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1. Bathymetric Study;
2. Climatic Data;
3. Geotechnical Investigation Report;
4. Seawater Intake Drawings;
5. Geography & Topography Survey;
6. Water Sample Report; and
7. Environmental Impact Assessment Report

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# SOIL TESTING SERVICES

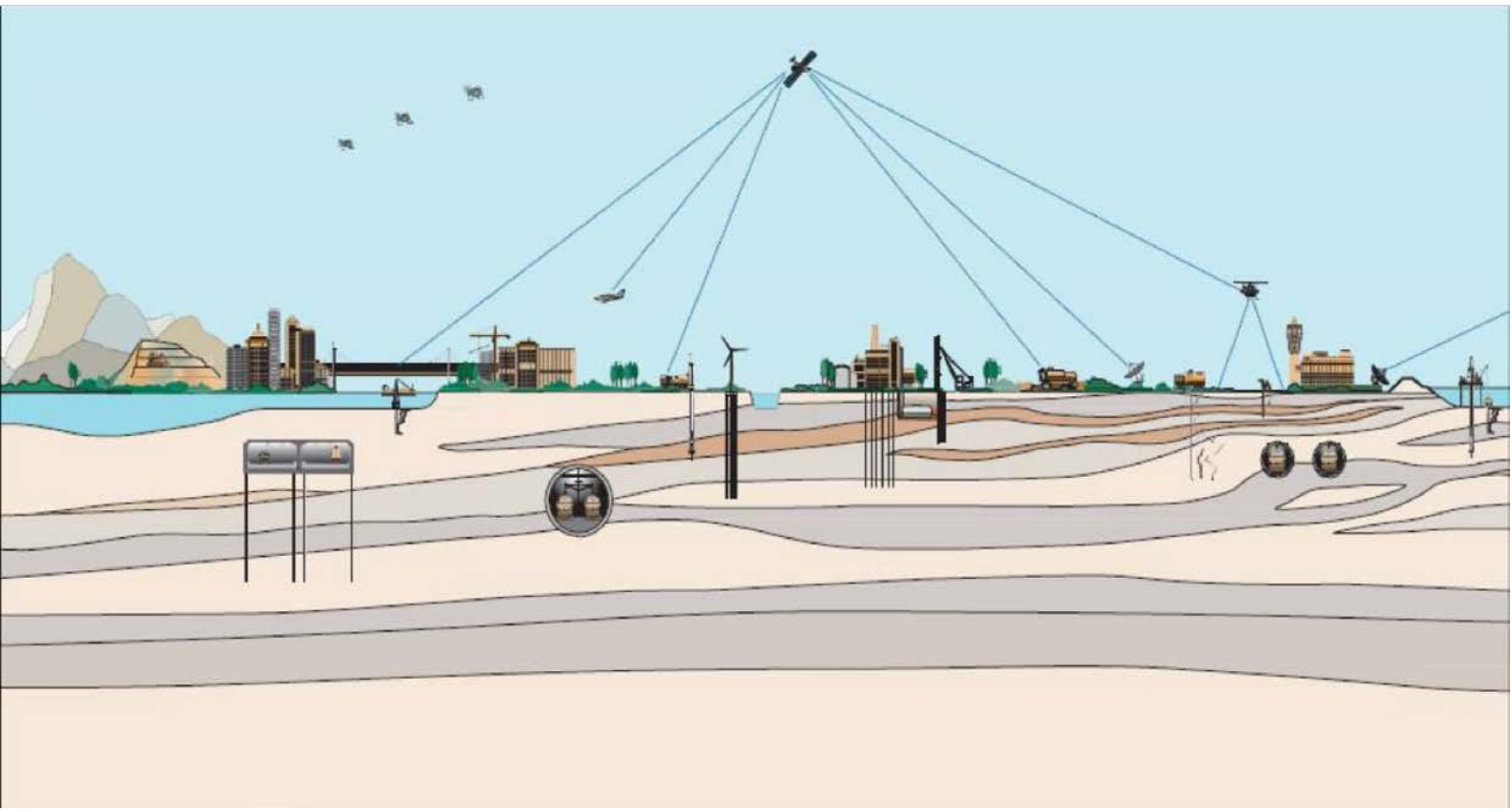
**Geotechnical Engineers and Testing Laboratory**

Report No. K22-1175-101

## GEOTECHNICAL INVESTIGATION REPORT FOR INSTALLATION OF 5 MGD DESALINATION PLANT AT IBRAHIM HYDERI, KARACHI

**(REV. 1.0, DATED: SEPTEMBER 22, 2022)**

## CLIENT: M/S. TECHNO CONSULT INTERNATIONAL



# SOIL TESTING SERVICES

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| SOIL TESTING SERVICES | Geotechnical Investigation Report | Revision | |
|---|---|---|---|
| | | # | Date |
| | Report No.: Vol I | 01 | 22/09/2022 |

**PROJECT: Geotechnical Investigation Report for Installation of 5 MGD Desalination Plant at Ibrahim Hayderi, Karachi**

| | NAME | SIGNATURE | DATE |
|---|---|---|---|
| *PREPARED BY:* (Project Engineer) | Riaan Ali Hasan | | |
| *REVIEWED BY:* (Project Manager) | Zainab Abbasi | | |
| *APPROVED BY:* (General Manager) | Naveed Anwer | | |

# ISSUE/REVISION INDEX

| Issue Code | Revision | | | | | Revision Details |
|---|---|---|---|---|---|---|
| | No. | By | Rev'd. | App. | Date | |
| RD | 00 | RAH | ZA | NA | 16/09/2022 | |
| RD | 01 | RAH | ZA | NA | 22/09/2022 | Ground Improvement included |
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Issue Codes: RC = Released for Construction, RD = Released for Design, RF = Released for Fabrication, RI = Released for Information, RP = Released for Purchase, RPA = Released for Permit Application, RQ = Released for Quotation, RR = Released for Review and Comments.

SOIL TESTING SERVICES

## EXECUTIVE SUMMARY

Geotechnical Investigation for installation of 5 MGD desalination plant at Ibrahim Hyderi, Karachi was carried out in order to determine geotechnical parameters of subsurface deposits. Scope of field work included drilling of three boreholes up to the depth of 15.0 meters below existing ground level. Soil and ground water samples were collected during field investigation. Laboratory testing of these samples has been carried out in the Soil Testing Services laboratory, Karachi.

The deposition of the area mainly consists of '*loose to very dense dense, fine to coarse grained*, *silty* sand*',* '*soft to hard*, clayey silt' and '*soft to hard*, *silty* clay'. Groundwater table was encountered at the depth range of 0.8 – 1.1 meters below the existing ground level in the boreholes drilled at site, at the time of this investigation.

Keeping these conditions under consideration:

- Recommendations for soil improvement are provided and bearing pressures have been given for shallow foundations post ground improvement at a depth of 1.5 meters below the existing ground level as the main foundation system.
- Pile foundation is recommended as the main foundation system for the project site.
- Recommendations for deep foundation i.e. bored cast in-situ pile foundation is also provided.
- Allowable pile capacities have been provided for various diameters.
- Earth pressure parameters have been provided for earth retaining structures.
- Liquefaction potential of the subsurface deposits at the project site are assessed and results are discussed in the report.
- Seismic soil profile has been taken as *'$S_D$'* for the foundations in accordance with UBC-97.

The exposure of underground concrete to aggressive chemicals is found to be *'moderate'* for sulphates and chlorides which have influenced the selection of cement for underground concreting and it is recommended to use *Ordinary Portland Cement (OPC) with slag* for all underground concrete works.

## CONTENTS

## 1. INTRODUCTION

Planning for the installation of 5 MGD desalination plant at Ibrahim Hyderi, Karachi is underway. In order to determine the geotechnical parameters of the subsurface deposits, *M/s. Soil Testing Services (STS)* were entrusted by *M/s. Techno Consult International* to perform the geotechnical investigation at the project site.

Scope of field work included drilling of three boreholes up to the depth of 15.0 meters below existing ground level. Elevation of the drilling platform at each borehole location was noted with respect to the mean sea level and is mentioned in borehole logs attached in Appendix B. Standard penetration tests were carried out at regular intervals in the boreholes along with the collection of soil samples via split spoon sampler. Groundwater samples were also collected from the boreholes drilled at the site. The samples retrieved from the field work were tested in the laboratory and this report is prepared from the information obtained from the field and laboratory tests.

The report consists of five chapters with *Chapter 2* describing the site's existing condition, *Chapter 3* discusses the subsurface deposits in detail, *Chapter 4* includes the recommendations for foundation design, and *Chapter 5* contains a summary of conclusions regarding the ground conditions, with respect to geotechnical engineering for this project.

## 2. THE SITE

The project site is located in UC-1 Ibrahim Hayderi in the neighbourhood of Korangi Creek. Other nearby industries include Al Asif communication, Shezad Jamrud JT Bangali Daka Office and Ibrahim Hyderi Football Stadium.

The topography of the plot is almost plain with no major changes in elevation observed across the site. Figure 2.1 shows the google image of the site.


*Fig 2.1: Google image of the the Neighbourhood area (Courtesy: Google Earth)*

## 3. REGIONAL GEOLOGY

Geotechnical investigations at Ibrahim Hyderi area reveals the presence of middle and upper tertiary rock formations. The creek area is covered with mudflats that support mangrove vegetation and does not exhibit much diversity.

The formation found in the area is fresh and slightly weathered recent and sub recent shoreline deposits. These deposits are derived from Gaj / Manchar Formations of lower Miocene to Middle Miocene / Upper Miocene to Pliocene age. Similar deposits are found all along coastal belt of Karachi and adjoining areas.

The coastal line of Karachi is 90 kilometres long and oriented NW-SE. On the western side, it is bounded by the Hub River and on the east by the mangrove swamps and creeks of the Port Muhammad Bin Qasim Area.

The seabed is dominantly sand and silt while the sediment of the delta is fine grained and resembles the soil from continental shelf at the mouth of the Indus Delta.

*Table 3.1: Geological Formations*

| FORMATION | AGE |
|---|---|
| Manchar Formation | Pliocene |
| Gaj Formation | Miocene |
| Nari Formation | Oligocene to early Miocene |

## 4. GROUND CONDITIONS

The subsurface deposits up to the explored depth consist of the following units:

- Sand
- Silt
- Clay

Following sub-sections describe the strength characteristics of the geological unit and the groundwater conditions. Fill material consisting of fine to coarse grained sand was encountered in all of the boreholes drilled at site up to the maximum depth of 1.30 meters below the existing ground level, at the time of this geotechnical investigation.

### 4.1 SAND

Deposits of *fine to coarse grained, silty* sand were encountered in all of the boreholes drilled at site. State of compactness according to SPT 'N' counts has been determined to be '*loose to very dense'*. The grain size analysis has been carried out of samples collected from these deposits. Unified Classification System (UCS) classifies these deposits as *'SM' & 'SP-SM'*. Table 4.1 summarizes the details of these deposits.

*Table 4.1: Deposits of Sand*

| Borehole No. | Depth (meters) |
|---|---|
| BH-01 | 1.3 – 2.5<br>12.5 – 15.0 |
| BH-02 | 13.5 – 15.0 |
| BH-03 | 1.3 – 2.2 |

### 4.2 SILT

Deposits of *clayey* silt were encountered in all the boreholes drilled at site. State of compactness according to SPT 'N' counts has been determined to be '*soft to hard'*. The grain size analysis has been carried out of samples collected from these deposits. Unified Classification System (UCS) classifies these deposits as *'ML'.* Table 4.2 summarizes the details of these deposits.

*Table 4.2: Deposits of Silt*

| Borehole No. | Depth (meters) |
|---|---|
| BH-01 | 2.5 – 6.5 |
| BH-02 | 1.3 – 5.0<br>10.0 – 13.5 |
| BH-03 | 5.3 – 10.0 |

### 4.3 CLAY

Deposits of sandy, fine grained clay were encountered in one of the boreholes drilled at site. State of compactness according to SPT 'N' counts has been determined to be '*stiff to hard'*. The grain size analysis has been carried out of samples collected from these deposits. Unified Classification System (UCS) classifies these deposits as *'CL' & 'CL-ML'.* Table 4.3 summarizes the details of these deposits.

*Table 4.3 Deposits of Clay*

| Borehole No. | Depth (meters) |
|---|---|
| BH-01 | 6.5 – 12.5 |
| BH-02 | 5.0 – 10.0 |
| BH-03 | 2.2 – 5.3<br>10.0 – 15.0 |

### 4.4 GROUNDWATER CONDITIONS

Groundwater was encountered at the depth range of 0.8 – 1.1 meters below existing ground level in both the boreholes drilled at the site at the time of this geotechnical investigation. However, this may fluctuate due to tidal, seasonal and other environmental variations.

## 5. ENGINEERING DESIGN CONSIDERATIONS

Foundation type for a structure depends on the expected loads taken by the foundation and the type of soil underlying it. The characteristics of the subsurface soil deposits have been discussed in the previous section. Keeping in view the subsoil conditions prevailing at the site, liquefaction potential of the subsurface deposits and loads expected to be transferred to the foundations, **ground improvement** via Vibro-Compaction is recommended. Recommendations for shallow foundation after ground improvement is provided in the preceding sections. Moreover, recommendations for deep foundation i.e. bored cast in-situ pile foundation is also provided. The following section discusses the recommendations for shallow and deep foundations in detail.

### 5.1 LIQUEFACTION POTENTIAL OF SOIL

The potential for liquefaction at this project site was evaluated using Peysanj software. This program is based on the most recent publications of the NCEER Workshop (1996) and Ambraseys (1988). The method evaluates liquefaction potential based on soil type and density, groundwater conditions, peak surface acceleration, magnitude of the design earthquake.

The method is used to compare the cyclic shear stresses indicated during the design earthquake, with those that would be required to cause liquefaction to determine whether any zone exists within the soil where liquefaction may be expected.

A peak ground acceleration of 0.20g was evaluated based on PBC Seismic provision 2007 for design, and has been adopted for the current study. We based our liquefaction analyses for an earthquake magnitude of M = 6.6.

Using the design parameters and procedures discussed above, the factors of safety against liquefaction is calculated. The factor of safety against liquefaction is observed as greater than 1.0 for earthquakes of magnitude 6.6. Hence, the subsurface deposits at project site are not susceptible to liquefaction.

### 5.2 SOIL IMPROVEMENT

The subsurface strata encountered at site shows loose sand, soft to medium stiff silty clay and soft clayey silt, from 1.0 – 6.0 meters below the existing ground level. Due to this strata, the site becomes susceptible to liquefaction and also the total anticipated settlements for shallow foundations are on the higher sides along with the low shear strength thus reducing the allowable bearing capacities. Therefore, to mitigate the effects

of liquefaction and to increase the bearing capacity of sub-surface strata, ***soil improvement*** may be required.

The most effective method for soil improvement in this type of soil is installation of *Vibro Compaction*. The following sections describe the process of installation of stone columns in detail.

### 5.2.1 VIBROCOMPACTION

Vibrocompaction, also known as 'vibroflotation' refers to deep compaction of soil with a vibroflot. The principle is to increase the density and load carrying capacity of loose partially and fully saturated soil by the vibration and displacement of the particles. The improved inter-granular friction reduces settlement under applied load.

The loose soil or well graded granular fill can be compacted to depth by the penetration of vibroflot. The maintained vibrations and the addition of water via jets along the probe lead to localized liquefaction of the soil, allowing the grains to rearrange in to a denser arrangement. After the fill placement, program of SPTs and CPTs tests shall be conducted to verify the state of compactness of engineered fill as per the design.

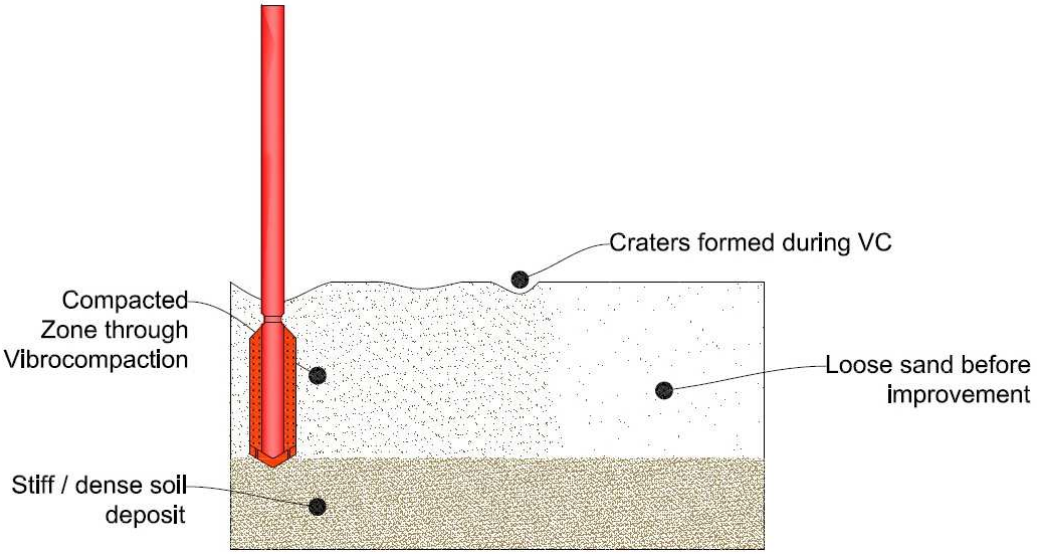



*Fig. 5.1: Process of Vibro-compaction*

*Fig. 5.2: Site image of vibro-compaction*

### 5.2.2 FIELD TESTING FOLLOWING SOIL IMPROVEMENT

If soil improvement is undertaken at the site then confirmatory field testing should be carried out to determine the extent of soil improvement. This can be carried out by either or all of the following in-situ tests:

- Standard Penetration Test (SPT)
- Plate Load Test
- Zone load Test

## 5.3 ALLOWABLE BEARING PRESSURES FOR SHALLOW FOUNDATION AFTER SOIL IMPROVEMENT

*Table 5.1* gives the tentative net allowable bearing pressure for shallow foundations expected after soil improvement at a depth of 1.5 meters from final grade level.

*Table 5.1: Tentative Net Allowable Bearing Pressures (with soil improvement)*

| Minimum Embedment below Existing Ground Level (meter) | Isolated/Strip Foundation (kPa) |
|---|---|
| 1.5 | 100.0 |

The bearing capacity values provided above are tentative and should be verified by a detailed and comprehensive stone column design. However, such design is beyond the scope of this investigation report, and should be performed by a qualified soil improvement contractor.

### 5.4 DEEP FOUNDATIONS - ALLOWABLE PILE CAPACITIES

The ultimate compressive capacity, Q, for a given bored concrete pile penetration is taken as the sum of the skin friction on the pile wall, Qs, and the end bearing on the pile tip, Qp, so that:

$$Q = Q_s + Q_p = \Sigma f A_s + q A_p$$

Where $A_s$ and $A_p$ represent, respectively, the embedded surface and pile end area; f and q represent, respectively, the unit skin friction and unit end bearing. When computing ultimate tensile capacity, the end bearing term in the above equation is neglected. Therefore, the value of the ultimate tensile capacity is the same value as the ultimate compression capacity due to skin friction Qs.

The design parameters for calculating pile capacities have been derived from shear strength determination, through in-situ field tests and laboratory tests of collected soil samples. The results of analysis for 0.60, 0.76 and 0.90 meter diameter drilled concrete piles are presented below in Table 5.2.

*Table 5.2: Allowable Pile Capacities*

| Borehole No. | Diameter (mm) | Length (m) below existing ground level | Tension (kN) | Compression (kN) |
|---|---|---|---|---|
| BH-01 | 600 | 15.0 | 247 | 559 |
| | 760 | 15.0 | 313 | 814 |

| Borehole No. | Diameter (mm) | Length (m) below existing ground level | Tension (kN) | Compression (kN) |
|---|---|---|---|---|
| BH-01 | 900 | 15.0 | 370 | 1074 |
| BH-02 | 600 | 15.0 | 265 | 595 |
| | 760 | 15.0 | 335 | 864 |
| | 900 | 15.0 | 397 | 1139 |
| BH-03 | 600 | 15.0 | 323 | 493 |
| | 760 | 15.0 | 409 | 647 |
| | 900 | 15.0 | 484 | 779 |

The design approach followed is based on FOS and as per this design approach, the settlement criteria of "Net settlement not to exceed 1% of the pile diameter at working load and Total penetration of the base not to exceed 10% of the pile diameter at test load" shall be fulfilled.

### 5.5 RECOMMENDED DRILLING METHOD AND CONFIRMATORY TESTING

The recommended drilling method for the construction of bored cast in-situ piles is straight rotary. Tentative pile capacity values given in Table 5.2 have been computed by static formulae which suffer from limitations. As such capacity values shall be verified by full scale load tests under the guidance of geotechnical engineer. Pile capacity shall be suitably adjusted if warranted by results of load tests. This report will be valid only if requirement of pile load tests is fulfilled.

The test pile should be loaded to 2.0 to 2.5 times the Specified Working Load (SWL) and the working pile should be loaded to 1.5 times the Specified Working Load (SWL). The calculations for allowable pile capacities for 600, 760 and 900 mm diameter bored cast in-situ piles are presented in appendix E of this report.

## 5.6 PILE CONSTRUCTION

Allowable pile capacities have been derived from combination of end bearing and skin friction components. It is, therefore, essential to adopt the following construction methodology to satisfy following requirements:

1. Excessive disturbance to sub-surface along shaft and pile tip shall be avoided during the course of drilling.
2. The bottom of pile shall be cleaned of all loose materials which may accumulate during the course of drilling.

Pile concreting shall be undertaken only when above conditions are fulfilled. It is understood that subsurface materials will be carefully examined during pilling and it shall be ensured that all piles are placed in proper stratum. This exercise will serve as safeguard against variations in quality and level of occurrence of dense stratum.

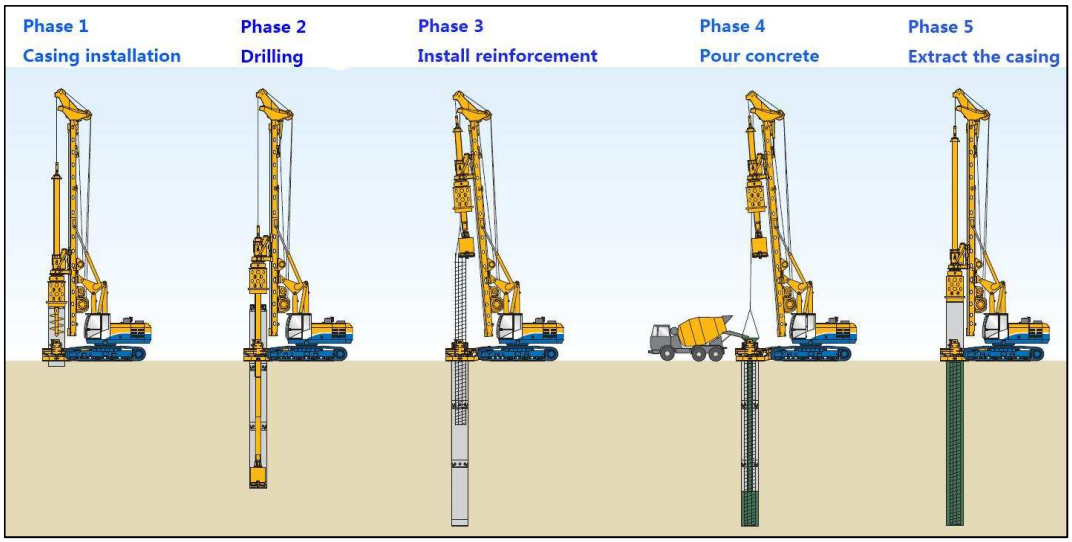



*Fig 5.3: Construction of cast in situ piles by straight rotary*

## 5.7 DEWATERING

Groundwater level lies at the depth range of 0.8 – 1.1 meters below the existing ground level. However, this may fluctuate due to seasonal, tidal and environmental variations. In case the groundwater is encountered at the level of foundations, some positive measures of effectively controlling groundwater level should be provided to enable the construction to be completed in the dry. For the construction of foundation below ground water table, proper dewatering system may be required. However, the design of dewatering system is not in the scope of this report.

