type of foundation.

The field investigation was performed from September 15 through 20, 2023. Number and location of borings was selected to cover the plinth area of the proposed building. Boring 1 through 3 were drilled 24.5-M below the Existing Ground Level (EGL). Borings were terminated after encountering hard strata with SPT "N" $\geq$ 100 in at least two successive tests. NX Diamond bit core barrel as used for drilling the last 2-M of the borings in order to identify the continuity of hard strata. Tests were conducted to determine the pertinent index and engineering properties of the soils and weathered rock encountered. We then performed engineering analyses to develop the required design data.

Topography of the site reflects a relatively flat terrain. Visual observation infers site's EGL was about the Existing Road Level (ERL) of road in front of the site. Site had compound walls along all four boundaries. Many trees, bushes, and shrubs were present in the site during the field work. Proposed construction will be the first major construction activity of this magnitude to cover this site. Typical soil stratigraphy of the borings was summarized below:

**Boring – 1:**

| Stratum | Penetration, M From | To | Description |
|---|---|---|---|
| I | 0 | 7.0 | Gray and Brown Firm to Stiff Clay |
| II | 7.0 | 12.5 | Gray Fine to Medium Sand |
| III | 12.5 | 19.0 | Gray Firm to Stiff Clay |
| IV | 19.0 | 22.0 | Gray Green Silty Fine to Medium Sand with Limestone Nodules |
| V | 22.0 | 24.5+ | Brown Yellow Weathered Rock |

**Boring – 2:**

| Stratum | Penetration, M From | To | Description |
|---|---|---|---|
| I | 0 | 1.0 | Brown Silty Fine to Medium Sand with Brick and Stone Pieces – Filled up soil |
| II | 1.0 | 2.0 | Brown Stiff Clay |
| III | 2.0 | 3.75 | Brown Gray Silty Fine Sand with clay |
| IV | 3.75 | 6.0 | Gray Stiff Clay |
| V | 6.0 | 7.25 | Gray Fine to Medium Sand with Silt |
| VI | 7.25 | 8.25 | Gray Stiff Sandy Clay |
| VII | 8.25 | 11.0 | Gray Fine to Medium Sand with Silt |
| VIII | 11.0 | 19.0 | Gray Very Stiff to Stiff Clay |
| IX | 19.0 | 21.7 | Gray Green Silty Fine to Medium Sand with Limestone Nodules |
| X | 21.7 | 24.5+ | Brown Weathered Rock |

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**Boring – 3:**

| Stratum | Penetration, M From | To | Description |
|---|---|---|---|
| I | 0 | 2.0 | Brown Gray Stiff Clay |
| II | 2.0 | 2.75 | Brown Gray Silty Fine Sand with Clay Binder |
| III | 2.75 | 6.0 | Gray Stiff Clay |
| IV | 6.0 | 6.75 | Gray Fine to Medium Sand with Silt |
| V | 6.75 | 8.0 | Gray Stiff Clay |
| VI | 8.0 | 11.0 | Gray Silty Fine to Medium Sand |
| VII | 11.0 | 19.0 | Gray Firm to Stiff Clay |
| VIII | 19.0 | 21.8 | Gray Green Silty Fine to Medium Sand with Limestone Nodules |
| IX | 21.8 | 24.5+ | Brown Weathered Rock |

Data from the borings indicate presence of highly variable soils with alternative layers of sand and clay in the top 11-M. Also, groundwater level in the site was quite high. Expected maximum column load was about 150 tons. With the variable soil profiles of the site and shallow groundwater, shallow foundations will undergo high and variable total settlements leading to differential settlement issues apart from the potential liquefaction issues Therefore, to avoid these issues for the proposed building it was recommended to provide "**Tractor Mounted Direct Mud Circulation (DMC) Cast In-Situ Pile**" foundation. This type of pile installation work will have low construction vibrations otherwise it may affect the existing building foundations and also lead to objections from adjacent building owners. For this site it was recommended to provide a minimum **22.5- and 21.5-M total and effective length below EGL with pile cutoff at 1-M for pile caps, tie beams, etc.** Ultimate and allowable pile capacities of various pile diameters were summarized below.

| Pile Dia. M | Compressive Capacity | | Uplift Capacity | | Lateral Capacity @ 5 mm Defl. |
|---|---|---|---|---|---|
| | Ultimate Tons | Allowable Tons | Ultimate Tons | Allowable Tons | Allowable Tons |
| 0.45 | 212.62 | 85 | 145.08 | 48 | 1.73 |
| 0.50 | 260.37 | 104 | 161.79 | 54 | 2.15 |
| 0.60 | 375.72 | 150 | 195.57 | 65 | 3.09 |
| 0.75 | 510.04 | 204 | 247.12 | 82 | 4.79 |
| 0.90 | 678.35 | 271 | 299.74 | 100 | 6.78 |

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 for better resistance to bending forces from the column loads and seismic forces. In case of columns for lift or staircase area with close spacing and / or low loads 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 the pile caps should be tied together through rigid tie beams. If single pile and single column unit is considered then extreme care should be taken to match center line of pile and column to minimize eccentricity to avoid additional bending moments in the pile. **All the piles should be terminated with at least 0.8-M embedment in the hard strata weathered rock layer. In the initial piles and at least one pile per two columns at pile termination depth SPT should be performed to confirm the presence of hard stratum and confirm proper washing of the bore.**

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In the site a 2.9-M diameter and unknown depth open well was present at about 16.4-M from Boring 3 in the North East area of the site. The open well location appears to fall within the proposed building footprint. In the open well groundwater was at about 1.4-M below EGL. Groundwater sample was collected from this open well for construction suitability test. Test results inferred that open well groundwater was suitable for construction purposes as per IS: 456 - 2000 guidelines. Six soil samples at the rate of two samples per bore (one sample from shallow depth and another one from deeper depth) were tested for pH, chlorides and sulphates to check if the soils can affect the proposed foundation elements in contact with site soils. Test results infer that the tested soils had acceptable pH and acceptable concentration of chlorides, and sulphates as per IS: 456 – 2000 for construction water.

**We do expect construction problems at this site due to site high groundwater conditions in rainy season.** Site's EGL was at about ERL of road in front of the site. The Finished Ground Level (FGL) of the site should be raised by at least 0.6-M above ERL, and the stilt floor's Finished Floor Level (FFL) may be maintained at 0.25-M above FGL of the site. Backfilling of the building basement and site filling should be done with granular soil. Filling should be compacted properly to achieve proper densification to avoid settlements in flooring.

In case of pile foundation proper care should be taken in pile installation to minimize / avoid **pile bulging / necking / improper concreting** due to presence of variable soil profiles. 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. At pile termination depth bore should be **properly washed and cleaned of all loosened material** to prevent concrete contamination due to possible collapse of sand from pile side surface. **For the encountered site soil profiles "Hydraulic Rotary Rig" was not recommended due to presence of thick layers of sand soils. 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. **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.**

In the site a 2.9-M diameter open well was present in the north east portion of the site. This well appears to fall within the footing print of the proposed building. Therefore, it will be necessary to plan foundations at this location with due consideration to the presence of the open well. In case the open well was planned to be closed then the filling should be done using granular material. The orientation of the foundations should be selected to avoid foundations in the filled up well 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 and half. Seismic events of 5.1 magnitude on August 24, 2021, 5.1 magnitude on February 12, 2019, 7.9 magnitude on April 25, 2015, 6.0 magnitude on May 21, 2014, 8.4 magnitude on April 11, 2012, 7.2 magnitude on June 13, 2010, and 7.6 magnitude on August 11, 2009 with epicenters in Himalayas, Bay of Bengal, and near Andaman Islands were felt at Chennai. It is recommended to provide rigid plinth beams in ground level, columns designed for shear forces or shear walls in the structure, and continuous lintels in each floor. Lintels must be integrated into columns of the structure. Plinth beams must be designed to be rigid to allow redistribution of

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loads in case of differential settlements. Site Boring 3 soil profile with Ground Water Level (GWL) at 0-M below EGL infers "**Low to Medium**" seismic susceptibility. Under a seismic event of **6.0 Richter scale**, and peak ground acceleration of **0.16g** the total estimated vertical settlement was 10.10 cms and total horizontal displacement was about 5.01 cms at EGL. Iwasaki liquefaction potential was 0.0 inferring "**No Liquefaction**." As per IS code for **Zone III** design horizontal acceleration was **0.16g**.

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# INTRODUCTION

## Purpose and Scope

Prasad Armstrong Yen G E C (P) Ltd. performed a geotechnical site investigation at the Proposed Residential Apartments Building Site, S. No. 260 / 1A Part (As per Patta No. 2592 – S. No. 260/246), Porur Village, Chennai 600 116, Maduravoyal Taluk, Chennai District, 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. Expected typical maximum column load was about 150 tons due to expected large column span and spacing. 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 through 3 were drilled 24.5-M below EGL to explore subsurface stratigraphy to obtain soil and weathered rock samples for lab tests;

(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 the site for the proposed building area were explored by Boring 1 through 3. Boring location details are presented on Plate 1. Number and location of borings was selected to cover the plinth area of the proposed building. Boring 1 through 3 were drilled 24.5-M below EGL. Borings were terminated after encountering hard strata with SPT "N" $\geq$ 100 in at least two successive tests. NX Diamond bit core barrel as used for drilling the last 2-M of the borings in order to identify the continuity of hard strata. Tests were conducted to determine the pertinent index and engineering properties of the soils and weathered rock encountered. We then performed engineering analyses to develop the required design data. Groundwater was seen in the site's open well at 1.4-M below EGL. Log of Boring is presented on Plate 2 through 4.

## Field and Laboratory Tests

Borings were drilled using Calyx drilling unit. In the borings SPT was performed at 1-M interval upto 10-M, at 1.5-M interval upto 20.5-M, at 2-M interval beyond 20.5-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

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required for 30-cm of penetration of sampler in soil is designated as N value and it is termed as 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 or rock samples were collected at 1-, 1.5-, and 2-M intervals either disturbed or undisturbed as the case may be. All 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 5. Grain size distribution curves of tested soil are presented on Plate 6. Summary of Water and Soil Chemical Test Results are presented on Plate 7.

## GENERAL SOIL CONDITIONS

### Topography

Topography of the site reflects a relatively flat terrain. Visual observation infers site's EGL was about ERL of road in front of the site. Site had compound walls along all four boundaries. Many trees, bushes, and shrubs were present in the site during the field work. Proposed construction will be the first major construction activity of this magnitude to cover this site.

### Soil Stratigraphy

The soil stratigraphy disclosed by our investigation is presented on the log of boring on Plate 2 through 4. 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 | 7.0 | Gray and Brown Firm to Stiff Clay |
| II | 7.0 | 12.5 | Gray Fine to Medium Sand |
| III | 12.5 | 19.0 | Gray Firm to Stiff Clay |
| IV | 19.0 | 22.0 | Gray Green Silty Fine to Medium Sand with Limestone Nodules |
| V | 22.0 | 24.5+ | Brown Yellow Weathered Rock |

**Boring – 2:**

| Stratum | Penetration, M From | To | Description |
|---|---|---|---|
| I | 0 | 1.0 | Brown Silty Fine to Medium Sand with Brick and Stone Pieces – Filled up soil |
| II | 1.0 | 2.0 | Brown Stiff Clay |
| III | 2.0 | 3.75 | Brown Gray Silty Fine Sand with clay |
| IV | 3.75 | 6.0 | Gray Stiff Clay |
| V | 6.0 | 7.25 | Gray Fine to Medium Sand with Silt |
| VI | 7.25 | 8.25 | Gray Stiff Sandy Clay |
| VII | 8.25 | 11.0 | Gray Fine to Medium Sand with Silt |
| VIII | 11.0 | 19.0 | Gray Very Stiff to Stiff Clay |



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| | | | |
|---|---|---|---|
| IX | 19.0 | 21.7 | Gray Green Silty Fine to Medium Sand with Limestone Nodules |
| X | 21.7 | 24.5+ | Brown Weathered Rock |

**Boring – 3:**

| Stratum | Penetration, M From | To | Description |
|---|---|---|---|
| I | 0 | 2.0 | Brown Gray Stiff Clay |
| II | 2.0 | 2.75 | Brown Gray Silty Fine Sand with Clay Binder |
| III | 2.75 | 6.0 | Gray Stiff Clay |
| IV | 6.0 | 6.75 | Gray Fine to Medium Sand with Silt |
| V | 6.75 | 8.0 | Gray Stiff Clay |
| VI | 8.0 | 11.0 | Gray Silty Fine to Medium Sand |
| VII | 11.0 | 19.0 | Gray Firm to Stiff Clay |
| VIII | 19.0 | 21.8 | Gray Green Silty Fine to Medium Sand with Limestone Nodules |
| IX | 21.8 | 24.5+ | Brown Weathered Rock |

Detailed soil descriptions that include textural variations and inclusions were noted on log of boring presented on Plate 2 through 4.

