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# GEOTECHNICAL SITE INVESTIGATION

## BORING 1 AND 2

## PROPOSED RESIDENTIAL APARTMENTS BUILDING SITE

## "DWARAKA DHARSHAN"

## BLOCK NO. 79, DWARAKA FLATS

## AMBATTUR ESTATE – THIRUMANGALAM ROAD

## ANNA NAGAR WESTERN EXTENSION, CHENNAI 600 101, TN.

**(Comprised in Old S. No. 289 Part of Padi Village, S. Nos. 297/3B, 297/1A Part, 1B Part, 2A Part, 2B Part, 290 Part, T. S. No. 87/9, 87/10, 87/11, 87/12, Block No. 9, Ward - H of Mogappair Village, Within the limits of Greater Chennai Corporation.)**

Report to

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

**Dr. B. Ram Prasad ME, Ph D (Texas A&M)**
**N. No. 821, O. No. 439/4 Poonamallee High Road**
**Arumbakkam, Chennai 600 106.**
**Phone: 09384752446; E-Mail: paygec@gmail.com**

Report No. 004/BRP/24-25.
May 7, 2024.

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

**Attention: Mr. R. Surya**
**Asst. Structural Engineer**

**Geotechnical Site Investigation**
**Boring 1 and 2**
**Proposed Residential Apartments Building Site**
**"Dwaraka Dharshan"**
**Block No. 79, Dwaraka Flats**
**Ambattur Estate – Thirumangalam Road**
**Anna Nagar West Extension, Chennai 600 101, TN.**
**(Comprised in Old S. No. 289 Part of Padi Village, S. Nos. 297/3B, 297/1A Part, 1B Part, 2A Part, 2B Part, 290 Part, T. S. No. 87/9, 87/10, 87/11, 87/12, Block No. 9, Ward - H of Mogappair Village, Within the limits of Greater Chennai Corporation.)**

I am pleased to submit this report on the geotechnical site investigation conducted at the above location. This work was authorized by your confirmation e-mail dated April 15, 2024.

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

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

Sincerely,



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

Copies Submitted: (3)

**CHENNAI METROPOLITAN DEVELOPMENT AUTHORITY**
Thalamuthu Natarajan Building, No.1, Gandhi Irwin Road, Egmore,
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Web site: www.cmdachennai.gov.in.

## PROFESSIONAL REGISTRATION CERTIFICATE

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

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

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

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



A Meganathan

Superintendent

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## SUMMARY

I performed a geotechnical site investigation at the Proposed Residential Apartments Building Site, "**Dwaraka Dharshan**", Block No 79, Dwaraka Flats, Ambattur Estate – Thirumangalam Road, Anna Nagar West Extension, Chennai 600 101, TN. Comprised in Old S. No. 289 Part of Padi Village, S. Nos. 297/3B, 297/1A Part, 1B Part, 2A Part, 2B Part, 290 Part, T. S. No. 87/9, 87/10, 87/11, 87/12, Block No. 9, Ward - H of Mogappair Village, Within the limits of Greater Chennai Corporation. The primary purpose of our investigation was to obtain data to identify foundation type and estimate load carrying capacity of the selected foundation for the proposed Stilt + 5 floors building. For the proposed building type typical maximum column load will be about 200 tons. These load details were used only for estimating the preliminary foundation size and type of foundation.

The field investigation was performed April 24 through 28, 2024. Number and location of the borings was selected to cover the proposed building area with due consideration to presence of a G + 2 floor RCC building in the site. Boring 1 and 2 were drilled to 22.5-M below the Existing Ground Level (EGL.) Both borings were terminated with at least 2-M drilling through the hard strata shale (Very Hard Clay) with SPT "$N_{avg}$" $\geq$ 75. Borings were drilled beyond 10-M due to presence of clay soils and potentially liquefiable soils in the soil profiles. 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 site's EGL was at about the Existing Road Level (ERL) of road in front of the site. Compound wall was present along all boundaries of the site. During this investigation a G + 2 floors RCC building was present in the site. Some well grown trees were present in the site. Proposed construction will be the first major construction activity of this magnitude to cover the site. Soil stratigraphy at the borings is tabulated below:

**Boring – 1:**

| Stratum | Penetration, M From | To | Description |
|---|---|---|---|
| I | 0 | 3.75 | Brown Fine to Medium Sand with Silt |
| II | 3.75 | 5.75 | Brown Gray Stiff to Very Stiff Clay with Silty Sand Seams |
| III | 5.75 | 17.5 | Gray Firm to Stiff Clay |
| IV | 17.5 | 19.25 | Brown Gray Gravelly Fine to Coarse Sand |
| V | 19.25 | 22.5+ | Brown Yellow Gray Hard to Very Hard Clay |

**Boring – 2:**

| Stratum | Penetration, M From | To | Description |
|---|---|---|---|
| I | 0 | 1.0 | Brown Silty Fine to Medium Sand with Brick and Stone Pieces |
| II | 1.0 | 2.0 | Brown Gray Very Stiff Silty Clay |
| III | 2.0 | 3.75 | Brown Gray Fine to Medium Sand with Silt |
| IV | 3.75 | 9.0 | Gray Firm to Very Stiff Clay |

| | | | |
|---|---|---|---|
| V | 9.0 | 11.0 | Gray Fine to Medium Sand with Silt |
| VI | 11.0 | 17.5 | Gray Firm to Very Stiff Clay |
| VII | 17.5 | 19.0 | Brown Red Gray Fine to Coarse Sand with Gravel |
| VIII | 19.0 | 22.5+ | Brown Yellow Red Gray Hard to Very Hard Clay |

Data from borings infer presence of soil profiles with variable thickness and variable consistency clay layers in the top 10-M below EGL. Encountered soil profiles infer high potential for differential settlements. Therefore, for the encountered soil profiles and expected column loads shallow foundation was not recommended as foundation can undergo significant total and differential settlements. For the proposed building with expected column load, and encountered soil profiles it was **recommended** to provide "**Tractor Mounted Direct Mud Circulation (DMC) Cast In-Situ Pile**" foundation. Recommended type of pile installation work will have low construction vibrations otherwise it may affect the existing building foundations and also lead to objections from adjacent building owners. It was recommended to provide a minimum **21- and 20-M total and effective length piles** with top 1-M pile cutoff for pile caps and plinth beams. Ultimate and allowable pile capacities of various pile diameters were summarized below:

| Pile Dia. M | Compressive Capacity | | Uplift Capacity | | Lateral Capacity @ 5 mm Defl. |
|---|---|---|---|---|---|
| | Ultimate Tons | Allowable Tons | Ultimate Tons | Allowable Tons | Allowable Tons |
| **0.45** | 174.92 | **70** | 129.25 | **43** | **2.75** |
| **0.50** | 200.54 | **80** | 144.16 | **48** | **3.42** |
| **0.60** | 255.50 | **102** | 174.32 | **58** | **4.94** |
| **0.75** | 347.22 | **139** | 220.37 | **73** | **7.68** |
| **0.90** | 450.07 | **180** | 267.42 | **89** | **10.91** |

It was recommended to provide at least a two-pile group using suitable pile diameter instead of single pile - single column for better resistance to bending forces from column loads and seismic forces. In case of columns for lift or staircase area or places with close column spacing, and low column loads single pile per column can be provided with a common pile cap. All the pile caps should be tied together through rigid plinth beams. In case single pile and single column unit is considered then extreme care should be taken to match center line of pile and column to minimize eccentricity to avoid additional bending moments in the pile. **All piles should be terminated in the hard strata shale with at least 0.5-M embedment.**

There was no known groundwater source in the site or in any nearby plots. Groundwater was at about 2.15-M below EGL in the Boring 1 about 36 hours after completion of drilling, and bailing out drilling fluid a few times before taking the final groundwater level. Groundwater sample was collected from the Boring 1 for construction suitability tests just before leaving the site and back filling the boring. Test results indicate that tested groundwater from the Boring 1 was **suitable** for construction purposes as per IS: 456-2000. Chemical tests were performed on soil samples from 1-, and 17.5-M of Boring 1, and 2- and 20.5-M of Boring 2. Soil samples were tested for pH, Chlorides, and Sulphates. A 5% soil solution was initially prepared by mixing with distilled water. This solution was allowed to soak and settle for 24 hours. After that soil solution was filtered pH test was performed on the derived solution. Test results on soil samples inferred presence of adverse chemicals in the tested soil samples **just below the limiting concentrations** as per IS: 456 – 2000 code guidelines for construction water.

This general site area was known to have high salinity groundwater. For that reason deep bore well were generally not installed in this area. After installing a bore well in the site, groundwater from the site should be checked for construction suitability purposes at regular intervals from the beginning of construction activities. If necessary, treatment should be adopted make groundwater suitable for construction purposes. With regular checking of groundwater, water treatment should be suitably adjusted to make groundwater acceptable for construction purposes. In case groundwater is found to be highly saline then as an abundant precaution it was recommended to provide steel and cement resistant to saline environment up to stilt floor roof slab level.

We not expect construction problems at this site due to site soil and groundwater conditions during non-rainy season. Site's EGL was at about ERL of road in front of the site. In order to minimize future site flooding from road runoff it was recommended to raise site's FGL by **at least 0.75-M above ERL** of road in front of the site, and the Finished Floor Level (FFL) of stilt floor should be 0.15-M above FGL of the site. Foundation excavation, site, and building basement fillings should be done with granular soils with proper compaction to achieve a minimum unit weight of 2.0 tons/$M^3$. Old buildings present the site has to be cleared for the proposed construction.