## 5.8 EARTH RETAINING STRUCTURE

All measures shall be taken to provide safety to adjacent structures. Properly designed earth retaining structure must be constructed prior to deep excavation.

Earth pressure parameters required for the design of structure to retain the excavation are given in *Table 5.3.*

*Table 5.3: Earth pressure parameters*

| Strata | Φ' (Undisturbed) | $k_a$ (Coefficient of active earth pressure) | $k_p$ (Coefficient of passive earth pressure) |
|---|---|---|---|
| Clay/Silt | 0° | 1.000 | 1.000 |
| Sand | 28° | 0.361 | 2.770 |

## 5.9 LIQUEFACTION POTENTIAL OF SOIL

The potential for liquefaction at this project site was evaluated using Peysanj software. This program is based on the most recent publications of the NCEER Workshop (1996) and Ambraseys (1988). The method evaluates liquefaction potential based on soil type and density, groundwater conditions, peak surface acceleration, magnitude of the design earthquake.

The method is used to compare the cyclic shear stresses indicated during the design earthquake, with those that would be required to cause liquefaction to determine whether any zone exists within the soil where liquefaction may be expected.

A peak ground acceleration of 0.20g was evaluated based on PBC Seismic provision 2007 for design, and has been adopted for the current study. We based our liquefaction analyses for an earthquake magnitude of M = 6.6.

Using the design parameters and procedures discussed above, the factors of safety against liquefaction is calculated. The factor of safety against liquefaction is observed as greater than 1.0 for earthquakes of magnitude 6.6. Hence, the subsurface deposits at project site are not susceptible to liquefaction.

## 5.10 SOIL PROFILE TYPE (ACCORDING TO UBC-97)

Chapter 16, Division V, Section 1636 of UBC-97 deals with the determination of Soil Profile Types. Design practice involves using seismic parameters of zone 2B for the area under consideration.

### 5.10.1 SEISMIC ZONE FACTOR

Table 16-I of UBC-97 defines the seismic zone factor to be used in choosing seismic coefficients for a location. The seismic zone factor **"Z"** will be taken as 0.20.

### 5.10.2 SOIL PROFILE TYPE

Table 16-J of UBC-97 defines the soil profile types to be used for determining seismic coefficients. Based on the field data obtained from sub-soil exploration, the soil profile will be taken as **"$S_D$"**.

### 5.10.3 SEISMIC COEFFICIENTS

Seismic coefficients are as under:

**For $S_D$: $C_a$ = 0.28 & $C_V$ = 0.40**

## 5.11 TYPE OF CEMENT

Tests on groundwater samples obtained from the boreholes indicate '*moderate'* exposure to sulphate and chloride. Under these conditions it is recommended to use *Ordinary Portland Cement (OPC) with slag* for all underground concrete works.

## 6. CONCLUSIONS

Geotechnical Investigation for the installation of 5 MGD desalination plant at Ibrahim Hyderi, Karachi was carried out in order to determine geotechnical parameters of subsurface deposits. Scope of field work included drilling of three boreholes up to the depth of 15.0 meters below existing ground level. Soil and groundwater samples were collected during the field investigation. Laboratory testing on these samples has been carried out in the lab and includes determination of index properties through grain size analysis, Atterberg limits, density, moisture content etc. Chemical characteristics of soil and water samples have also been assessed through determination of total dissolved solids, sulphate content, chloride content and pH.

Keeping in view, the results from field, and laboratory tests, type of structure and the expected loads being transferred to the founding stratum, soil improvement recommended as the main foundation system. Allowable bearing pressure for shallow foundations post ground improvement at the depth of 1.5 meters are given. Also, allowable pile capacities for different diameters have been provided. Exposure to chloride and sulphate salts is '*moderate'* for water samples; therefore, *Ordinary Portland Cement (OPC) with slag* should be used for underground concreting.

**Appendix A**

# Boreholes Location Plan


| S.No | Coordinates | | | |
|---|---|---|---|---|
| | Utm (m) | | Geodetic | |
| | X | Y | Latitude | Longitude |
| 1 | 313391.574 | 2743460.384 | 24° 47' 40.3957" N | 67° 09' 14.4189" E |
| 2 | 313686.157 | 2743485.545 | 24° 47' 38.7362" N | 67° 09' 24.2156" E |
| 3 | 313564.433 | 2743261.920 | 24° 47' 34.0346" N | 67° 09' 23.8719" E |
| 4 | 313379.850 | 2743315.829 | 24° 47' 35.6951" N | 67° 09' 14.0711" E |

**Appendix B**

# Borehole Logs

# Mud Rotary Log BH-01

**Project Info.**
Project : Geotechnical Investigation Works
Client : Techno Consult
Location : Ibrahim Hyderi, Karachi
Job No. : K22-1175-101

**Borehole Info.**
Depth : 15 (m) Elevation : 0.61m from MSL
GWL : 1 (m) Easting :
Drill Date : 01.09.2022 Northing :
Logged By : AR Method : Mud Rotary

**Company Info.**
Geotechnical Engineering & Material Testing Laboratory
www.sts.com.pk

| Depth (m) | GWL (m) | Sample Type | Lithology Description | Field Tests (* SPT) | Symbol | USCS / AASHTO | Gravel (%) | Sand (%) | Silt (%) | Clay (%) | LL (%) | PL (%) | PI (%) | w (%) | Dry Unit Weight (gr/cm3) | Bulk | Direct Shear Test: Test Type | C (kg/cm2) | Fi (o) | qu (kg/cm2) | Consolidation: Cc | Cs | Pc (kg/cm2) | Chemical Tests: PH | SO3 | CL | Depth (m) | Remarks & Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | **FILLED MATERIAL** *Yellowish brown to yellowish grey, fine to coarse grained sand with garbage* | | | | | | | | | | | | | | | | | | | | | | | | 0 | |
| 1 | ▽ | U | **SAND** *Greyish brown, medium dense, fine to medium grained, traces of silt* | * 18 | | SP-SM A-1-b(0) | | 90.3 | 9.7 | | NLL | - | NPI | 15.6 | 1.5 | 1.7 | | | | | | | | 7.4 | 0.03 | 0.51 | 1 | SPT - 1 |
| 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | |
| 3 | | U | **SILT** *Brownish grey, soft, clayey, traces of sand* | * 2 | | | | | | | | | | | | | | | | | | | | | | | 3 | SPT - 2 |
| 4 | | U | | * 4 | | ML A-4(5) | | 2.8 | 52.6 | 44.6 | 31.1 | 26.2 | 4.9 | 30.7 | 1.32 | 1.7 | | | | | | | | | | | 4 | SPT - 3 |
| 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 | |
| 6 | | U | **SILT** *Greyish brown, medium stiff, little clay & traces of sand* | * 11 | | ML A-4(0) | | 9.6 | 72.1 | 18.3 | NLL | - | NPI | 25.6 | 1.34 | 1.7 | | | | | | | | | | | 6 | SPT - 4 |
| 7 | | | **CLAY** *Brownish grey, medium stiff to very stiff, silty, traces of sand* | | | | | | | | | | | | | | | | | | | | | | | | 7 | |
| 8 | | U | | * 7 | | CL A-4(8) | | 2.2 | 45.5 | 52.3 | 29.9 | 21.1 | 8.8 | 27.4 | 1.27 | 1.6 | | | | | | | | | | | 8 | SPT - 5 |
| 9 | | | | | | | | | | | | | | | | | | | | | | | | | | | 9 | |
| 10 | | U | | * 9 | | | | | | | | | | | | | | | | | | | | | | | 10 | SPT - 6 |

**Sample Types**
- ● Disturbed
- + Undisturbed
- □ Shelby / U4
- ■ Core Cutter
- U SPT Sample
- Water Sample
- ▽ Groundwater Level

**Abbreviations**
- LL : Liquid Limit
- PL : Plastic Limit
- PI : Plastic Index
- NPI : None PI
- C : Cohesion
- Phi : Friction Angle
- C' : Cohesion (CU)
- Phi' : Friction Angle (CU)
- Cc : Cc
- Cs : Cs
- Pc : Pre-Consolidation Pressure
- K : Permeability Coeff.
- w : Moisture Content
- qu : Unconfined Comp. Qu
- F : Fast
- S : Slow
- CD : Consolidated, Drained
- UU : Unconsolidated, Undrained
- CU : Consolidated, Undrained

# Mud Rotary Log BH-01

**Project Info.**
Project : Geotechnical Investigation Works
Client : Techno Consult
Location : Ibrahim Hyderi, Karachi
Job No. : K22-1175-101

**Borehole Info.**
Depth : 15 (m)
GWL : 1 (m)
Drill Date : 01.09.2022
Logged By : AR
Elevation : 0.61m from MSL
Easting :
Northing :
Method : Mud Rotary

**Company Info.**
Geotechnical Engineering & Material Testing Laboratory
www.sts.com.pk

| Depth (m) | GWL (m) | Sample Type | Lithology Description | Field Tests (* SPT) | Symbol | Depth (m) | USCS / AASHTO | Sieve Analysis Test: Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Atterberg Limits: LL (%) | PL (%) | PI (%) | w (%) | Dry Unit Weight (gr/cm3) | Bulk | Direct Shear Test: Test Type | C (kg/cm2) | Fi (o) | qu (kg/cm2) | Consolidation: Cc | Cs | Pc (kg/cm2) | Chemical Tests: PH | SO3 | CL | Depth (m) | Remarks & Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | | U | **CLAY** *Brownish grey, medium stiff to very stiff, silty, traces of sand* | * 14 | | 10 | | | | | | | | | | | | | | | | | | | | | | 10 | SPT - 7 |
| 11 | | | | | | 11 | | | | | | | | | | | | | | | | | | | | | | 11 | |
| 12 | | U | | * 17 | | 12 | | | | | | | | | | | | | | | | | | | | | | 12 | SPT - 8 |
| 13 | | | **SAND** *Greyish brown, very dense, silty fine grained* | | | 13 | | | | | | | | | | | | | | | | | | | | | | 13 | |
| 14 | | U | | * 50 | | 14 | SM A-2-4(0) | | 69 | 31 | | NLL | - | NPI | 19.8 | 1.47 | 1.8 | | | | | | | | | | | 14 | SPT - 9 SPT Drive - 150mm |
| 15 | | U | End of Log @ 15 (m) | * 50 | | 15 | | | | | | | | | | | | | | | | | | | | | | 15 | SPT - 10 SPT Drive - 100mm |

**Sample Types**
- Disturbed
- Undisturbed
- Shelby / U4
- Core Cutter
- SPT Sample
- Water Sample
- Groundwater Level

**Abbreviations**
- LL : Liquid Limit
- PL : Plastic Limit
- PI : Plastic Index
- NPI : None PI
- C : Cohesion
- Phi : Friction Angle
- C' : Cohesion (CU)
- Phi' : Friction Angle (CU)
- Cc : Cc
- Cs : Cs
- Pc : Pre-Consolidation Pressure
- K : Permeability Coeff.
- w : Moisture Content
- qu : Unconfined Comp. Qu
- F : Fast
- S : Slow
- CD : Consolidated, Drained
- UU : Unconsolidated, Undrained
- CU : Consolidated, Undrained

# Mud Rotary Log BH-02

**Project Info.**
Project : Geotechnical Investigation Works
Client : Techno Consult
Location : Ibrahim Hyderi, Karachi
Job No. : K22-1175-101

**Borehole Info.**
Depth : 15 (m) Elevation : 0.61m from MSL
GWL : 0.8 (m) Easting :
Drill Date : 03.09.2022 Northing :
Logged By : AR Method : Mud Rotary

**Company Info.**
Geotechnical Engineering & Material Testing Laboratory
www.sts.com.pk

| Depth (m) | GWL (m) | Sample Type | Lithology Description | Field Tests (* SPT) | Symbol | USCS / AASHTO | Gravel (%) | Sand (%) | Silt (%) | Clay (%) | LL (%) | PL (%) | PI (%) | w (%) | Dry Unit Weight (gr/cm3) | Bulk | Direct Shear Test: Test Type | C (kg/cm2) | Fi (o) | qu (kg/cm2) | Consolidation: Cc | Cs | Pc (kg/cm2) | Chemical Tests: PH | SO3 | CL | Remarks & Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | **FILLED MATERIAL** *Brownish grey to black, fine to coarse grained sand with garbage* | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | ▽ | U | **SILT** *Brownish grey, stiff, clayey, some sand* | * 12 | | ML A-4(1) | | 27 | 41.1 | 31.9 | 25.4 | 22.1 | 3.3 | 28.6 | 1.4 | 1.8 | | | | | | | | 7.3 | 0.02 | 0.61 | SPT - 1 |
| 2 | | | **SILT** *Brownish grey, soft, fine grained sandy, little clay* | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | | U | | * 4 | | | | | | | | | | | | | | | | | | | | | | | SPT - 2 |
| 4 | | U | | * 4 | | ML A-4(0) | | 35.4 | 53 | 11.6 | NLL | - | NPI | 34 | 1.35 | 1.8 | | | | | | | | | | | SPT - 3 |
| 5 | | | **CLAY / SILT** *Greyish brown, soft to very stiff, silty clay / clayey silt, little sand* | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | | U | | * 4 | | | | | | | | | | | | | | | | | | | | | | | SPT - 4 |
| 7 | | U | | * 18 | | CL-ML A-4(4) | | 12.6 | 48.9 | 38.5 | 26.1 | 20.1 | 6 | 22.2 | 1.44 | 1.8 | | | | | | | | | | | SPT - 5 |
| 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | | U | | * 19 | | | | | | | | | | | | | | | | | | | | | | | SPT - 6 |
| 10 | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Sample Types**
- ● Disturbed
- + Undisturbed
- ☐ Shelby / U4
- ■ Core Cutter
- SPT Sample
- Water Sample
- ▽ Groundwater Level

**Abbreviations**
- LL : Liquid Limit
- PL : Plastic Limit
- PI : Plastic Index
- NPI : None PI
- C : Cohesion
- Phi : Friction Angle
- C' : Cohesion (CU)
- Phi' : Friction Angle (CU)
- Cc : Cc
- Cs : Cs
- Pc : Pre-Consolidation Pressure
- K : Permeability Coeff.
- w : Moisture Content
- qu : Unconfined Comp. Qu
- F : Fast
- S : Slow
- CD : Consolidated, Drained
- UU : Unconsolidated, Undrained
- CU : Consolidated, Undrained

# Mud Rotary Log BH-02

**Project Info.**
Project : Geotechnical Investigation Works
Client : Techno Consult
Location : Ibrahim Hyderi, Karachi
Job No. : K22-1175-101

**Borehole Info.**
Depth : 15 (m) Elevation : 0.61m from MSL
GWL : 0.8 (m) Easting :
Drill Date : 03.09.2022 Northing :
Logged By : AR Method : Mud Rotary

**Company Info.**
Geotechnical Engineering & Material Testing Laboratory
www.sts.com.pk

| Depth (m) | GWL (m) | Sample Type | Lithology Description | Field Tests (* SPT) | Symbol | Depth (m) | USCS / AASHTO | Sieve Analysis Test: Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Atterberg Limits: LL (%) | PL (%) | PI (%) | w (%) | Dry Unit Weight (gr/cm3) | Bulk | Direct Shear Test: Test Type | C (kg/cm2) | Fi (o) | qu (kg/cm2) | Consolidation: Cc | Cs | Pc (kg/cm2) | Chemical Tests: PH | SO3 | CL | Depth (m) | Remarks & Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | | U | **SILT** *Greyish brown, very stiff to hard, some clay & little sand* | * 30 | | 10 | ML A-4(0) | | 11.4 | 66.6 | 22 | NLL | - | NPI | 17.7 | 1.52 | 1.8 | | | | | | | | | | | 10 | SPT - 7 |
| 11 | | | | | | 11 | | | | | | | | | | | | | | | | | | | | | | 11 | |
| 12 | | U | | * 50 | | 12 | | | | | | | | | | | | | | | | | | | | | | 12 | SPT - 8<br>SPT Drive - 150mm |
| 13 | | U | **SAND** *Greyish brown, very dense, silty fine grained* | * 50 | | 13 | SM A-2-4(0) | | 69.1 | 30.9 | | NLL | - | NPI | 24.2 | 1.52 | 1.9 | | | | | | | | | | | 13 | SPT - 9<br>SPT Drive - 125mm |
| 14 | | | | | | 14 | | | | | | | | | | | | | | | | | | | | | | 14 | |
| 15 | | U | End of Log @ 15 (m) | * 50 | | 15 | | | | | | | | | | | | | | | | | | | | | | 15 | SPT - 10<br>SPT Drive - 150mm |

**Sample Types**
- Disturbed
- Undisturbed
- Shelby / U4
- Core Cutter
- SPT Sample
- Water Sample
- Groundwater Level

**Abbreviations**
- LL : Liquid Limit
- PL : Plastic Limit
- PI : Plastic Index
- NPI : None PI
- C : Cohesion
- Phi : Friction Angle
- C' : Cohesion (CU)
- Phi' : Friction Angle (CU)
- Cc : Cc
- Cs : Cs
- Pc : Pre-Consolidation Pressure
- K : Permeability Coeff.
- w : Moisture Content
- qu : Unconfined Comp. Qu
- F : Fast
- S : Slow
- CD : Consolidated, Drained
- UU : Unconsolidated, Undrained
- CU : Consolidated, Undrained

# Mud Rotary Log BH-03

**Project Info.**
Project : Geotechnical Investigation Works
Client : Techno Consult
Location : Ibrahim Hyderi, Karachi
Job No. : K22-1175-101

**Borehole Info.**
Depth : 15 (m) Elevation : 0.61m from MSL
GWL : 1.1 (m) Easting :
Drill Date : 03.09.2022 Northing :
Logged By : AR Method : Mud Rotary

**Company Info.**
Geotechnical Engineering & Material Testing Laboratory
www.sts.com.pk

| Depth (m) | GWL (m) | Sample Type | Lithology Description | Field Tests (* SPT) | Symbol | Depth (m) | USCS / AASHTO | Gravel (%) | Sand (%) | Silt (%) | Clay (%) | LL (%) | PL (%) | PI (%) | w (%) | Dry Unit Weight (gr/cm3) | Bulk | Direct Shear Test: Test Type | C (kg/cm2) | Fi (o) | qu (kg/cm2) | Consolidation: Cc | Cs | Pc (kg/cm2) | Chemical Tests: PH | SO3 | CL | Depth (m) | Remarks & Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | **FILLED MATERIAL** *Brownish grey, fine to coarse grained sand with garbage* | | | 0 | | | | | | | | | | | | | | | | | | | | | | 0 | |
| 1 | ▽ | U | **SAND** *Brownish grey, loose, fine to medium grained, some silt, little gravel* | * 7 | | 1 | SM A-2-4(0) | 17.5 | 60.7 | 21.8 | | NLL | - | NPI | 15.2 | 1.51 | 1.7 | | | | | | | | 7.6 | 0.02 | 0.42 | 1 | SPT - 1 |
| 2 | | | **CLAY** *Greyish brown, soft to medium stiff, clayey, traces of sand* | | | 2 | | | | | | | | | | | | | | | | | | | | | | 2 | |
| 3 | | U | | * 5 | | 3 | | | | | | | | | | | | | | | | | | | | | | 3 | SPT - 2 |
| 4 | | | | | | 4 | | | | | | | | | | | | | | | | | | | | | | 4 | |
| 5 | | U | | * 2 | | 5 | CL A-4(7) | | 5.2 | 42.3 | 52.5 | 29.3 | 21.3 | 8 | 36.3 | 1.33 | 1.8 | | | | | | | | | | | 5 | SPT - 3 |
| 6 | | | **SILT** *Greyish brown, stiff to very stiff, fine grained sandy* | | | 6 | | | | | | | | | | | | | | | | | | | | | | 6 | |
| 7 | | U | | * 14 | | 7 | | | | | | | | | | | | | | | | | | | | | | 7 | SPT - 4 |
| 8 | | | | | | 8 | | | | | | | | | | | | | | | | | | | | | | 8 | |
| 9 | | U | | * 20 | | 9 | ML A-4(0) | | 37.3 | 62.7 | | NLL | - | NPI | 26.8 | 1.4 | 1.8 | | | | | | | | | | | 9 | SPT - 5 |
| 10 | | | | | | 10 | | | | | | | | | | | | | | | | | | | | | | 10 | |
| | | U | | * 9 | | | | | | | | | | | | | | | | | | | | | | | | | SPT - 6 |

**Sample Types**
- ● Disturbed
- + Undisturbed
- ☐ Shelby / U4
- ■ Core Cutter
- U SPT Sample
- Water Sample
- ▽ Groundwater Level

**Abbreviations**
- LL : Liquid Limit
- PL : Plastic Limit
- PI : Plastic Index
- NPI : None PI
- C : Cohesion
- Phi : Friction Angle
- C' : Cohesion (CU)
- Phi' : Friction Angle (CU)
- Cc : Cc
- Cs : Cs
- Pc : Pre-Consolidation Pressure
- K : Permeability Coeff.
- w : Moisture Content
- qu : Unconfined Comp. Qu
- F : Fast
- S : Slow
- CD : Consolidated, Drained
- UU : Unconsolidated, Undrained
- CU : Consolidated, Undrained

# Mud Rotary Log BH-03

**Project Info.**
Project : Geotechnical Investigation Works
Client : Techno Consult
Location : Ibrahim Hyderi, Karachi
Job No. : K22-1175-101

**Borehole Info.**
Depth : 15 (m) Elevation : 0.61m from MSL
GWL : 1.1 (m) Easting :
Drill Date : 03.09.2022 Northing :
Logged By : AR Method : Mud Rotary

**Company Info.**
Geotechnical Engineering & Material Testing Laboratory
www.sts.com.pk

| Depth (m) | GWL (m) | Sample Type | Lithology Description | Field Tests (* SPT) | Symbol | Depth (m) | USCS / AASHTO | Sieve Analysis Test: Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Atterberg Limits: LL (%) | PL (%) | PI (%) | w (%) | Dry Unit Weight (gr/cm3) | Bulk | Direct Shear Test: Test Type | C (kg/cm2) | Fi (o) | qu (kg/cm2) | Consolidation: Cc | Cs | Pc (kg/cm2) | Chemical Tests: PH | SO3 | CL | Depth (m) | Remarks & Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | | U | **CLAY** *Greyish brown, stiff to hard, silty, traces of sand* | * 11 | | 10 | | | | | | | | | | | | | | | | | | | | | | 10 | SPT - 7 |
| 11 | | | | | | 11 | | | | | | | | | | | | | | | | | | | | | | 11 | |
| 12 | | U | | * 43 | | 12 | CL A-6(11) | | 5.8 | 43.9 | 50.3 | 33 | 20.9 | 12.1 | 16.1 | 1.51 | 1.8 | | | | | | | | | | | 12 | SPT - 8 |
| 13 | | U | | * 50 | | 13 | | | | | | | | | | | | | | | | | | | | | | 13 | SPT - 9<br>SPT Drive - 100mm |
| 14 | | | | | | 14 | | | | | | | | | | | | | | | | | | | | | | 14 | |
| 15 | | U | End of Log @ 15 (m) | * 50 | | 15 | CL A-6(10) | | 4.4 | 40.3 | 55.3 | 30.8 | 20.5 | 10.3 | 17 | 1.39 | 1.6 | | | | | | | | | | | 15 | SPT - 10<br>SPT Drive - 50mm |