**Interpretation of Soil Properties**

Shear strength parameters for cohesion less soils were selected based on the field SPT results, grain size distribution analyses, and associated correlation. Shear strength parameters for cohesive soils were selected based on the field SPT results, and associated correlation. 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 Boring 3. 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 From | To | Properties |
|---|---|---|---|
| Ia | 0 | 2.0 | $C_u = 4$ tons/M$^2$; $\gamma_{sat} = 1.55$ tons/M$^3$ |
| Ib | 2.0 | 2.75 | $C_u = 6$ tons/M$^2$; $\gamma_{sat} = 1.6$ tons/M$^3$ |
| Ic | 2.75 | 4.0 | $C_u = 4.5$ tons/M$^2$; $\gamma_{sat} = 1.55$ tons/M$^3$ |
| Id | 4.0 | 5.75 | $C_u = 8$ tons/M$^2$; $\gamma_{sat} = 1.65$ tons/M$^3$ |
| Ie | 5.75 | 7.0 | $C_u = 4.5$ tons/M$^2$; $\gamma_{sat} = 1.55$ tons/M$^3$ |
| IIa | 7.0 | 8.0 | $\phi = 33^o$; $\gamma_{sat} = 1.75$ tons/M$^3$ |
| IIb | 8.0 | 8.75 | $\phi = 33^o$; $\gamma_{sat} = 1.75$ tons/M$^3$ |
| IIc | 8.75 | 10.0 | $\phi = 32^o$; $\gamma_{sat} = 1.7$ tons/M$^3$ |
| IId | 10.0 | 11.0 | $\phi = 36^o$; $\gamma_{sat} = 2.0$ tons/M$^3$ |

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| | | | |
|---|---|---|---|
| IIe | 11.0 | 12.5 | $\phi = 33^o$; $\gamma_{sat} = 1.75$ tons/M$^3$ |
| IIIa | 12.5 | 14.0 | $C_u = 6$ tons/M$^2$; $\gamma_{sat} = 1.6$ tons/M$^3$ |
| IIIb | 14.0 | 17.5 | $C_u = 3.5$ tons/M$^2$; $\gamma_{sat} = 1.55$ tons/M$^3$ |
| IIIc | 17.5 | 19.0 | $C_u = 5.5$ tons/M$^2$; $\gamma_{sat} = 1.6$ tons/M$^3$ |
| IV | 19.0 | 22.0 | $\phi = 34^o$; $\gamma_{sat} = 1.85$ tons/M$^3$ |
| Va | 22.0 | 24.5 | $\phi = 38^o$; $\gamma_{sat} = 2.2$ tons/M$^3$ |
| Vb | 24.5+ | | $\phi = 39^o$; $\gamma_{sat} = 2.25$ tons/M$^3$ |

**Boring – 2:**

| Stratum | Penetration, M From | To | Properties |
|---|---|---|---|
| I | 0 | 1.0 | $\phi = 26^o$; $\gamma_{sat} = 1.5$ tons/M$^3$ |
| II | 1.0 | 2.0 | $C_u = 5.5$ tons/M$^2$; $\gamma_{sat} = 1.6$ tons/M$^3$ |
| IIIa | 2.0 | 3.0 | $\phi = 27^o$; $\gamma_{sat} = 1.6$ tons/M$^3$ |
| IIIb | 3.0 | 3.75 | $\phi = 31^o$; $\gamma_{sat} = 1.75$ tons/M$^3$ |
| IV | 3.75 | 6.0 | $C_u = 6.5$ tons/M$^2$; $\gamma_{sat} = 1.65$ tons/M$^3$ |
| V | 6.0 | 7.25 | $\phi = 33^o$; $\gamma_{sat} = 1.75$ tons/M$^3$ |
| VI | 7.25 | 8.25 | $C_u = 5$ tons/M$^2$; $\gamma_{sat} = 1.6$ tons/M$^3$ |
| VIIa | 8.25 | 10.0 | $\phi = 34^o$; $\gamma_{sat} = 1.85$ tons/M$^3$ |
| VIIb | 10.0 | 11.0 | $\phi = 36^o$; $\gamma_{sat} = 2.0$ tons/M$^3$ |
| VIIIa | 11.0 | 17.5 | $C_u = 4$ tons/M$^2$; $\gamma_{sat} = 1.55$ tons/M$^3$ |
| VIIIb | 17.5 | 19.0 | $C_u = 9$ tons/M$^2$; $\gamma_{sat} = 1.7$ tons/M$^3$ |
| IXa | 19.0 | 20.5 | $\phi = 32^o$; $\gamma_{sat} = 1.7$ tons/M$^3$ |
| IXb | 20.5 | 21.7 | $\phi = 35^o$; $\gamma_{sat} = 2.0$ tons/M$^3$ |
| X | 21.7 | 24.5+ | $\phi = 39^o$; $\gamma_{sat} = 2.3$ tons/M$^3$ |

**Boring – 3:**

| Stratum | Penetration, M From | To | Properties |
|---|---|---|---|
| I | 0 | 2.0 | $C_u = 7$ tons/M$^2$; $\gamma_{sat} = 1.65$ tons/M$^3$ |
| II | 2.0 | 2.75 | $\phi = 26^o$; $\gamma_{sat} = 1.6$ tons/M$^3$ |
| III | 2.75 | 6.0 | $C_u = 5.5$ tons/M$^2$; $\gamma_{sat} = 1.6$ tons/M$^3$ |
| IV | 6.0 | 6.75 | $\phi = 31^o$; $\gamma_{sat} = 1.65$ tons/M$^3$ |
| V | 6.75 | 8.0 | $C_u = 4.5$ tons/M$^2$; $\gamma_{sat} = 1.6$ tons/M$^3$ |
| VIa | 8.0 | 9.0 | $\phi = 26^o$; $\gamma_{sat} = 1.55$ tons/M$^3$ |
| VIb | 9.0 | 10.0 | $\phi = 35^o$; $\gamma_{sat} = 1.95$ tons/M$^3$ |
| VIc | 10.0 | 11.0 | $\phi = 36^o$; $\gamma_{sat} = 2.0$ tons/M$^3$ |
| VIIa | 11.0 | 12.5 | $C_u = 8$ tons/M$^2$; $\gamma_{sat} = 1.65$ tons/M$^3$ |
| VIIb | 12.5 | 17.5 | $C_u = 3$ tons/M$^2$; $\gamma_{sat} = 1.5$ tons/M$^3$ |
| VIIc | 17.5 | 19.0 | $C_u = 5$ tons/M$^2$; $\gamma_{sat} = 1.6$ tons/M$^3$ |
| VIIIa | 19.0 | 20.5 | $\phi = 33^o$; $\gamma_{sat} = 1.75$ tons/M$^3$ |
| VIII | 20.5 | 21.8 | $\phi = 36^o$; $\gamma_{sat} = 2.0$ tons/M$^3$ |
| IX | 21.8 | 24.5+ | $\phi = 39^o$; $\gamma_{sat} = 2.3$ tons/M$^3$ |

## DESIGN INFORMATION

Data from the borings indicate presence of highly variable soils with alternative layers of sand and clay in the top 11-M. Also, groundwater level in the site was quite high. Expected maximum column load was about 150 tons. With the variable soil profiles of the site and shallow groundwater, shallow



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foundations will undergo high and variable total settlements leading to differential settlement issues apart from the potential liquefaction issues Therefore, to avoid these issues for the proposed building it was **recommended** to provide "**Tractor Mounted Direct Mud Circulation (DMC) Cast In-Situ Pile**" foundation. This type of pile installation work will have low construction vibrations otherwise it may affect the existing building foundations and also lead to objections from adjacent building owners. For this site it was recommended to provide a minimum **22.5- and 21.5-M total and effective length below EGL with pile cutoff at 1-M for pile caps, tie beams, etc.** Pile capacity was estimated as per the IS: 2911 - 2010 (Part 1 / Section 2) Code guidelines. Ultimate and allowable pile capacities of various pile diameters were summarized below.

| Pile Dia. M | Compressive Capacity | | Uplift Capacity | | Lateral Capacity @ 5 mm Defl. |
|---|---|---|---|---|---|
| | Ultimate Tons | Allowable Tons | Ultimate Tons | Allowable Tons | Allowable Tons |
| 0.45 | 212.62 | 85 | 145.08 | 48 | 1.73 |
| 0.50 | 260.37 | 104 | 161.79 | 54 | 2.15 |
| 0.60 | 375.72 | 150 | 195.57 | 65 | 3.09 |
| 0.75 | 510.04 | 204 | 247.12 | 82 | 4.79 |
| 0.90 | 678.35 | 271 | 299.74 | 100 | 6.78 |

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 for better resistance to bending forces from the column loads and seismic forces. In case of columns for lift or staircase area with close spacing and / or low loads 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 the pile caps should be tied together through rigid tie beams. If single pile and single column unit is considered then extreme care should be taken to match center line of pile and column to minimize eccentricity to avoid additional bending moments in the pile. **All the piles should be terminated with at least 0.8-M embedment in the hard strata weathered rock layer. In the initial piles and at least one pile per two columns at pile termination depth SPT should be performed to confirm the presence of hard stratum and confirm proper washing of the bore.** Foundation capacity calculations were presented on Plate 8.

## GROUNDWATER AND SOIL CHEMICAL ANALYSIS

In the site a 2.9-M diameter and unknown depth open well was present at about 16.4-M from Boring 3 in the North East area of the site. The open well location appears to fall within the proposed building footprint. In the open well groundwater was at about 1.4-M below EGL. Groundwater sample was collected from this open well for construction suitability test. Test results inferred that open well groundwater was **suitable** for construction purposes as per IS: 456 - 2000 guidelines. Six soil samples at the rate of two samples per bore (one sample from shallow depth and another one from deeper depth) were tested for pH, chlorides and sulphates to check if the soils can affect the proposed foundation elements in contact with site soils. Test results infer that the tested soils had acceptable pH and acceptable concentration of chlorides, and sulphates as per IS: 456 – 2000 for construction water. Summary of groundwater and soil chemical tests results were presented on Plate 7.

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## CONSTRUCTION CONSIDERATIONS

We do expect construction problems at this site due to site high groundwater conditions in rainy season. Site's EGL was at about ERL of road in front of the site. FGL of the site should be raised by at least 0.6-M above ERL, and the stilt floor's FFL may be maintained at 0.25-M above FGL of the site. Backfilling of the building basement and site filling should be done with granular soil. Filling should be compacted properly to achieve proper densification to avoid settlements in flooring.

In case of pile foundation proper care should be taken in pile installation to minimize / avoid pile bulging / necking / improper concreting due to presence of variable soil profiles. 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. At pile termination depth bore should be **properly washed and cleaned of all loosened material** to prevent concrete contamination due to possible collapse of sand from pile side surface. **For the encountered site soil profiles "Hydraulic Rotary Rig" was not recommended due to presence of thick layers of sand soils. 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. **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**.

In the site a 2.9-M diameter open well was present in the north east portion of the site. This well appears to fall within the footing print of the proposed building. Therefore, it will be necessary to plan foundations at this location with due consideration to the presence of the open well. In case the open well was planned to be closed then the filling should be done using granular material. The orientation of the foundations should be selected to avoid foundations in the filled up well 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 and half. Seismic events of 5.1 magnitude on August 24, 2021, 5.1 magnitude on February 12, 2019, 7.9 magnitude on April 25, 2015, 6.0 magnitude on May 21, 2014, 8.4 magnitude on April 11, 2012, 7.2 magnitude on June 13, 2010, and 7.6 magnitude on August 11, 2009 with epicenters in Himalayas, Bay of Bengal, and near Andaman Islands were felt at Chennai. It is recommended to provide rigid plinth beams in ground level, columns designed for shear forces or shear walls in the structure, and continuous lintels in each floor. Lintels must be integrated into columns of the structure. Plinth beams must be designed to be rigid to allow redistribution of loads in case of differential settlements. Site Boring 3 soil profile with GWL at 0-M below EGL infers "Low to Medium" seismic susceptibility. Under a seismic event of **6.0 Richter scale**, and peak ground acceleration of **0.16g** the total estimated vertical settlement was 10.10 cms and total horizontal displacement was about 5.01 cms at EGL. Iwasaki liquefaction potential was 0.0 inferring "No Liquefaction." As per IS code for **Zone III** design horizontal acceleration was **0.16g**. Liquefaction Analysis results are presented on Plate 9.