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

All structures have to be designed for higher seismic forces (**Zone III**) due to increased seismic activity in peninsular India for the past two decades. Seismic events of 3.9 magnitude on March 14, 2024, 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. Plinth beams must be designed to be rigid to allow redistribution of loads in case of differential settlements. Under a seismic event of **6.0 Richter scale**, and **0.16g** peak ground acceleration (IS code for **Zone III** design horizontal acceleration) for the site's lower bound soil profile (Boring 2) with groundwater at 2-M below EGL inferred **"No"** seismic susceptibility with total estimated vertical settlement was 2.41 cms at EGL and total horizontal displacement was about 0.38 cms. Iwasaki liquefaction potential was 0.0 inferring "**No Liquefaction.**"

# INTRODUCTION

## Purpose and Scope

I performed a geotechnical site investigation at the Proposed Residential Apartments Building Site, "**Dwaraka Dharshan**", Block No 79, Dwaraka Flats, Ambattur Estate – Thirumangalam Road, Anna Nagar West Extension, Chennai 600 101, TN. Comprised in Old S. No. 289 Part of Padi Village, S. Nos. 297/3B, 297/1A Part, 1B Part, 2A Part, 2B Part, 290 Part, T. S. No. 87/9, 87/10, 87/11, 87/12, Block No. 9, Ward - H of Mogappair Village, Within the limits of Greater Chennai Corporation. The primary purpose of our investigation was to obtain data to identify foundation type and estimate load carrying capacity of the selected foundation for the proposed Stilt + 5 floors building. For the proposed building type typical maximum column load will be about 200 tons. These load details were used only for estimating the preliminary foundation size and type of foundation. To accomplish these purposes, the following tasks were performed:

(1) Boring 1, and 2 were drilled to 22.5-M below 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. Bore location details were presented on Plate 1. Number and location of the borings was selected to cover the proposed building area with due consideration to presence of a G + 2 floor RCC building in the site. Boring 1 and 2 were drilled to 22.5-M below EGL. Both borings were terminated with at least 2-M drilling through the hard strata shale (Very Hard Clay) with SPT "$N_{avg}$" $\geq$ 75. Borings were drilled beyond 10-M due to presence of clay soils and potentially liquefiable soils in the soil profiles. Tests were conducted to determine the pertinent index and engineering properties of the soils encountered. We then performed engineering analyses to develop the required design data. Groundwater was at about 2.15-M below EGL in Boring 1. Log of Boring were presented on Plate 2 and 3.

## Field and Laboratory Tests

Boring was drilled using Calyx drilling unit. In the boring SPT was performed at 1-M interval up to 10-M, at 1.5-M interval up to 20.5-M, and at 2-M beyond 20.5-M. Soil samples for laboratory tests

were collected from SPT split spoon sampler. SPT consists of driving a standard split spoon sampler, 50.8-mm outside diameter and 35-mm inside diameter into soil under the blows of a drop hammer of 63.5 kg falling weight freely through 75-cm. The number of blows required for 30-cm of penetration of sampler in soil is designated as N value and it is termed as the SPT blow count. Detailed information regarding SPT can be found in the IS: 2131 code of practice.

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

## GENERAL SOIL CONDITIONS

### Topography

Natural topography of the site reflects a flat terrain. Visual observation infers site's EGL was at about ERL of road in front of the site. Compound wall was present along all boundaries of the site. During this investigation a G + 2 floors RCC building was present in the site. Some well grown trees were present in the site. Proposed construction will be the first major construction activity of this magnitude to cover the site.

### Soil Stratigraphy

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

**Boring – 1:**

| Stratum | Penetration, M From | To | Description |
|---|---|---|---|
| I | 0 | 3.75 | Brown Fine to Medium Sand with Silt |
| II | 3.75 | 5.75 | Brown Gray Stiff to Very Stiff Clay with Silty Sand Seams |
| III | 5.75 | 17.5 | Gray Firm to Stiff Clay |
| IV | 17.5 | 19.25 | Brown Gray Gravelly Fine to Coarse Sand |
| V | 19.25 | 22.5+ | Brown Yellow Gray Hard to Very Hard Clay |

**Boring – 2:**

| Stratum | Penetration, M From | To | Description |
|---|---|---|---|
| I | 0 | 1.0 | Brown Silty Fine to Medium Sand with Brick and Stone Pieces |
| II | 1.0 | 2.0 | Brown Gray Very Stiff Silty Clay |
| III | 2.0 | 3.75 | Brown Gray Fine to Medium Sand with Silt |
| IV | 3.75 | 9.0 | Gray Firm to Very Stiff Clay |

| | | | |
|---|---|---|---|
| V | 9.0 | 11.0 | Gray Fine to Medium Sand with Silt |
| VI | 11.0 | 17.5 | Gray Firm to Very Stiff Clay |
| VII | 17.5 | 19.0 | Brown Red Gray Fine to Coarse Sand with Gravel |
| VIII | 19.0 | 22.5+ | Brown Yellow Red Gray Hard to Very Hard Clay |

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

## Interpretation of Soil Properties

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

Recommendations presented herein are based on the soil properties encountered in the Boring 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:**

| | Penetration, M | | |
|---|---|---|---|
| Stratum | From | To | Properties |
| Ia | 0 | 1.0 | $\gamma_{sat}$ = 1.55 tons/M$^3$ |
| Ib | 1.0 | 2.0 | $\phi = 30^o$; $\gamma_{sat}$ = 1.65 tons/M$^3$ |
| Ic | 2.0 | 3.75 | $\phi = 35^o$; $\gamma_{sat}$ = 1.95 tons/M$^3$ |
| IIa | 3.75 | 5.0 | $C_u$ = 5 tons/M$^2$; $\gamma_{sat}$ = 1.6 tons/M$^3$ |
| IIb | 5.0 | 5.75 | $C_u$ = 12 tons/M$^2$; $\gamma_{sat}$ = 1.7 tons/M$^3$ |
| IIIa | 5.75 | 6.75 | $C_u$ = 8 tons/M$^2$; $\gamma_{sat}$ = 1.65 tons/M$^3$ |
| IIIb | 6.75 | 8.0 | $C_u$ = 5 tons/M$^2$; $\gamma_{sat}$ = 1.6 tons/M$^3$ |
| IIIc | 8.0 | 11.0 | $C_u$ = 8 tons/M$^2$; $\gamma_{sat}$ = 1.65 tons/M$^3$ |
| IIId | 11.0 | 12.5 | $C_u$ = 5 tons/M$^2$; $\gamma_{sat}$ = 1.6 tons/M$^3$ |
| IIIe | 12.5 | 16.0 | $C_u$ = 3 tons/M$^2$; $\gamma_{sat}$ = 1.5 tons/M$^3$ |
| IIIf | 16.0 | 17.5 | $C_u$ = 7 tons/M$^2$; $\gamma_{sat}$ = 1.65 tons/M$^3$ |
| IV | 17.5 | 19.25 | $\phi = 34^o$; $\gamma_{sat}$ = 1.85 tons/M$^3$ |
| Va | 19.25 | 20.5 | $C_u$ = 21 tons/M$^2$; $\gamma_{sat}$ = 1.9 tons/M$^3$ |
| Vb | 20.5 | 22.5+ | $C_u$ = 35 tons/M$^2$; $\gamma_{sat}$ = 2.1 tons/M$^3$ |

**Boring – 2:**

| | Penetration, M | | |
|---|---|---|---|
| Stratum | From | To | Properties |
| I | 0 | 1.0 | $\gamma_{sat}$ = 1.65 tons/M$^3$ |
| II | 1.0 | 2.0 | $C_u$ = 16 tons/M$^o$; $\gamma_{sat}$ = 1.85 tons/M$^3$ |
| IIIa | 2.0 | 3.0 | $\phi = 34^o$; $\gamma_{sat}$ = 1.85 tons/M$^3$ |
| IIIb | 3.0 | 3.75 | $\phi = 35^o$; $\gamma_{sat}$ = 1.95 tons/M$^3$ |
| IVa | 3.75 | 6.0 | $C_u$ = 3 tons/M$^2$; $\gamma_{sat}$ = 1.5 tons/M$^3$ |

| | | | |
|---|---|---|---|
| IVb | 6.0 | 8.0 | $C_u$ = 6 tons/M$^2$; $\gamma_{sat}$ = 1.65 tons/M$^3$ |
| IVc | 8.0 | 9.0 | $C_u$ = 10 tons/M$^2$; $\gamma_{sat}$ = 1.7 tons/M$^3$ |
| Va | 9.0 | 10.0 | $\phi$ = 36$^o$; $\gamma_{sat}$ = 2.0 tons/M$^3$ |
| Vb | 10.0 | 11.0 | $\phi$ = 32$^o$; $\gamma_{sat}$ = 1.7 tons/M$^3$ |
| VIa | 11.0 | 16.0 | $C_u$ = 3 tons/M$^2$; $\gamma_{sat}$ = 1.5 tons/M$^3$ |
| VIb | 16.0 | 17.5 | $C_u$ = 14 tons/M$^2$; $\gamma_{sat}$ = 1.75 tons/M$^3$ |
| VII | 17.5 | 19.0 | $\phi$ = 36$^o$; $\gamma_{sat}$ = 2.0 tons/M$^3$ |
| VIIIa | 19.0 | 20.5 | $C_u$ = 27 tons/M$^2$; $\gamma_{sat}$ = 2.0 tons/M$^3$ |
| VIIIb | 20.5 | 22.5+ | $C_u$ = 35 tons/M$^2$; $\gamma_{sat}$ = 2.1 tons/M$^3$ |

## DESIGN INFORMATION

Data from borings infer presence of soil profiles with variable thickness and variable consistency clay layers in the top 10-M below EGL. Encountered soil profiles infer high potential for differential settlements. Therefore, for the encountered soil profiles and expected column loads shallow foundation was not recommended as foundation can undergo significant total and differential settlements. For the proposed building with expected column load, and encountered soil profiles it was **recommended** to provide "**Tractor Mounted Direct Mud Circulation (DMC) Cast In-Situ Pile**" foundation. Recommended type of pile installation work will have low construction vibrations otherwise it may affect the existing building foundations and also lead to objections from adjacent building owners. It was recommended to provide a minimum **21- and 20-M total and effective length piles** with top 1-M pile cutoff for pile caps and plinth beams.. Pile capacity was estimated as per the IS: 2911 - 2010 (Part 1 / Section 2) Code guidelines. Ultimate and allowable pile capacities of various pile diameters are summarized below:

| Pile Dia. M | Compressive Capacity | | Uplift Capacity | | Lateral Capacity @ 5 mm Defl. |
|---|---|---|---|---|---|
| | Ultimate Tons | Allowable Tons | Ultimate Tons | Allowable Tons | Allowable Tons |
| **0.45** | 174.92 | **70** | 129.25 | **43** | **2.75** |
| **0.50** | 200.54 | **80** | 144.16 | **48** | **3.42** |
| **0.60** | 255.50 | **102** | 174.32 | **58** | **4.94** |
| **0.75** | 347.22 | **139** | 220.37 | **73** | **7.68** |
| **0.90** | 450.07 | **180** | 267.42 | **89** | **10.91** |

It was recommended to provide at least a two-pile group using suitable pile diameter instead of single pile - single column for better resistance to bending forces from column loads and seismic forces. In case of columns for lift or staircase area or places with close column spacing, and low column loads single pile per column can be provided with a common pile cap. All the pile caps should be tied together through rigid plinth beams. In case single pile and single column unit is considered then extreme care should be taken to match center line of pile and column to minimize eccentricity to avoid additional bending moments in the pile. **All piles should be terminated in the hard strata shale with at least 0.5-M embedment.** Foundation capacity calculations were presented on Plate 7.