**Sample Types**
● Disturbed
+ Undisturbed
☐ Shelby / U4
■ Core Cutter
SPT Sample
Water Sample
Groundwater Level

**Abbreviations**
LL : Liquid Limit
PL : Plastic Limit
PI : Plastic Index
NPI : None PI
C : Cohesion
Phi : Friction Angle
C' : Cohesion (CU)
Phi' : Friction Angle (CU)
Cc : Cc
Cs : Cs
Pc : Pre-Consolidation Pressure
K : Permeability Coeff.
w : Moisture Content
qu : Unconfined Comp. Qu
F : Fast
S : Slow
CD : Consolidated, Drained
UU : Unconsolidated, Undrained
CU : Consolidated, Undrained

**Appendix C**

# Laboratory Test Results

# Summary of Lab. Tests

Project : Geotechnical Investigation Works
Client : Techno Consult
Job No.: K22-1175-101
Location : Ibrahim Hyderi, Karachi

**Sieve Analysis Test**

| Borehole | Sample Depth (m) | Soil Class | D10 mm | D30 mm | D60 mm | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | Cobble (%) | LL | PL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BH-01 | 1.5 | SP-SM A-1-b(0) | 0.077 | 0.168 | 0.219 | | 9.7 | 90.3 | | | - | - |
| BH-01 | 4.5 | ML A-4(5) | | | | 44.6 | 52.6 | 2.8 | | | 31.1 | 26.2 |
| BH-01 | 6 | ML A-4(0) | | | | 18.3 | 72.1 | 9.6 | | | - | - |
| BH-01 | 7.5 | CL A-4(8) | | | | 52.3 | 45.5 | 2.2 | | | 29.9 | 21.1 |
| BH-01 | 13.5 | SM A-2-4(0) | | | 0.153 | | 31 | 69 | | | - | - |
| BH-02 | 1.5 | ML A-4(1) | | | | 31.9 | 41.1 | 27 | | | 25.4 | 22.1 |
| BH-02 | 4.5 | ML A-4(0) | | | | 11.6 | 53 | 35.4 | | | - | - |
| BH-02 | 7.5 | CL-ML A-4(4) | | | | 38.5 | 48.9 | 12.6 | | | 26.1 | 20.1 |
| BH-02 | 10.5 | ML A-4(0) | | | | 22 | 66.6 | 11.4 | | | - | - |
| BH-02 | 13.5 | SM A-2-4(0) | | | 0.198 | | 30.9 | 69.1 | | | - | - |
| BH-03 | 1.5 | SM A-2-4(0) | | 0.114 | 0.218 | | 21.8 | 60.7 | 17.5 | | - | - |
| BH-03 | 4.5 | CL A-4(7) | | | | 52.5 | 42.3 | 5.2 | | | 29.3 | 21.3 |
| BH-03 | 7.5 | ML A-4(0) | | | | | 62.7 | 37.3 | | | - | - |
| BH-03 | 12 | CL A-6(11) | | | | 50.3 | 43.9 | 5.8 | | | 33 | 20.9 |
| BH-03 | 15 | CL A-6(10) | | | | 55.3 | 40.3 | 4.4 | | | 30.8 | 20.5 |

**ATTERBERG LIMITS TEST**

| Borehole | Sample Depth (m) | Soil Class | Liquid Limit (LL) | Plastic Limit (PL) |
|---|---|---|---|---|
| BH-01 | 4.5 | ML A-4(5) | 31.1 | 26.2 |
| BH-01 | 7.5 | CL A-4(8) | 29.9 | 21.1 |
| BH-02 | 1.5 | ML A-4(1) | 25.4 | 22.1 |
| BH-02 | 7.5 | CL-ML A-4(4) | 25.1 | 20.1 |
| BH-03 | 4.5 | CL A-4(7) | 29.3 | 21.3 |
| BH-03 | 12 | CL A-6(11) | 33 | 20.9 |
| BH-03 | 15 | CL A-6(10) | 30.8 | 20.5 |

**Density & Moisture Test**

# Summary of Lab. Tests

Project : Geotechnical Investigation Works
Client : Techno Consult
Job No.: K22-1175-101
Location : Ibrahim Hyderi, Karachi

| Borehole | Sample Depth (m) | Soil Class | Moisture Content (%) | Dry Density (gr/cm3) |
|---|---|---|---|---|
| BH-01 | 1.5 | SP-SM<br>A-1-b(0) | 15.62 | 1.5 |
| BH-01 | 4.5 | ML<br>A-4(5) | 30.67 | 1.315 |
| BH-01 | 6 | ML<br>A-4(0) | 25.57 | 1.34 |
| BH-01 | 7.5 | CL<br>A-4(8) | 27.4 | 1.27 |
| BH-01 | 13.5 | SM<br>A-2-4(0) | 19.75 | 1.47 |
| BH-02 | 1.5 | ML<br>A-4(1) | 28.64 | 1.405 |
| BH-02 | 4.5 | ML<br>A-4(0) | 34.03 | 1.347 |
| BH-02 | 7.5 | CL-ML<br>A-4(4) | 22.23 | 1.438 |
| BH-02 | 10.5 | ML<br>A-4(0) | 17.74 | 1.518 |
| BH-02 | 13.5 | SM<br>A-2-4(0) | 24.23 | 1.516 |
| BH-03 | 1.5 | SM<br>A-2-4(0) | 15.17 | 1.513 |
| BH-03 | 4.5 | CL<br>A-4(7) | 36.32 | 1.33 |
| BH-03 | 7.5 | ML<br>A-4(0) | 26.75 | 1.401 |
| BH-03 | 12 | CL<br>A-6(11) | 16.12 | 1.515 |
| BH-03 | 15 | CL<br>A-6(10) | 16.97 | 1.395 |

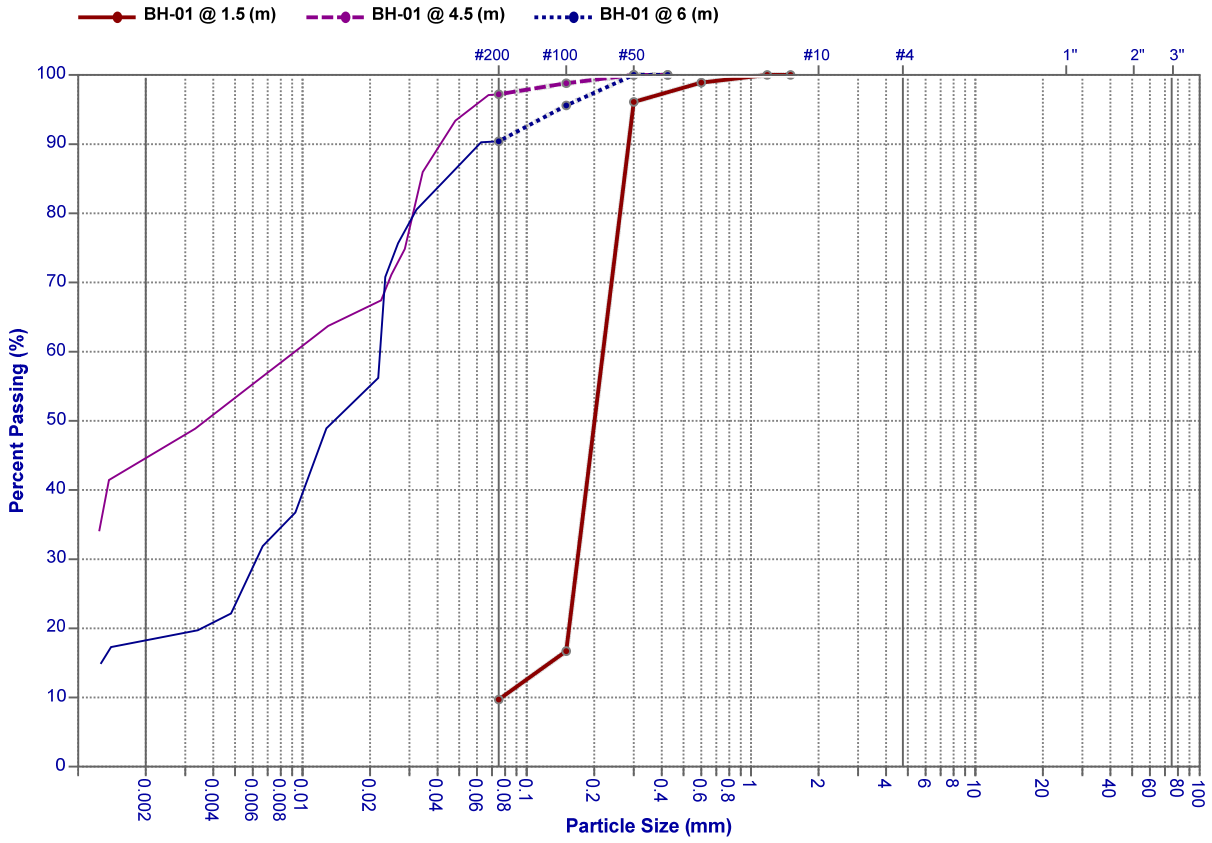
**Chemical Test Results**

| Borehole | Sample Depth (m) | Soil Class | # | Value |
|---|---|---|---|---|
| BH-01 | 1.5 | SP-SM<br>A-1-b(0) | 9 | 0.51 |
| BH-01 | 1.5 | SP-SM<br>A-1-b(0) | 6 | 0.03 |
| BH-01 | 1.5 | SP-SM<br>A-1-b(0) | 2 | 7.45 |
| BH-02 | 1.5 | ML<br>A-4(1) | 9 | 0.61 |
| BH-02 | 1.5 | ML<br>A-4(1) | 6 | 0.02 |
| BH-02 | 1.5 | ML<br>A-4(1) | 2 | 7.3 |
| BH-03 | 1.5 | SM<br>A-2-4(0) | 9 | 0.42 |
| BH-03 | 1.5 | SM<br>A-2-4(0) | 6 | 0.02 |
| BH-03 | 1.5 | SM<br>A-2-4(0) | 2 | 7.6 |

# Sieve Analysis Test

Project : Geotechnical Investigation Works
Client : Techno Consult
Job No.: K22-1175-101
Location : Ibrahim Hyderi, Karachi

ASTM C136




**Particle Distribution (%)**

| Clay | Silt | Sand | Gravel | Cobble |
|---|---|---|---|---|
| - | 9.7 | 90.3 | - | - |
| 44.6 | 52.6 | 2.8 | - | - |
| 18.3 | 72.1 | 9.6 | - | - |

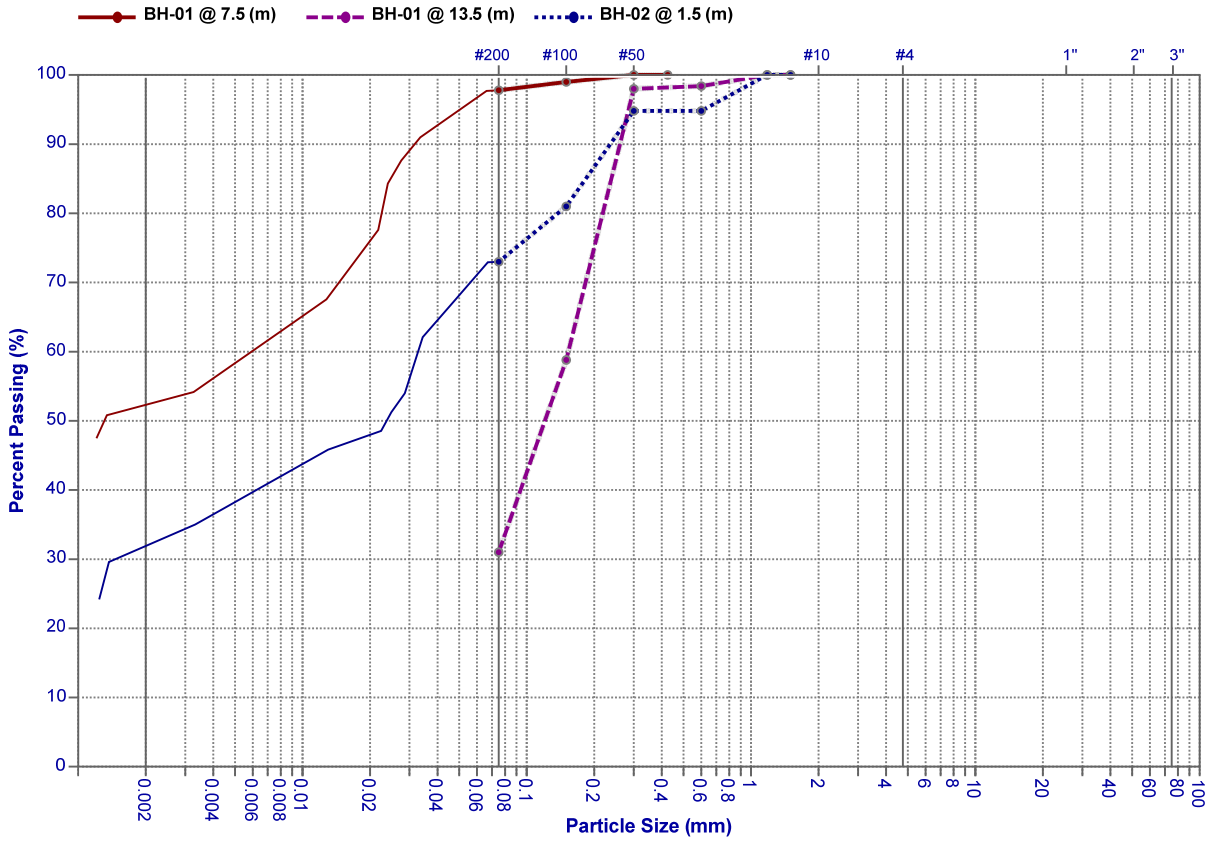
**Classification**

| Borehole | Sample Depth (m) | D10 (mm) | D30 (mm) | D50 (mm) | D60 (mm) | Cc | Cu | LL (%) | PI (%) | Disp. (%) | USCS | AASHTO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BH-01 | 1.5 | 0.077 | 0.168 | 0.201 | 0.219 | 1.674 | 2.844 | - | - | N/A | SP-SM | A-1-b(0) |
| BH-01 | 4.5 | 0.001 | 0.001 | 0.004 | 0.009 | 0.111 | 9 | 31.1 | 4.9 | N/A | ML | A-4(5) |
| BH-01 | 6 | 0.001 | 0.006 | 0.014 | 0.022 | 1.636 | 22 | - | - | N/A | ML | A-4(0) |

# Sieve Analysis Test

Project : Geotechnical Investigation Works
Client : Techno Consult
Job No.: K22-1175-101
Location : Ibrahim Hyderi, Karachi

ASTM C136




**Particle Distribution (%)**

| Clay | Silt | Sand | Gravel | Cobble |
|---|---|---|---|---|
| 52.3 | 45.5 | 2.2 | - | - |
| - | 31 | 69 | - | - |
| 31.9 | 41.1 | 27 | - | - |

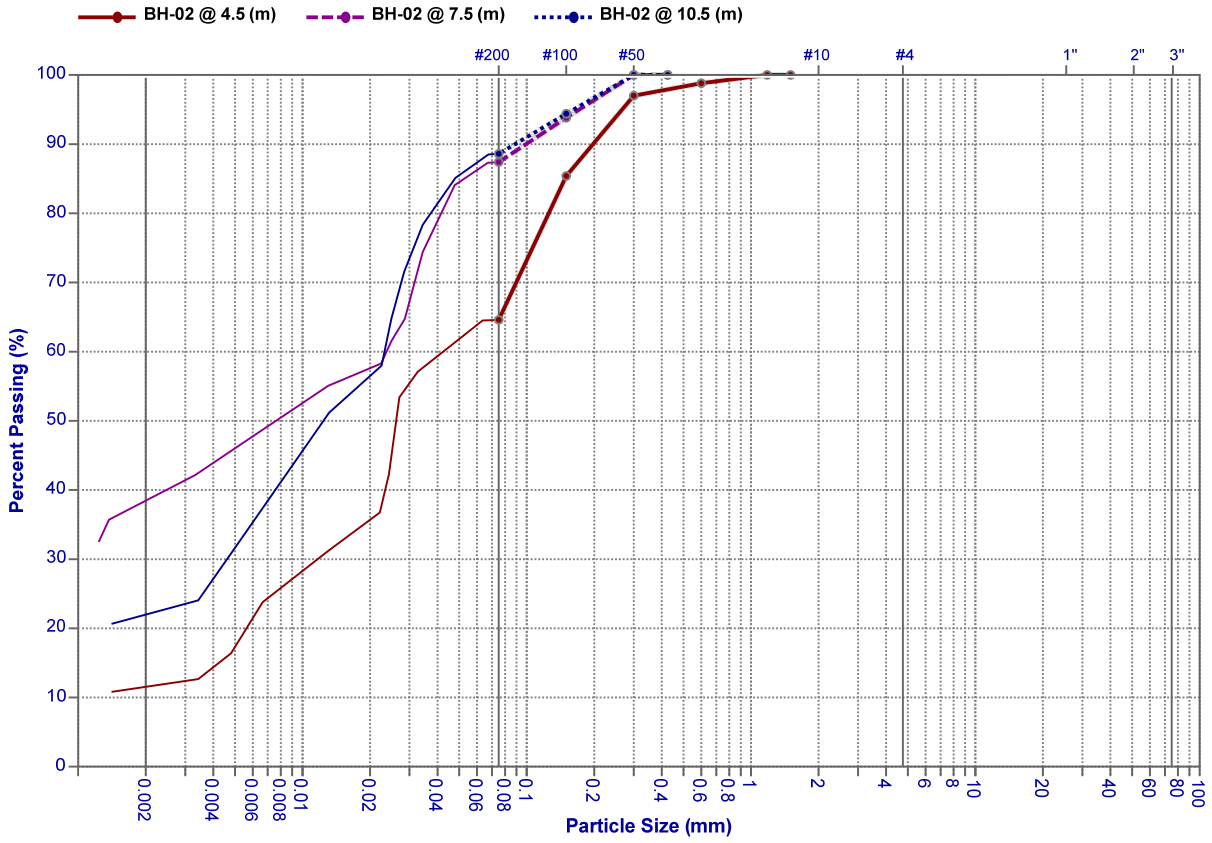
**Classification**

| Borehole | Sample Depth (m) | D10 (mm) | D30 (mm) | D50 (mm) | D60 (mm) | Cc | Cu | LL (%) | PI (%) | Disp. (%) | USCS | AASHTO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BH-01 | 7.5 | 0.001 | 0.001 | 0.001 | 0.006 | 0.167 | 6 | 29.9 | 8.8 | N/A | CL | A-4(8) |
| BH-01 | 13.5 | - | - | 0.12 | 0.153 | - | - | - | - | N/A | SM | A-2-4(0) |
| BH-02 | 1.5 | 0.001 | 0.001 | 0.024 | 0.033 | 0.03 | 33 | 25.4 | 3.3 | N/A | ML | A-4(1) |

# Sieve Analysis Test

Project : Geotechnical Investigation Works
Client : Techno Consult
Job No.: K22-1175-101
Location : Ibrahim Hyderi, Karachi

ASTM C136




**Particle Distribution (%)**

| Clay | Silt | Sand | Gravel | Cobble |
|---|---|---|---|---|
| 11.6 | 53 | 35.4 | - | - |
| 38.5 | 48.9 | 12.6 | - | - |
| 22 | 66.6 | 11.4 | - | - |

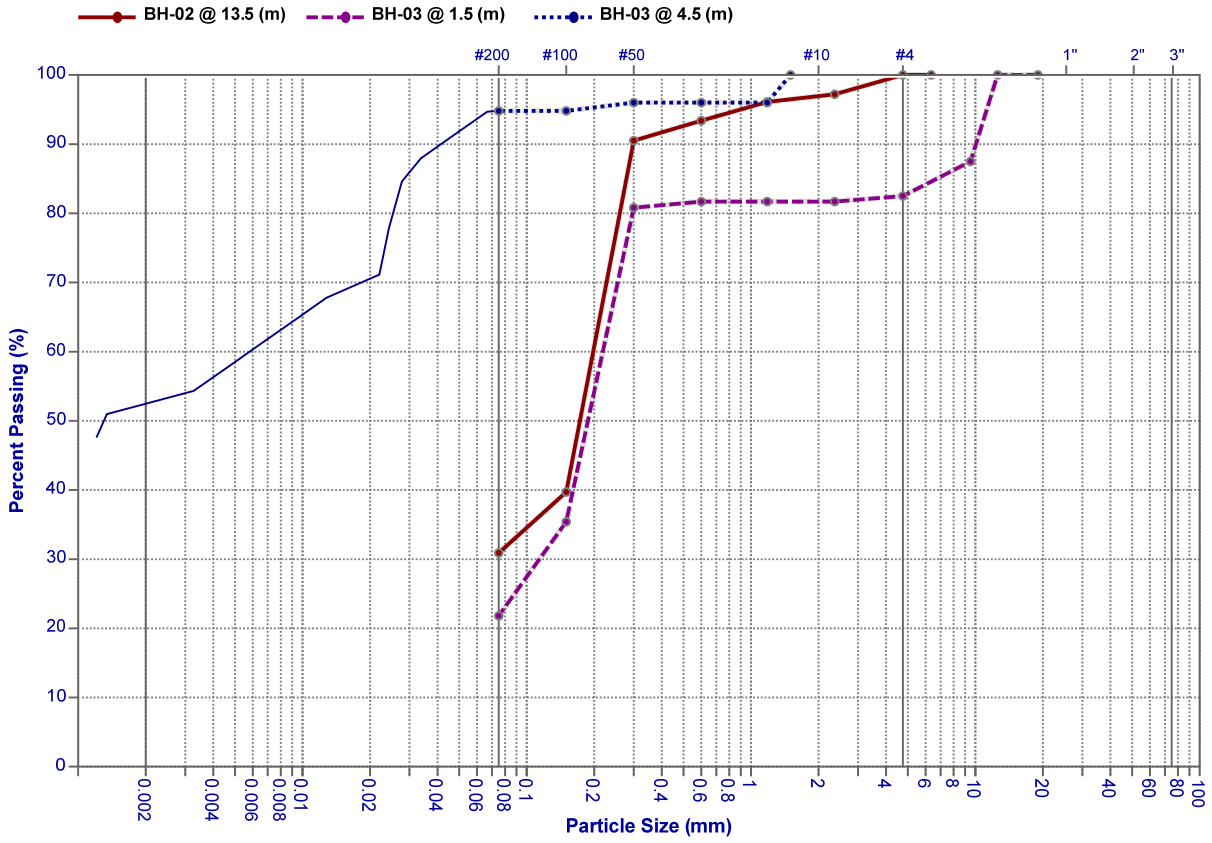
**Classification**

| Borehole | Sample Depth (m) | D10 (mm) | D30 (mm) | D50 (mm) | D60 (mm) | Cc | Cu | LL (%) | PI (%) | Disp. (%) | USCS | AASHTO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BH-02 | 4.5 | 0.001 | 0.012 | 0.026 | 0.042 | 3.429 | 42 | - | - | N/A | ML | A-4(0) |
| BH-02 | 7.5 | 0.001 | 0.001 | 0.008 | 0.024 | 0.042 | 24 | 26.1 | 6 | N/A | CL-ML | A-4(4) |
| BH-02 | 10.5 | 0.001 | 0.005 | 0.012 | 0.023 | 1.087 | 23 | - | - | N/A | ML | A-4(0) |