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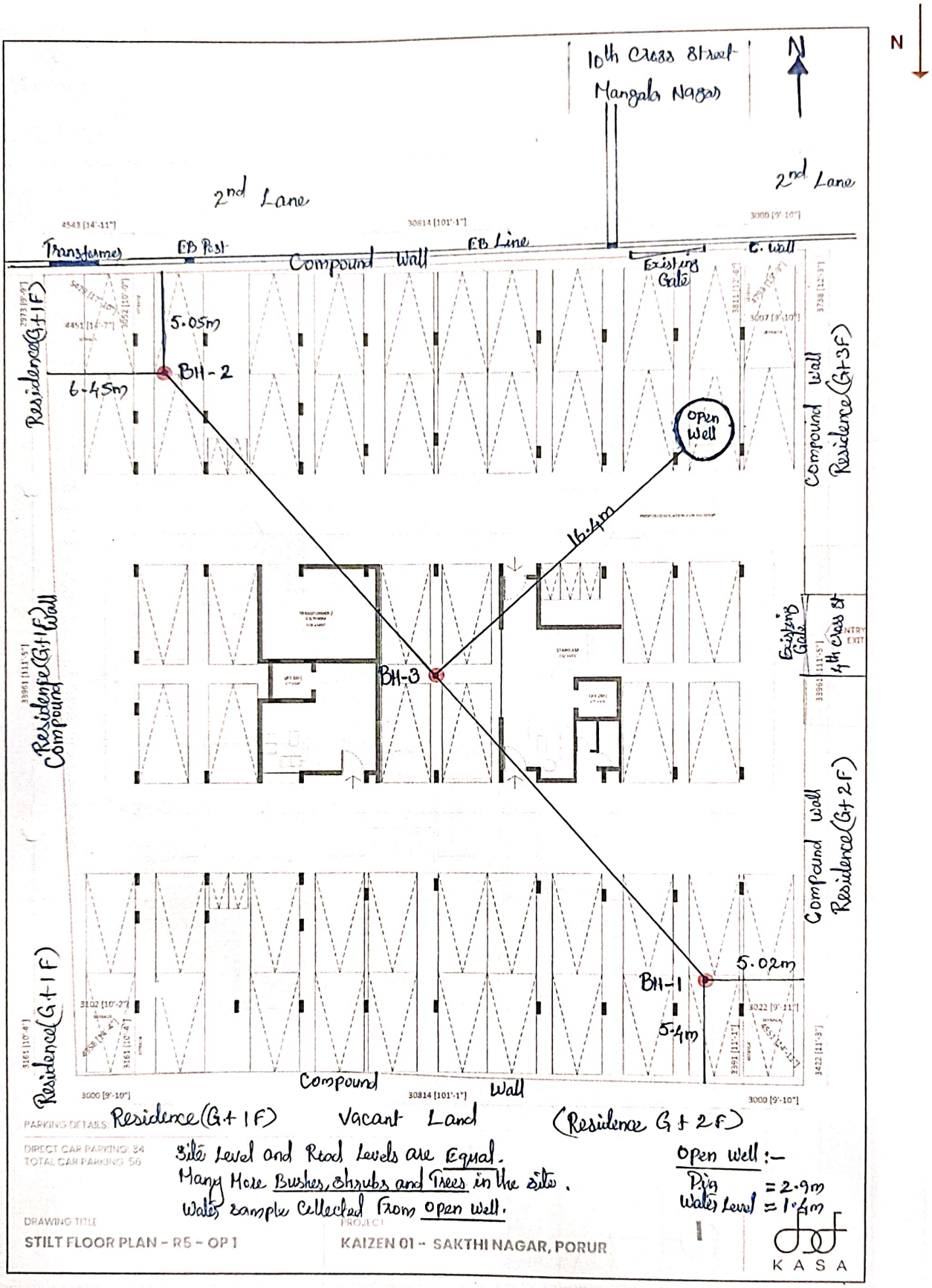
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(Not to Scale)

Site EGL = ERL of Road In Front of the Site

BORE HOLE LOCATION DETAILS.

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PLATE 1

# LOG OF BORING

**Project:** Proposed Residential Apartments Building Site, S. No. 260 / 1A part (As per Patta No. 2592 - S. No. 260 / 246), Porur Village, Chennai 600 116, Maduravoyal Taluk, Chennai District, TN.

**Bore Hole No.:** 1 **Type of Boring:** Calyx Drill **Dia. of Hole:** 150 mm
**Started on:** 15-09-'23 **Ended on:** 17-09-'23 **Field Work In Charge:** M Munivel
**Final Depth:** 24.5-M **Depth to G W S:** 1.4-M **Remarks:** GWL from Site Open Well.

| DEPTH, M | SOIL DESCRIPTION | SPT / VANE & SAMPLE TYPE |
|---|---|---|
| | **GRAY AND BROWN FIRM TO STIFF CLAY (To 7.0-M)** | SPT @ 0.25 M 2/2/3 = 5 Blows |
| | -brown gray color at 0.25-m | SPT @ 1 M |
| 1.0 | 0.0- to 2.0-m – $C_u$ = 4 tons/M$^2$; $\gamma_t$ = 1.55 tons/M$^3$ ($N_{avg}$ = 6) | 2/3/4 = 7 Blows |
| GWL | | |
| 2.0 | | SPT @ 2 M 4/4/6 = 10 Blows |
| | 2.0- to 2.75-m – $C_u$ = 6 tons/M$^2$; $\gamma_t$ = 1.6 tons/M$^3$ $N_{avg}$ = 10) | |
| 3.0 | -brown gray color, 3- to 5-m | SPT @ 3 M 4/2/5 = 7 Blows |
| | 2.75- to 4.0-m – $C_u$ = 4.5 tons/M$^2$; $\gamma_t$ = 1.55 tons/M$^3$ ($N_{avg}$ = 7) | |
| 4.0 | | SPT @ 4 M 5/6/8 = 14 Blows |
| | -brown gray color, 5- to 7-m | SPT @ 5 M |
| 5.0 | 4.0- to 5.75-m – $C_u$ = 8 tons/M$^2$; $\gamma_t$ = 1.65 tons/M$^3$ ($N_{avg}$ = 12) | 3/4/6 = 10 Blows |
| 6.0 | | SPT @ 6 M 3/3/4 = 7 Blows |
| | 5.75- to 7.0-m – $C_u$ = 4.5 tons/M$^2$; $\gamma_t$ = 1.55 tons/M$^3$ ($N_{avg}$ = 7) | |
| 7.0 | -silty at 7-m | SPT @ 7 M 7/10/12 = 22 Blows |
| | **GRAY FINE TO MEDIUM SAND (To 12.5-M)** 7.0- to 8.0-m – $\phi$ = 33°; $\gamma_t$ = 1.75 tons/M$^3$ ($N_{avg}$ = 22) | SPT @ 8 M |
| 8.0 | | 11/12/9 = 21 Blows |
| | 8.0- to 8.75-m – $\phi$ = 33°; $\gamma_t$ = 1.75 tons/M$^3$ ($N_{avg}$ = 21) | |
| 9.0 | -with silt at 9-m | SPT @ 9 M 9/6/11 = 17 Blows |
| | 8.75- to 10.0-m – $\phi$ = 32°; $\gamma_t$ = 1.7 tons/M$^3$ ($N_{avg}$ = 17) | |
| 10.0 | | SPT @ 10 M 19/22/24 = 46 Blows |
| | 10.0- to 11.0-m – $\phi$ = 36°; $\gamma_t$ = 2.0 tons/M$^3$ ($N_{avg}$ = 46) | |
| 11.0 | | |

SPT @ 12 M 25/28/50 = 78 Blows

SPT @ 13 M 50/50 = 100 Blows

SPT @ 14 M 50/50 = 100 Blows

SPT @ 15 M 50/50 = 100 Blows

SPT @ 16 M 50/50 = 100 Blows

SPT @ 17 M 50/50 = 100 Blows

SPT @ 18 M 50/50 = 100 Blows

SPT @ 19 M 50/50 = 100 Blows

SPT @ 20 M 50/50 = 100 Blows

SPT @ 21 M 50/50 = 100 Blows

SPT @ 22 M 50/50 = 100 Blows

SPT @ 23 M 50/50 = 100 Blows

SPT @ 24 M 50/50 = 100 Blows

SPT @ 24.5 M 50/50 = 100 Blows

SPT "N" PROFILE: 25 50 75

INDEX TEST DATA: 25 50 75

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

For PRASAD ARMSTRONG YEN
GEOTECH ENGINEERING CONSULTANTS (P) LTD.

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Reg. No. GTE/2024/2/0055
Managing Director

PLATE 2a

# LOG OF BORING

**Project:** Proposed Residential Apartments Building Site, S. No. 260 / 1A part (As per Patta No. 2592 - S. No. 260 / 246), Porur Village, Chennai 600 116, Maduravoyal Taluk, Chennai District, TN.

**Bore Hole No.:** 1 **Type of Boring:** Calyx Drill **Dia. of Hole:** 150 mm
**Started on:** 15-09-'23 **Ended on:** 17-09-'23 **Field Work In Charge:** M Munivel
**Final Depth:** 24.5-M **Depth to G W S:** 1.4-M **Remarks:** Continued from Plate 2a.

| DEPTH, M | SOIL DESCRIPTION | SPT / VANE & SAMPLE TYPE |
|---|---|---|
| | **GRAY FINE TO MEDIUM SAND (To 12.5-M)** | SPT @ 11.5 M<br>14/14/8 = 22 Blows |
| | 11.0- to 12.5-m – $\phi = 33°$; $\gamma_t = 1.75$ tons/M$^3$<br>($N_{avg} = 22$) | |
| 12.0 | | |
| | **GRAY FIRM TO STIFF CLAY (To 19.0-M)** | SPT @ 13 M<br>3/4/6 = 10 Blows |
| 13.0 | | |
| | 12.5- to 14.0-m – $C_u = 6$ tons/M$^2$; $\gamma_t = 1.6$ tons/M$^3$<br>($N_{avg} = 10$) | |
| 14.0 | | |
| | -with shell fragments, 14.5- to 17.5-m | SPT @ 14.5 M<br>2/3/3 = 6 Blows |
| 15.0 | | |
| | 14.0- to 17.5-m – $C_u = 3.5$ tons/M$^2$; $\gamma_t = 1.55$ tons/M$^3$<br>($N_{avg} = 5.5$) | SPT @ 16 M<br>1/2/3 = 5 Blows |
| 16.0 | | |
| 17.0 | | |
| | | SPT @ 17.5 M<br>3/4/5= 9 Blows |
| 18.0 | | |
| | 17.5- to 19.0-m – $C_u = 5.5$ tons/M$^2$; $\gamma_t = 1.6$ tons/M$^3$<br>($N_{avg} = 9$) | |
| 19.0 | -silty at 19-m | SPT @ 19 M<br>11/12/16 = 28 Blows |
| | **GRAY GREEN SILTY FINE TO MEDIUM SAND with limestone nodules (To 22.0-M)** | |
| 20.0 | | |
| | 19.0- to 22.0-m – $\phi = 34°$; $\gamma_t = 1.85$ tons/M$^3$<br>($N_{avg} \sim 30$) | SPT @ 20.5 M<br>26/15/18 = 33 Blows |
| 21.0 | | |
| 22.0 | -hard drilling from 22-m | |

SPT "N" PROFILE: 25 50 75

INDEX TEST DATA: 25 50 75

CONTINUED ON PLATE 2c.

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

For PRASAD ARMSTRONG YEN
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Managing Director

PLATE 2b

# LOG OF BORING

**Project:** Proposed Residential Apartments Building Site, S. No. 260 / 1A part (As per Patta No. 2592 - S. No. 260 / 246), Porur Village, Chennai 600 116, Maduravoyal Taluk, Chennai District, TN.

**Bore Hole No.:** 1 **Type of Boring:** Calyx Drill **Dia. of Hole:** 150 mm

**Started on:** 15-09-'23 **Ended on:** 17-09-'23 **Field Work In Charge:** M Munivel

**Final Depth:** 24.5-M **Depth to G W S:** 1.4-M **Remarks:** Continued from Plate 2b.

| DEPTH, M | SOIL DESCRIPTION | SPT / VANE & SAMPLE TYPE | SPT "N" PROFILE 25 50 75 | INDEX TEST DATA 25 50 75 |
|---|---|---|---|---|
| | BROWN YELLOW WEATHERED ROCK (Below 22.0-M) | SPT @ 22.5 M 7 cms for 20 Blows | | ♦ ■ |
| 23.0 | -NX Diamond bit drilling from 22.5-m | 2 cms for 10 Blows (Hammer Rebound) | | |
| | 22.0- to 24.5-m – $\phi = 38^{o}$; $\gamma_t = 2.2$ tons/M$^3$ ($N_{avg} > 100$) | | | |
| 24.0 | | | | |
| | -drilled from 22.5- to 24.5-m in 55 minutes | SPT @ 24.5 M 2 cms for 10 Blows | | ■ |
| 25.0 | 24.5-m+ – $\phi = 39^{o}$; $\gamma_t = 2.25$ tons/M$^3$ ($N_{avg} >> 100$) | 1 cm for 10 Blows (Hammer Rebound) | | |
| 26.0 | | | | |
| 27.0 | | | | |
| 28.0 | | | | |
| 29.0 | | | | |
| 30.0 | | | | |
| 31.0 | | | | |
| 32.0 | | | | |
| 33.0 | | | | |

BORE HOLE TERMINATED AT 24.5-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

For PRASAD ARMSTRONG YEN
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PLATE 2c

Prasad Armstrong Yen GEC (P) Ltd., Chennai 106.