## GROUNDWATER AND SOIL CHEMICAL ANALYSIS

There was no known groundwater source in the site or in any nearby plots. Groundwater was at about 2.15-M below EGL in the Boring 1 about 36 hours after completion of drilling, and bailing out drilling fluid a few times before taking the final groundwater level. Groundwater sample was collected

from the Boring 1 for construction suitability tests just before leaving the site and back filling the boring. Test results indicate that tested groundwater from the Boring 1 was **suitable** for construction purposes as per IS: 456-2000. Chemical tests were performed on soil samples from 1-, and 17.5-M of Boring 1, and 2- and 20.5-M of Boring 2. Soil samples were tested for pH, Chlorides, and Sulphates. A 5% soil solution was initially prepared by mixing with distilled water. This solution was allowed to soak and settle for 24 hours. After that soil solution was filtered pH test was performed on the derived solution. Test results on soil samples inferred presence of adverse chemicals in the tested soil samples **just below the limiting concentrations** as per IS: 456 – 2000 code guidelines for construction water. This general site area was known to have high salinity groundwater. For that reason deep bore well were generally not installed in this area. After installing a bore well in the site, groundwater from the site should be checked for construction suitability purposes at regular intervals from the beginning of construction activities. If necessary, treatment should be adopted make groundwater suitable for construction purposes. With regular checking of groundwater, water treatment should be suitably adjusted to make groundwater acceptable for construction purposes. In case groundwater is found to be highly saline then as an abundant precaution it was recommended to provide steel and cement resistant to saline environment up to stilt floor roof slab level. Summary of groundwater and soil chemical test results are presented on Plate 6.

## CONSTRUCTION CONSIDERATIONS

We not expect construction problems at this site due to site soil and groundwater conditions during non-rainy season. Site's EGL was at about ERL of road in front of the site. In order to minimize future site flooding from road runoff it was recommended to raise site's FGL by **at least 0.75-M above ERL** of road in front of the site, and FFL of stilt floor should be 0.15-M above FGL of the site. Foundation excavation, site, and building basement fillings should be done with granular soils with proper compaction to achieve a minimum unit weight of 2.0 tons/$M^3$. Old buildings present the site has to be cleared for the proposed construction.

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

All structures have to be designed for higher seismic forces (**Zone III**) due to increased seismic activity in peninsular India for the past two decades. Seismic events of 3.9 magnitude on March 14, 2024, 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. Plinth beams must be designed to be rigid to allow redistribution of loads in case of differential settlements. Under a seismic event of **6.0 Richter scale**, and **0.16g** peak ground acceleration (IS code for **Zone III** design horizontal acceleration) for the site's lower bound soil profile (Boring 2) with groundwater at 2-M below EGL inferred **"No"** seismic susceptibility with total estimated vertical settlement was 2.41 cms at EGL and total horizontal displacement was about 0.38 cms. Iwasaki liquefaction potential was 0.0 inferring "**No Liquefaction.**" Liquefaction Analysis results are presented on Plate 8.

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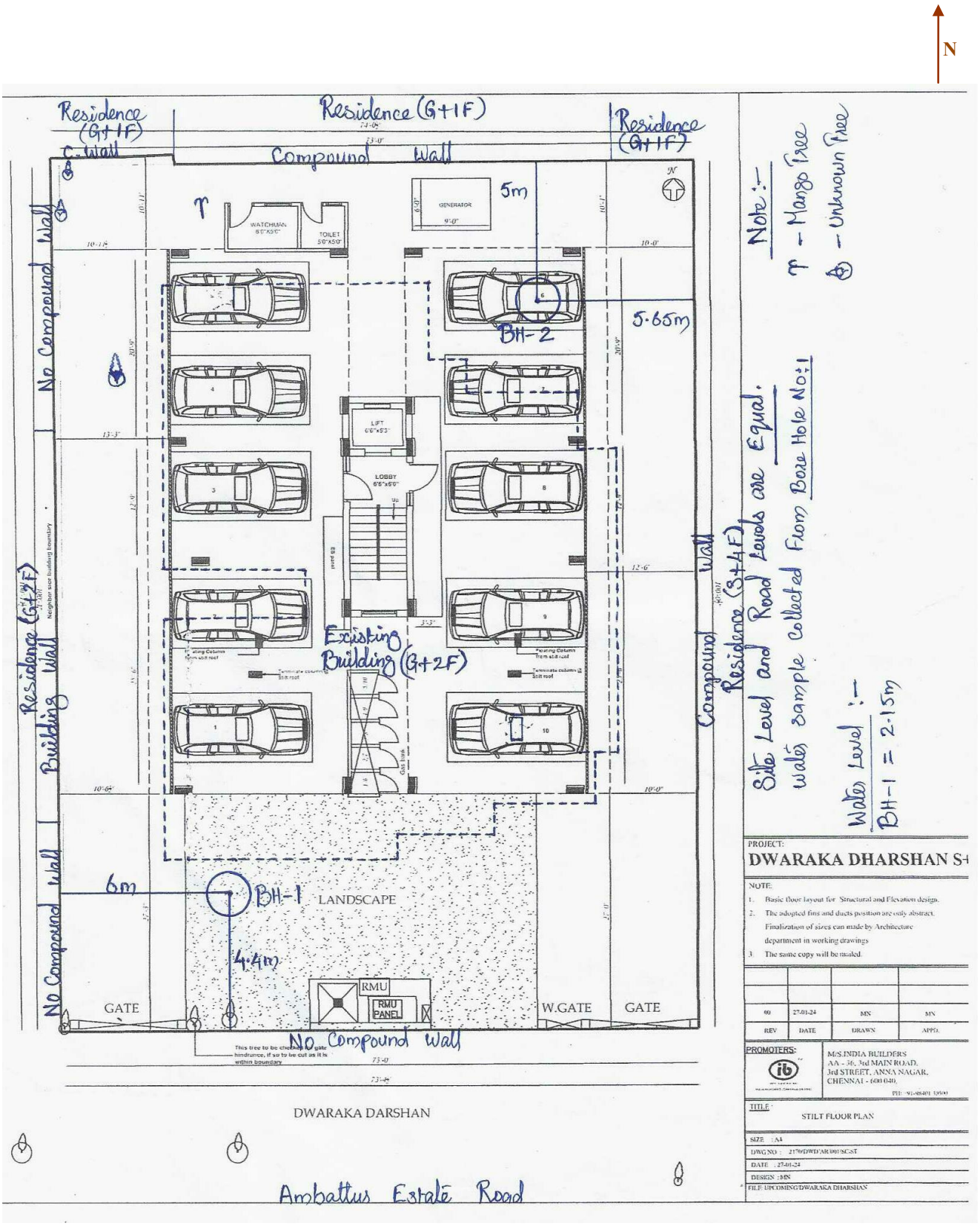
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(Not To Scale)

**Site EGL = ERL of Road In-Front of the Site.**

**SITE PLAN WITH BORE LOCATION DETAILS.**

**PLATE 1**

# LOG OF BORING

**Project:** Proposed Residential Apartments Building Site, "**Dwaraka Dharshan**", Block No. 79, Dwaraka Flats, Ambattur Estate – Thirumangalam Road, Anna Nagar West Extension, Chennai 600 101, TN.