# Sieve Analysis Test

Project : Geotechnical Investigation Works
Client : Techno Consult
Job No.: K22-1175-101
Location : Ibrahim Hyderi, Karachi

ASTM C136




**Particle Distribution (%)**

| Clay | Silt | Sand | Gravel | Cobble |
|---|---|---|---|---|
| - | 30.9 | 69.1 | - | - |
| - | 21.8 | 60.7 | 17.5 | - |
| 52.5 | 42.3 | 5.2 | - | - |

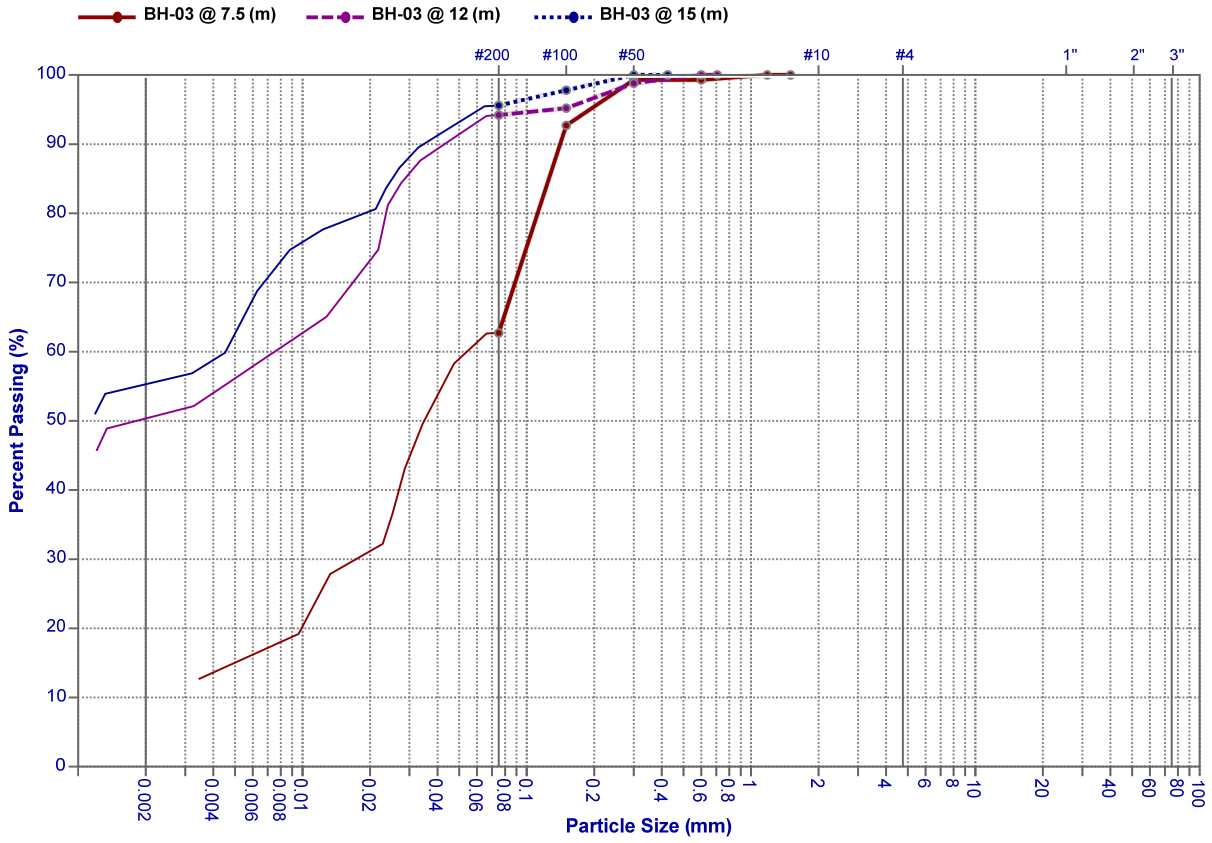
**Classification**

| Borehole | Sample Depth (m) | D10 (mm) | D30 (mm) | D50 (mm) | D60 (mm) | Cc | Cu | LL (%) | PI (%) | Disp. (%) | USCS | AASHTO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BH-02 | 13.5 | - | - | 0.173 | 0.198 | - | - | - | - | N/A | SM | A-2-4(0) |
| BH-03 | 1.5 | - | 0.114 | 0.187 | 0.218 | 0.795 | - | - | - | N/A | SM | A-2-4(0) |
| BH-03 | 4.5 | 0.001 | 0.001 | 0.001 | 0.006 | 0.167 | 6 | 29.3 | 8 | N/A | CL | A-4(7) |

# Sieve Analysis Test

Project : Geotechnical Investigation Works
Client : Techno Consult
Job No.: K22-1175-101
Location : Ibrahim Hyderi, Karachi

ASTM C136




**Particle Distribution (%)**

| Clay | Silt | Sand | Gravel | Cobble |
|---|---|---|---|---|
| - | 62.7 | 37.3 | - | - |
| 50.3 | 43.9 | 5.8 | - | - |
| 55.3 | 40.3 | 4.4 | - | - |

**Classification**

| Borehole | Sample Depth (m) | D10 (mm) | D30 (mm) | D50 (mm) | D60 (mm) | Cc | Cu | LL (%) | PI (%) | Disp. (%) | USCS | AASHTO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BH-03 | 7.5 | - | - | - | - | - | - | - | - | N/A | ML | A-4(0) |
| BH-03 | 12 | 0.001 | 0.001 | 0.002 | 0.008 | 0.125 | 8 | 33 | 12.1 | N/A | CL | A-6(11) |
| BH-03 | 15 | 0.001 | 0.001 | 0.001 | 0.005 | 0.2 | 5 | 30.8 | 10.3 | N/A | CL | A-6(10) |

# ATTERBERG LIMITS TEST

| | | | |
|---|---|---|---|
| Project : | Geotechnical Investigation Works | Borehole : | BH-01 |
| Client : | Techno Consult | Sample Depth : | 4.5 (m) |
| Job No.: | K22-1175-101 | Classification : | ML \| A-4(5) |
| Location : | Ibrahim Hyderi, Karachi | Sample Type : | SPT Split Spoon |

ASTM D2216-90, D854

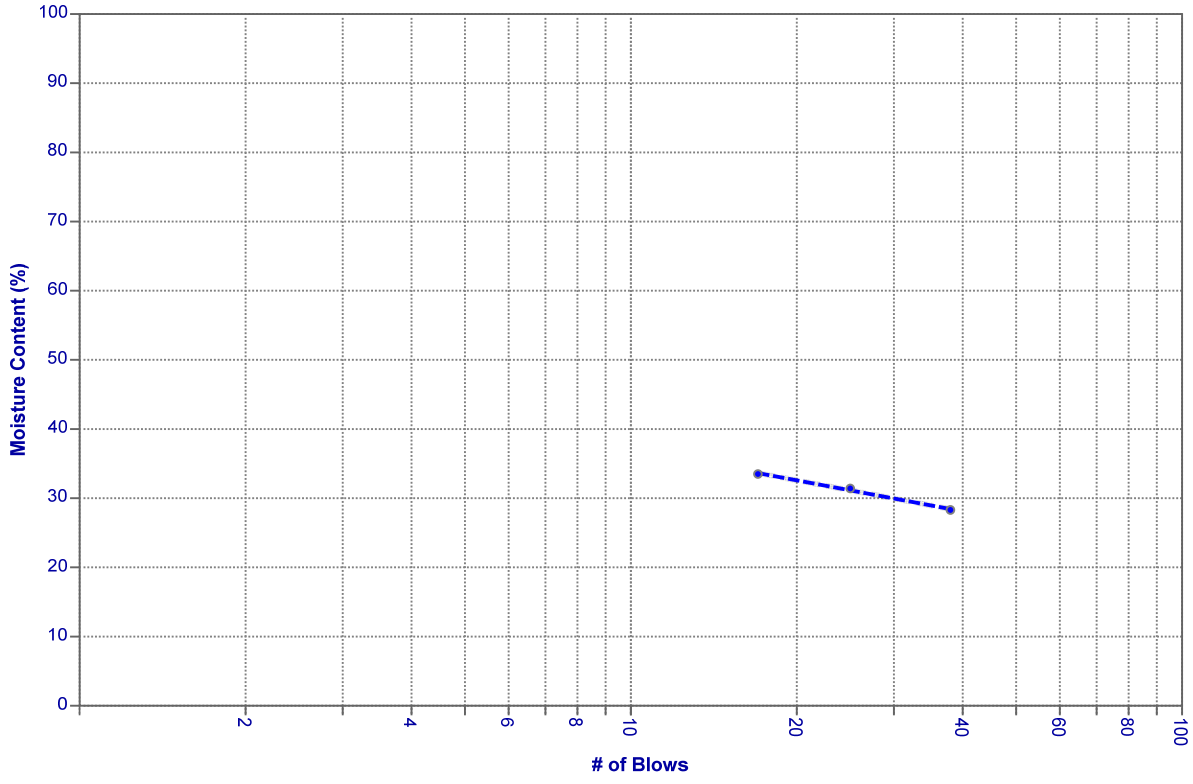
**Liquid Limit**

| Cont. W (gr) | Cont. + Wet Soil W (gr) | Cont. + Dry Soil W (gr) | # of Blows | Moisture Content (%) |
|---|---|---|---|---|
| 19.62 | 39.52 | 34.53 | 17 | 33.5 |
| 10.35 | 35.01 | 29.12 | 25 | 31.4 |
| 10.1 | 34.32 | 28.98 | 38 | 28.3 |
| | | | | - |

**Plastic Limit**

| Cont. W (gr) | Cont. + Wet Soil W (gr) | Cont. + Dry Soil W (gr) | Moisture Content (%) |
|---|---|---|---|
| 20.28 | 31.85 | 29.45 | 26.2 |

**LL = 31.1 %** **PL = 26.2 %** **PI=4.9**




USCS Soil Description : Low Plasticity Silt With Sand
AASHTO Soil Description : A-4, Silty soils (5)

Tested By :

# ATTERBERG LIMITS TEST

| | | | |
|---|---|---|---|
| Project : | Geotechnical Investigation Works | Borehole : | BH-01 |
| Client : | Techno Consult | Sample Depth : | 7.5 (m) |
| Job No.: | K22-1175-101 | Classification : | CL \| A-4(8) |
| Location : | Ibrahim Hyderi, Karachi | Sample Type : | SPT Split Spoon |

ASTM D2216-90, D854

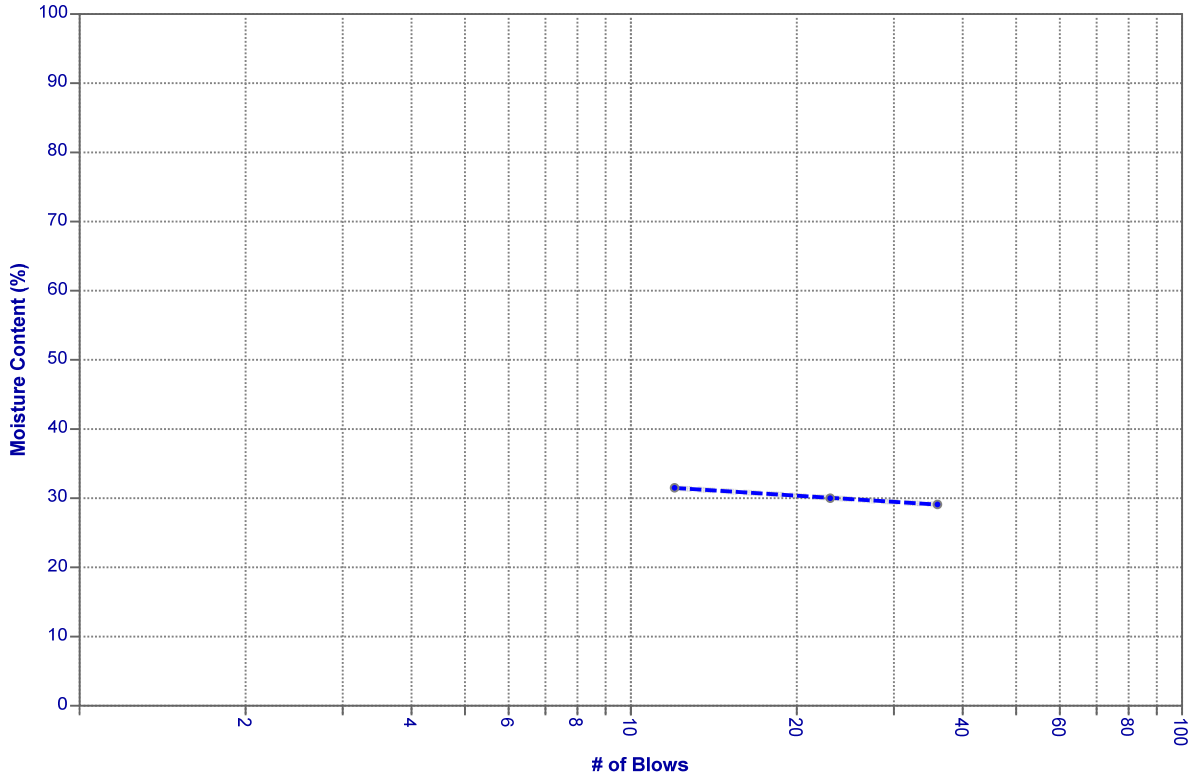
**Liquid Limit**

| Cont. W (gr) | Cont. + Wet Soil W (gr) | Cont. + Dry Soil W (gr) | # of Blows | Moisture Content (%) |
|---|---|---|---|---|
| 24.95 | 74.76 | 62.83 | 12 | 31.5 |
| 32.3 | 78.48 | 67.81 | 23 | 30 |
| 32.92 | 85.67 | 73.77 | 36 | 29.1 |
| | | | | - |

**Plastic Limit**

| Cont. W (gr) | Cont. + Wet Soil W (gr) | Cont. + Dry Soil W (gr) | Moisture Content (%) |
|---|---|---|---|
| 16.71 | 46.75 | 41.52 | 21.1 |

**LL = 29.9 %** **PL = 21.1 %** **PI=8.8**




USCS Soil Description : Low Plasticity Clay With Sand
AASHTO Soil Description : A-4, Silty soils (8)

Tested By :

# ATTERBERG LIMITS TEST

| | | | |
|---|---|---|---|
| Project : | Geotechnical Investigation Works | Borehole : | BH-02 |
| Client : | Techno Consult | Sample Depth : | 1.5 (m) |
| Job No.: | K22-1175-101 | Classification : | ML \| A-4(1) |
| Location : | Ibrahim Hyderi, Karachi | Sample Type : | SPT Split Spoon |

ASTM D2216-90, D854

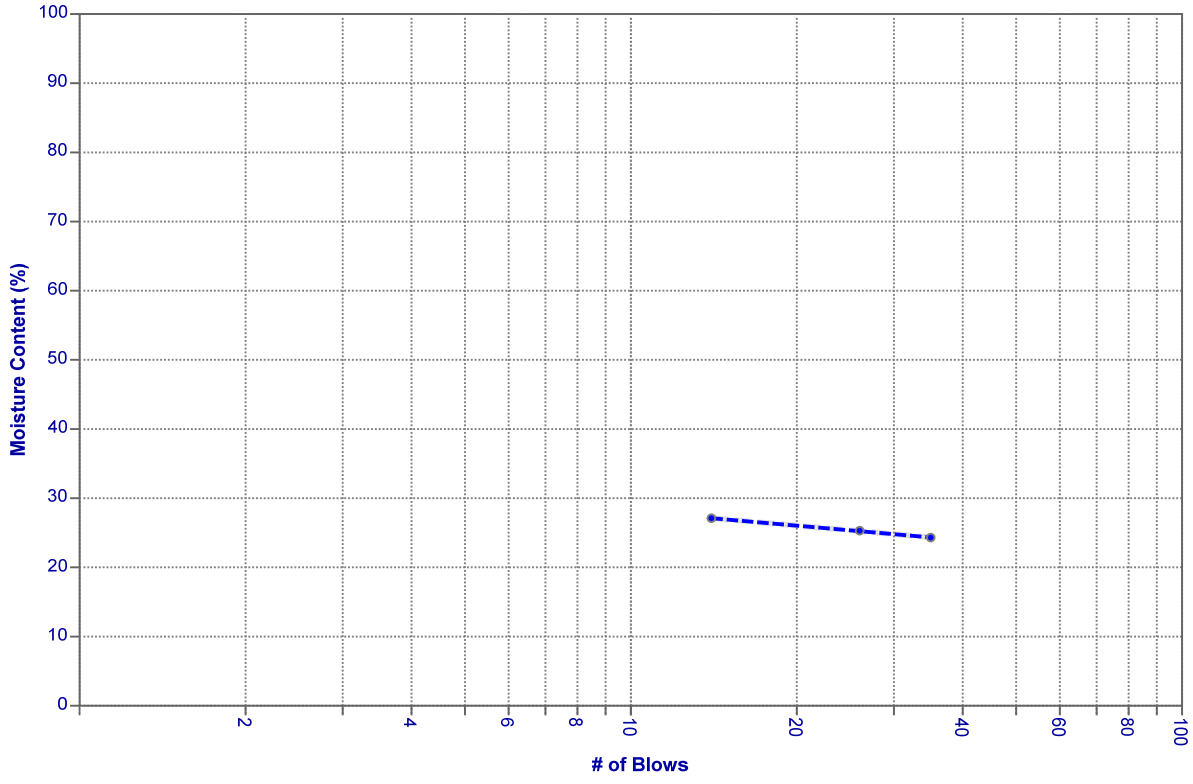
**Liquid Limit**

| Cont. W (gr) | Cont. + Wet Soil W (gr) | Cont. + Dry Soil W (gr) | # of Blows | Moisture Content (%) |
|---|---|---|---|---|
| 23.92 | 70.08 | 60.23 | 14 | 27.1 |
| 32.09 | 76.29 | 67.37 | 26 | 25.3 |
| 32.31 | 82.15 | 72.41 | 35 | 24.3 |
| | | | | - |

**Plastic Limit**

| Cont. W (gr) | Cont. + Wet Soil W (gr) | Cont. + Dry Soil W (gr) | Moisture Content (%) |
|---|---|---|---|
| 16.91 | 47.58 | 42.03 | 22.1 |

**LL = 25.4 %** **PL = 22.1 %** **PI=3.3**




USCS Soil Description : Low Plasticity Silt With Sand
AASHTO Soil Description : A-4, Silty soils (1)

Tested By :

# ATTERBERG LIMITS TEST

| | | | |
|---|---|---|---|
| Project : | Geotechnical Investigation Works | Borehole : | BH-02 |
| Client : | Techno Consult | Sample Depth : | 7.5 (m) |
| Job No.: | K22-1175-101 | Classification : | CL-ML \| A-4(4) |
| Location : | Ibrahim Hyderi, Karachi | Sample Type : | SPT Split Spoon |

ASTM D2216-90, D854

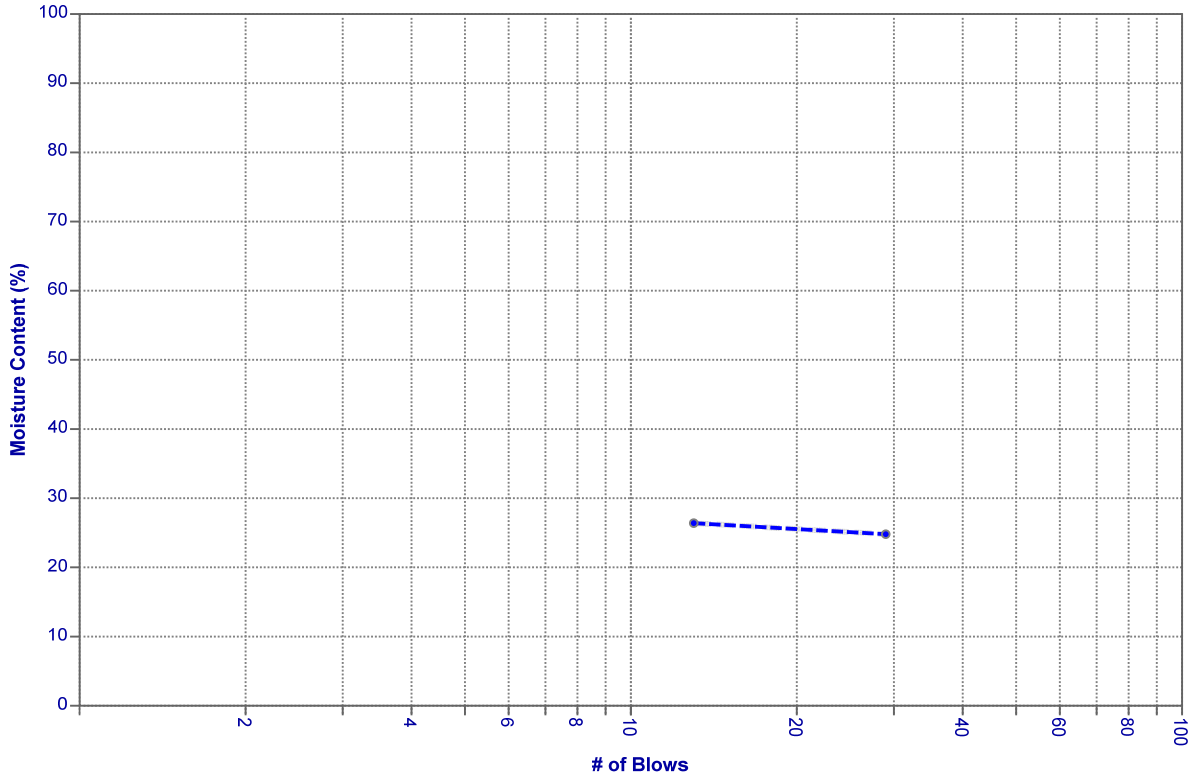
**Liquid Limit**

| Cont. W (gr) | Cont. + Wet Soil W (gr) | Cont. + Dry Soil W (gr) | # of Blows | Moisture Content (%) |
|---|---|---|---|---|
| 13.92 | 34.32 | 30.06 | 13 | 26.4 |
| 10.91 | 30.57 | 26.66 | 29 | 24.8 |
| | | | | - |

**Plastic Limit**

| Cont. W (gr) | Cont. + Wet Soil W (gr) | Cont. + Dry Soil W (gr) | Moisture Content (%) |
|---|---|---|---|
| 19.44 | 28.6 | 27.07 | 20.1 |

**LL = 25.1 %** **PL = 20.1 %** **PI=5**




USCS Soil Description : Silty Clay With Sand
AASHTO Soil Description : A-4, Silty soils (4)

Tested By :

# ATTERBERG LIMITS TEST

| | | | |
|---|---|---|---|
| Project : | Geotechnical Investigation Works | Borehole : | BH-03 |
| Client : | Techno Consult | Sample Depth : | 4.5 (m) |
| Job No.: | K22-1175-101 | Classification : | CL \| A-4(7) |
| Location : | Ibrahim Hyderi, Karachi | Sample Type : | SPT Split Spoon |