# LOG OF BORING

**Project:** Proposed Residential Apartments Building Site, S. No. 260 / 1A part (As per Patta No. 2592 - S. No. 260 / 246), Porur Village, Chennai 600 116, Maduravoyal Taluk, Chennai District, TN.

**Bore Hole No.:** 2 **Type of Boring:** Calyx Drill **Dia. of Hole:** 150 mm
**Started on:** 17-09-'23 **Ended on:** 19-09-'23 **Field Work In Charge:** M Munivel
**Final Depth:** 24.5-M **Depth to G W S:** 1.4-M **Remarks:** GWL from Site Open Well.

| DEPTH, M | SOIL DESCRIPTION | SPT / VANE & SAMPLE TYPE |
|---|---|---|
| | **BROWN SILTY FINE TO MEDIUM SAND with brick and stone pieces – Filled Up Soil (To 1.0-M)** | SPT @ 0.25 M 2/3/2 = 5 Blows |
| 1.0 | 0.0- to 1.0-m – $\phi = 26^{o}$; $\gamma_t = 1.5$ tons/M$^3$ ($N_{avg} = 5$) | SPT @ 1 M 3/5/4 = 9 Blows |
| GWL | **BROWN STIFF CLAY (To 2.0-M)** | |
| 2.0 | 1.0- to 2.0-m – $C_u = 5.5$ tons/M$^2$; $\gamma_t = 1.6$ tons/M$^3$ ($N_{avg} = 9$) | SPT @ 2 M 5/4/4 = 8 Blows |
| | **BROWN GRAY SILTY FINE SAND with clay (To 3.75-M)** | |
| 3.0 | 2.0- to 3.0-m – $\phi = 27^{o}$; $\gamma_t = 1.6$ tons/M$^3$ ($N_{avg} = 8$) | SPT @ 3 M 9/11/11 = 22 Blows |
| | 3.0- to 3.75-m – $\phi = 31^{o}$; $\gamma_t = 1.75$ tons/M$^3$ ($N_{avg} = 22$) | |
| 4.0 | **GRAY STIFF CLAY (To 6.0-M)** | SPT @ 4 M 4/4/5 = 9 Blows |
| 5.0 | 3.75- to 6.0-m – $C_u = 6.5$ tons/M$^2$; $\gamma_t = 1.65$ tons/M$^3$ ($N_{avg} = 10.5$) | SPT @ 5 M 4/5/7 = 12 Blows |
| 6.0 | | SPT @ 6 M 5/9/11 = 20 Blows |
| | **GRAY FINE TO MEDIUM SAND with silt (To 7.25-M)** | |
| 7.0 | 6.0- to 7.25-m – $\phi = 33^{o}$; $\gamma_t = 1.75$ tons/M$^3$ ($N_{avg} = 22$) | SPT @ 7 M 13/11/5 = 16 Blows |
| | **GRAY STIFF SANDY CLAY (To 8.25-M)** | |
| 8.0 | 7.25- to 8.25-m – $C_u = 5$ tons/M$^2$; $\gamma_t = 1.6$ tons/M$^3$ ($N_{avg} = 10$) | SPT @ 8 M 5/14/17 = 31 Blows |
| | **GRAY FINE TO MEDIUM SAND with silt (To 11.0-M)** | |
| 9.0 | | SPT @ 9 M 14/16/17 = 33 Blows |
| 10.0 | 8.25- to 10.0-m – $\phi = 34^{o}$; $\gamma_t = 1.85$ tons/M$^3$ ($N_{avg} = 32$) | SPT @ 10 M 13/19/24 = 43 Blows |
| 11.0 | 10.0- to 11.0-m – $\phi = 36^{o}$; $\gamma_t = 2.0$ tons/M$^3$ ($N_{avg} = 43$) | |

SPT "N" PROFILE: 25 50 75

INDEX TEST DATA: 25 50 75

CONTINUED ON PLATE 3b.

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

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PLATE 3a

# LOG OF BORING

**Project:** Proposed Residential Apartments Building Site, S. No. 260 / 1A part (As per Patta No. 2592 - S. No. 260 / 246), Porur Village, Chennai 600 116, Maduravoyal Taluk, Chennai District, TN.

**Bore Hole No.:** 2 **Type of Boring:** Calyx Drill **Dia. of Hole:** 150 mm
**Started on:** 17-09-'23 **Ended on:** 19-09-'23 **Field Work In Charge:** M Munivel
**Final Depth:** 24.5-M **Depth to G W S:** 1.4-M **Remarks:** Continued from Plate 3a.

| DEPTH, M | SOIL DESCRIPTION | SPT / VANE & SAMPLE TYPE | SPT "N" PROFILE 25 50 75 | INDEX TEST DATA 25 50 75 |
|---|---|---|---|---|
| | **GRAY VERY SIFT TO STIFF CLAY (To 19.0-M)** | SPT @ 11.5 M 3/3/4 = 7 Blows | | |
| 12.0 | | | | |
| 13.0 | | SPT @ 13 M 2/2/4 = 6 Blows | | |
| 14.0 | 11.0- to 17.5-m – $C_u$ = 4 tons/M$^2$; $\gamma_t$ = 1.55 tons/M$^3$ ($N_{avg}$ = 6) | | | |
| | -with shell fragments, 14.5- to 17.5-m | SPT @ 14.5 M 1/3/3 = 6 Blows | | |
| 15.0 | | | | |
| 16.0 | | SPT @ 16 M 1/2/3 = 5 Blows | | |
| 17.0 | | | | |
| | | SPT @ 17.5 M 3/5/10 = 15 Blows | | |
| 18.0 | | | | |
| | 17.5- to 19.0-m – $C_u$ = 9 tons/M$^2$; $\gamma_t$ = 1.7 tons/M$^3$ ($N_{avg}$ = 15) | | | |
| 19.0 | -silty at 19-m | SPT @ 19 M 6/7/10 = 17 Blows | | |
| | **GRAY GREEN SILTY FINE TO MEDIUM SAND with limestone nodules (To 21.7-M)** | | | |
| 20.0 | 19.0- to 20.5-m – $\phi$ = 32°; $\gamma_t$ = 1.7 tons/M$^3$ ($N_{avg}$ = 17) | | | |
| | -brown gray green color at 20.5-m | SPT @ 20.5 M 10/18/23 = 41 Blows | | |
| 21.0 | | | | |
| | 20.5- to 21.7-m – $\phi$ = 35°; $\gamma_t$ = 2.0 tons/M$^3$ ($N_{avg}$ = 41) | | | |
| 22.0 | **BROWN WEATHERED ROCK (Below 21.7-M)** | | | |

CONTINUED ON PLATE 3c.

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

For PRASAD ARMSTRONG YEN
GEOTECH ENGINEERING CONSULTANTS (P) LTD.

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Managing Director

**PLATE 3b**

# LOG OF BORING

**Project:** Proposed Residential Apartments Building Site, S. No. 260 / 1A part (As per Patta No. 2592 - S. No. 260 / 246), Porur Village, Chennai 600 116. Maduravoyal Taluk, Chennai District, TN.

**Bore Hole No.:** 2 **Type of Boring:** Calyx Drill **Dia. of Hole:** 150 mm
**Started on:** 17-09-'23 **Ended on:** 19-09-'23 **Field Work In Charge:** M Munivel
**Final Depth:** 24.5-M **Depth to G W S:** 1.4-M **Remarks:** Continued from Plate 3b.

| DEPTH, M | SOIL DESCRIPTION | SPT / VANE & SAMPLE TYPE | SPT "N" PROFILE 25 50 75 | INDEX TEST DATA 25 50 75 |
|---|---|---|---|---|
| | **BROWN WEATHERED ROCK (Below 21.7-M)** | SPT @ 22.5 M | | |
| | -NX Diamond bit drilling from 22.5-m | 2 cms for 10 Blows | | ■ ♦ |
| 23.0 | | 1 cm for 10 Blows (Hammer Rebound) | | |
| | 21.7- to 24.5-m – $\phi = 39°$; $\gamma_t = 2.3$ tons/M$^3$ ($N_{avg}$ >> 100) | | | |
| 24.0 | | | | |
| | -drilled from 22.5- to 24.5-m in 55 minutes | SPT @ 24.5 M 1 cm for 10 Blows | | ♦ |
| | -brown blue color at 24.5-m | 1 cm for 10 Blows (Hammer Rebound) | | |
| 25.0 | | | | |
| 26.0 | | | | |
| 27.0 | | | | |
| 28.0 | | | | |
| 29.0 | | | | |
| 30.0 | | | | |
| 31.0 | | | | |
| 32.0 | | | | |
| 33.0 | | | | |

BORE HOLE TERMINATED AT 24.5-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

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PLATE 3c

# LOG OF BORING

**Project:** Proposed Residential Apartments Building Site, S. No. 260 / 1A part (As per Patta No. 2592 - S. No. 260 / 246), Porur Village, Chennai 600 116, Maduravoyal Taluk, Chennai District, TN.

**Bore Hole No.:** 3 **Type of Boring:** Calyx Drill **Dia. of Hole:** 150 mm
**Started on:** 19-09-'23 **Ended on:** 20-09-'23 **Field Work In Charge:** M Munivel
**Final Depth:** 24.5-M **Depth to G W S:** 1.4-M **Remarks:** GWL from Site Open Well.

| DEPTH, M | SOIL DESCRIPTION | SPT / VANE & SAMPLE TYPE | SPT "N" PROFILE 25 50 75 | INDEX TEST DATA 25 50 75 |
|---|---|---|---|---|
| | **BROWN GRAY STIFF CLAY (To 2.0-M)** | SPT @ 0.25 M 3/6/7 = 13 Blows | | |
| 1.0 | 0.0- to 2.0-m – $C_u$ = 7 tons/M$^2$; $\gamma_t$ = 1.65 tons/M$^3$ ($N_{avg}$ = 11) | SPT @ 1 M 2/4/6 = 10 Blows | | |
| GWL | | | | |
| 2.0 | | SPT @ 2 M 3/5/3 = 8 Blows | | |
| | **BROWN GRAY SILTY FINE SAND with clay binder (To 2.75-M)** ($N_{avg}$ = 8) | | | |
| | 2.0- to 2.75-m – $\phi$ = 26°; $\gamma_t$ = 1.6 tons/M$^3$ | SPT @ 3 M 2/3/5 = 8 Blows | | |
| 3.0 | **GRAY STIFF CLAY (To 6.0-M)** | | | |
| 4.0 | | SPT @ 4 M 3/3/6 = 9 Blows | | |
| | 2.75- to 6.0-m – $C_u$ = 5.5 tons/M$^2$; $\gamma_t$ = 1.6 tons/M$^3$ ($N_{avg}$ = 8.5) | | | |
| 5.0 | | SPT @ 5 M 2/4/4 = 8 Blows | | |
| 6.0 | | SPT @ 6 M 3/8/6 = 14 Blows | | |
| | **GRAY FINE TO MEDIUM SAND with silt (To 6.75-M)** ($N_{avg}$ = 14) | | | |
| | 6.0- to 6.75-m – $\phi$ = 31°; $\gamma_t$ = 1.65 tons/M$^3$ | SPT @ 7 M 2/5/3 = 8 Blows | | |
| 7.0 | **GRAY STIFF CLAY (To 8.0-M)** | | | |
| | 6.75- to 8.0-m – $C_u$ = 4.5 tons/M$^2$; $\gamma_t$ = 1.6 tons/M$^3$ ($N_{avg}$ = 8) | SPT @ 8 M 2/3/3 = 6 Blows | | |
| 8.0 | -silty at 8-m | | | |
| | **GRAY SILTY FINE TO MEDIUM SAND (To 11.0-M)** | | | |
| 9.0 | 8.0- to 9.0-m – $\phi$ = 26°; $\gamma_t$ = 1.55 tons/M$^3$ ($N_{avg}$ = 6) | SPT @ 9 M 9/16/21 = 37 Blows | | |
| | 9.0- to 10.0-m – $\phi$ = 35°; $\gamma_t$ = 1.95 tons/M$^3$ ($N_{avg}$ = 37) | | | |
| 10.0 | | SPT @ 10 M 15/26/27 = 53 Blows | | |
| | 10.0- to 11.0-m – $\phi$ = 36°; $\gamma_t$ = 2.0 tons/M$^3$ ($N_{avg}$ = 53) | | | |
| 11.0 | | | | |

CONTINUED ON PLATE 4b.