**Bore Hole No.:** 1 **Type of Boring:** Calyx Drill **Dia. of Hole:** 150 mm
**Started on:** 25-04-'24 **Ended on:** 26-04-'24 **Field Work In Charge:** M Munivel
**Final Depth:** 22.5-M **Depth to G W S:** 2.15-M **Remarks:** GWL from Boring 1.

| DEPTH, M | SOIL DESCRIPTION | SPT / VANE & SAMPLE TYPE |
|---|---|---|
| | **BROWN FINE TO MEDIUM SAND with silt (To 3.75-M)** | DS @ 0.25 M |
| | -with brick and stone pieces at 0.25-m | SPT @ 1 M |
| 1.0 | 0.0- to 1.0-m – $\gamma_t$ = 1.55 tons/M$^3$ ($N_{avg}$ ~ 6) | 3/5/6 = 11 Blows |
| | 1.0- to 2.0-m – $\phi$ = 30°; $\gamma_t$ = 1.65 tons/M$^3$ ($N_{avg}$ = 11) | SPT @ 2 M |
| 2.0 | -with very stiff clay seams at 2-m | 11/17/21 = 38 Blows |
| GWL | | |
| | 2.0- to 3.75-m – $\phi$ = 35°; $\gamma_t$ = 1.95 tons/M$^3$ ($N_{avg}$ = 38) | SPT @ 3 M |
| 3.0 | | 16/18/20 = 38 Blows |
| | | SPT @ 4 M |
| 4.0 | **BROWN GRAY STIFF TO VERY STIFF CLAY with silty sand seams (To 5.75-M)** | 2/4/7 = 11 Blows |
| | 3.75- to 5.0-m – $C_u$ = 5 tons/M$^2$; $\gamma_t$ = 1.6 tons/M$^3$ ($N_{avg}$ ~ 8) | SPT @ 5 M |
| 5.0 | | 5/8/10 = 18 Blows |
| | 5.0- to 5.75-m – $C_u$ = 12 tons/M$^2$; $\gamma_t$ = 1.7 tons/M$^3$ ($N_{avg}$ = 18) | |
| | | SPT @ 6 M |
| 6.0 | **GRAY FIRM TO STIFF CLAY (To 17.5-M)** | 4/6/7 = 13 Blows |
| | 5.75- to 6.75-m – $C_u$ = 8 tons/M$^2$; $\gamma_t$ = 1.65 tons/M$^3$ ($N_{avg}$ = 13) | |
| | | SPT @ 7 M |
| 7.0 | | 3/3/6 = 9 Blows |
| | 6.75- to 8.0-m – $C_u$ = 5 tons/M$^2$; $\gamma_t$ = 1.6 tons/M$^3$ ($N_{avg}$ = 9) | |
| | | SPT @ 8 M |
| 8.0 | | 6/6/8 = 14 Blows |
| | | |
| | | SPT@ 9 M |
| 9.0 | | 4/6/8 = 14 Blows |
| | 8.0- to 11.0-m – $C_u$ = 8 tons/M$^2$; $\gamma_t$ = 1.65 tons/M$^3$ ($N_{avg}$ = 13) | |
| | | SPT @ 10 M |
| 10.0 | | 3/5/7 = 12 Blows |
| | | |
| 11.0 | | |

SPT "N" PROFILE: 25 50 75

INDEX TEST DATA: 25 50 75

CONTINUED ON PLATE 2b.

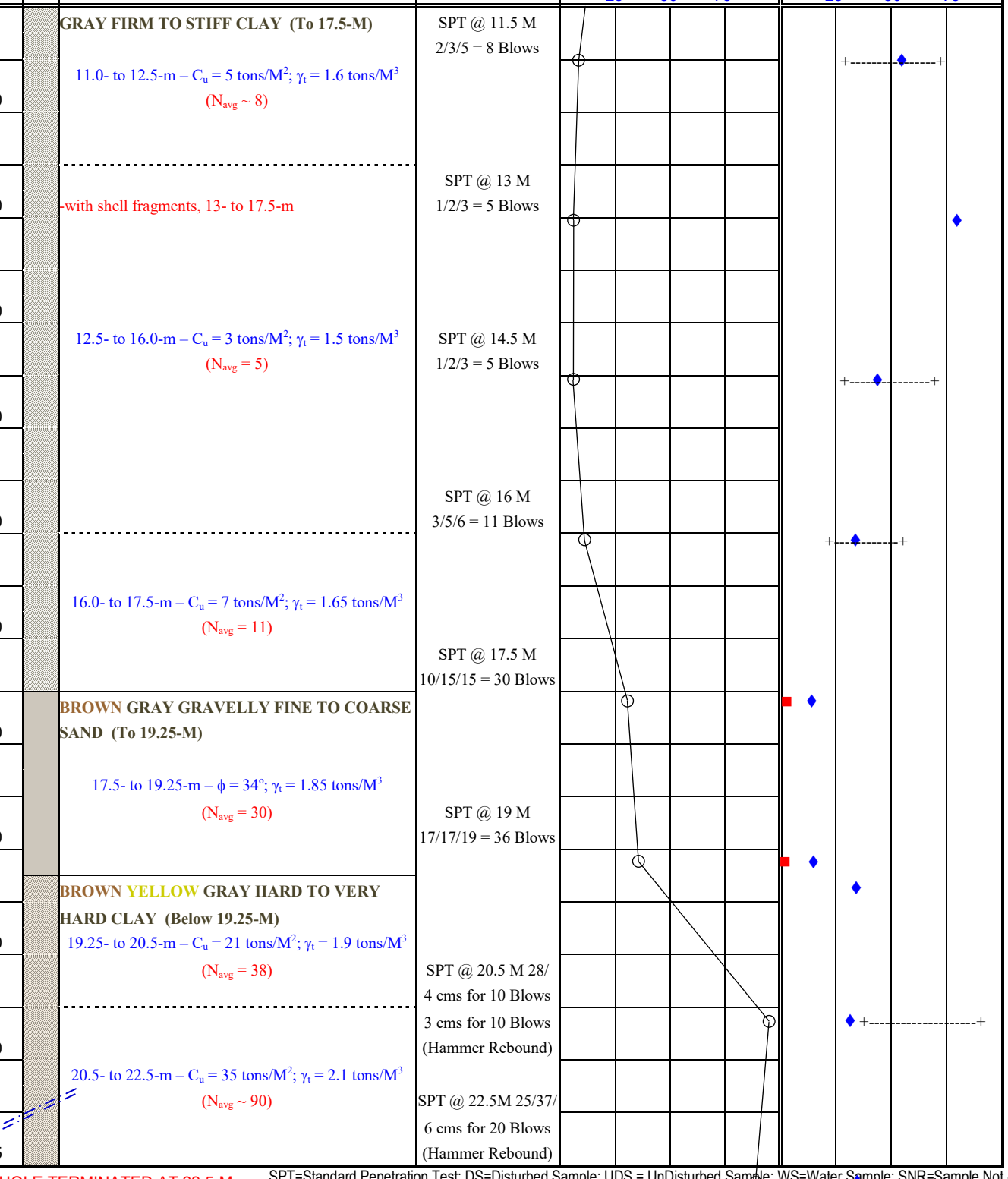
SPT=Standard Penetration Test; DS=Disturbed Sample; UDS = UnDisturbed Sample; WS=Water Sample; SNR=Sample Not Recovered; LS = Liner Sample; +----+ = Plastic and Liquid Limits; ♦ = N M C; ■ = % -75μ Size

# LOG OF BORING

**Project:** Proposed Residential Apartments Building Site, "**Dwaraka Dharshan**", Block No. 79, Dwaraka Flats, Ambattur Estate – Thirumangalam Road, Anna Nagar West Extension, Chennai 600 101, TN.

**Bore Hole No.:** 1 **Type of Boring:** Calyx Drill **Dia. of Hole:** 150 mm
**Started on:** 25-04-'24 **Ended on:** 26-04-'24 **Field Work In Charge:** M Munivel
**Final Depth:** 22.5-M **Depth to G W S:** 2.15-M **Remarks:** Continued from Plate 2a.

| DEPTH, M | SOIL DESCRIPTION | SPT / VANE & SAMPLE TYPE |
|---|---|---|
| | **GRAY FIRM TO STIFF CLAY (To 17.5-M)** | SPT @ 11.5 M 2/3/5 = 8 Blows |
| 12.0 | 11.0- to 12.5-m – $C_u$ = 5 tons/M$^2$; $\gamma_t$ = 1.6 tons/M$^3$ ($N_{avg}$ ~ 8) | |
| 13.0 | -with shell fragments, 13- to 17.5-m | SPT @ 13 M 1/2/3 = 5 Blows |
| 14.0 | | |
| 15.0 | 12.5- to 16.0-m – $C_u$ = 3 tons/M$^2$; $\gamma_t$ = 1.5 tons/M$^3$ ($N_{avg}$ = 5) | SPT @ 14.5 M 1/2/3 = 5 Blows |
| 16.0 | | SPT @ 16 M 3/5/6 = 11 Blows |
| 17.0 | 16.0- to 17.5-m – $C_u$ = 7 tons/M$^2$; $\gamma_t$ = 1.65 tons/M$^3$ ($N_{avg}$ = 11) | |
| 18.0 | **BROWN GRAY GRAVELLY FINE TO COARSE SAND (To 19.25-M)** | SPT @ 17.5 M 10/15/15 = 30 Blows |
| 19.0 | 17.5- to 19.25-m – $\phi$ = 34°; $\gamma_t$ = 1.85 tons/M$^3$ ($N_{avg}$ = 30) | SPT @ 19 M 17/17/19 = 36 Blows |
| 20.0 | **BROWN YELLOW GRAY HARD TO VERY HARD CLAY (Below 19.25-M)** 19.25- to 20.5-m – $C_u$ = 21 tons/M$^2$; $\gamma_t$ = 1.9 tons/M$^3$ ($N_{avg}$ = 38) | SPT @ 20.5 M 28/ 4 cms for 10 Blows |
| 21.0 | | 3 cms for 10 Blows (Hammer Rebound) |
| 22.5 | 20.5- to 22.5-m – $C_u$ = 35 tons/M$^2$; $\gamma_t$ = 2.1 tons/M$^3$ ($N_{avg}$ ~ 90) | SPT @ 22.5M 25/37/ 6 cms for 20 Blows (Hammer Rebound) |




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 2b

# LOG OF BORING

**Project:** Proposed Residential Apartments Building Site, "**Dwaraka Dharshan**", Block No. 79, Dwaraka Flats, Ambattur Estate – Thirumangalam Road, Anna Nagar West Extension, Chennai 600 101, TN.