ASTM D2216-90, D854

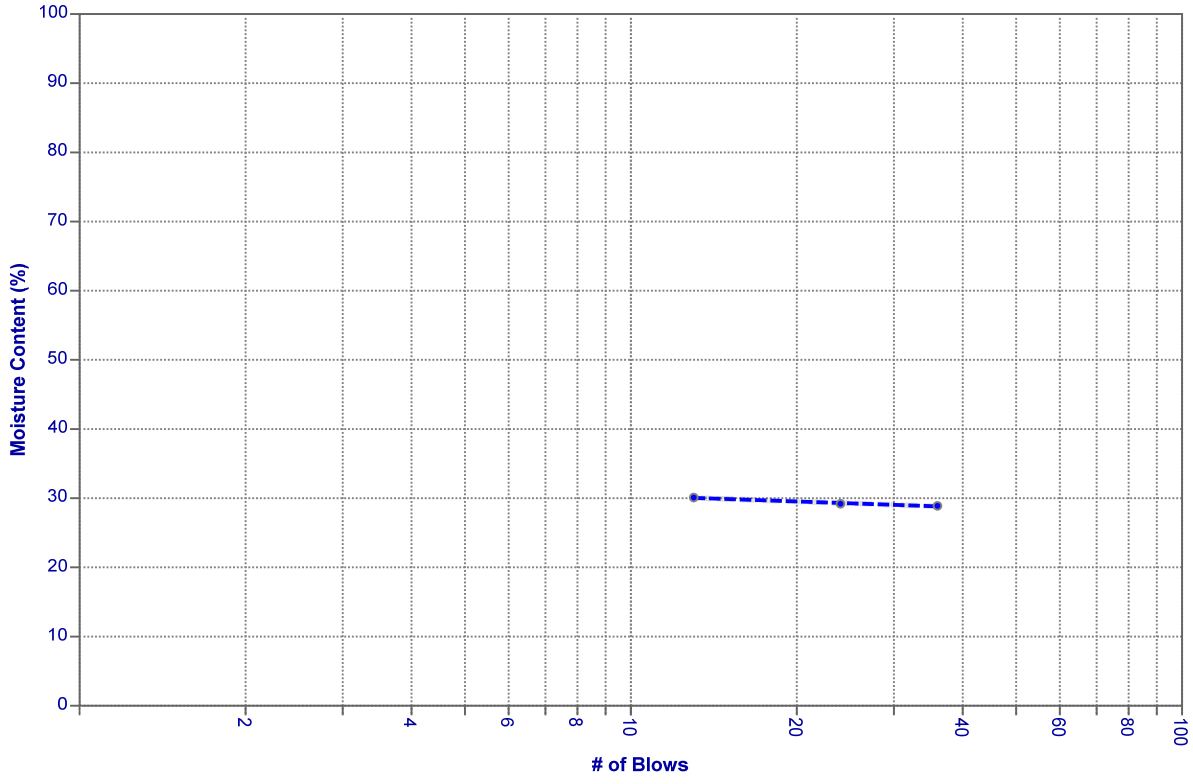
**Liquid Limit**

| Cont. W (gr) | Cont. + Wet Soil W (gr) | Cont. + Dry Soil W (gr) | # of Blows | Moisture Content (%) |
|---|---|---|---|---|
| 24.11 | 71.73 | 60.71 | 13 | 30.1 |
| 32.98 | 79.83 | 69.25 | 24 | 29.2 |
| 32.67 | 84.96 | 73.23 | 36 | 28.9 |
| | | | | - |

**Plastic Limit**

| Cont. W (gr) | Cont. + Wet Soil W (gr) | Cont. + Dry Soil W (gr) | Moisture Content (%) |
|---|---|---|---|
| 17.03 | 47.69 | 42.31 | 21.3 |

**LL = 29.3 %** **PL = 21.3 %** **PI=8**




USCS Soil Description : Low Plasticity Clay With Sand
AASHTO Soil Description : A-4, Silty soils (7)

Tested By :

# ATTERBERG LIMITS TEST

| | | | |
|---|---|---|---|
| Project : | Geotechnical Investigation Works | Borehole : | BH-03 |
| Client : | Techno Consult | Sample Depth : | 12 (m) |
| Job No.: | K22-1175-101 | Classification : | CL \| A-6(11) |
| Location : | Ibrahim Hyderi, Karachi | Sample Type : | SPT Split Spoon |

ASTM D2216-90, D854

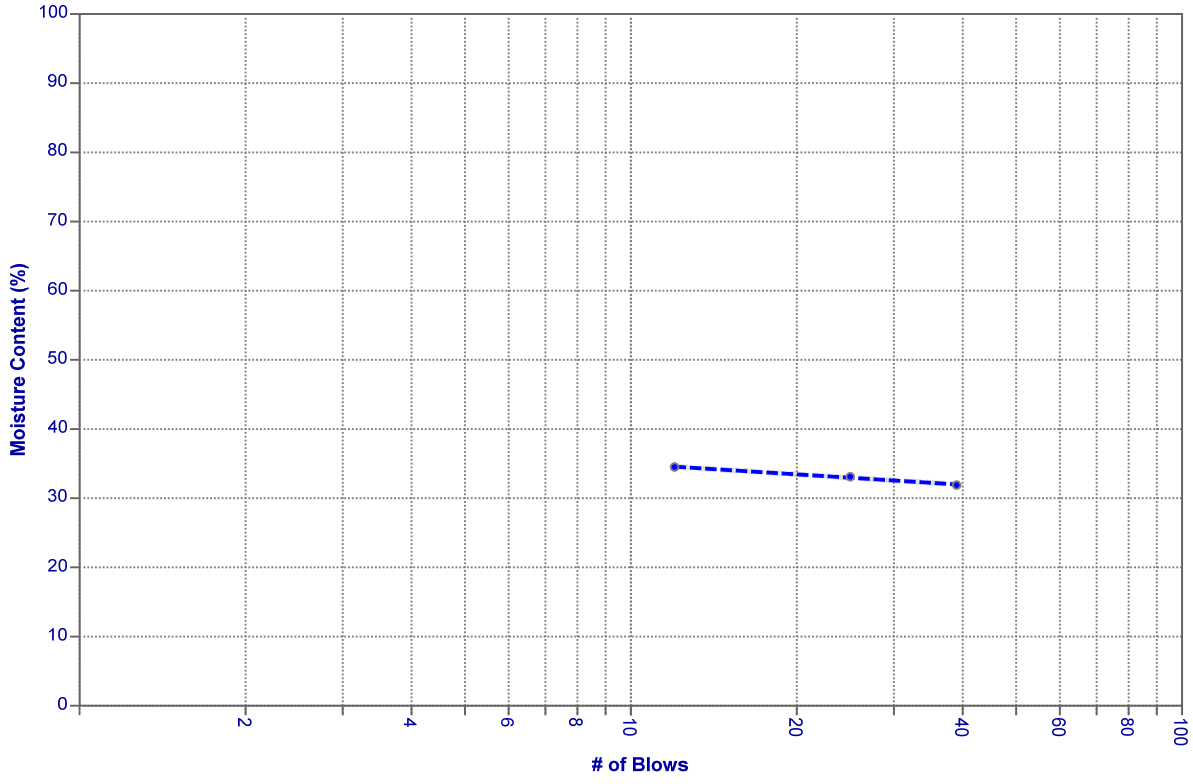
**Liquid Limit**

| Cont. W (gr) | Cont. + Wet Soil W (gr) | Cont. + Dry Soil W (gr) | # of Blows | Moisture Content (%) |
|---|---|---|---|---|
| 23.97 | 72.92 | 60.36 | 12 | 34.5 |
| 32.81 | 80.85 | 68.89 | 25 | 33.1 |
| 32.45 | 85.56 | 72.73 | 39 | 31.9 |
| | | | | - |

**Plastic Limit**

| Cont. W (gr) | Cont. + Wet Soil W (gr) | Cont. + Dry Soil W (gr) | Moisture Content (%) |
|---|---|---|---|
| 16.81 | 46.98 | 41.77 | 20.9 |

**LL = 33 %** **PL = 20.9 %** **PI=12.1**




USCS Soil Description : Low Plasticity Clay With Sand
AASHTO Soil Description : Clayey soils (11)

Tested By :

# ATTERBERG LIMITS TEST

| | | | |
|---|---|---|---|
| Project : | Geotechnical Investigation Works | Borehole : | BH-03 |
| Client : | Techno Consult | Sample Depth : | 15 (m) |
| Job No.: | K22-1175-101 | Classification : | CL \| A-6(10) |
| Location : | Ibrahim Hyderi, Karachi | Sample Type : | SPT Split Spoon |

ASTM D2216-90, D854

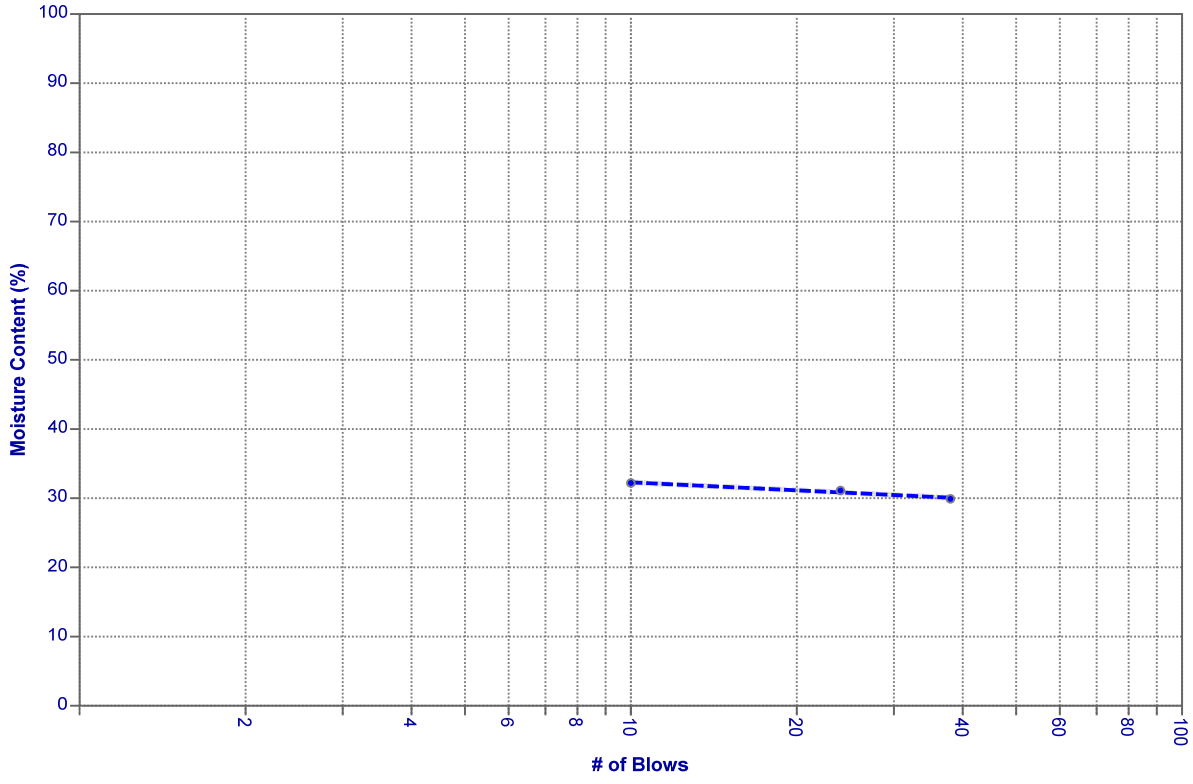
**Liquid Limit**

| Cont. W (gr) | Cont. + Wet Soil W (gr) | Cont. + Dry Soil W (gr) | # of Blows | Moisture Content (%) |
|---|---|---|---|---|
| 23.75 | 71.41 | 59.8 | 10 | 32.2 |
| 32.96 | 80.47 | 69.21 | 24 | 31.1 |
| 32.59 | 85.13 | 73.05 | 38 | 29.9 |
| | | | | - |

**Plastic Limit**

| Cont. W (gr) | Cont. + Wet Soil W (gr) | Cont. + Dry Soil W (gr) | Moisture Content (%) |
|---|---|---|---|
| 16.75 | 46.73 | 41.62 | 20.5 |

**LL = 30.8 %** **PL = 20.5 %** **PI=10.3**




USCS Soil Description : Low Plasticity Clay With Sand
AASHTO Soil Description : Clayey soils (10)

Tested By :

# Density & Moisture Test

Project : Geotechnical Investigation Works
Client : Techno Consult
Job No.: K22-1175-101
Location : Ibrahim Hyderi, Karachi

ASTM D4643, D2216

| Borehole | Sample Depth (m) | Moisture Content (%) | Dry Density (gr/cm3) | Wet Density (gr/cm3) |
|---|---|---|---|---|
| BH-01 | 1.5 | 15.62 | 1.5 | 1.73 |
| BH-01 | 4.5 | 30.67 | 1.32 | 1.72 |
| BH-01 | 6 | 25.57 | 1.34 | 1.68 |
| BH-01 | 7.5 | 27.4 | 1.27 | 1.62 |
| BH-01 | 13.5 | 19.75 | 1.47 | 1.76 |
| BH-02 | 1.5 | 28.64 | 1.4 | 1.81 |
| BH-02 | 4.5 | 34.03 | 1.35 | 1.81 |
| BH-02 | 7.5 | 22.23 | 1.44 | 1.76 |
| BH-02 | 10.5 | 17.74 | 1.52 | 1.79 |
| BH-02 | 13.5 | 24.23 | 1.52 | 1.88 |
| BH-03 | 1.5 | 15.17 | 1.51 | 1.74 |
| BH-03 | 4.5 | 36.32 | 1.33 | 1.81 |
| BH-03 | 7.5 | 26.75 | 1.4 | 1.78 |
| BH-03 | 12 | 16.12 | 1.51 | 1.76 |
| BH-03 | 15 | 16.97 | 1.39 | 1.63 |

# Chemical Test Results

Project : Geotechnical Investigation Works
Client : Techno Consult
Job No.: K22-1175-101
Location : Ibrahim Hyderi, Karachi

ASTM D516, D512, D1293

| Borehole | Sample Depth (m) | Description | Value |
|---|---|---|---|
| BH-01 | 1.5 | pH value | 7.45 |
| BH-02 | 1.5 | | 7.3 |
| BH-03 | 1.5 | | 7.6 |
| BH-01 | 1.5 | Sulphate Content (%) | 0.03 |
| BH-02 | 1.5 | | 0.02 |
| BH-03 | 1.5 | | 0.02 |
| BH-01 | 1.5 | Chloride Content (%) | 0.51 |
| BH-02 | 1.5 | | 0.61 |
| BH-03 | 1.5 | | 0.42 |

# Water Chemical Test Results

Project : Geotechnical Investigation Works
Client : Techno Consult
Job No.: K22-1175-101
Location : Ibrahim Hyderi, Karachi

Soil Testing Services

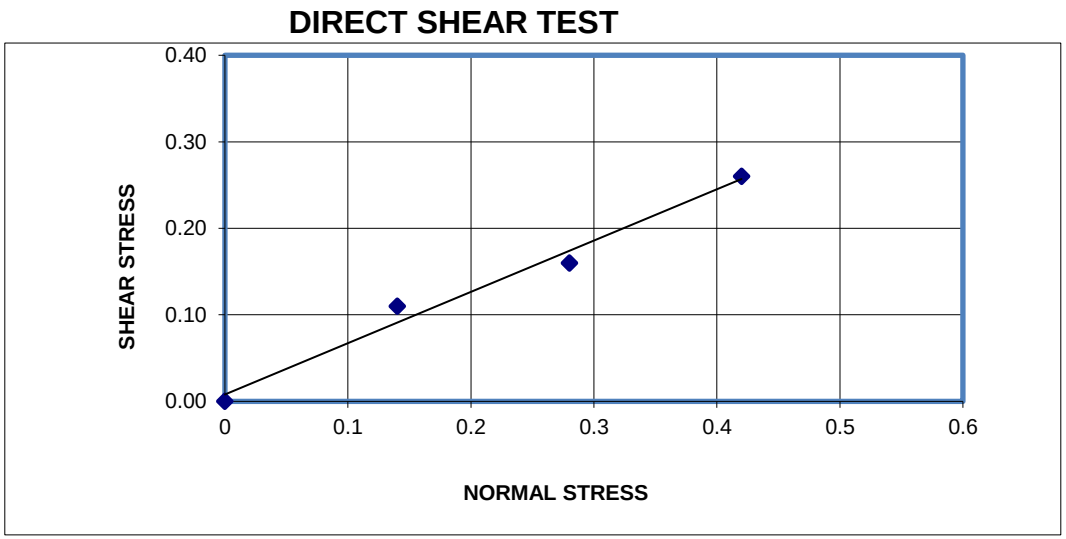
| Borehole | Sample | Total Salt Content (ppm) | Chloride Content (ppm) | Sulphate (ppm) | pH Values |
|---|---|---|---|---|---|
| BH-01 | WS-1 | 15663 | 8964 | 815 | 6.8 |

SOIL TESTING SERVICS

| | | | | | |
|---|---|---|---|---|---|
| **Project** | : | **Geotechnical Investigation Works** | **Borehole** | : | **BH-01** |
| **Client** | : | **Techno Consult** | **Sample Depth** | : | **1.5 (m)** |
| **Job No.** | : | **K22-1175-101** | **Classification** | : | **SP-SM** |
| **Location** | : | **Ibrahim Hyderi, Karachi** | **Sample Type** | : | **SPT Split Spoon** |

| NORMAL STRESS ($kg/cm^2$) | SHEAR STRESS ($kg/cm^2$) |
|---|---|
| 0.00 | 0.00 |
| 0.14 | 0.11 |
| 0.28 | 0.16 |
| 0.42 | 0.26 |

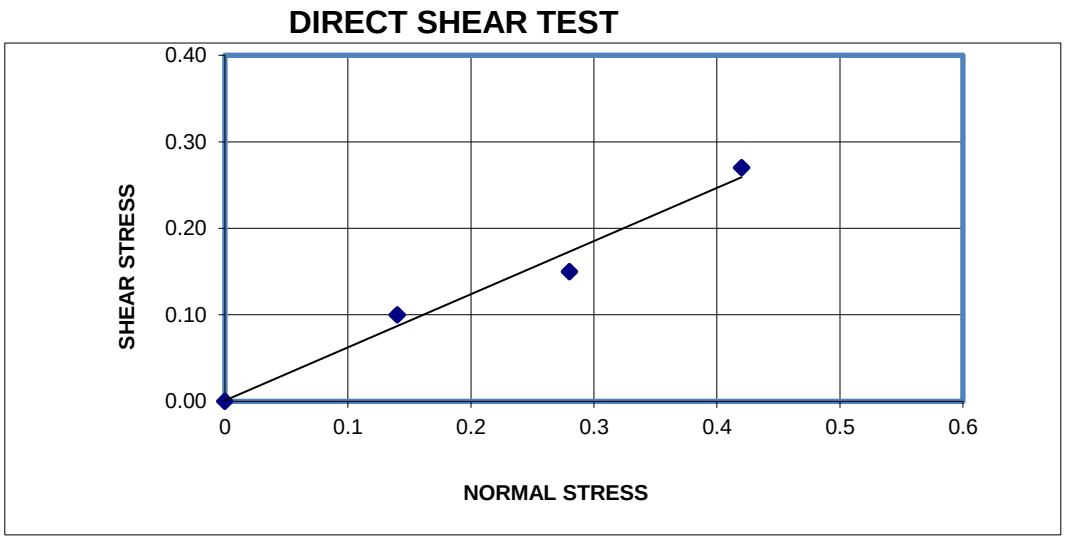
| | |
|---|---|
| **Cohesion ( c )** | 0.00 |
| **Angle of friction (Φ)** | 31.76 |



SOIL TESTING SERVICS

| | | | | | |
|---|---|---|---|---|---|
| **Project** | : | **Geotechnical Investigation Works** | **Borehole** | : | **BH-02** |
| **Client** | : | **Techno Consult** | **Sample Depth** | : | **13.5 (m)** |
| **Job No.** | : | **K22-1175-101** | **Classification** | : | **SM** |
| **Location** | : | **Ibrahim Hyderi, Karachi** | **Sample Type** | : | **SPT Split Spoon** |

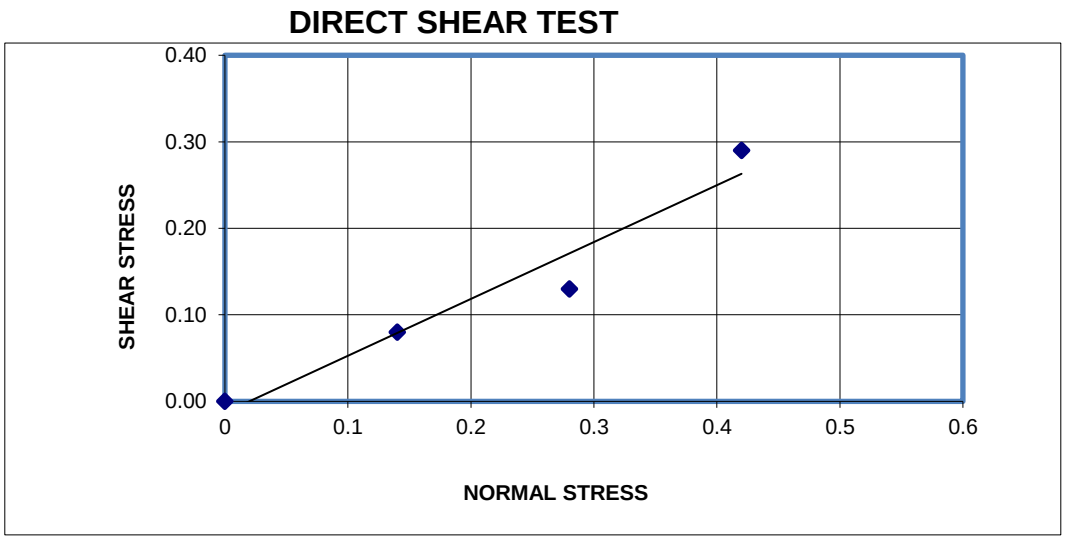
| NORMAL STRESS ($kg/cm^2$) | SHEAR STRESS ($kg/cm^2$) |
|---|---|
| 0.00 | 0.00 |
| 0.14 | 0.10 |
| 0.28 | 0.15 |
| 0.42 | 0.27 |
| **Cohesion ( c )** | 0.00 |
| **Angle of friction (Φ)** | 32.74 |



SOIL TESTING SERVICS

| | | | | | |
|---|---|---|---|---|---|
| **Project** | : | **Geotechnical Investigation Works** | **Borehole** | : | **BH-03** |
| **Client** | : | **Techno Consult** | **Sample Depth** | : | **1.5 (m)** |
| **Job No.** | : | **K22-1175-101** | **Classification** | : | **SM** |
| **Location** | : | **Ibrahim Hyderi, Karachi** | **Sample Type** | : | **SPT Split Spoon** |

| NORMAL STRESS ($kg/cm^2$) | SHEAR STRESS ($kg/cm^2$) |
|---|---|
| 0.00 | 0.00 |
| 0.14 | 0.08 |
| 0.28 | 0.13 |
| 0.42 | 0.29 |
| **Cohesion ( c )** | 0.00 |
| **Angle of friction (Φ)** | 34.63 |



# General Information on Testing Procedures

## A. DRILLING, FIELD TESTING & SAMPLING

The field testing program consisted of drilling works, and in-situ testing including Standard Penetration Tests (SPT), collection of soil samples and collection of ground water samples. The following sections describe these activities in further detail.