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

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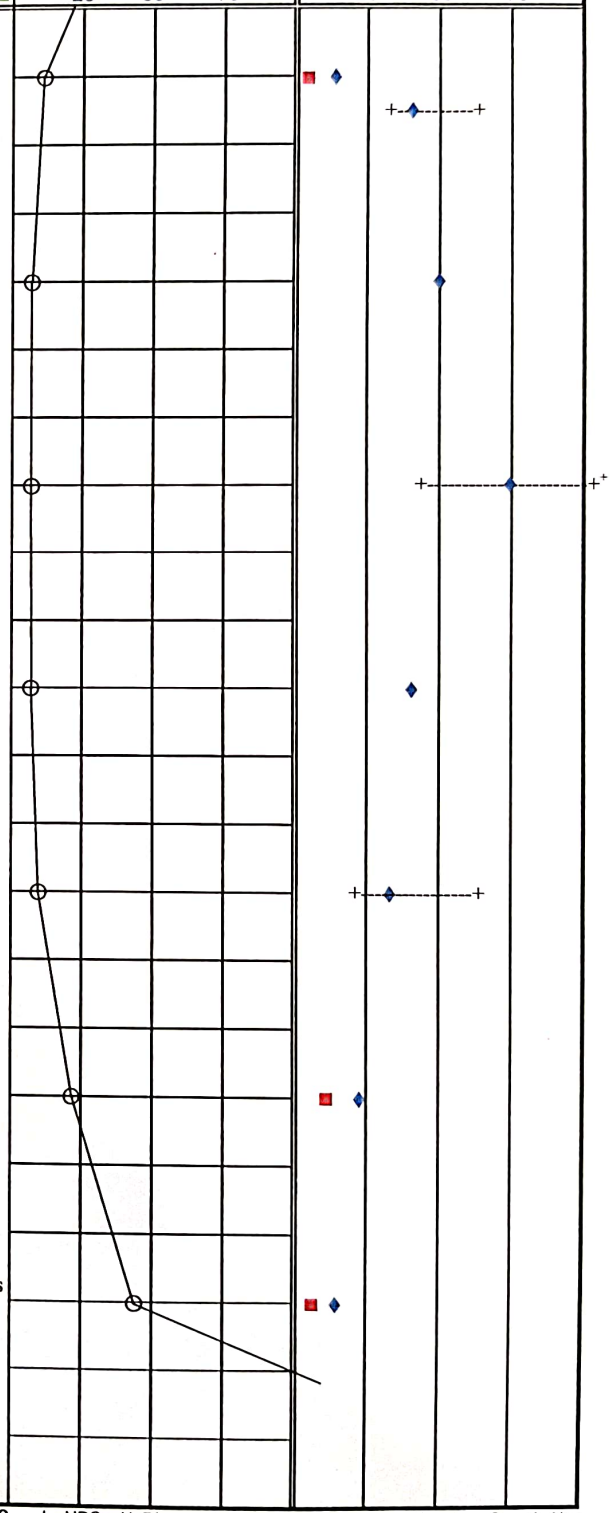
PLATE 4a

# LOG OF BORING

**Project:** Proposed Residential Apartments Building Site, S. No. 260 / 1A part (As per Patta No. 2592 - S. No. 260 / 246), Porur Village, Chennai 600 116, Maduravoyal Taluk, Chennai District, TN.

**Bore Hole No.:** 3 **Type of Boring:** Calyx Drill **Dia. of Hole:** 150 mm
**Started on:** 19-09-'23 **Ended on:** 20-09-'23 **Field Work In Charge:** M Munivel
**Final Depth:** 24.5-M **Depth to G W S:** 1.4-M **Remarks:** Continued from Plate 3a.

| DEPTH, M | SOIL DESCRIPTION | SPT / VANE & SAMPLE TYPE |
|---|---|---|
| | **GRAY FIRM TO STIFF CLAY (To 19.0-M)** | SPT @ 11.5 M<br>13/8/4 = 12 Blows |
| | 11.0- to 12.5-m – $C_u$ = 8 tons/M$^2$; $\gamma_t$ = 1.65 tons/M$^3$<br>($N_{avg}$ = 12) | |
| 12.0 | | |
| | | SPT @ 13 M<br>2/2/3 = 5 Blows |
| 13.0 | | |
| | | |
| 14.0 | | |
| | | SPT @ 14.5 M<br>1/2/3 = 5 Blows |
| | -with shell fragments, 14.5- to 19-m | |
| 15.0 | 12.5- to 17.5-m – $C_u$ = 3 tons/M$^2$; $\gamma_t$ = 1.5 tons/M$^3$<br>($N_{avg}$ = 5) | |
| | | SPT @ 16 M<br>1/2/3 = 5 Blows |
| 16.0 | | |
| | | |
| 17.0 | | |
| | | SPT @ 17.5 M<br>1/3/6 = 9 Blows |
| 18.0 | | |
| | 17.5- to 19.0-m – $C_u$ = 5 tons/M$^2$; $\gamma_t$ = 1.6 tons/M$^3$<br>($N_{avg}$ = 9) | |
| 19.0 | -silty at 19-m | SPT @ 19 M<br>7/11/12 = 23 Blows |
| | **GRAY GREEN SILTY FINE TO MEDIUM SAND with limestone nodules (To 21.8-M)** | |
| 20.0 | 19.0- to 20.5-m – $\phi$ = 33°; $\gamma_t$ = 1.75 tons/M$^3$<br>($N_{avg}$ = 23) | |
| | -brown gray green color at 20.5-m | SPT @ 20.5 M<br>12/18/28 = 46 Blows |
| 21.0 | | |
| | 20.5- to 21.8-m – $\phi$ = 36°; $\gamma_t$ = 2.0 tons/M$^3$<br>($N_{avg}$ = 46) | |
| 22.0 | **BROWN WEATHERED ROCK (Below 21.8-M)** | |




CONTINUED ON PLATE 4c.

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

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PLATE 4b

# LOG OF BORING

**Project:** Proposed Residential Apartments Building Site, S. No. 260 / 1A part (As per Patta No. 2592 - S. No. 260 / 246), Porur Village, Chennai 600 116, Maduravoyal Taluk, Chennai District, TN.

**Bore Hole No.:** 3 **Type of Boring:** Calyx Drill **Dia. of Hole:** 150 mm

**Started on:** 19-09-'23 **Ended on:** 20-09-'23 **Field Work In Charge:** M Munivel

**Final Depth:** 24.5-M **Depth to G W S:** 1.4-M **Remarks:** Continued from Plate 4b.

| DEPTH, M | SOIL DESCRIPTION | SPT / VANE & SAMPLE TYPE | SPT "N" PROFILE 25 50 75 | INDEX TEST DATA 25 50 75 |
|---|---|---|---|---|
| | **BROWN WEATHERED ROCK (Below 21.8-M)** | SPT @ 22.5 M | | ♦ ■ |
| | -NX Diamond bit drilling from 22.5-m | 2 cms for 10 Blows | | |
| 23.0 | | 1 cm for 10 Blows | | |
| | 21.8- to 24.5-m – $\phi = 39°$; $\gamma_t = 2.3$ tons/M$^3$ | (Hammer Rebound) | | |
| | ($N_{avg}$ >> 100) | | | |
| 24.0 | | | | |
| | | SPT @ 24.5M (SNR) | | |
| | -drilled from 22.5- to 24.5-m in 55 minutes | 2 cms for 20 Blows | | |
| 25.0 | | (Hammer Rebound) | | |
| | | | | |
| 26.0 | | | | |
| | | | | |
| 27.0 | | | | |
| | | | | |
| 28.0 | | | | |
| | | | | |
| 29.0 | | | | |
| | | | | |
| 30.0 | | | | |
| | | | | |
| 31.0 | | | | |
| | | | | |
| 32.0 | | | | |
| | | | | |
| 33.0 | | | | |

BORE HOLE TERMINATED AT 24.5-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

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PLATE 4c

# SUMMARY OF TEST RESULTS

| Boring | Depth, | w % | PL | LL | -75μ% | SAND | | | GRAVEL | IS |
|---|---|---|---|---|---|---|---|---|---|---|
| No. | M | | | | | Fine% | Medium% | Coarse% | % | CLASS. |
| 1 | 0.25 | 23 | | | | | | | | |
| | 1.0 | 23 | 20 | 50 | | | | | | CH |
| | 2.0 | 23 | 20 | 42 | | | | | | CL |
| | 3.0 | 33 | 32 | 60 | | | | | | CH |
| | 4.0 | 37 | | | | | | | | |
| | 5.0 | 32 | 24 | 54 | | | | | | CH |
| | 6.0 | 38 | | | | | | | | |
| | 7.0 | 22 | | | 16 | 72 | 12 | 0 | 0 | SM |
| | 8.0 | 15 | | | 4 | 36 | 56 | 4 | 0 | SP |
| | 9.0 | 15 | | | 9 | | | | | |
| | 10.0 | 18 | | | 5 | 40 | 50 | 5 | 0 | SP |
| | 11.5 | 15 | | | 3 | | | | | |
| | 13.0 | 47 | 37 | 70 | | | | | | CH |
| | 14.5 | 57 | | | | | | | | |
| | 16.0 | 37 | 30 | 66 | | | | | | CH |
| | 17.5 | 38 | 37 | 76 | | | | | | CH |
| | 19.0 | 18 | | | 12 | 57 | 25 | 3 | 3 | SM |
| | 20.5 | 15 | | | 5 | | | | | |
| | 22.5 | 17 | | | 21 | 62 | 17 | 0 | 0 | SM |
| | 24.5 | 15 | | | 17 | 54 | 19 | 2 | 8 | SM |
| 2 | 0.25 | 13 | | | 13 | | | | | |
| | 1.0 | 20 | 16 | 47 | | | | | | CL |
| | 2.0 | 28 | | | 35 | 65 | 0 | 0 | 0 | SM |
| | 3.0 | 28 | | | 30 | 70 | 0 | 0 | 0 | SM |
| | 4.0 | 38 | 31 | 62 | | | | | | CH |
| | 5.0 | 38 | 31 | 62 | | | | | | CH |
| | 6.0 | 28 | | | 8 | 70 | 21 | 1 | 0 | SP |
| | 7.0a | 20 | | | 6 | | | | | |
| | 7.0b | 45 | | | | | | | | |
| | 8.0a | 24 | 17 | 36 | | | | | | CL |
| | 8.0b | 20 | | | 7 | 56 | 35 | 2 | 0 | SP |
| | 9.0 | 16 | | | 8 | | | | | |
| | 10.0 | 19 | | | 6 | 44 | 47 | 3 | 0 | SP |
| | 11.5 | 45 | 30 | 62 | | | | | | CH |
| | 13.0 | 59 | | | | | | | | |
| | 14.5 | 58 | 37 | 81 | | | | | | CH |
| | 16.0 | 51 | | | | | | | | |
| | 17.5 | 34 | 28 | 74 | | | | | | CH |
| | 19.0 | 24 | | | 16 | 58 | 23 | 2 | 1 | SM |
| | 20.5 | 17 | | | 3 | | | | | |
| | 22.5 | 17 | | | 12 | 32 | 52 | 4 | 0 | SM |
| | 24.5 | 9 | stone | pieces | | | | | | |
| 3 | 0.25 | 23 | | | | | | | | |
| | 1.0 | 21 | 19 | 54 | | | | | | CH |
| | 2.0 | 26 | | | 36 | 59 | 5 | 0 | 0 | SM |
| | 3.0 | 34 | 23 | 54 | | | | | | CH |
| | 4.0 | 40 | | | | | | | | |
| | 5.0 | 40 | 32 | 62 | | | | | | CH |
| | 6.0 | 25 | | | 6 | 69 | 25 | 0 | 0 | SP |
| | 7.0 | 42 | 30 | 59 | | | | | | CH |
| | 8.0 | 28 | | | 31 | 64 | 5 | 0 | 0 | SM |
| | 9.0 | 18 | | | 7 | | | | | |
| | 10.0 | 18 | | | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | SP |