**Bore Hole No.:** 2 **Type of Boring:** Calyx Drill **Dia. of Hole:** 150 mm
**Started on:** 27-04-'24 **Ended on:** 28-04-'24 **Field Work In Charge:** M Munivel
**Final Depth:** 22.5-M **Depth to G W S:** 2.15-M **Remarks:** GWL from Boring 1.

| DEPTH, M | SOIL DESCRIPTION | SPT / VANE & SAMPLE TYPE |
|---|---|---|
| | **BROWN SILTY FINE TO MEDIUM SAND with brick and stone pieces (To 1.0-M)** | DS @ 0.25 M |
| | 0.0- to 1.0-m – $\gamma_t$ = 1.65 tons/M$^3$ | SPT @ 1 M |
| 1.0 | ($N_{avg}$ ~ 10) | 6/12/14 = 26 Blows |
| | **BROWN GRAY VERY STIFF SILTY CLAY (To 2.0-M)** | |
| | 1.0- to 2.0-m – $C_u$ = 16 tons/M$^2$; $\gamma_t$ = 1.85 tons/M$^3$ | SPT @ 2 M |
| 2.0 | ($N_{avg}$ = 26) | 12/15/17 = 32 Blows |
| GWL | **BROWN GRAY FINE TO MEDIUM SAND with silt (To 3.75-M)** | |
| | 2.0- to 3.0-m – $\phi$ = 34°; $\gamma_t$ = 1.85 tons/M$^3$ | SPT @ 3 M |
| 3.0 | ($N_{avg}$ = 32) | 12/18/21 = 39 Blows |
| | 3.0- to 3.75-m – $\phi$ = 35°; $\gamma_t$ = 1.95 tons/M$^3$ | |
| | ($N_{avg}$ = 39) | |
| | | SPT @ 4 M |
| 4.0 | **GRAY FIRM TO VERY STIFF CLAY (To 9.0-M)** | 1/2/3 = 5 Blows |
| | | |
| | | SPT @ 5 M |
| 5.0 | 3.75- to 6.0-m – $C_u$ = 3 tons/M$^2$; $\gamma_t$ = 1.5 tons/M$^3$ | 2/3/3 = 6 Blows |
| | ($N_{avg}$ = 5) | |
| | | SPT @ 6 M |
| 6.0 | | 2/4/6 = 10 Blows |
| | | |
| | | SPT @ 7 M |
| 7.0 | 6.0- to 8.0-m – $C_u$ = 6 tons/M$^2$; $\gamma_t$ = 1.65 tons/M$^3$ | 3/4/6 = 10 Blows |
| | ($N_{avg}$ = 10) | |
| | | SPT @ 8 M |
| 8.0 | | 5/7/10 = 17 Blows |
| | 8.0- to 9.0-m – $C_u$ = 10 tons/M$^2$; $\gamma_t$ = 1.7 tons/M$^3$ | |
| | ($N_{avg}$ = 17) | SPT@ 9 M |
| 9.0 | | 18/21/26 = 47 Blows |
| | **GRAY FINE TO MEDIUM SAND with silt (To 11.0-M)** | |
| | 9.0- to 10.0-m – $\phi$ = 36°; $\gamma_t$ = 2.0 tons/M$^3$ | SPT @ 10 M |
| 10.0 | ($N_{avg}$ = 47) | 16/9/7 = 16 Blows |
| | 10.0- to 11.0-m – $\phi$ = 32°; $\gamma_t$ = 1.7 tons/M$^3$ | |
| | ($N_{avg}$ = 16) | |
| 11.0 | | |

SPT "N" PROFILE: 25 50 75

INDEX TEST DATA: 25 50 75

CONTINUED ON PLATE 3b.

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

# LOG OF BORING

**Project:** Proposed Residential Apartments Building Site, "**Dwaraka Dharshan**", Block No. 79, Dwaraka Flats, Ambattur Estate – Thirumangalam Road, Anna Nagar West Extension, Chennai 600 101, TN.

**Bore Hole No.:** 2 **Type of Boring:** Calyx Drill **Dia. of Hole:** 150 mm
**Started on:** 27-04-'24 **Ended on:** 28-04-'24 **Field Work In Charge:** M Munivel
**Final Depth:** 22.5-M **Depth to G W S:** 2.14-M **Remarks:** Continued from Plate 3a.

| DEPTH, M | SOIL DESCRIPTION | SPT / VANE & SAMPLE TYPE |
|---|---|---|
| | **GRAY FIRM TO VERY STIFF CLAY (To 17.5-M)** | SPT @ 11.5 M 2/2/4 = 6 Blows |
| 12.0 | | |
| 13.0 | | SPT @ 13 M 2/2/3 = 5 Blows |
| | 11.0- to 16.0-m – $C_u$ = 3 tons/M$^2$; $\gamma_t$ = 1.5 tons/M$^3$ ($N_{avg}$ = 5) | |
| 14.0 | -with shell fragments at 13-m | |
| | | SPT @ 14.5 M 2/2/3 = 5 Blows |
| 15.0 | | |
| 16.0 | -with limestone nodules at 16-m | SPT @ 16 M 7/10/13 = 23 Blows |
| | 16.0- to 17.5-m – $C_u$ = 14 tons/M$^2$; $\gamma_t$ = 1.75 tons/M$^3$ ($N_{avg}$ = 23) | |
| 17.0 | | SPT @ 17.5 M 18/22/29 = 51 Blows |
| 18.0 | **BROWN GRAY RED FINE TO COARSE SAND with gravel (To 19.0-M)** | |
| | 17.5- to 19.0-m – $\phi$ = 36°; $\gamma_t$ = 2.0 tons/M$^3$ ($N_{avg}$ = 51) | |
| 19.0 | | SPT @ 19 M 20/22/31 = 53 Blows |
| | **BROWN YELLOW RED GRAY HARD TO VERY HARD CLAY (Below 19.0-M)** | |
| | 19.0- to 20.5-m – $C_u$ = 27 tons/M$^2$; $\gamma_t$ = 2.0 tons/M$^3$ ($N_{avg}$ = 53) | |
| 20.0 | | SPT @ 20.5M 26/38/ 3 cms for 10 Blows |
| | | 2 cms for 10 Blows (Hammer Rebound) |
| 21.0 | | |
| | 20.5- to 22.5-m – $C_u$ = 35 tons/M$^2$; $\gamma_t$ = 2.1 tons/M$^3$ ($N_{avg}$ > 75) | SPT @ 22.5M 28/36/ 6 cms for 20 Blows (Hammer Rebound) |
| 22.5 | | |

SPT "N" PROFILE: 25 50 75

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

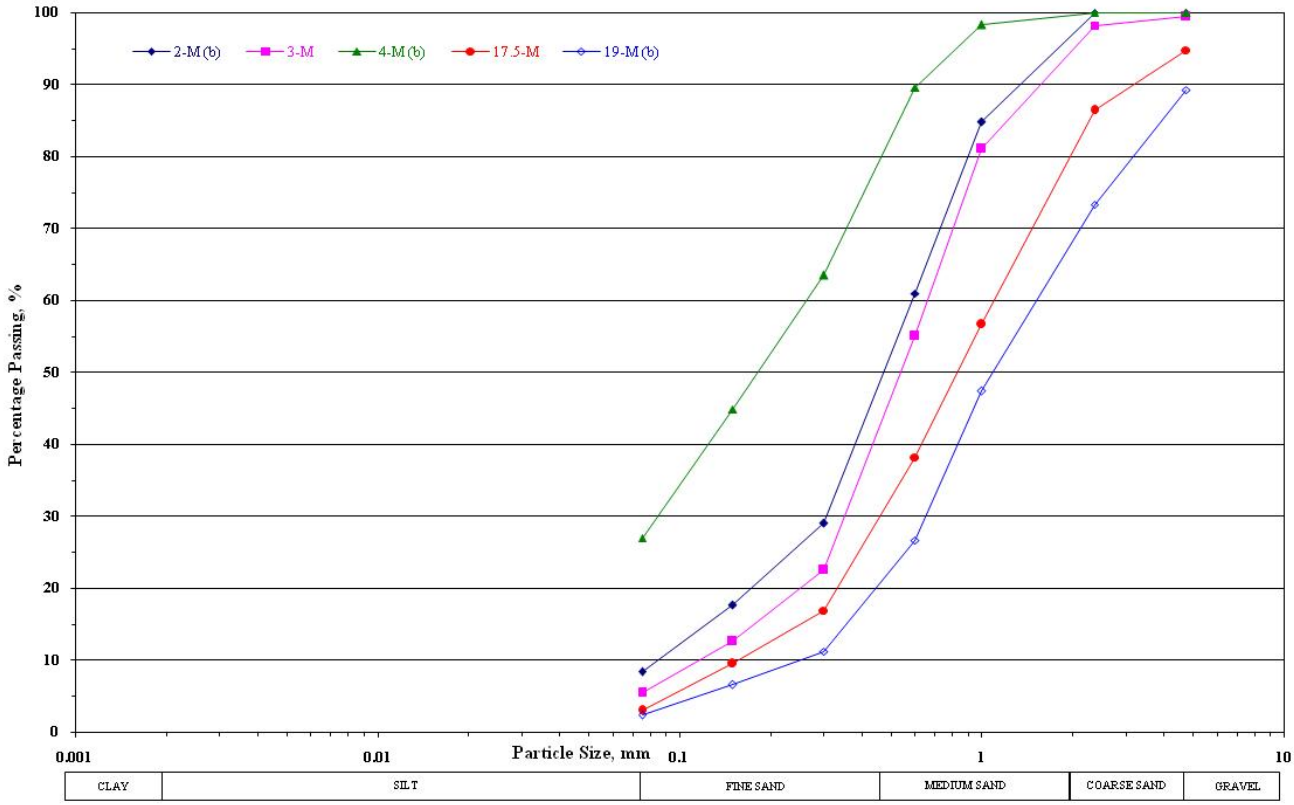
| Boring No. | Depth, M | w % | PL | LL | -75μ% | SAND | | | GRAVEL | IS CLASS. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Fine% | Medium% | Coarse% | % | |
| 1 | 0.25 | 4 | | | 5 | | | | | |
| | 1.0 | 14 | | | 8 | | | | | |
| | 2.0a | 29 | 24 | 58 | | | | | | CH |
| | 2.0b | 14 | | | 8 | 39 | 50 | 3 | 0 | SP |
| | 3.0 | 15 | | | 5 | 36 | 54 | 5 | 0 | SP |
| | 4.0a | 45 | | | | | | | | |
| | 4.0b | 25 | | | 27 | 51 | 21 | 1 | 0 | SM |
| | 5.0 | 32 | 28 | 57 | | | | | | CH |
| | 6.0 | 35 | | | | | | | | |
| | 7.0 | 43 | 32 | 66 | | | | | | CH |
| | 8.0 | 30 | | | | | | | | |
| | 9.0 | 33 | 26 | 52 | | | | | | CH |
| | 10.0 | 41 | | | | | | | | |
| | 11.5 | 55 | 29 | 74 | | | | | | CH |
| | 13.0 | 80 | | | | | | | | |
| | 14.5 | 42 | 28 | 72 | | | | | | CH |
| | 16.0 | 29 | 21 | 56 | | | | | | CH |
| | 17.5 | 14 | | | 3 | 26 | 51 | 15 | 5 | SP |
| | 19.0a | 16 | | | 2 | 18 | 48 | 21 | 11 | SP |
| | 19.0b | 32 | | | | | | | | |
| | 20.5 | 30 | 36 | 92 | | | | | | CH |
| | 22.5 | 33 | 39 | 104 | | | | | | CH |
| 2 | 0.25 | 12 | | | 12 | | | | | |
| | 1.0 | 20 | 15 | 49 | | | | | | CL |
| | 2.0 | 19 | | | 6 | 57 | 37 | 0 | 0 | SP |
| | 3.0 | 18 | | | 5 | 44 | 48 | 3 | 0 | SP |
| | 4.0 | 42 | 23 | 59 | | | | | | CH |
| | 5.0 | 29 | | | | | | | | |
| | 6.0 | 40 | 24 | 59 | | | | | | CH |
| | 7.0 | 44 | | | | | | | | |
| | 8.0 | 38 | 31 | 64 | | | | | | CH |
| | 9.0 | 19 | | | 5 | 51 | 43 | 1 | 0 | SP |
| | 10.0 | 19 | | | 3 | 38 | 57 | 2 | 0 | SP |
| | 11.5 | 60 | 41 | 77 | | | | | | CH |
| | 13.0 | 74 | | | | | | | | |
| | 14.5 | 44 | 24 | 69 | | | | | | CH |
| | 16.0 | 31 | 20 | 64 | | | | | | CH |
| | 17.5 | 13 | | | 2 | 16 | 56 | 21 | 5 | SP |
| | 19.0 | 29 | 31 | 98 | | | | | | CH |
| | 20.5 | 32 | 33 | 110 | | | | | | CH |
| | 22.5 | 33 | shale | | | | | | | |