### A.1. DRILLING METHOD

Both the boreholes were drilled by using rotary/wash boring method; in this method soil or rock is cut by the constant rotation of various types of bits. Drilling fluid, which is either water or bentonite slurry, is circulated through drilling rods. The returning fluid lifts loosened material.

Details of the boreholes are given in Table A.1.

*Table A.1 Detail of Boreholes*

| Borehole No. | Borehole Depth (meters) | Water table Depth (meters) |
|---|---|---|
| BH-01 | 15.0 | 1.0 |
| BH-02 | 15.0 | 0.8 |
| BH-03 | 15.0 | 1.1 |

*Figure A-1: Drilling works in progress*

## A.2. FIELD TESTING

Field testing carried out at the site includes Standard Penetration Test (SPT). Soil samples were extracted from the boreholes with the help of “SPT sampler for all types of soils”.

Following sections indicate the processes carried out in each of the field tests.

### A.2.1. STANDARD PENETRATION TESTS

The standard penetration tests (SPT) were carried out at interval of 1.0 - 1.5 meter in the overburden above the bedrock. The standard penetration test was carried out by “Safety” type sliding hammer. Split-spoon sampler was used in cohesive and fine granular soils to conduct SPT.

The standard penetration test was carried out by an assembly of the following parts:

- Drive-weight assembly, consisting of a drive head and a 63.5kg impact hammer, a hammer fall guide and the drop system. The drop mechanism will ensure a constant free fall of 760mm.
- Drive rods connect the drive-weight assembly to the sampler.
- The split spoon sampler was used to carry out the test, along with retrieving disturbed samples.

The base of the borehole was made clean and reasonably undisturbed at the test elevation. Following precautions were taken during the testing sequence:

- The level of water or bentonite slurry was maintained at a sufficient level above the groundwater level, to ensure any entry of water through the bottom of the borehole.
- The casing was not driven below the level at which the test will start.

The test was executed in the following steps:

- The sampler and the drive rods were lowered in the borehole and the hammer assembly added to it.
- The sampler is penetrated over seating drive of 150mm and the numbers of blows are recorded.
- In the same way the sampler is driven over a test drive of 300mm in two increments of 150mm.
- The numbers of blows are recorded during each of the last two increments.

- The test was deemed finished when total number of blows equal to 50 was reached.

The standard penetration test was carried out in accordance with the procedure given in BS 1377-9:1990.

*Figure A.2: Performance of Standard Penetration test in progress*

### A.3. SAMPLING

Sampling forms an essential part of the geotechnical investigation process and good sampling is essential for proper laboratory testing of samples for determining strength and compressibility characteristics of soil.

#### A.3.1. SPT SAMPLES

Samples were recovered from standard penetration testing. The samples were recovered in split-spoon sampler and then stored in plastic bags. The storage of split-spoon samples in bags ensured retention of natural moisture of the samples which were later tested for gradation, consistency and chemical characteristics.

*Figure A.3: Sampling via Split Spoon Sampler*

#### A.3.2. WATER SAMPLES

In order to determine the chemical characteristic of groundwater, water samples were collected from the boreholes. The samples were preserved in airtight bottle & later transported to the testing laboratory. Chemical characteristics of water samples have also been assessed through determination of sulphate content, chloride content, TDS and pH.

## B. LABORATORY TESTING

Laboratory testing was carried out on retrieved samples. The following section enlists and gives details of relevant tests carried out on selected samples as required for determining the subsurface conditions and correlating with the information obtained from field testing and sampling.

### B.1. GRAIN SIZE ANALYSIS

The purpose of grain size analysis is to determine the sizes of the assemblage of particles that make up the soil. The grain size analysis is conducted in two parts: for particles above the "# 200 US sieve", sieve analysis is carried out by passing the selected soil sample from various sieves. For particles finer than the "# 200 US sieve", hydrometer analysis is carried out. The combined process of determination of the size of particles is termed as the grain size analysis.

The results are appended with the report in Appendix C. Grain size analysis of fifteen (15) soil samples was carried out as per *ASTM C-136 & ASTM D-6918*.

### B.2. LIQUID AND PLASTIC LIMITS

The liquid and plastic limits of soil are parameters that define the state of the soil at different water content levels. The liquid limit is the water content above which the soil goes from solid phase to liquid phase and the plastic limit indicates the water content below which the soil mass makes the transition from a plastic, remould able solid to a brittle mass which cannot be remoulded any more. The difference in the water contents at Liquid and Plastic limits is termed as the plasticity index and it is a measure of the plasticity of the soil under consideration. The samples used for determining the limits are finer than the "#40 US sieve". The limits were determined in accordance with the *ASTM D-4318.*

Liquid and plastic limits of eight (08) samples extracted from boreholes were carried out in accordance with the given procedure.

### B.3. NATURAL MOISTURE CONTENT

Natural moisture content is the quantity of water contained in a soil or rock sample. It is the ratio of the weight of water to the weight of solids in a given volume of soil or rock

sample. Natural moisture content of fifteen (15) samples was determined in accordance with *ASTM 2216-05.*

### B.4. DENSITY

The weight per unit volume of the solid portion of soil is called particle (dry) density. Whereas, the oven dry weight of a unit volume of soil inclusive of pore spaces is called bulk (wet) density. The bulk density of a soil is always smaller than its particle density. Density of fifteen (15) samples was determined in accordance with the procedure described in ASTM D 7263-09.

### B.5. CHEMICAL TESTS

Sulphate in groundwater or soil can attack concrete placed in the ground or on surface. A reaction takes place between the sulphate and the aluminate compounds present in the cement, causing crystallisation of complex compounds. The expansion, which accompanies crystallisation, induces stresses in the concrete, which results in mechanical disintegration. In moist conditions, such as exposure to seawater, the presence of chloride ion, $Cl^-$, presents a serious possibility of the corrosion of the reinforcement. The presence of $Ca(OH)_2$ provides a strong alkaline environment in which a thin film of iron oxide is formed on the metal surface which protects it against corrosion. However, if the concrete is permeable to the extent that the soluble chlorides can reach up to the reinforcing steel, then in the presence of water and oxygen, the corrosion of the reinforcement will take place. Rust occupies more volume than the original steel, and hence the ensuing expansion of concrete, results in cracking and spalling.

Due to adverse effect of sulphates and chlorides on the quality of concrete it is essential to conduct chemical tests on soil and groundwater. This helps in quantifying the expected exposure of concrete to these chemicals and in devising precautionary measures to ensure integrity of concrete. The following chemical tests were carried out on groundwater samples:

- Total dissolved solids
- Chloride content
- Sulphate content
- pH

Chemical tests were carried out in accordance with *ASTM C 1580-09, and D 4972-01*. The selection of cement for underground concreting and is discussed in *Chapter 4*.

*Table B.1: ACI standards for concrete for sulphate exposure*

| Sulphate Exposure | Water Soluble Sulphates in Soil (%) | Sulphate in Water (mg/L) | Cement Type |
|---|---|---|---|
| Negligible | 0.00-0.10 | 0- 150 | OPC |
| Moderate | 0.10-0.20 | 150- 1500 | Type II |
| Severe | 0.20-2.00 | 1500-10000 | Type V |
| Very Severe | Over 2.00 | Over 10000 | Type V plus pozzolan |

Appendix E

# Pile Capacity Calculations

Appendix D

**( A ) - CALCULATION OF ALLOWABLE SKIN FRICTION : BH-01**

| Depth | Rock Encountered | Diameter of Pile (m) | Length of Layer (m) | Effective σ for this layer | Effective overburden ($kN/m^2$) | phi | c ($kN/m^2$) | $q_{uc}$ ($kN/m^2$) | α adhesion | α reduction-rock | β correction | δ | tan δ | $k_s$ | FOS | $Q_{skin}$ (kN) | $Q_{skin\ (Cum)}$ (kN) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-1 | Fill Material | 0.60 | 1 | 0.0 | 0.0 | - | - | - | - | - | - | - | - | - | 2.0 | - | 0 |
| 1-2 | Fill Material | 0.60 | 1 | 0.0 | 0.0 | - | - | - | - | - | - | - | - | - | 2.0 | - | 0 |
| 2-3 | Cohesive | 0.60 | 1 | 6.0 | 3.0 | - | 10 | - | 0.50 | - | - | - | - | - | 2.0 | 5 | 5 |
| 3-4 | Cohesive | 0.60 | 1 | 6.0 | 9.0 | - | 10 | - | 0.50 | - | - | - | - | - | 2.0 | 5 | 9 |
| 4-5 | Cohesive | 0.60 | 1 | 6.0 | 15.0 | - | 12 | - | 0.50 | - | - | - | - | - | 2.0 | 6 | 15 |
| 5-6 | Cohesive | 0.60 | 1 | 6.0 | 21.0 | - | 12 | - | 0.50 | - | - | - | - | - | 2.0 | 6 | 21 |
| 6-7 | Cohesionless | 0.60 | 1 | 6.5 | 27.3 | 16 | - | - | - | - | - | 12.0 | 0.21 | 0.792 | 2.0 | 4 | 25 |
| 7-8 | Cohesive | 0.60 | 1 | 6.5 | 33.8 | - | 45 | - | 0.50 | - | - | - | - | - | 2.0 | 21 | 46 |
| 8-9 | Cohesive | 0.60 | 1 | 6.5 | 40.3 | - | 45 | - | 0.50 | - | - | - | - | - | 2.0 | 21 | 67 |
| 9-10 | Cohesive | 0.60 | 1 | 6.5 | 46.8 | - | 45 | - | 0.50 | - | - | - | - | - | 2.0 | 21 | 89 |
| 10-11 | Cohesive | 0.60 | 1 | 6.5 | 53.3 | - | 85 | - | 0.50 | - | - | - | - | - | 2.0 | 40 | 129 |
| 11-12 | Cohesive | 0.60 | 1 | 6.5 | 59.8 | - | 85 | - | 0.50 | - | - | - | - | - | 2.0 | 40 | 169 |
| 12-13 | Cohesive | 0.60 | 1 | 6.5 | 66.3 | - | 85 | - | 0.50 | - | - | - | - | - | 2.0 | 40 | 209 |
| 13-14 | Cohesionless | 0.60 | 1 | 9.0 | 74.0 | 30 | - | - | - | - | - | 22.5 | 0.41 | 0.617 | 2.0 | 18 | 227 |
| 14-15 | Cohesionless | 0.60 | 1 | 9.0 | 83.0 | 30 | - | - | - | - | - | 22.5 | 0.41 | 0.617 | 2.0 | 20 | 247 |

**( A ) - CALCULATION OF ALLOWABLE SKIN FRICTION : BH-01**

| Depth | Rock Encountered | Diameter of Pile (m) | Length of Layer (m) | Effective σ for this layer | Effective overburden ($kN/m^2$) | phi | c ($kN/m^2$) | $q_{uc}$ ($kN/m^2$) | α adhesion | α reduction-rock | β correction | δ | tan δ | $k_s$ | FOS | $Q_{skin}$ (kN) | $Q_{skin\ (Cum)}$ (kN) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-1 | Fill Material | 0.76 | 1 | 0.0 | 0.0 | - | - | - | - | - | - | - | - | - | 2.0 | - | 0 |
| 1-2 | Fill Material | 0.76 | 1 | 0.0 | 0.0 | - | - | - | - | - | - | - | - | - | 2.0 | - | 0 |
| 2-3 | Cohesive | 0.76 | 1 | 6.0 | 3.0 | - | 10 | - | 0.50 | - | - | - | - | - | 2.0 | 6 | 6 |
| 3-4 | Cohesive | 0.76 | 1 | 6.0 | 9.0 | - | 10 | - | 0.50 | - | - | - | - | - | 2.0 | 6 | 12 |
| 4-5 | Cohesive | 0.76 | 1 | 6.0 | 15.0 | - | 12 | - | 0.50 | - | - | - | - | - | 2.0 | 7 | 19 |
| 5-6 | Cohesive | 0.76 | 1 | 6.0 | 21.0 | - | 12 | - | 0.50 | - | - | - | - | - | 2.0 | 7 | 26 |
| 6-7 | Cohesionless | 0.76 | 1 | 6.5 | 27.3 | 16 | - | - | - | - | - | 12.0 | 0.21 | 0.792 | 2.0 | 5 | 32 |
| 7-8 | Cohesive | 0.76 | 1 | 6.5 | 33.8 | - | 45 | - | 0.50 | - | - | - | - | - | 2.0 | 27 | 59 |
| 8-9 | Cohesive | 0.76 | 1 | 6.5 | 40.3 | - | 45 | - | 0.50 | - | - | - | - | - | 2.0 | 27 | 85 |
| 9-10 | Cohesive | 0.76 | 1 | 6.5 | 46.8 | - | 45 | - | 0.50 | - | - | - | - | - | 2.0 | 27 | 112 |
| 10-11 | Cohesive | 0.76 | 1 | 6.5 | 53.3 | - | 85 | - | 0.50 | - | - | - | - | - | 2.0 | 51 | 163 |
| 11-12 | Cohesive | 0.76 | 1 | 6.5 | 59.8 | - | 85 | - | 0.50 | - | - | - | - | - | 2.0 | 51 | 214 |
| 12-13 | Cohesive | 0.76 | 1 | 6.5 | 66.3 | - | 85 | - | 0.50 | - | - | - | - | - | 2.0 | 51 | 265 |
| 13-14 | Cohesionless | 0.76 | 1 | 9.0 | 74.0 | 30 | - | - | - | - | - | 22.5 | 0.41 | 0.617 | 2.0 | 23 | 287 |
| 14-15 | Cohesionless | 0.76 | 1 | 9.0 | 83.0 | 30 | - | - | - | - | - | 22.5 | 0.41 | 0.617 | 2.0 | 25 | 313 |

**( A ) - CALCULATION OF ALLOWABLE SKIN FRICTION : BH-01**

| Depth | Rock Encountered | Diameter of Pile (m) | Length of Layer (m) | Effective σ for this layer | Effective overburden ($kN/m^2$) | phi | c ($kN/m^2$) | $q_{uc}$ ($kN/m^2$) | α adhesion | α reduction-rock | β correction | δ | tan δ | $k_s$ | FOS | $Q_{skin}$ (kN) | $Q_{skin\ (Cum)}$ (kN) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-1 | Fill Material | 0.90 | 1 | 0.0 | 0.0 | - | - | - | - | - | - | - | - | - | 2.0 | - | 0 |
| 1-2 | Fill Material | 0.90 | 1 | 0.0 | 0.0 | - | - | - | - | - | - | - | - | - | 2.0 | - | 0 |
| 2-3 | Cohesive | 0.90 | 1 | 6.0 | 3.0 | - | 10 | - | 0.50 | - | - | - | - | - | 2.0 | 7 | 7 |
| 3-4 | Cohesive | 0.90 | 1 | 6.0 | 9.0 | - | 10 | - | 0.50 | - | - | - | - | - | 2.0 | 7 | 14 |
| 4-5 | Cohesive | 0.90 | 1 | 6.0 | 15.0 | - | 12 | - | 0.50 | - | - | - | - | - | 2.0 | 8 | 23 |
| 5-6 | Cohesive | 0.90 | 1 | 6.0 | 21.0 | - | 12 | - | 0.50 | - | - | - | - | - | 2.0 | 8 | 31 |
| 6-7 | Cohesionless | 0.90 | 1 | 6.5 | 27.3 | 16 | - | - | - | - | - | 12.0 | 0.21 | 0.792 | 2.0 | 6 | 38 |
| 7-8 | Cohesive | 0.90 | 1 | 6.5 | 33.8 | - | 45 | - | 0.50 | - | - | - | - | - | 2.0 | 32 | 69 |
| 8-9 | Cohesive | 0.90 | 1 | 6.5 | 40.3 | - | 45 | - | 0.50 | - | - | - | - | - | 2.0 | 32 | 101 |
| 9-10 | Cohesive | 0.90 | 1 | 6.5 | 46.8 | - | 45 | - | 0.50 | - | - | - | - | - | 2.0 | 32 | 133 |
| 10-11 | Cohesive | 0.90 | 1 | 6.5 | 53.3 | - | 85 | - | 0.50 | - | - | - | - | - | 2.0 | 60 | 193 |
| 11-12 | Cohesive | 0.90 | 1 | 6.5 | 59.8 | - | 85 | - | 0.50 | - | - | - | - | - | 2.0 | 60 | 253 |
| 12-13 | Cohesive | 0.90 | 1 | 6.5 | 66.3 | - | 85 | - | 0.50 | - | - | - | - | - | 2.0 | 60 | 313 |
| 13-14 | Cohesionless | 0.90 | 1 | 9.0 | 74.0 | 30 | - | - | - | - | - | 22.5 | 0.41 | 0.617 | 2.0 | 27 | 340 |
| 14-15 | Cohesionless | 0.90 | 1 | 9.0 | 83.0 | 30 | - | - | - | - | - | 22.5 | 0.41 | 0.617 | 2.0 | 30 | 370 |

## ALLOWABLE END BEARING RESISTANCE : BH-01

| Socket Strata | Diameter of Pile (mm) | Pile Length (m) Below EGL | $N_q$ | Effective Overburden (kN/m2) | FOS | $Q_{END}$ (kN) |
|---|---|---|---|---|---|---|
| Cohesionless | 600.0 | 15.0 | 40.0 | 83.0 | 3.0 | 313 |
| Cohesionless | 760.0 | 15.0 | 40.0 | 83.0 | 3.0 | 502 |
| Cohesionless | 900.0 | 15.0 | 40.0 | 83.0 | 3.0 | 704 |

**( A ) - CALCULATION OF ALLOWABLE SKIN FRICTION : BH-02**

| Depth | Rock Encountered | Diameter of Pile (m) | Length of Layer (m) | Effective σ for this layer | Effective overburden ($kN/m^2$) | phi | c ($kN/m^2$) | $q_{uc}$ ($kN/m^2$) | α adhesion | α reduction-rock | β correction | δ | tan δ | $k_s$ | FOS | $Q_{skin}$ (kN) | $Q_{skin\ (Cum)}$ (kN) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-1 | Fill Material | 0.60 | 1 | 0.0 | 0.0 | - | - | - | - | - | - | - | - | - | 2.0 | - | 0 |
| 1-2 | Fill Material | 0.60 | 1 | 0.0 | 0.0 | - | - | - | - | - | - | - | - | - | 2.0 | - | 0 |
| 2-3 | Cohesionless | 0.60 | 1 | 6.0 | 3.0 | 15 | - | - | - | - | - | 11.3 | 0.20 | 0.805 | 2.0 | 0 | 0 |
| 3-4 | Cohesionless | 0.60 | 1 | 6.0 | 9.0 | 15 | - | - | - | - | - | 11.3 | 0.20 | 0.805 | 2.0 | 1 | 2 |
| 4-5 | Cohesionless | 0.60 | 1 | 6.0 | 15.0 | 15 | - | - | - | - | - | 11.3 | 0.20 | 0.805 | 2.0 | 2 | 4 |
| 5-6 | Cohesive | 0.60 | 1 | 6.0 | 21.0 | - | 25 | - | 0.50 | - | - | - | - | - | 2.0 | 12 | 16 |
| 6-7 | Cohesive | 0.60 | 1 | 6.5 | 27.3 | - | 75 | - | 0.50 | - | - | - | - | - | 2.0 | 35 | 51 |
| 7-8 | Cohesive | 0.60 | 1 | 6.5 | 33.8 | - | 100 | - | 0.50 | - | - | - | - | - | 2.0 | 47 | 98 |
| 8-9 | Cohesive | 0.60 | 1 | 6.5 | 40.3 | - | 100 | - | 0.50 | - | - | - | - | - | 2.0 | 47 | 146 |
| 9-10 | Cohesive | 0.60 | 1 | 6.5 | 46.8 | - | 100 | - | 0.50 | - | - | - | - | - | 2.0 | 47 | 193 |
| 10-11 | Cohesionless | 0.60 | 1 | 7.5 | 53.8 | 20 | - | - | - | - | - | 15.0 | 0.27 | 0.741 | 2.0 | 10 | 203 |
| 11-12 | Cohesionless | 0.60 | 1 | 7.5 | 61.3 | 20 | - | - | - | - | - | 15.0 | 0.27 | 0.741 | 2.0 | 11 | 214 |
| 12-13 | Cohesionless | 0.60 | 1 | 9.0 | 69.5 | 22 | - | - | - | - | - | 16.5 | 0.30 | 0.716 | 2.0 | 14 | 228 |
| 13-14 | Cohesionless | 0.60 | 1 | 9.0 | 78.5 | 22 | - | - | - | - | - | 16.5 | 0.30 | 0.716 | 2.0 | 16 | 244 |
| 14-15 | Cohesionless | 0.60 | 1 | 9.0 | 87.5 | 30 | - | - | - | - | - | 22.5 | 0.41 | 0.617 | 2.0 | 21 | 265 |

**( A ) - CALCULATION OF ALLOWABLE SKIN FRICTION : BH-02**

| Depth | Rock Encountered | Diameter of Pile (m) | Length of Layer (m) | Effective σ for this layer | Effective overburden ($kN/m^2$) | phi | c ($kN/m^2$) | $q_{uc}$ ($kN/m^2$) | α adhesion | α reduction-rock | β correction | δ | tan δ | $k_s$ | FOS | $Q_{skin}$ (kN) | $Q_{skin\ (Cum)}$ (kN) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-1 | Fill Material | 0.76 | 1 | 0.0 | 0.0 | - | - | - | - | - | - | - | - | - | 2.0 | - | 0 |
| 1-2 | Fill Material | 0.76 | 1 | 0.0 | 0.0 | - | - | - | - | - | - | - | - | - | 2.0 | - | 0 |
| 2-3 | Cohesionless | 0.76 | 1 | 6.0 | 3.0 | 15 | - | - | - | - | - | 11.3 | 0.20 | 0.805 | 2.0 | 1 | 1 |
| 3-4 | Cohesionless | 0.76 | 1 | 6.0 | 9.0 | 15 | - | - | - | - | - | 11.3 | 0.20 | 0.805 | 2.0 | 2 | 2 |
| 4-5 | Cohesionless | 0.76 | 1 | 6.0 | 15.0 | 15 | - | - | - | - | - | 11.3 | 0.20 | 0.805 | 2.0 | 3 | 5 |
| 5-6 | Cohesive | 0.76 | 1 | 6.0 | 21.0 | - | 25 | - | 0.50 | - | - | - | - | - | 2.0 | 15 | 20 |
| 6-7 | Cohesive | 0.76 | 1 | 6.5 | 27.3 | - | 75 | - | 0.50 | - | - | - | - | - | 2.0 | 45 | 65 |
| 7-8 | Cohesive | 0.76 | 1 | 6.5 | 33.8 | - | 100 | - | 0.50 | - | - | - | - | - | 2.0 | 60 | 125 |
| 8-9 | Cohesive | 0.76 | 1 | 6.5 | 40.3 | - | 100 | - | 0.50 | - | - | - | - | - | 2.0 | 60 | 184 |
| 9-10 | Cohesive | 0.76 | 1 | 6.5 | 46.8 | - | 100 | - | 0.50 | - | - | - | - | - | 2.0 | 60 | 244 |
| 10-11 | Cohesionless | 0.76 | 1 | 7.5 | 53.8 | 20 | - | - | - | - | - | 15.0 | 0.27 | 0.741 | 2.0 | 13 | 257 |
| 11-12 | Cohesionless | 0.76 | 1 | 7.5 | 61.3 | 20 | - | - | - | - | - | 15.0 | 0.27 | 0.741 | 2.0 | 15 | 271 |
| 12-13 | Cohesionless | 0.76 | 1 | 9.0 | 69.5 | 22 | - | - | - | - | - | 16.5 | 0.30 | 0.716 | 2.0 | 18 | 289 |
| 13-14 | Cohesionless | 0.76 | 1 | 9.0 | 78.5 | 22 | - | - | - | - | - | 16.5 | 0.30 | 0.716 | 2.0 | 20 | 309 |
| 14-15 | Cohesionless | 0.76 | 1 | 9.0 | 87.5 | 30 | - | - | - | - | - | 22.5 | 0.41 | 0.617 | 2.0 | 27 | 335 |