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PLATE 5a

# SUMMARY OF TEST RESULTS

| Boring No. | Depth, M | w % | PL | LL | -75μ% | SAND | | | GRAVEL | IS CLASS. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Fine% | Medium% | Coarse% | % | |
| 3 | 11.5a | 15 | | | 3 | | | | | |
| | 11.5b | 42 | 32 | 63 | | | | | | CH |
| | 13.0 | 50 | | | | | | | | |
| | 14.5 | 75 | 44 | 102 | | | | | | CH |
| | 16.0 | 41 | | | | | | | | |
| | 17.5 | 32 | 22 | 63 | | | | | | CH |
| | 19.0 | 24 | | | 13 | 58 | 24 | 3 | 2 | SM |
| | 20.5 | 16 | | | 5 | 47 | 44 | 3 | 1 | SP |
| | 22.5 | 13 | | | 19 | | | | | |
| | 24.5 | SNR | | | | | | | | |

## FREE SWELL INDEX TEST RESULTS

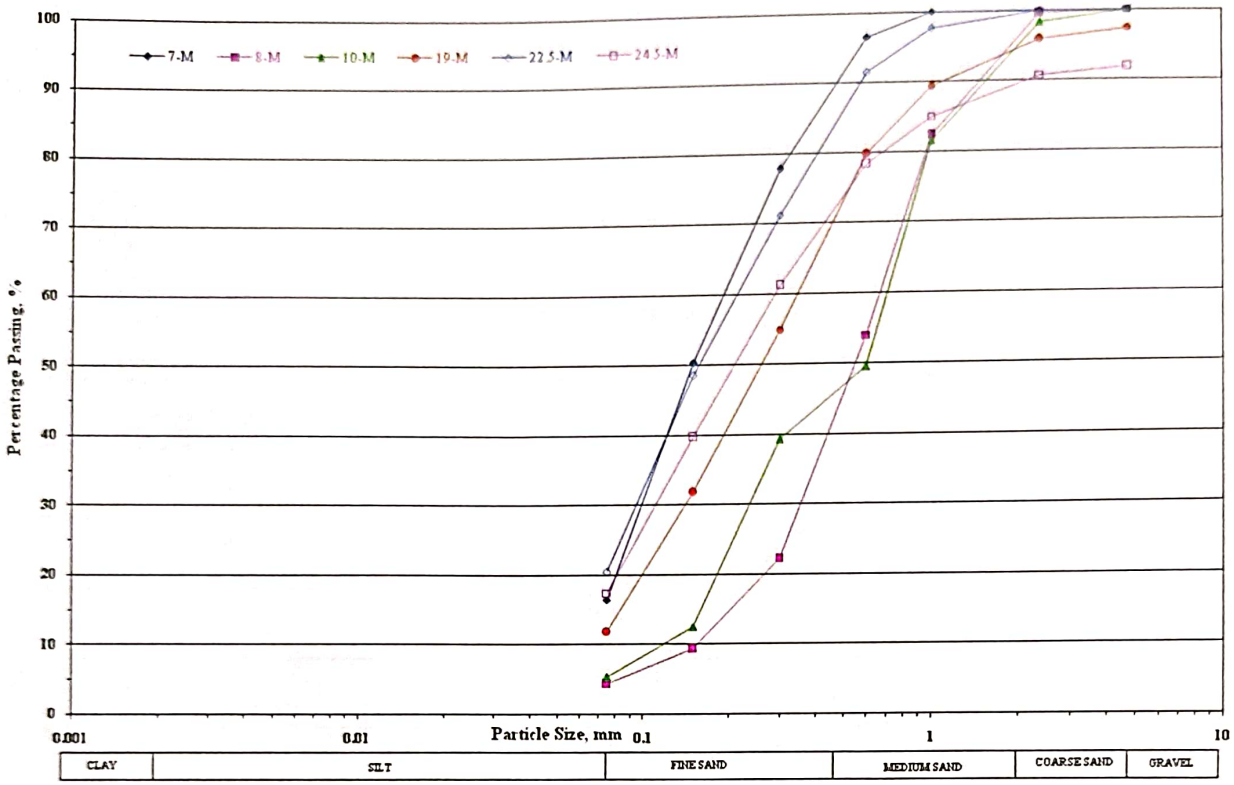
| BORE NO. | DEPTH, M | FREE SWELL INDEX, % |
|---|---|---|
| 1 | 0.25 | 120 |
| | 1.0 | 100 |
| | 2.0 | 50 |
| | 3.0 | 178 |
| 2 | 1.0 | 133 |
| 3 | 1.0 | 121 |
| | 3.0 | 138 |

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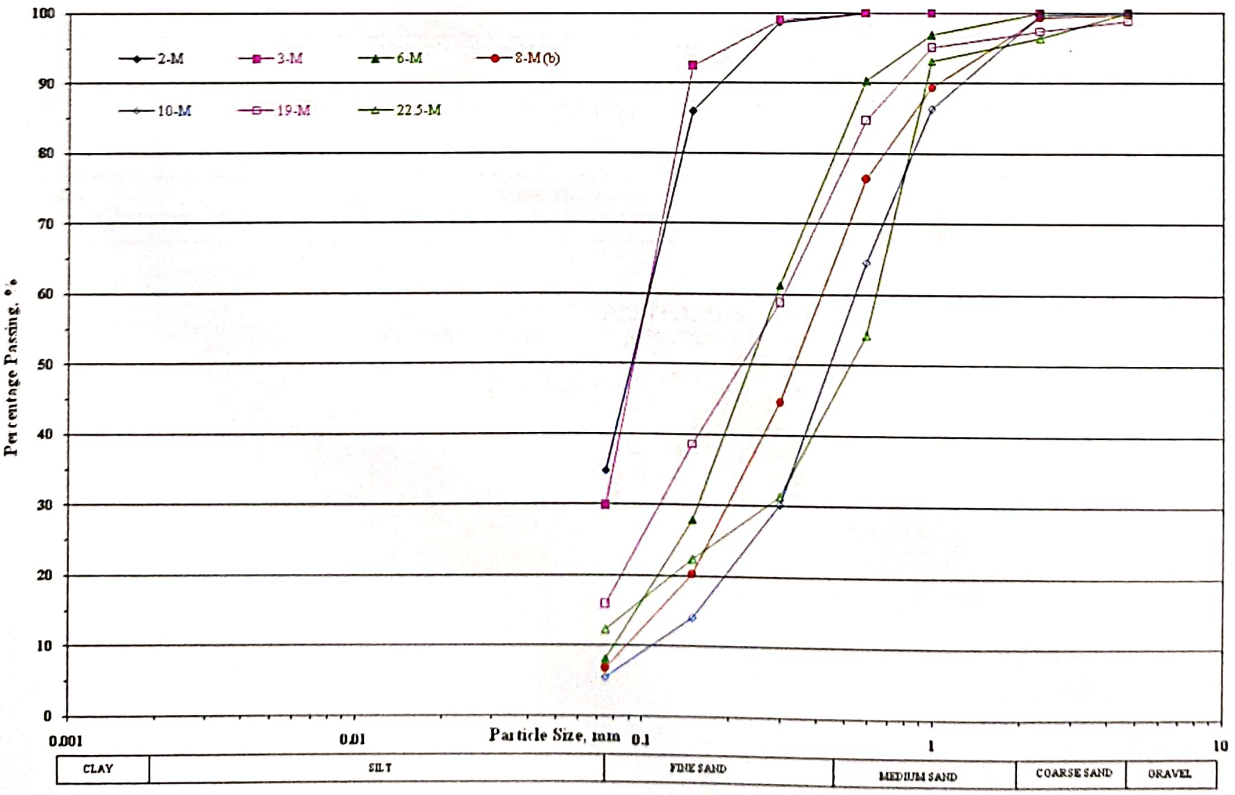
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PLATE 5b

## Grain Size Distribution Curves
### Boring 1




## Grain Size Distribution Curves
### Boring 2

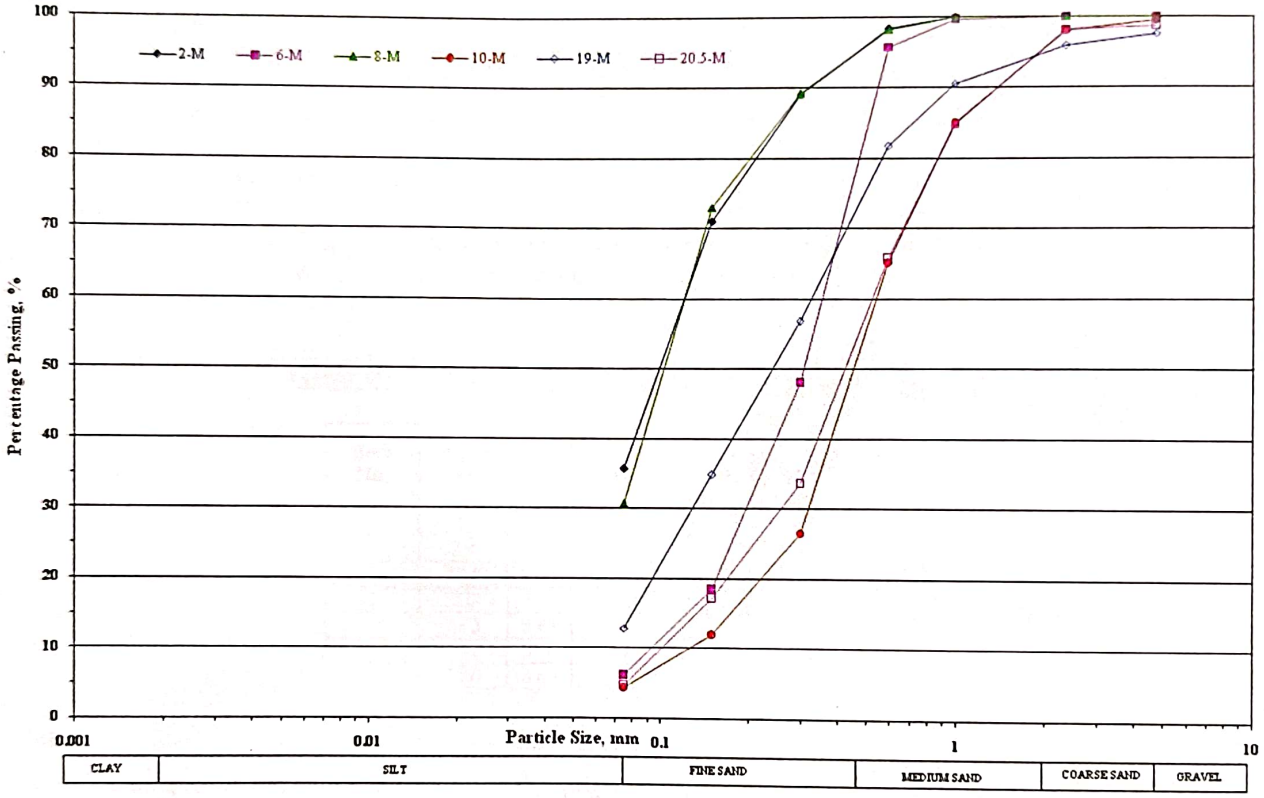



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PLATE 6a

## Grain Size Distribution Curves
### Boring 3




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PLATE 6b

# SUMMARY OF WATER TEST RESULTS

## SITE OPEN WELL; DIAMETER = 2.9-M; DEPTH = UNKNOWN

## DISTANCE FROM BORING 3 ~ 16.4-M; WATER LEVEL ~ 1.4-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 | 24.50 ml | Not more than 25 ml of 0.02N $H_2SO_4$ |
| 3 | a | Organic Solids, mg/liter | 30 | 200 Max. |
| | b | Inorganic Solids, mg/liter | 730 | 3,000 Max. |
| | c | Sulphates as $SO_3$, mg/liter | 96 | 400 Max. |
| | d | Chlorides as Cl, mg/liter | 160 | 2,000 Max. - Plain Concrete<br>500 Max. RCC |
| | e | Suspended Solids, mg/liter | 0 | 2,000 Max. |
| | f | Ph | 7.00 | 6 Min. |

Remarks: The sample meets the requirements of above clauses.
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 | 7.92 | 170 | 98 | 82 |
| | 22.5 | 8.07 | 120 | 68 | 57 |
| 2 | 2.0 | 7.15 | 110 | 70 | 58 |
| | 20.5 | 8.63 | 160 | 96 | 80 |
| 3 | 1.0 | 6.98 | 165 | 95 | 79 |
| | 19.0 | 8.63 | 160 | 98 | 82 |

Remarks:

Tests on soil samples were performed on soil solution prepared with 5% soil and distilled water. Soil solution was soaked in distilled 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.