## FREE SWELL INDEX TEST RESULTS

| BORE NO. | DEPTH, M | FREE SWELL INDEX, % |
|---|---|---|
| 1 | 2.0a | 80 |
| 2 | 1.0 | 140 |

PLATE 4

## Grain Size Distribution Curves
## Boring 1




## Grain Size Distribution Curves
## Boring 2

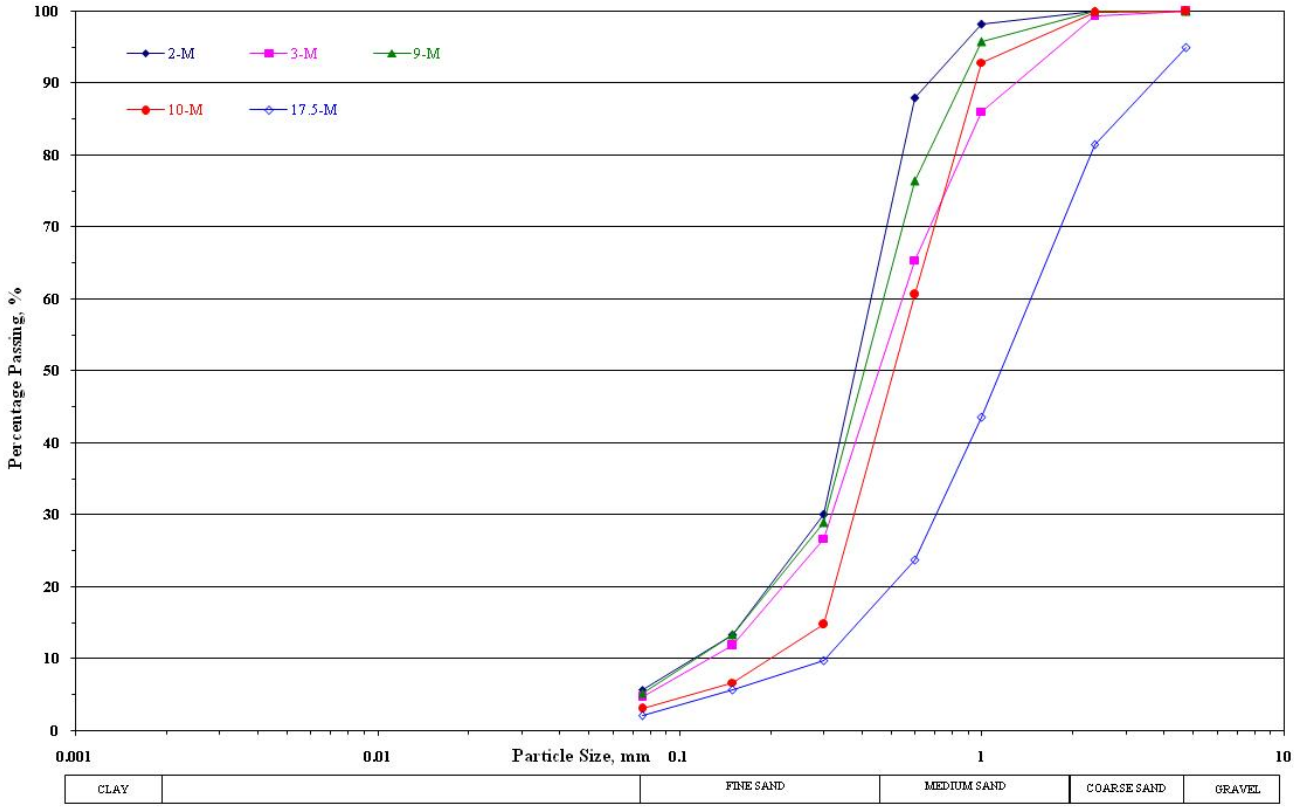



**PLATE 5**

# SUMMARY OF WATER TEST RESULTS

## BORING 1; DEPTH = 22.5-M; WATER LEVEL = 2.15-M

| S. No. | | Description | Results Obtained | As per IS:456 – 2000 |
|---|---|---|---|---|
| 1 | | To neutralize 100 cc of water using phenolphthalein as indicator | 1.00 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 | 950 | 3,000 Max. |
| | c | Sulphates as $SO_3$, mg/liter | 72 | 400 Max. |
| | d | Chlorides as Cl, mg/liter | 113 | 2,000 Max. - Plain Concrete<br>500 Max. RCC |
| | e | Suspended Solids, mg/liter | 0 | 2,000 Max. |
| | f | pH | 6.90 | 6 Min. |

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

# SUMMARY OF SOIL CHEMICAL TEST RESULTS

| Boring | Depth, M | pH | Chlorides | Sulphates, ppm | |
|---|---|---|---|---|---|
| | | | ppm | $SO_4$ | $SO_3$ |
| **1** | 1.0 | 6.14 | 460 | 296 | 247 |
| | 17.5 | 8.34 | 496 | 312 | 267 |
| **2** | 2.0 | 6.78 | 308 | 150 | 121 |
| | 20.5 | 7.30 | 430 | 268 | 230 |

Remarks:

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

Sulphates and chlorides content were for total soil weight.

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

# SAMPLE CALCULATIONS FOR DMC BORED CAST IN SITU PILES.

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

## PROPOSED RESIDENTIAL APARTMENTS BUILDING SITE

"Dwaraka Dharshan", Block No. 79, Dwaraka Flats., Ambattur Estate - Thirumangalam Road, Anna Nagar West Ext., Chennai 101, TN.

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

Total Pile Length = **21.00 M** below EGL

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

Pile Effective Concreting Length = 20.00 M

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

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

| S.No. | Soil Description | From | To | $N_{avg}$ | $C_u$, T/M$^2$ | $\phi^0$ | $\gamma_T$, T/M$^3$ |
|---|---|---|---|---|---|---|---|
| 1 | Brown F to M Sand with …. | 0.00 | 1.00 | ~ 10 | | | 1.65 |
| 2 | Brown Gray Very Stiff Silty Clay | 1.00 | 2.00 | 26 | 16.00 | | 1.85 |
| 3a | Brown Gray F to M Sand with Silt | 2.00 | 3.00 | 32 | | 34 | 1.85 |
| 3b | Brown Gray F to M Sand with Silt | 3.00 | 3.75 | 39 | | 35 | 1.95 |
| 4a | Gray Firm to Very Stiff Clay | 3.75 | 6.00 | 5 | 3.00 | | 1.50 |
| 4b | Gray Firm to Very Stiff Clay | 6.00 | 8.00 | 10 | 6.00 | | 1.65 |
| 4c | Gray Firm to Very Stiff Clay | 8.00 | 9.00 | 17 | 10.00 | | 1.70 |
| 5a | Gray F to M Sand with Silt | 9.00 | 10.00 | 47 | | 36 | 2.00 |
| 5b | Gray F to M Sand with Silt | 10.00 | 11.00 | 16 | | 32 | 1.70 |
| 6a | Gray Firm to Very Stiff Clay | 11.00 | 16.00 | 5 | 3.00 | | 1.50 |
| 6b | Gray Firm to Very Stiff Clay | 16.00 | 17.50 | 23 | 14.00 | | 1.75 |
| 7 | Brown Gray Red F to C Sand with …. | 17.50 | 19.00 | 51 | | 36 | 2.00 |
| 8a | Br. Yel. Red Gray Hard to V. Hard Clay | 19.00 | 20.50 | 53 | 27.00 | | 2.00 |
| 8b | Br. Yel. Red Gray Hard to V. Hard Clay | 20.50 | 22.50 | > 75 | 35.00 | | 2.10 |