**( A ) - CALCULATION OF ALLOWABLE SKIN FRICTION : BH-02**

| Depth | Rock Encountered | Diameter of Pile (m) | Length of Layer (m) | Effective σ for this layer | Effective overburden ($kN/m^2$) | phi | c ($kN/m^2$) | $q_{uc}$ ($kN/m^2$) | α adhesion | α reduction-rock | β correction | δ | tan δ | $k_s$ | FOS | $Q_{skin}$ (kN) | $Q_{skin\ (Cum)}$ (kN) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-1 | Fill Material | 0.90 | 1 | 0.0 | 0.0 | - | - | - | - | - | - | - | - | - | 2.0 | - | 0 |
| 1-2 | Fill Material | 0.90 | 1 | 0.0 | 0.0 | - | - | - | - | - | - | - | - | - | 2.0 | - | 0 |
| 2-3 | Cohesionless | 0.90 | 1 | 6.0 | 3.0 | 15 | - | - | - | - | - | 11.3 | 0.20 | 0.805 | 2.0 | 1 | 1 |
| 3-4 | Cohesionless | 0.90 | 1 | 6.0 | 9.0 | 15 | - | - | - | - | - | 11.3 | 0.20 | 0.805 | 2.0 | 2 | 3 |
| 4-5 | Cohesionless | 0.90 | 1 | 6.0 | 15.0 | 15 | - | - | - | - | - | 11.3 | 0.20 | 0.805 | 2.0 | 3 | 6 |
| 5-6 | Cohesive | 0.90 | 1 | 6.0 | 21.0 | - | 25 | - | 0.50 | - | - | - | - | - | 2.0 | 18 | 24 |
| 6-7 | Cohesive | 0.90 | 1 | 6.5 | 27.3 | - | 75 | - | 0.50 | - | - | - | - | - | 2.0 | 53 | 77 |
| 7-8 | Cohesive | 0.90 | 1 | 6.5 | 33.8 | - | 100 | - | 0.50 | - | - | - | - | - | 2.0 | 71 | 148 |
| 8-9 | Cohesive | 0.90 | 1 | 6.5 | 40.3 | - | 100 | - | 0.50 | - | - | - | - | - | 2.0 | 71 | 218 |
| 9-10 | Cohesive | 0.90 | 1 | 6.5 | 46.8 | - | 100 | - | 0.50 | - | - | - | - | - | 2.0 | 71 | 289 |
| 10-11 | Cohesionless | 0.90 | 1 | 7.5 | 53.8 | 20 | - | - | - | - | - | 15.0 | 0.27 | 0.741 | 2.0 | 15 | 304 |
| 11-12 | Cohesionless | 0.90 | 1 | 7.5 | 61.3 | 20 | - | - | - | - | - | 15.0 | 0.27 | 0.741 | 2.0 | 17 | 321 |
| 12-13 | Cohesionless | 0.90 | 1 | 9.0 | 69.5 | 22 | - | - | - | - | - | 16.5 | 0.30 | 0.716 | 2.0 | 21 | 342 |
| 13-14 | Cohesionless | 0.90 | 1 | 9.0 | 78.5 | 22 | - | - | - | - | - | 16.5 | 0.30 | 0.716 | 2.0 | 24 | 366 |
| 14-15 | Cohesionless | 0.90 | 1 | 9.0 | 87.5 | 30 | - | - | - | - | - | 22.5 | 0.41 | 0.617 | 2.0 | 32 | 397 |

## ALLOWABLE END BEARING RESISTANCE : BH-02

| Socket Strata | Diameter of Pile (mm) | Pile Length (m) Below EGL | $N_q$ | Effective Overburden (kN/m2) | FOS | $Q_{END}$ (kN) |
|---|---|---|---|---|---|---|
| Cohesionless | 600.0 | 15.0 | 40.0 | 87.5 | 3.0 | 330 |
| Cohesionless | 760.0 | 15.0 | 40.0 | 87.5 | 3.0 | 529 |
| Cohesionless | 900.0 | 15.0 | 40.0 | 87.5 | 3.0 | 742 |

**( A ) - CALCULATION OF ALLOWABLE SKIN FRICTION : BH-03**

| Depth | Strata Encountered | Diameter of Pile (m) | Length of Layer (m) | Effective σ for this layer | Effective overburden ($kN/m^2$) | phi | c ($kN/m^2$) | $q_{uc}$ ($kN/m^2$) | α adhesion | α reduction-rock | β correction | δ | tan δ | $k_s$ | FOS | $Q_{skin}$ (kN) | $Q_{skin\ (Cum)}$ (kN) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-1 | Fill Material | 0.60 | 1 | 0.0 | 0.0 | - | - | - | - | - | - | - | - | - | 2.0 | 0 | 0 |
| 1-2 | Fill Material | 0.60 | 1 | 0.0 | 0.0 | - | - | - | - | - | - | - | - | - | 2.0 | 0 | 0 |
| 2-3 | Cohesive | 0.60 | 1 | 6.0 | 3.0 | - | 15 | - | 0.50 | - | - | - | - | - | 2.0 | 7 | 7 |
| 3-4 | Cohesive | 0.60 | 1 | 6.0 | 9.0 | - | 15 | - | 0.50 | - | - | - | - | - | 2.0 | 7 | 14 |
| 4-5 | Cohesive | 0.60 | 1 | 6.0 | 15.0 | - | 15 | - | 0.50 | - | - | - | - | - | 2.0 | 7 | 21 |
| 5-6 | Cohesive | 0.60 | 1 | 6.0 | 21.0 | - | 15 | - | 0.50 | - | - | - | - | - | 2.0 | 7 | 28 |
| 6-7 | Cohesionless | 0.60 | 1 | 6.5 | 27.3 | 18 | - | - | - | - | - | 13.5 | 0.24 | 0.766 | 2.0 | 5 | 33 |
| 7-8 | Cohesionless | 0.60 | 1 | 6.5 | 33.8 | 18 | - | - | - | - | - | 13.5 | 0.24 | 0.766 | 2.0 | 6 | 39 |
| 8-9 | Cohesionless | 0.60 | 1 | 6.5 | 40.3 | 18 | - | - | - | - | - | 13.5 | 0.24 | 0.766 | 2.0 | 7 | 46 |
| 9-10 | Cohesionless | 0.60 | 1 | 6.5 | 46.8 | 18 | - | - | - | - | - | 13.5 | 0.24 | 0.766 | 2.0 | 8 | 54 |
| 10-11 | Cohesive | 0.60 | 1 | 7.0 | 53.5 | - | 70 | - | 0.50 | - | - | - | - | - | 2.0 | 33 | 87 |
| 11-12 | Cohesive | 0.60 | 1 | 8.5 | 61.3 | - | 125 | - | 0.50 | - | - | - | - | - | 2.0 | 59 | 146 |
| 12-13 | Cohesive | 0.60 | 1 | 9.0 | 70.0 | - | 125 | - | 0.50 | - | - | - | - | - | 2.0 | 59 | 205 |
| 13-14 | Cohesive | 0.60 | 1 | 9.0 | 79.0 | - | 125 | - | 0.50 | - | - | - | - | - | 2.0 | 59 | 264 |
| 14-15 | Cohesive | 0.60 | 1 | 9.0 | 88.0 | - | 125 | - | 0.50 | - | - | - | - | - | 2.0 | 59 | 323 |

**( A ) - CALCULATION OF ALLOWABLE SKIN FRICTION : BH-03**

| Depth | Strata Encountered | Diameter of Pile (m) | Length of Layer (m) | Effective σ for this layer | Effective overburden ($kN/m^2$) | phi | c ($kN/m^2$) | $q_{uc}$ ($kN/m^2$) | α adhesion | α reduction-rock | β correction | δ | tan δ | $k_s$ | FOS | $Q_{skin}$ (kN) | $Q_{skin\ (Cum)}$ (kN) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-1 | Fill Material | 0.76 | 1 | 0.0 | 0.0 | - | - | - | - | - | - | - | - | - | 2.0 | 0 | 0 |
| 1-2 | Fill Material | 0.76 | 1 | 0.0 | 0.0 | - | - | - | - | - | - | - | - | - | 2.0 | 0 | 0 |
| 2-3 | Cohesive | 0.76 | 1 | 6.0 | 3.0 | - | 15 | - | 0.50 | - | - | - | - | - | 2.0 | 9 | 9 |
| 3-4 | Cohesive | 0.76 | 1 | 6.0 | 9.0 | - | 15 | - | 0.50 | - | - | - | - | - | 2.0 | 9 | 18 |
| 4-5 | Cohesive | 0.76 | 1 | 6.0 | 15.0 | - | 15 | - | 0.50 | - | - | - | - | - | 2.0 | 9 | 27 |
| 5-6 | Cohesive | 0.76 | 1 | 6.0 | 21.0 | - | 15 | - | 0.50 | - | - | - | - | - | 2.0 | 9 | 36 |
| 6-7 | Cohesionless | 0.76 | 1 | 6.5 | 27.3 | 18 | - | - | - | - | - | 13.5 | 0.24 | 0.766 | 2.0 | 6 | 42 |
| 7-8 | Cohesionless | 0.76 | 1 | 6.5 | 33.8 | 18 | - | - | - | - | - | 13.5 | 0.24 | 0.766 | 2.0 | 7 | 49 |
| 8-9 | Cohesionless | 0.76 | 1 | 6.5 | 40.3 | 18 | - | - | - | - | - | 13.5 | 0.24 | 0.766 | 2.0 | 9 | 58 |
| 9-10 | Cohesionless | 0.76 | 1 | 6.5 | 46.8 | 18 | - | - | - | - | - | 13.5 | 0.24 | 0.766 | 2.0 | 10 | 68 |
| 10-11 | Cohesive | 0.76 | 1 | 7.0 | 53.5 | - | 70 | - | 0.50 | - | - | - | - | - | 2.0 | 42 | 110 |
| 11-12 | Cohesive | 0.76 | 1 | 8.5 | 61.3 | - | 125 | - | 0.50 | - | - | - | - | - | 2.0 | 75 | 185 |
| 12-13 | Cohesive | 0.76 | 1 | 9.0 | 70.0 | - | 125 | - | 0.50 | - | - | - | - | - | 2.0 | 75 | 259 |
| 13-14 | Cohesive | 0.76 | 1 | 9.0 | 79.0 | - | 125 | - | 0.50 | - | - | - | - | - | 2.0 | 75 | 334 |
| 14-15 | Cohesive | 0.76 | 1 | 9.0 | 88.0 | - | 125 | - | 0.50 | - | - | - | - | - | 2.0 | 75 | 409 |

**( A ) - CALCULATION OF ALLOWABLE SKIN FRICTION : BH-03**

| Depth | Strata Encountered | Diameter of Pile (m) | Length of Layer (m) | Effective σ for this layer | Effective overburden ($kN/m^2$) | phi | c ($kN/m^2$) | $q_{uc}$ ($kN/m^2$) | α adhesion | α reduction-rock | β correction | δ | tan δ | $k_s$ | FOS | $Q_{skin}$ (kN) | $Q_{skin\ (Cum)}$ (kN) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-1 | Fill Material | 0.90 | 1 | 0.0 | 0.0 | - | - | - | - | - | - | - | - | - | 2.0 | 0 | 0 |
| 1-2 | Fill Material | 0.90 | 1 | 0.0 | 0.0 | - | - | - | - | - | - | - | - | - | 2.0 | 0 | 0 |
| 2-3 | Cohesive | 0.90 | 1 | 6.0 | 3.0 | - | 15 | - | 0.50 | - | - | - | - | - | 2.0 | 11 | 11 |
| 3-4 | Cohesive | 0.90 | 1 | 6.0 | 9.0 | - | 15 | - | 0.50 | - | - | - | - | - | 2.0 | 11 | 21 |
| 4-5 | Cohesive | 0.90 | 1 | 6.0 | 15.0 | - | 15 | - | 0.50 | - | - | - | - | - | 2.0 | 11 | 32 |
| 5-6 | Cohesive | 0.90 | 1 | 6.0 | 21.0 | - | 15 | - | 0.50 | - | - | - | - | - | 2.0 | 11 | 42 |
| 6-7 | Cohesionless | 0.90 | 1 | 6.5 | 27.3 | 18 | - | - | - | - | - | 13.5 | 0.24 | 0.766 | 2.0 | 7 | 50 |
| 7-8 | Cohesionless | 0.90 | 1 | 6.5 | 33.8 | 18 | - | - | - | - | - | 13.5 | 0.24 | 0.766 | 2.0 | 9 | 58 |
| 8-9 | Cohesionless | 0.90 | 1 | 6.5 | 40.3 | 18 | - | - | - | - | - | 13.5 | 0.24 | 0.766 | 2.0 | 10 | 69 |
| 9-10 | Cohesionless | 0.90 | 1 | 6.5 | 46.8 | 18 | - | - | - | - | - | 13.5 | 0.24 | 0.766 | 2.0 | 12 | 81 |
| 10-11 | Cohesive | 0.90 | 1 | 7.0 | 53.5 | - | 70 | - | 0.50 | - | - | - | - | - | 2.0 | 50 | 130 |
| 11-12 | Cohesive | 0.90 | 1 | 8.5 | 61.3 | - | 125 | - | 0.50 | - | - | - | - | - | 2.0 | 88 | 219 |
| 12-13 | Cohesive | 0.90 | 1 | 9.0 | 70.0 | - | 125 | - | 0.50 | - | - | - | - | - | 2.0 | 88 | 307 |
| 13-14 | Cohesive | 0.90 | 1 | 9.0 | 79.0 | - | 125 | - | 0.50 | - | - | - | - | - | 2.0 | 88 | 396 |
| 14-15 | Cohesive | 0.90 | 1 | 9.0 | 88.0 | - | 125 | - | 0.50 | - | - | - | - | - | 2.0 | 88 | 484 |

## ALLOWABLE END BEARING RESISTANCE : BH-03

| Socket Strata | Diameter of Pile (mm) | Length of Pile (m) Below EGL | Nc | Cohesion ($kN/m^2$) | FOS | $Q_{END}$ (kN) |
|---|---|---|---|---|---|---|
| Cohesive | 760 | 15.0 | 9.0 | 125.0 | 3.0 | 170 |
| Cohesive | 900 | 15.0 | 9.0 | 125.0 | 3.0 | 239 |
| Cohesive | 1000 | 15.0 | 9.0 | 125.0 | 3.0 | 295 |

**Appendix F**

# Geophysical Test Report

**Appendix D**

September, 2022

K22-1175-101

# GEOPHYSICAL TESTS FOR INSTALLATION OF 5 MGD DESALINATION PLANT AT IBRAHIM HYDERI, KARACHI

## Client: M/s. Techno Consult International

# SOIL TESTING SERVICES

GEOTECHNICAL ENGINEERS

&

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# Table of Contents

## 1.0 INTRODUCTION

Planning for installation of 5 MGD Desalination Plant at Ibrahim Hyderi, Karachi is underway. For this purpose, determination of the properties of subsurface deposits was essential. A program for geophysical testing was, therefore, chalked out to evaluate these properties. *M/s. Soil Testing Services* were entrusted by *M/s. Techno Consult International* to carry out the tests pertaining to the determination of properties of the subsurface deposits.

Scope of fieldwork included performance of four (04) electrical resistivity tests and one (01) downhole seismic test. This report presents a detailed account of these tests carried out at the project site.

The site conditions have been presented in Section 2 of this report. In Section 3, working principle, details of fieldwork and test results regarding the electrical resistivity tests are discussed. Section 4 discusses the above mentioned details of the downhole seismic tests.

## 2.0 SITE

The project site is located in UC-1 Ibrahim Hayderi in the neighbourhood of Korangi Creek. Other nearby industries include Al Asif communication, Shezad Jamrud JT Bangali Daka Office and Ibrahim Hyderi Football Stadium.

The topography of the plot is almost plain with no major changes in elevation observed across the site. Figure 2.1 shows the google image of the site.


*Fig 2.1: Google image of the the Neighbourhood area (Courtesy: Google Earth)*

# 3.0 ELECTRICAL RESISTIVITY TESTS

## 3.1 Working Principle

Electrical resistivity tests are performed in accordance with ASTM-6431-99 and ASTM G-57. Electrical resistivity tests require inserting four probes into the test area. The probes are installed in a straight line spaced according to the type of configuration to be used during the testing. Following configurations was used to perform the tests at the site.

### 1. Wenner Configuration

The probes are installed in a straight line and equally spaced. The probes establish an electrical contact with the earth. The meter injects current through the ground via the tester and the outer two probes. The current flowing through the earth (a resistive material) develops a voltage / potential difference. This voltage drop resulting from the current flow is then measured between the two inner probes.

The meter then knows the amount of current that is flowing through the earth and the voltage drop across the two center probes. With this information the meter uses ohms law (R=V/I) to calculate and display the resistance in ohms. The product of the measured resistance and geometric factor is known as apparent resistivity.

The calculated soil resistivity is the average of the soil resistivity from the surface to a depth equivalent to the probe spacing. For example, a probe spacing of 10 meters between each probe will provide the average soil resistivity between the surface and a depth of 10 meters.

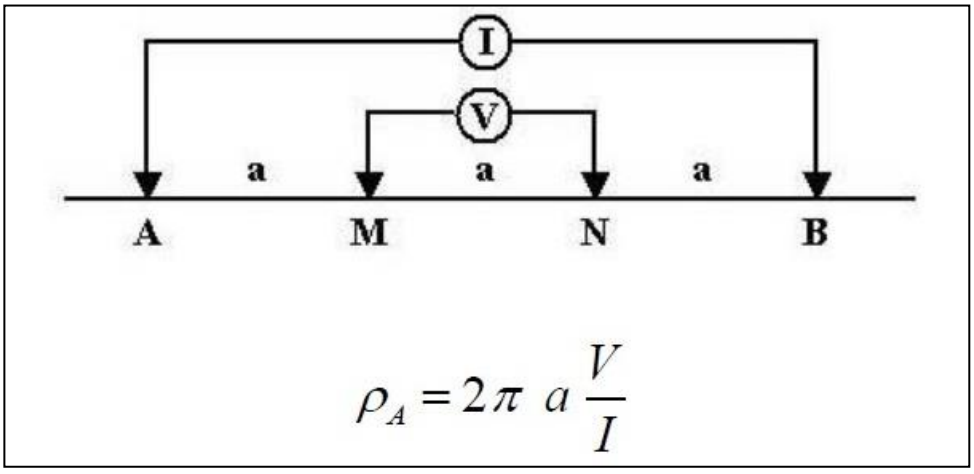



*Figure 3.1 Schematic Diagram of Wenner Array*

### 3.2 Electrical Properties of Ground

All materials, including soil and rock, have an intrinsic property, resistivity that governs the relation between the current density and the gradient of the electrical potential. Variations in the resistivity of earth materials either vertically or laterally, produce variations in the relations between the applied current and the potential distribution as measured on the surface or thereby reveal something about the composition, extent and physical properties of the subsurface materials. The various electrical geophysical techniques distinguish materials through whatever contrast exists in their electrical properties. Materials that differ geologically, such as described in a lithologic log from a drill hole, may or may not differ electrically and, therefore, may or may not be distinguished by an electrical resistivity survey. Properties that affect the resistivity of a soil or rock include porosity, water content, composition (clay mineral and metal content), salinity of the pore water, and grain size distribution.

Table 3.1 Typical electrical resistivity's of earth materials

| Material | Resistivity (Ωm) |
|---|---|
| Clay | 1-20 |
| Sand, wet to moist | 20-200 |
| Shale | 1-500 |
| Porous limestone | 100-1,000 |
| Dense limestone | 1,000-1,000,000 |
| Metamorphic rocks | 50-1,000,000 |
| Igneous rocks | 100-1,000,000 |

*Table 3.1* shows some typical ranges of resistivity values for manmade materials and natural minerals and rocks, similar to numerous tables found in the literature (van Blaricon 1980; Telford et al. 1976; Keller and Frischknecht 1966). The ranges of values shown are those

commonly encountered but do not represent extreme values. It may be inferred from the values listed that the user would expect to find in a typical resistivity survey. Low resistivities for the soil layers, with underlying bedrock producing higher resistivities. Usually, this will be the case, but the particular conditions of a site may change the resistivity relationships. For example, coarse sand or gravel, if it is dry, may have a resistivity like that of igneous rocks, whereas a layer of weathered rock may be more conductive than the soil overlying it. In any attempt to interpret resistivities in terms of soil types or lithology, consideration should be given to the various factors that affect resistivity.

Table 3.2 Resistivity versus Corrosivity of Soil

| **Corrosivity** | **Resistivity (Ω-m)** |
|---|---|
| Very Corrosive | Below 5 |
| Corrosive | 5-10 |
| Moderately Corrosive | 10-20 |
| Mildly Corrosive | 20-100 |
| Generally not Corrosive | > 100 |

## 3.3 Electrical Resistivity Interpretation

Electrical resistivity tests were conducted at four (04) different locations across the site of depth up to the maximum depth of 40.0 meters. The interpretation of resistivity values for each location is described in this section.

### 3.3.1 Soil resistivity for all lines

The resistivity values recorded at the site range from *0.57* Ω-*m* to *16.97* Ω-*m*. The underground environment is categorized as *very corrosive* to *moderately corrosive*. Table 3.3 corresponds to the corrosivity at various depths ranges in various test lines.

*Table 3.3 Corrosivity at various depths in test lines*

| Test Line | Depth Range (m) | Corrosivity |
|---|---|---|
| ERS-1 | 0.0 – 1.0 | Corrosive |
| | 1.0 – 3.0 | Moderately corrosive |
| | 3.0 – 20.0 | Very corrosive |
| | 20.0 – 30.0 | Corrosive |
| ERS-2 | 0.0 – 1.0 | Very corrosive |
| | 1.0 – 3.0 | Moderately corrosive |
| | 3.0 – 40.0 | Very corrosive |
| ERS-3 | 0.0 – 1.0 | Corrosive |
| | 1.0 – 3.0 | Moderately corrosive |
| | 3.0 – 7.0 | Very corrosive |
| | 7.0 – 10.0 | Corrosive |
| | 10.0 – 15.0 | Very corrosive |
| | 15.0 – 30.0 | Corrosive |
| ERS-4 | 0.0 – 1.0 | Very corrosive |
| | 1.0 – 3.0 | Corrosive |
| | 3.0 – 20.0 | Very corrosive |
| | 20.0 – 30.0 | Corrosive |
| | 30.0 – 40.0 | Moderately corrosive |

# 4.0 DOWNHOLE SEISMIC TESTS

## 4.1 Working Principle

The information regarding the seismic wave velocities is collected through downhole seismic tests. Seismic wave velocities include compression waves (P-wave) and shear waves (S-wave). Various geotechnical parameters including Poisson's ratio, shear modulus, bulk modulus and Young's modulus are related to P-wave and S-wave velocities. These parameters are helpful in analysing the behaviour of soil under static and dynamic loads. Different deformation states including elastic, elasto-plastic and failure are defined with the help of aforementioned soil moduli.