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# 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

S. No. 260 / 1A part (As per Patta No. 2592 - S. No. 260 / 246), Porur Village, Chennai 600 116, TN.

**Bored Cast In-Situ Pile Details:**

Total Pile Length = **22.50 M** below EGL

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

Pile Effective Concreting Length = 21.50 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 3 Data)**

| S.No. | Soil Description | From | To | $N_{avg}$ | $C_u$, T/M$^2$ | $\phi^0$ | $\gamma_T$, T/M$^3$ |
|---|---|---|---|---|---|---|---|
| 1a | Brown Gray Stiff Clay | 0.00 | 1.00 | 11 | 7.00 | | 1.65 |
| 1b | Brown Gray Stiff Clay | 1.00 | 2.00 | 11 | 7.00 | | 1.65 |
| 2 | Brown Gray Silty Fine Sand with .... | 2.00 | 2.75 | 8 | | 26 | 1.60 |
| 3 | Gray Stiff Clay | 2.75 | 6.00 | 8.5 | 5.50 | | 1.60 |
| 4 | Gray F to M Sand with Silt | 6.00 | 6.75 | 14 | | 31 | 1.65 |
| 5 | Gray Stiff Clay | 6.75 | 8.00 | 8 | 4.50 | | 1.60 |
| 6a | Gray Silty Fine to Medium Sand | 8.00 | 9.00 | 6 | | 26 | 1.55 |
| 6b | Gray Silty Fine to Medium Sand | 9.00 | 10.00 | 37 | | 35 | 1.95 |
| 6c | Gray Silty Fine to Medium Sand | 10.00 | 11.00 | 53 | | 36 | 2.00 |
| 7a | Gray Firm to Stiff Clay | 11.00 | 12.50 | 12 | 8.00 | | 1.65 |
| 7b | Gray Firm to Stiff Clay | 12.50 | 17.50 | 5 | 3.00 | | 1.50 |
| 7c | Gray Firm to Stiff Clay | 17.50 | 19.00 | 9 | 5.00 | | 1.60 |
| 8a | Gray Green Silty F to M Sand ..... | 19.00 | 20.50 | 23 | | 33 | 1.75 |
| 8b | Gray Green Silty F to M Sand ..... | 20.50 | 21.80 | 46 | | 36 | 2.00 |
| 9 | Brown Weathered Rock | 21.80 | 24.50 | >> 100 | | 39 | 2.30 |

For Cohesive Soils :-

| $C_u$ | $\alpha$ |
|---|---|
| 3.00 | 1.00 |
| 4.50 | 0.90 |
| 5.00 | 0.85 |
| 5.50 | 0.80 |
| 7.00 | 0.65 |
| 8.00 | 0.55 |

**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 Frition, $Q_{s\,ult}$ = $\Sigma Q_{si}$

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

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**

For PRASAD ARMSTRONG YEN
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## COMPRESSIVE PILE CAPACITY CALCULATIONS

### Skin Friction Calculations

| S.No. | Soil Description | From | To | $\phi^0$ / $C_u$ | $\delta = \phi$ | $\gamma'_s$, T/M$^3$ | $\sigma'_{Mid}$,T/M$^2$ | $f_s$,T/M$^2$ | Pile Dia 0.45 $Q_s$, T | 0.50 $Q_s$, T | 0.60 $Q_s$, T | 0.75 $Q_s$, T | 0.90 $Q_s$, T | -M. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1a | Brown Gray Stiff Clay | 0.00 | 1.00 | 7.00 | | 0.65 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | Cutoff |
| 1b | Brown Gray Stiff Clay | 1.00 | 2.00 | 7.00 | | 0.65 | 0.98 | 4.55 | 6.44 | 7.15 | 8.58 | 10.73 | 12.87 | |
| 2 | Brown Gray Silty Fine Sand with .... | 2.00 | 2.75 | 26 | 26 | 0.60 | 1.53 | 0.74 | 0.79 | 0.88 | 1.05 | 1.31 | 1.58 | |
| 3 | Gray Stiff Clay | 2.75 | 6.00 | 5.50 | | 0.60 | 2.73 | 4.40 | 20.22 | 22.47 | 26.97 | 33.71 | 40.45 | |
| 4 | Gray F to M Sand with Silt | 6.00 | 6.75 | 31 | 31 | 0.65 | 3.94 | 2.37 | 2.51 | 2.79 | 3.35 | 4.19 | 5.03 | |
| 5 | Gray Stiff Clay | 6.75 | 8.00 | 4.50 | | 0.60 | 4.56 | 4.05 | 7.16 | 7.96 | 9.55 | 11.93 | 14.32 | |
| 6a | Gray Silty Fine to Medium Sand | 8.00 | 9.00 | 26 | 26 | 0.55 | 5.21 | 2.54 | 3.60 | 3.99 | 4.79 | 5.99 | 7.19 | |
| 6b | Gray Silty Fine to Medium Sand | 9.00 | 10.00 | 35 | 35 | 0.95 | 5.96 | 4.17 | 5.90 | 6.56 | 7.87 | 9.84 | 11.81 | |
| 6c | Gray Silty Fine to Medium Sand | 10.00 | 11.00 | 36 | 36 | 1.00 | 6.94 | 5.04 | 7.13 | 7.92 | 9.50 | 11.88 | 14.26 | |
| 7a | Gray Firm to Stiff Clay | 11.00 | 12.50 | 8.00 | | 0.65 | 7.93 | 4.40 | 9.33 | 10.37 | 12.45 | 15.56 | 18.67 | |
| 7b | Gray Firm to Stiff Clay | 12.50 | 17.50 | 3.00 | | 0.50 | 9.66 | 3.00 | 21.21 | 23.57 | 28.29 | 35.36 | 42.43 | |
| 7c | Gray Firm to Stiff Clay | 17.50 | 19.00 | 5.00 | | 0.60 | 11.36 | 4.25 | 9.02 | 10.02 | 12.02 | 15.03 | 18.03 | |
| 8a | Gray Green Silty F to M Sand ..... | 19.00 | 20.50 | 33 | 33 | 0.75 | 12.38 | 8.04 | 17.05 | 18.94 | 22.73 | 28.41 | 34.10 | |
| 8b | Gray Green Silty F to M Sand ..... | 20.50 | 21.80 | 36 | 36 | 1.00 | 13.59 | 9.87 | 18.15 | 20.17 | 24.20 | 30.25 | 36.30 | |
| 9 | Brown Weathered Rock | 21.80 | 22.50 | 39 | 39 | 1.30 | 14.69 | 11.90 | 11.78 | 13.09 | 15.70 | 19.63 | 23.56 | |
| | | | | | | | Net Total Ultimate Skin Friction, $Q_{s\,ult}$= | | 140.29 | 155.88 | 187.05 | 233.82 | 280.58 | |

@ 22.5-M below EGL Soil Forma. - Weathered Rock

L/D of Pile = 23.0/0.45 > 20

L/D of Pile = 23.0/0.50 > 20

L/D of Pile = 23.0/0.60 > 20

L/D of Pile = 23.0/0.75 > 20

L/D of Pile = 23.0/0.90 > 20

Use Lim. Value or Actual $\sigma'_{base}$

N = >> 100

$N_q$ = 79

$N_\gamma$ = 72

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

| | 0.45 | 0.50 | 0.60 | 0.75 | 0.90 | |
|---|---|---|---|---|---|---|
| Base A= | 0.1591 | 0.1964 | 0.2829 | 0.4420 | 0.6364 | -M$^2$ |
| $\sigma'_{base}$ = | 5.49 | 6.44 | 8.09 | 9.66 | 11.21 | T/M$^2$ |
| $q_{b\,ult}$ = | 454.57 | 531.96 | 666.99 | 798.44 | 927.91 | T/M$^2$ |
| $q_{b\,ult}$ = | 625.00 | 625.00 | 625.00 | 625.00 | 625.00 | T/M$^2$ |
| $Q_{b\,ult}$ = | 72.33 | 104.49 | 188.66 | 276.23 | 397.77 | Tons |
| $Q_{s\,ult}$ = | 140.29 | 155.88 | 187.05 | 233.82 | 280.58 | Tons |
| $Q_{tot\,ult}$= | 212.62 | 260.37 | 375.72 | 510.04 | 678.35 | Tons |
| F.S. = | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | |
| Allowable Compressive Capacity = $Q_{All}$ = | 85.05 | 104.15 | 150.29 | 204.02 | 271.34 | Tons |
| Use $Q_{All}$ = | 85 | 104 | 150 | 204 | 271 | Tons |

**Note:-**

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

2 Pile installation must be done with extreme care to prevent "Necking" and "Buldging" problems due to presence of thick 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 IRC code was 500 tons/M$^2$. Therefore, $q_b$ (all) is limited to 250 tons/M$^2$ in Wea. Rock.

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PLATE 8 - 2

## UPLIFT PILE CAPACITY CALCULATIONS

**Skin Friction Calculations**

| S.No. | Soil Description | From | To | $\phi^0$ / $C_u$ | $\delta = \phi$ | $\gamma'_s$, T/M$^3$ | $\sigma'_{Mid}$,T/M$^2$ | $f_s$,T/M$^2$ | Pile Dia 0.45 $Q_s$, T | 0.50 $Q_s$, T | 0.60 $Q_s$, T | 0.75 $Q_s$, T | 0.90 $Q_s$, T | -M. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1a | Brown Gray Stiff Clay | 0.00 | 1.00 | 7.00 | | 0.65 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | Cutoff |
| 1b | Brown Gray Stiff Clay | 1.00 | 2.00 | 7.00 | | 0.65 | 0.98 | 4.55 | 6.44 | 7.15 | 8.58 | 10.73 | 12.87 | |
| 2 | Brown Gray Silty Fine Sand with .... | 2.00 | 2.75 | 26 | 26 | 0.60 | 1.53 | 0.74 | 0.79 | 0.88 | 1.05 | 1.31 | 1.58 | |
| 3 | Gray Stiff Clay | 2.75 | 6.00 | 5.50 | | 0.60 | 2.73 | 4.40 | 20.22 | 22.47 | 26.97 | 33.71 | 40.45 | |
| 4 | Gray F to M Sand with Silt | 6.00 | 6.75 | 31 | 31 | 0.65 | 3.94 | 2.37 | 2.51 | 2.79 | 3.35 | 4.19 | 5.03 | |
| 5 | Gray Stiff Clay | 6.75 | 8.00 | 4.50 | | 0.60 | 4.56 | 4.05 | 7.16 | 7.96 | 9.55 | 11.93 | 14.32 | |
| 6a | Gray Silty Fine to Medium Sand | 8.00 | 9.00 | 26 | 26 | 0.55 | 5.21 | 2.54 | 3.60 | 3.99 | 4.79 | 5.99 | 7.19 | |
| 6b | Gray Silty Fine to Medium Sand | 9.00 | 10.00 | 35 | 35 | 0.95 | 5.96 | 4.17 | 5.90 | 6.56 | 7.87 | 9.84 | 11.81 | |
| 6c | Gray Silty Fine to Medium Sand | 10.00 | 11.00 | 36 | 36 | 1.00 | 6.94 | 5.04 | 7.13 | 7.92 | 9.50 | 11.88 | 14.26 | |
| 7a | Gray Firm to Stiff Clay | 11.00 | 12.50 | 8.00 | | 0.65 | 7.93 | 4.40 | 9.33 | 10.37 | 12.45 | 15.56 | 18.67 | |
| 7b | Gray Firm to Stiff Clay | 12.50 | 17.50 | 3.00 | | 0.50 | 9.66 | 3.00 | 21.21 | 23.57 | 28.29 | 35.36 | 42.43 | |
| 7c | Gray Firm to Stiff Clay | 17.50 | 19.00 | 5.00 | | 0.60 | 11.36 | 4.25 | 9.02 | 10.02 | 12.02 | 15.03 | 18.03 | |
| 8a | Gray Green Silty F to M Sand ..... | 19.00 | 20.50 | 33 | 33 | 0.75 | 12.38 | 8.04 | 17.05 | 18.94 | 22.73 | 28.41 | 34.10 | |
| 8b | Gray Green Silty F to M Sand ..... | 20.50 | 21.80 | 36 | 36 | 1.00 | 13.59 | 9.87 | 18.15 | 20.17 | 24.20 | 30.25 | 36.30 | |
| 9 | Brown Weathered Rock | 21.80 | 22.50 | 39 | 39 | 1.30 | 14.69 | 11.90 | 11.78 | 13.09 | 15.70 | 19.63 | 23.56 | |
| | | | | | | | Net Total Ultimate Skin Friction, $Q_{s\,ult}$= | | 140.29 | 155.88 | 187.05 | 233.82 | 280.58 | |

Unit Weight of Pile RCC = $\gamma_{conc}$ 2.40 T/M$^3$

| | 0.45 | 0.50 | 0.60 | 0.75 | 0.90 | |
|---|---|---|---|---|---|---|
| Base A= | 0.1591 | 0.1964 | 0.2829 | 0.4420 | 0.6364 | -M$^2$ |
| Pile Length, L = | 21.50 | 21.50 | 21.50 | 21.50 | 21.50 | -M |
| Pile Volume, V = | 3.42 | 4.22 | 6.08 | 9.50 | 13.68 | -M$^3$ |
| Submerged Pile Weight W = | 4.79 | 5.91 | 8.51 | 13.30 | 19.16 | Tons |
| $Q_{s\,ult}$ = | 140.29 | 155.88 | 187.05 | 233.82 | 280.58 | Tons |
| $Q_{tot\,ult}$= | **145.08** | **161.79** | **195.57** | **247.12** | **299.74** | Tons |
| F.S. = | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | |
| Allowable Uplift Capacity = $Q_{All}$ = | 48.36 | 53.93 | 65.19 | 82.37 | 99.91 | Tons |
| Use $Q_{All}$ = | **48** | **54** | **65** | **82** | **100** | Tons |

**Note:-**

1 Pile Load Test must be conducted as per relavant IS Code to confirm the above estimated pile capacities before completion of installtion of all piles.
2 Pile installation must be done with extreme care to prevent "Necking" and "Buldging" problems due to presence of thick layers of sand soils.
3 Ground water level was assumed to rise to ground level in worst case conditions; and
4 Uplift Capacity was estimated for Trancient Condition only. No negative skin friction was considered.