For Cohesive Soils :-

| $C_u$ | $\alpha$ |
|---|---|
| 3.00 | 1.00 |
| 6.00 | 0.75 |
| 10.00 | 0.44 |
| 14.00 | 0.32 |
| 16.00 | 0.28 |
| 27.00 | 0.28 |
| 35.00 | 0.28 |

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

Unit Skin Friction in Clay Soils, $f_s$ = $\alpha C_u$

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**

## 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. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Brown F to M Sand with …. | 0.00 | 1.00 | 0 | 0 | 0.65 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | Cutoff |
| 2 | Brown Gray Very Stiff Silty Clay | 1.00 | 2.00 | 16.00 | | 0.85 | 1.08 | 4.48 | 6.34 | 7.04 | 8.45 | 10.56 | 12.67 | |
| 3a | Brown Gray F to M Sand with Silt | 2.00 | 3.00 | 34 | 34 | 0.85 | 1.93 | 1.30 | 1.84 | 2.04 | 2.45 | 3.06 | 3.67 | |
| 3b | Brown Gray F to M Sand with Silt | 3.00 | 3.75 | 35 | 35 | 0.95 | 2.71 | 1.89 | 2.01 | 2.23 | 2.68 | 3.35 | 4.02 | |
| 4a | Gray Firm to Very Stiff Clay | 3.75 | 6.00 | 3.00 | | 0.50 | 3.63 | 3.00 | 9.55 | 10.61 | 12.73 | 15.91 | 19.09 | |
| 4b | Gray Firm to Very Stiff Clay | 6.00 | 8.00 | 6.00 | | 0.65 | 4.84 | 4.50 | 12.73 | 14.14 | 16.97 | 21.21 | 25.46 | |
| 4c | Gray Firm to Very Stiff Clay | 8.00 | 9.00 | 10.00 | | 0.70 | 5.84 | 4.40 | 6.22 | 6.91 | 8.30 | 10.37 | 12.45 | |
| 5a | Gray F to M Sand with Silt | 9.00 | 10.00 | 36 | 36 | 1.00 | 6.69 | 4.86 | 6.87 | 7.63 | 9.16 | 11.45 | 13.74 | |
| 5b | Gray F to M Sand with Silt | 10.00 | 11.00 | 32 | 32 | 0.70 | 7.54 | 4.71 | 6.66 | 7.40 | 8.88 | 11.10 | 13.32 | |
| 6a | Gray Firm to Very Stiff Clay | 11.00 | 16.00 | 3.00 | | 0.50 | 9.14 | 3.00 | 21.21 | 23.57 | 28.29 | 35.36 | 42.43 | |
| 6b | Gray Firm to Very Stiff Clay | 16.00 | 17.50 | 14.00 | | 0.75 | 10.95 | 4.48 | 9.50 | 10.56 | 12.67 | 15.84 | 19.01 | |
| 7 | Brown Gray Red F to C Sand with …. | 17.50 | 19.00 | 36 | 36 | 1.00 | 12.26 | 8.91 | 18.90 | 21.00 | 25.20 | 31.50 | 37.80 | |
| 8a | Br. Yel. Red Gray Hard to V. Hard Clay | 19.00 | 20.50 | 27.00 | | 1.00 | 13.76 | 7.56 | 16.04 | 17.82 | 21.38 | 26.73 | 32.08 | |
| 8b | Br. Yel. Red Gray Hard to V. Hard Clay | 20.50 | 21.00 | 35.00 | | 1.10 | 14.79 | 9.80 | 6.93 | 7.70 | 9.24 | 11.55 | 13.86 | |
| | | | | | | | | Net Total Ultimate Skin Friction, $Q_{s\,ult}$= | 124.80 | 138.66 | 166.40 | 208.00 | 249.60 | |

@ 21-M below EGL Soil
Formation - Very Hard Clay
L/D of Pile = 21.0/0.45 > 20
L/D of Pile = 21.0/0.50 > 20
L/D of Pile = 21.0/0.60 > 20
L/D of Pile = 21.0/0.75 > 20
L/D of Pile = 21.0/0.90 > 20
Use Lim. Value or Actual $\sigma'_{base}$

N = > 75
$N_c$ = 9

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

| | 0.45 | 0.50 | 0.60 | 0.75 | 0.90 | -M |
|---|---|---|---|---|---|---|
| Base A= | 0.1591 | 0.1964 | 0.2829 | 0.4420 | 0.6364 | -M$^2$ |
| $\sigma'_{base}$ = | 6.19 | 7.19 | 8.39 | 9.89 | 12.01 | T/M$^2$ |
| $q_{b\,ult}$ = | 315.00 | 315.00 | 315.00 | 315.00 | 315.00 | T/M$^2$ |
| **$q_{b\,ult}$ =** | **500.00** | **500.00** | **500.00** | **500.00** | **500.00** | **T/M$^2$** |
| $Q_{b\,ult}$ = | 50.12 | 61.88 | 89.10 | 139.22 | 200.48 | Tons |
| $Q_{s\,ult}$ = | 124.80 | 138.66 | 166.40 | 208.00 | 249.60 | Tons |
| $Q_{tot\,ult}$= | **174.92** | **200.54** | **255.50** | **347.22** | **450.07** | Tons |
| F.S. = | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | |
| Allowable Compressive Capacity = $Q_{All}$ = | **69.97** | **80.22** | **102.20** | **138.89** | **180.03** | Tons |
| **Use $Q_{All}$ =** | **70** | **80** | **102** | **139** | **180** | **Tons** |

**Note:-**

1 Pile Load Test must be conducted as per relavant IS Code to confirm the above estimated pile capacities before completion of installtion of all piles.
2 Pile installation must be done with extreme care to prevent "Necking" and "Buldging" problems due to presence of thick layers of sand soils;
3 Ground water level was assumed to rise to ground level in worst case conditions.
4 Limiting All. End Bearing Pressure in "**Hard Rock**" as per IRC code was 500 tons/M$^2$. Hence, $q_b$ (all) is limited to 200 tons/M$^2$ for Very Hard Clay.

## 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. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Brown F to M Sand with …. | 0.00 | 1.00 | 0 | 0 | 0.65 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | Cutoff |
| 2 | Brown Gray Very Stiff Silty Clay | 1.00 | 2.00 | 16.00 | | 0.85 | 1.08 | 4.48 | 6.34 | 7.04 | 8.45 | 10.56 | 12.67 | |
| 3a | Brown Gray F to M Sand with Silt | 2.00 | 3.00 | 34 | 34 | 0.85 | 1.93 | 1.30 | 1.84 | 2.04 | 2.45 | 3.06 | 3.67 | |
| 3b | Brown Gray F to M Sand with Silt | 3.00 | 3.75 | 35 | 35 | 0.95 | 2.71 | 1.89 | 2.01 | 2.23 | 2.68 | 3.35 | 4.02 | |
| 4a | Gray Firm to Very Stiff Clay | 3.75 | 6.00 | 3.00 | | 0.50 | 3.63 | 3.00 | 9.55 | 10.61 | 12.73 | 15.91 | 19.09 | |
| 4b | Gray Firm to Very Stiff Clay | 6.00 | 8.00 | 6.00 | | 0.65 | 4.84 | 4.50 | 12.73 | 14.14 | 16.97 | 21.21 | 25.46 | |
| 4c | Gray Firm to Very Stiff Clay | 8.00 | 9.00 | 10.00 | | 0.70 | 5.84 | 4.40 | 6.22 | 6.91 | 8.30 | 10.37 | 12.45 | |
| 5a | Gray F to M Sand with Silt | 9.00 | 10.00 | 36 | 36 | 1.00 | 6.69 | 4.86 | 6.87 | 7.63 | 9.16 | 11.45 | 13.74 | |
| 5b | Gray F to M Sand with Silt | 10.00 | 11.00 | 32 | 32 | 0.70 | 7.54 | 4.71 | 6.66 | 7.40 | 8.88 | 11.10 | 13.32 | |
| 6a | Gray Firm to Very Stiff Clay | 11.00 | 16.00 | 3.00 | | 0.50 | 9.14 | 3.00 | 21.21 | 23.57 | 28.29 | 35.36 | 42.43 | |
| 6b | Gray Firm to Very Stiff Clay | 16.00 | 17.50 | 14.00 | | 0.75 | 10.95 | 4.48 | 9.50 | 10.56 | 12.67 | 15.84 | 19.01 | |
| 7 | Brown Gray Red F to C Sand with …. | 17.50 | 19.00 | 36 | 36 | 1.00 | 12.26 | 8.91 | 18.90 | 21.00 | 25.20 | 31.50 | 37.80 | |
| 8a | Br. Yel. Red Gray Hard to V. Hard Clay | 19.00 | 20.50 | 27.00 | | 1.00 | 13.76 | 7.56 | 16.04 | 17.82 | 21.38 | 26.73 | 32.08 | |
| 8b | Br. Yel. Red Gray Hard to V. Hard Clay | 20.50 | 21.00 | 35.00 | | 1.10 | 14.79 | 9.80 | 6.93 | 7.70 | 9.24 | 11.55 | 13.86 | |
| | | | | | | | | Net Total Ultimate Skin Friction, $Q_{s\,ult}$= | 124.80 | 138.66 | 166.40 | 208.00 | 249.60 | |

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

| | 0.45 | 0.50 | 0.60 | 0.75 | 0.90 | -M |
|---|---|---|---|---|---|---|
| Base A= | 0.1591 | 0.1964 | 0.2829 | 0.4420 | 0.6364 | -M$^2$ |
| Pile Length, L = | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 | -M |
| Pile Volume, V = | 3.18 | 3.93 | 5.66 | 8.84 | 12.73 | -M$^3$ |
| Submerged Pile Weight W = | 4.46 | 5.50 | 7.92 | 12.38 | 17.82 | Tons |
| $Q_{s\,ult}$ = | 124.80 | 138.66 | 166.40 | 208.00 | 249.60 | Tons |
| $Q_{tot\,ult}$= | **129.25** | **144.16** | **174.32** | **220.37** | **267.42** | Tons |
| F.S. = | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | |
| Allowable Uplift Capacity = **$Q_{All}$ =** | **43.08** | **48.05** | **58.11** | **73.46** | **89.14** | Tons |
| **Use $Q_{All}$ =** | **43** | **48** | **58** | **73** | **89** | **Tons** |

**Note:-**

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

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

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

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

# SAMPLE CALCULATIONS FOR DMC BORED CAST IN SITU PILES.

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

## PROPOSED RESIDENTIAL APARTMENTS BUILDING SITE

"Dwaraka Dharshan", Block No. 79, Dwaraka Flats., Ambattur Estate - Thirumangalam Road, Anna Nagar West Ext., Chennai 101, TN.

Treat Soil Profile from 1- to 3-M = Sand
Average "N" Value = 22

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 = $\eta_h$ = **3000** kN/M$^2$/M (Accounting for possible weakening during seismic cond.)
(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 = M30
Min. % of Reinforcement Content = 0.40%
Modulus of Pile, $E_c$ = 273861 Kg/cm$^2$ = 2.74E+07 kN/M$^2$

Max. Comp. Stress in Bending $f_c$ = 3000 Tons/M$^2$ = 300 Kg/cm$^2$

$E_c$ = 5000 Sqrt($f_{ck}$) N/mm$^2$ = 30 N/mm$^2$ **$E_c$ = 27386.1 N/mm$^2$**

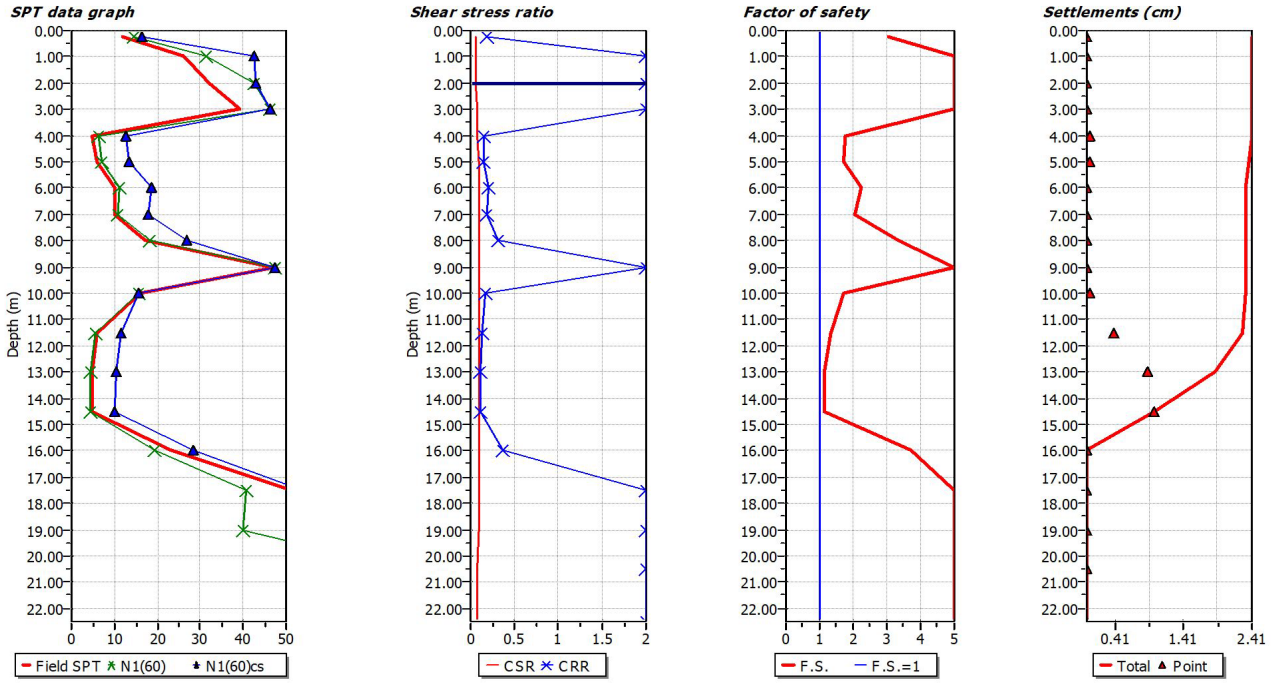
Pile Length Above Ground = $L_1$
Stiffness Factor = T (Sand & NC Clays)
Stiffness Factor = R (OC Clays)
Pile Fixity Length = $L_e$ Pile $L_e$/ T From Figure 4, Page 15, IS: 2911 (Part 2 / Sec/ 1) - 2010.

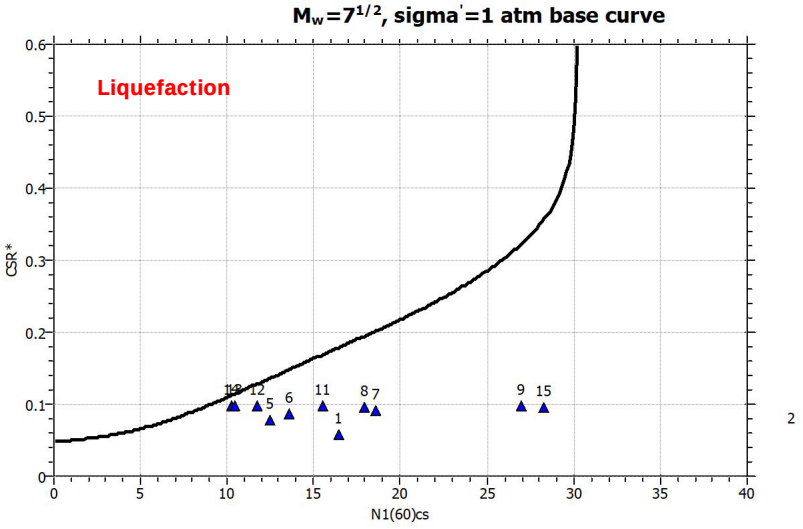
| Dia., D M | (I) Mom. of Inertia, M$^4$ | EI | T M | $L_1$ M | $L_1$/T | $L_e$/T | $L_e$ M | y mm | $L_1+L_e$ ($Z_f$) M | H Tons |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.45 | 0.00201 | 55124 | 1.79 | 1.00 | 0.559 | 2.20 | 3.94 | 5.00 | 4.94 | **2.75** |
| 0.50 | 0.00307 | 84017 | 1.95 | 1.00 | 0.514 | 2.20 | 4.28 | 5.00 | 5.28 | **3.42** |
| 0.60 | 0.00636 | 174218 | 2.25 | 1.00 | 0.444 | 2.20 | 4.96 | 5.00 | 5.96 | **4.94** |
| 0.75 | 0.01553 | 425337 | 2.69 | 1.00 | 0.371 | 2.20 | 5.93 | 5.00 | 6.93 | **7.68** |
| 0.90 | 0.03221 | 881978 | 3.12 | 1.00 | 0.321 | 2.20 | 6.86 | 5.00 | 7.86 | **10.91** |

# LIQUEFACTION ANALYSIS REPORT

**Project title : Block No. 79, Dwaraka Flats, Ambattur Estate - Thirumangalam Road, Anna Nagar West Extension, Chennai 600 101, TN.**
**Project subtitle : Boring 2 Soil Profile**
**Input parameters and analysis data**

| | | | |
|---|---|---|---|
| In-situ data type: | Standard Penetration Test | Depth to water table: | 2.00 m |
| Analysis type: | Deterministic | Earthquake magnitude $M_w$: | 6.00 |
| Analysis method: | NCEER 1998 | Peak ground accelaration: | 0.16 g |
| Fines correction method: | Idriss & Seed | User defined F.S.: | 1.00 |



## Horizontal Acceleration, $A_h$ = 0.16g

This software is licensed to : TRIAL VERSION

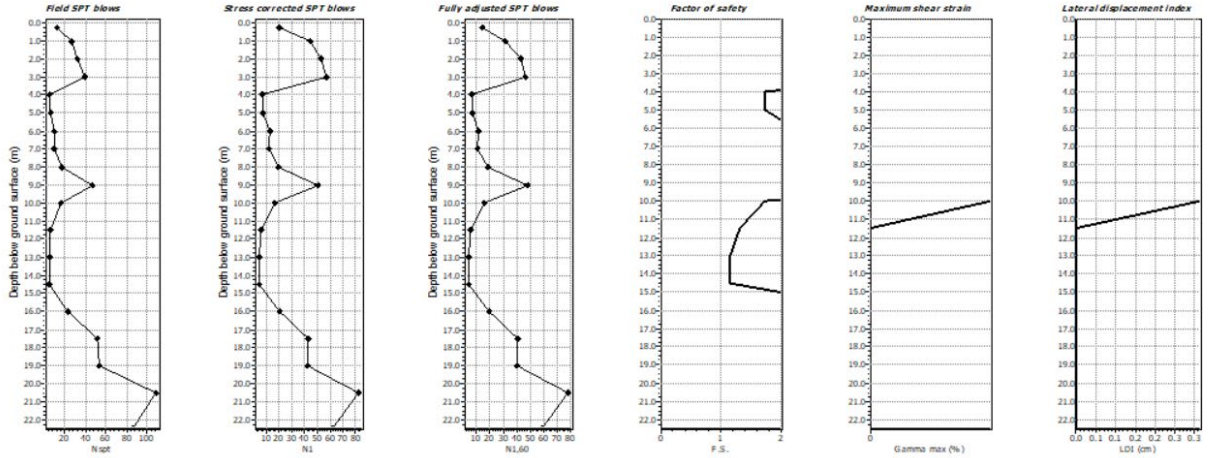
GEOLOGISMIKI Geotechnical Software

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

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

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

**Geometric parameters: Gently sloping ground without free face**
**Total lateral displacement estimation: 0.38 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

PLATE 8b

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