For PRASAD ARMSTRONG YEN
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Managing Director

PLATE 8 - 3

# 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

S. No. 260 / 1A part (As per Patta No. 2592 - S. No. 260 / 246), Porur Village, Chennai 600 116, TN.

Treat Soil Profile from 1- to 8-M = Silty Sand

Weighted Average "N" Value = ~ 8

As per IS : 2911 (Part 1 / Sec 2) : 2010, Annex C, Table 3, Page 14

For Submerged Sand Soil with Estimated $N_{avg}$ , Subgrade Modulus = $\eta_h$ = 1000 kN/M$^2$/M (Accounting for high % of fines in the soil)

(Medium Sand)

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

As per IS : 2911 (Part 1 / Sec 2) : 2010, Annex C, Page 14, Section C. 2.3.1

Stiffness Factor T, in M = $\sqrt[5]{\frac{EI}{\eta_h}}$

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

| | | | |
|---|---|---|---|
| Concrete Grade = | M25 | Max. Comp. Stress in Bending | 600 Tons/M$^2$ |
| Min. % of Reinforcement Content = | 0.40% | $f_c$ = | 60 Kg/cm$^2$ |
| Modulus of Pile, $E_c$ = | 200000 Kg/cm$^2$ = | 2.00E+07 kN/M$^2$ | |

Pile Length Above Ground = $L_1$

Stiffness Factor = T (Sand & NC Clays)

Stiffness Factor = R (OC Clays)

Pile Fixity Length = $L_e$ Pile $L_e$/ T From Figure 4, Page 15, IS: 2911 (Part 2 / Sec/ 1) - 2010.

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Managing Director

| Dia., D M | (I) Mom. of Inertia, M$^4$ | EI | T M | $L_1$ M | $L_1$/T | $L_e$/T | $L_e$ M | y mm | $L_1$+$L_e$ ($Z_f$) M | H Tons |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.45 | 0.00201 | 40257 | 2.09 | 1.00 | 0.478 | 2.00 | 4.19 | 5.00 | 5.19 | **1.73** |
| 0.50 | 0.00307 | 61357 | 2.28 | 1.00 | 0.439 | 2.00 | 4.56 | 5.00 | 5.56 | **2.15** |
| 0.60 | 0.00636 | 127231 | 2.64 | 1.00 | 0.379 | 2.00 | 5.27 | 5.00 | 6.27 | **3.09** |
| 0.75 | 0.01553 | 310622 | 3.15 | 1.00 | 0.317 | 2.00 | 6.30 | 5.00 | 7.30 | **4.79** |
| 0.90 | 0.03221 | 644106 | 3.65 | 1.00 | 0.274 | 2.00 | 7.29 | 5.00 | 8.29 | **6.78** |

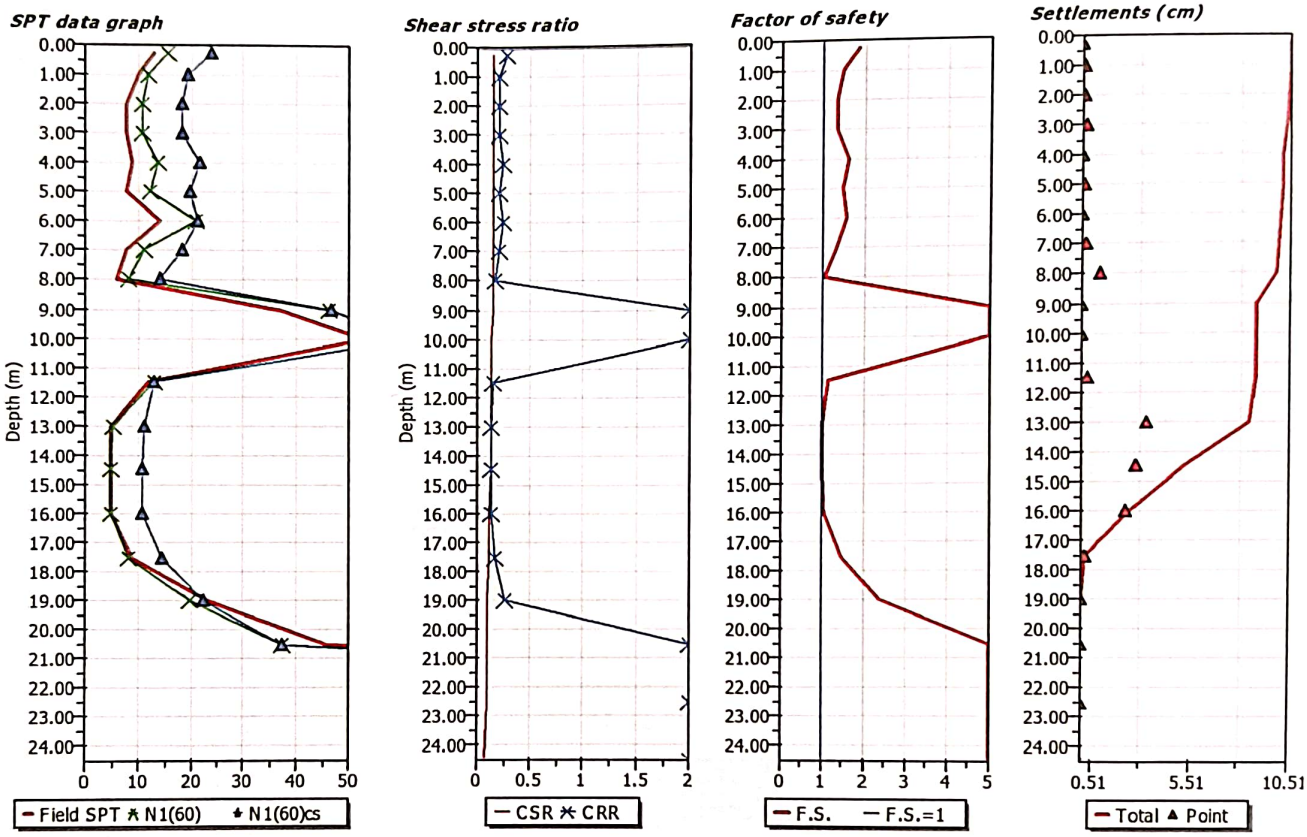
# LIQUEFACTION ANALYSIS REPORT

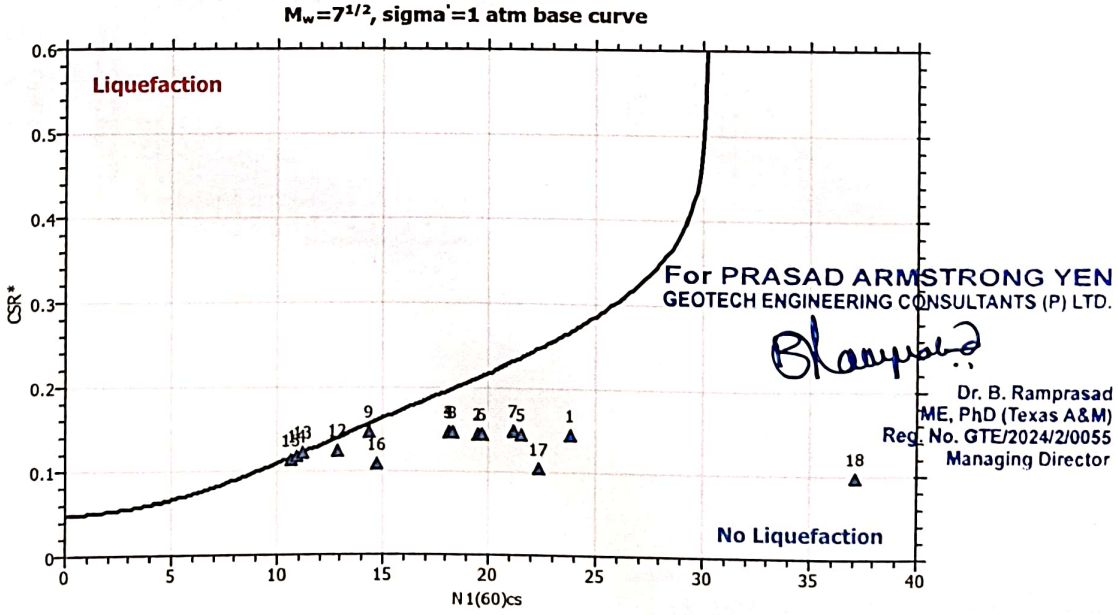
**Project title : S. No. 260 / 1A part (As per Patta No. 2592 - S. No. 260 / 246), Porur Village, Chennai 600 116. Maduravoyal Tlk, Chennai Dist, TN**

**Project subtitle : Boring 3 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 $M_w$: | 6.00 |
| Analysis method: | NCEER 1998 | Peak ground accelaration: | 0.16 g |
| Fines correction method: | Idriss & Seed | User defined F.S.: | 1.00 |




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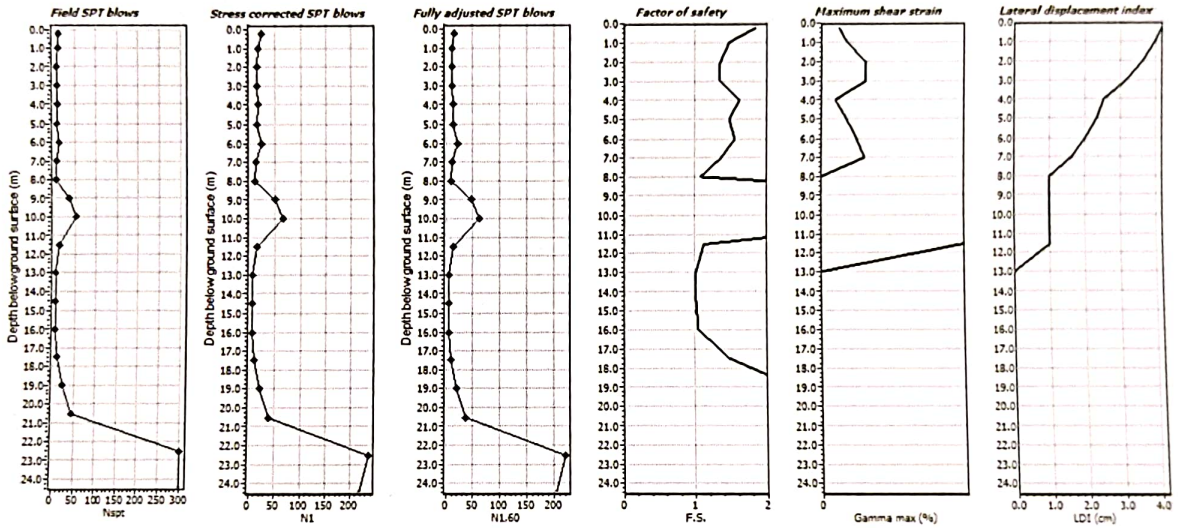
## Horizontal Acceleration, $A_h = 0.16g$

GeoLogismiki - Mora Nas. 58, 621 25 Serres, Greece
Url : http://www.geologismiki.gr - Email : info@geologismiki.gr

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

### LATERAL DISPLACEMENTS ESTIMATION DUE TO SOIL LIQUEFACTION[1]

**Geometric parameters: Gently sloping ground without free face**
**Total lateral displacement estimation: 5.01 cm**




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

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

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

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PLATE 9b



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