These tests are based on the assumption that medium which is being considered is laterally homogeneous. The trajectory of seismic waves change path based on Snell's law of refraction. The second assumption is based on the fact that the medium being considered can have transverse isotropy.

One (01) downhole seismic test was performed. The test was performed in accordance with ASTM D7400-08.

## 4.2 Performance of test

The test was performed by lowering a triaxial geophone inside the borehole and striking the shear beam. The strike produces seismic waves, including P and S waves, the arrival time of these waves were recorded by the geophone inside the borehole and the data was processed to determine various soil moduli. The graphical representation of results of seismic downhole tests are included in Appendices.

## 4.4 Data Processing

The data collected on the field is then processed. Data was processed with the help of "wave velocity logging system". On the basis of arrival time of compression waves (P-wave) and shear waves (S-wave), velocities for both the waves were calculated by the downhole seismic system. This was performed for both the compression waves (P-waves) and shear waves (S-waves). Elastic geotechnical parameters including Shear modulus, Elastic modulus, Bulk modulus and

Poisson's ratio were calculated with the help of data acquired for velocity of the seismic waves. Details of the results have been presented in Appendix-B.

### 4.5 Conclusions

The results along with the assumed densities were utilised to calculate various soil parameters including Shear modulus, Elastic modulus, Bulk modulus and Poisson's ratio. The parameters were calculated up to a depth of 30 meters at an interval of (01) meter. Based on the test results, seismic soil profile shall be "$S_D$". The summary of test results has been presented in table 4.1.

*Table 4.1 Summary of test results*

| **DHST-01** | |
|---|---|
| **P-wave velocities (m/sec)** | 153 – 2398 |
| **S-wave velocities (m/sec)** | 91 – 1324 |
| **Poisson's ratio** | 0.195 – 0.285 |
| **Elastic Modulus (MPa)** | 33 – 9157 |
| **Shear Modulus (MPa)** | 14 – 3575 |
| **Bulk Modulus (MPa)** | 20 – 6957 |

# APPENDICES

# APPENDIX-A

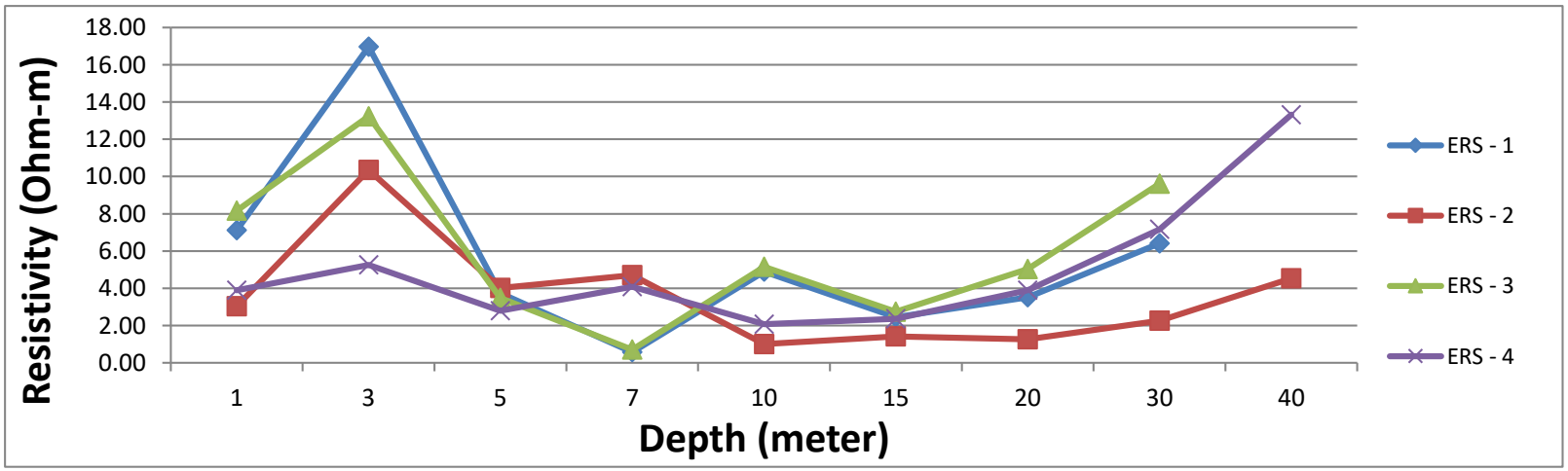
# TEST RESULTS FOR ELECTRICAL RESISTIVITY TESTS

K22-1175-101

**Project:** INSTALLATION OF 5 MGD DESALINATION PLANT AT IBRAHIM HYDERI, KARACHI

**Client:** TECHNO CONSULT INTERNATIONAL

| Depth (meters) | ERS - 1 | ERS - 2 | ERS - 3 | ERS - 4 |
|---|---|---|---|---|
| | Resistivity (Ohm-m) | | | |
| 1 | 7.11 | 3.04 | 8.16 | 3.90 |
| 3 | 16.97 | 10.35 | 13.23 | 5.26 |
| 5 | 3.74 | 4.02 | 3.49 | 2.80 |
| 7 | 0.57 | 4.71 | 0.70 | 4.09 |
| 10 | 4.90 | 1.01 | 5.15 | 2.07 |
| 15 | 2.45 | 1.41 | 2.73 | 2.36 |
| 20 | 3.52 | 1.26 | 5.03 | 3.90 |
| 30 | 6.41 | 2.26 | 9.61 | 7.16 |
| 40 | - | 4.52 | - | 13.32 |



# APPENDIX-B

# TEST RESULTS FOR DOWNHOLE SEISMIC TESTS

# DHST-01

**Project No. :** K22-1175-101

**Project:** DOWNHOLE SEISMIC TESTS FOR INSTALLATION OF 5 MGD DESALINATION PLANT AT IBRAHIM HYDERI, KARACHI

| | S-wave | | | P-wave | | |
|---|---|---|---|---|---|---|
| Depth (m) | Velocity (m/sec) | Time (sec) | Time (millisec) | Velocity (m/sec) | Time (sec) | Time (millisec) |
| 1 | 134 | 0.007 | 7.463 | 218 | 0.005 | 4.594 |
| 2 | 91 | 0.022 | 21.978 | 153 | 0.013 | 13.064 |
| 3 | 95 | 0.032 | 31.579 | 160 | 0.019 | 18.710 |
| 4 | 101 | 0.040 | 39.604 | 173 | 0.023 | 23.128 |
| 5 | 111 | 0.045 | 45.045 | 186 | 0.027 | 26.830 |
| 6 | 124 | 0.048 | 48.387 | 207 | 0.029 | 29.032 |
| 7 | 130 | 0.054 | 53.846 | 214 | 0.033 | 32.757 |
| 8 | 138 | 0.058 | 57.971 | 226 | 0.035 | 35.383 |
| 9 | 144 | 0.063 | 62.500 | 236 | 0.038 | 38.203 |
| 10 | 152 | 0.066 | 65.789 | 247 | 0.041 | 40.502 |
| 11 | 174 | 0.063 | 63.218 | 293 | 0.038 | 37.574 |
| 12 | 195 | 0.062 | 61.538 | 329 | 0.036 | 36.468 |
| 13 | 279 | 0.047 | 46.595 | 474 | 0.027 | 27.440 |
| 14 | 315 | 0.044 | 44.444 | 546 | 0.026 | 25.651 |
| 15 | 355 | 0.042 | 42.254 | 623 | 0.024 | 24.081 |
| 16 | 374 | 0.043 | 42.781 | 644 | 0.025 | 24.826 |
| 17 | 395 | 0.043 | 43.038 | 689 | 0.025 | 24.686 |
| 18 | 418 | 0.043 | 43.062 | 716 | 0.025 | 25.149 |
| 19 | 444 | 0.043 | 42.793 | 774 | 0.025 | 24.547 |
| 20 | 489 | 0.041 | 40.900 | 850 | 0.024 | 23.519 |

# DHST-01

**Project No. :** K22-1175-101

**Project:** DOWNHOLE SEISMIC TESTS FOR INSTALLATION OF 5 MGD DESALINATION PLANT AT IBRAHIM HYDERI, KARACHI

| | S-wave | | | P-wave | | |
|---|---|---|---|---|---|---|
| Depth (m) | Velocity (m/sec) | Time (sec) | Time (millisec) | Velocity (m/sec) | Time (sec) | Time (millisec) |
| 21 | 551 | 0.038 | 38.113 | 974 | 0.022 | 21.570 |
| 22 | 594 | 0.037 | 37.037 | 1024 | 0.021 | 21.484 |
| 23 | 699 | 0.033 | 32.904 | 1229 | 0.019 | 18.709 |
| 24 | 774 | 0.031 | 31.008 | 1347 | 0.018 | 17.822 |
| 25 | 841 | 0.030 | 29.727 | 1462 | 0.017 | 17.103 |
| 26 | 925 | 0.028 | 28.108 | 1616 | 0.016 | 16.091 |
| 27 | 1036 | 0.026 | 26.062 | 1818 | 0.015 | 14.855 |
| 28 | 1158 | 0.024 | 24.180 | 2028 | 0.014 | 13.807 |
| 29 | 1241 | 0.023 | 23.368 | 2263 | 0.013 | 12.817 |
| 30 | 1324 | 0.023 | 22.659 | 2398 | 0.013 | 12.512 |

# DHST-01

**Project No. :** K22-1175-101

**Project:** DOWNHOLE SEISMIC TESTS FOR INSTALLATION OF 5 MGD DESALINATION PLANT AT IBRAHIM HYDERI, KARACHI

| Depth (m) | Poisson's ratio | Young's Modulus (MPa) | Shear Modulus (MPa) | Bulk Modulus (MPa) |
|---|---|---|---|---|
| 1 | 0.195 | 70 | 29 | 38 |
| 2 | 0.227 | 33 | 14 | 20 |
| 3 | 0.230 | 36 | 15 | 22 |
| 4 | 0.241 | 41 | 17 | 27 |
| 5 | 0.225 | 49 | 20 | 30 |
| 6 | 0.219 | 61 | 25 | 36 |
| 7 | 0.206 | 67 | 28 | 38 |
| 8 | 0.203 | 77 | 32 | 43 |
| 9 | 0.202 | 84 | 35 | 47 |
| 10 | 0.195 | 93 | 39 | 51 |
| 11 | 0.227 | 129 | 52 | 79 |
| 12 | 0.229 | 162 | 66 | 100 |
| 13 | 0.235 | 343 | 139 | 215 |
| 14 | 0.250 | 443 | 177 | 296 |
| 15 | 0.259 | 599 | 238 | 415 |
| 16 | 0.246 | 658 | 264 | 432 |
| 17 | 0.255 | 739 | 294 | 502 |
| 18 | 0.241 | 818 | 330 | 527 |
| 19 | 0.255 | 933 | 372 | 634 |
| 20 | 0.253 | 1131 | 451 | 763 |
| 21 | 0.264 | 1448 | 573 | 1025 |
| 22 | 0.246 | 1659 | 666 | 1091 |
| 23 | 0.261 | 2325 | 922 | 1622 |
| 24 | 0.253 | 2833 | 1130 | 1914 |

# DHST-01

**Project No. :** K22-1175-101

**Project:** DOWNHOLE SEISMIC TESTS FOR INSTALLATION OF 5 MGD DESALINATION PLANT AT IBRAHIM HYDERI, KARACHI

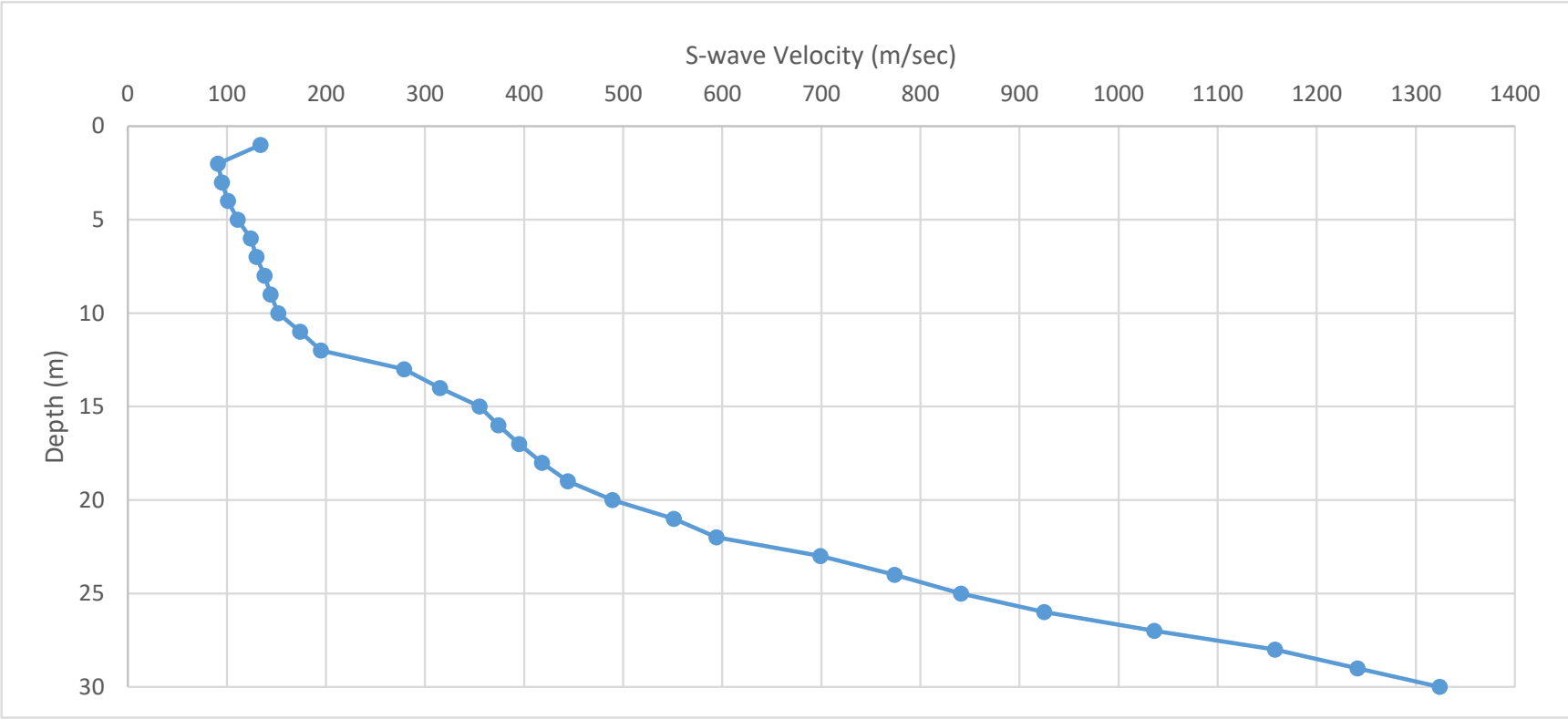
| Depth (m) | Poisson's ratio | Young's Modulus (MPa) | Shear Modulus (MPa) | Bulk Modulus (MPa) |
|---|---|---|---|---|
| 25 | 0.253 | 3614 | 1443 | 2434 |
| 26 | 0.256 | 4385 | 1745 | 2998 |
| 27 | 0.259 | 5514 | 2189 | 3819 |
| 28 | 0.258 | 6882 | 2735 | 4742 |
| 29 | 0.285 | 8072 | 3141 | 6254 |
| 30 | 0.281 | 9157 | 3575 | 6957 |

**Project No. :** K22-1175-101

**Project:** DOWNHOLE SEISMIC TESTS FOR INSTALLATION OF 5 MGD DESALINATION PLANT AT IBRAHIM HYDERI, KARACHI

**Borehole No. :** DHST-01

# S-Wave Velocity vs Depth Profile



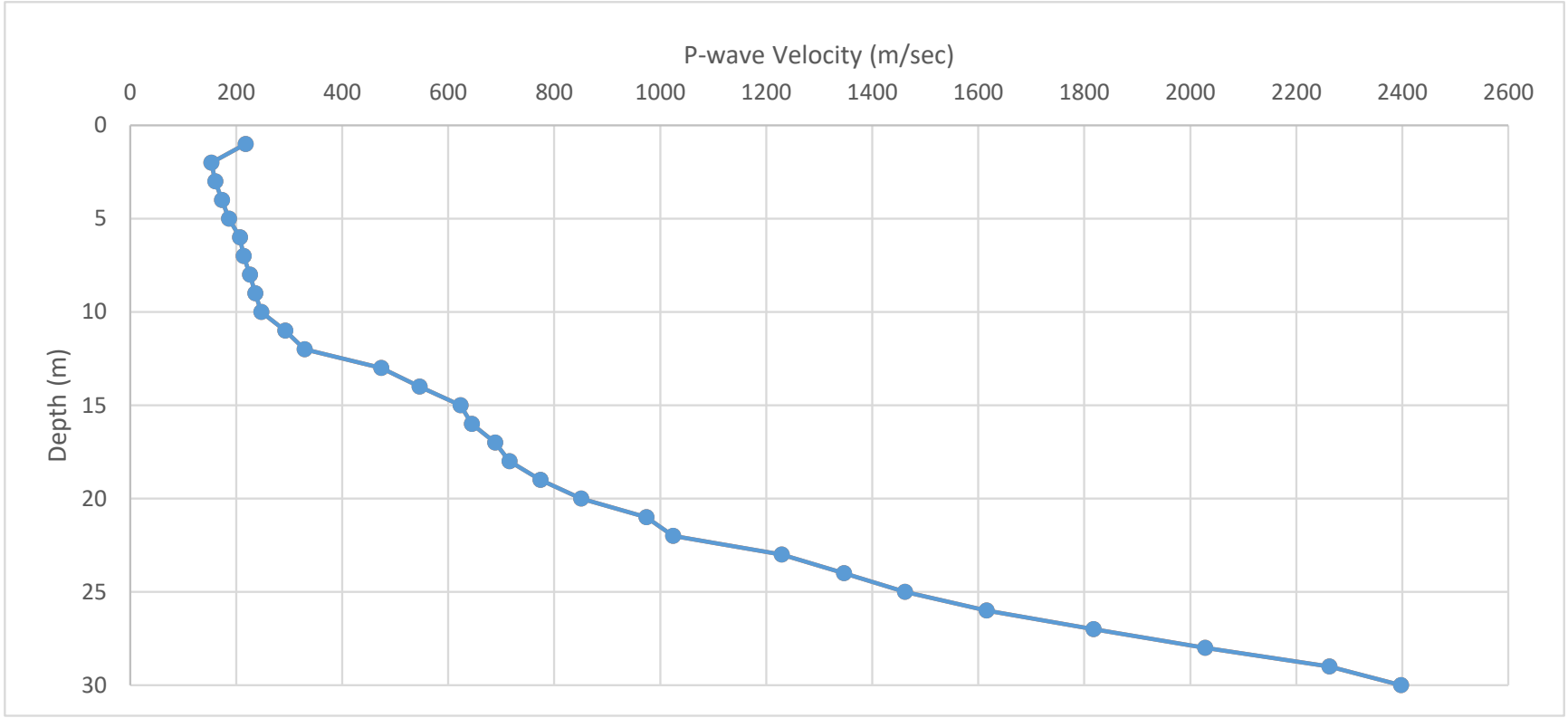

Soil Testing Services

**Project No. :** K22-1175-101

**Project:** DOWNHOLE SEISMIC TESTS FOR INSTALLATION OF 5 MGD DESALINATION PLANT AT IBRAHIM HYDERI, KARACHI

**Borehole No. :** DHST-01

# P-Wave Velocity vs Depth Profile



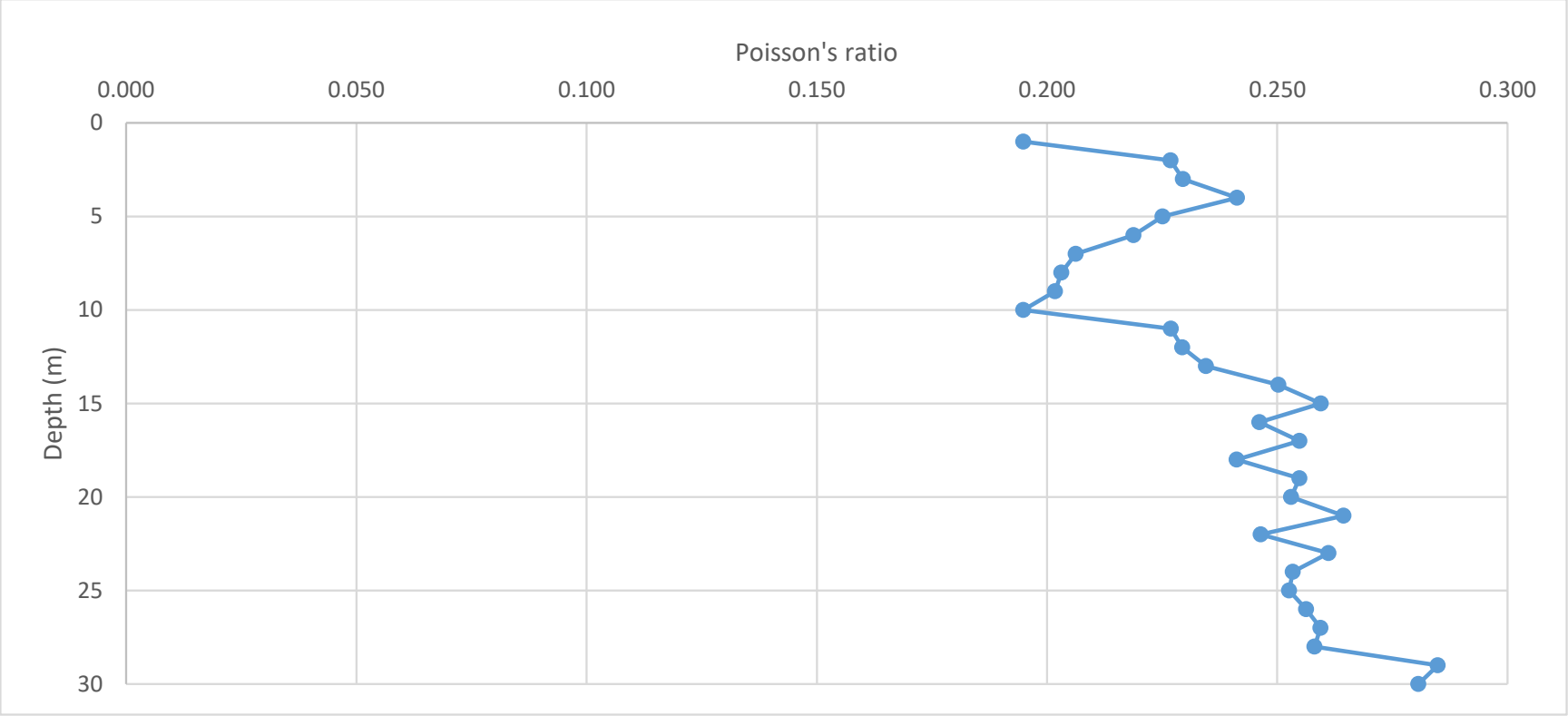

Soil Testing Services

**Project No. :** K22-1175-101

**Project:** DOWNHOLE SEISMIC TESTS FOR INSTALLATION OF 5 MGD DESALINATION PLANT AT IBRAHIM HYDERI, KARACHI

**Borehole No. :** DHST-01

# Poisson's Ratio vs Depth Profile



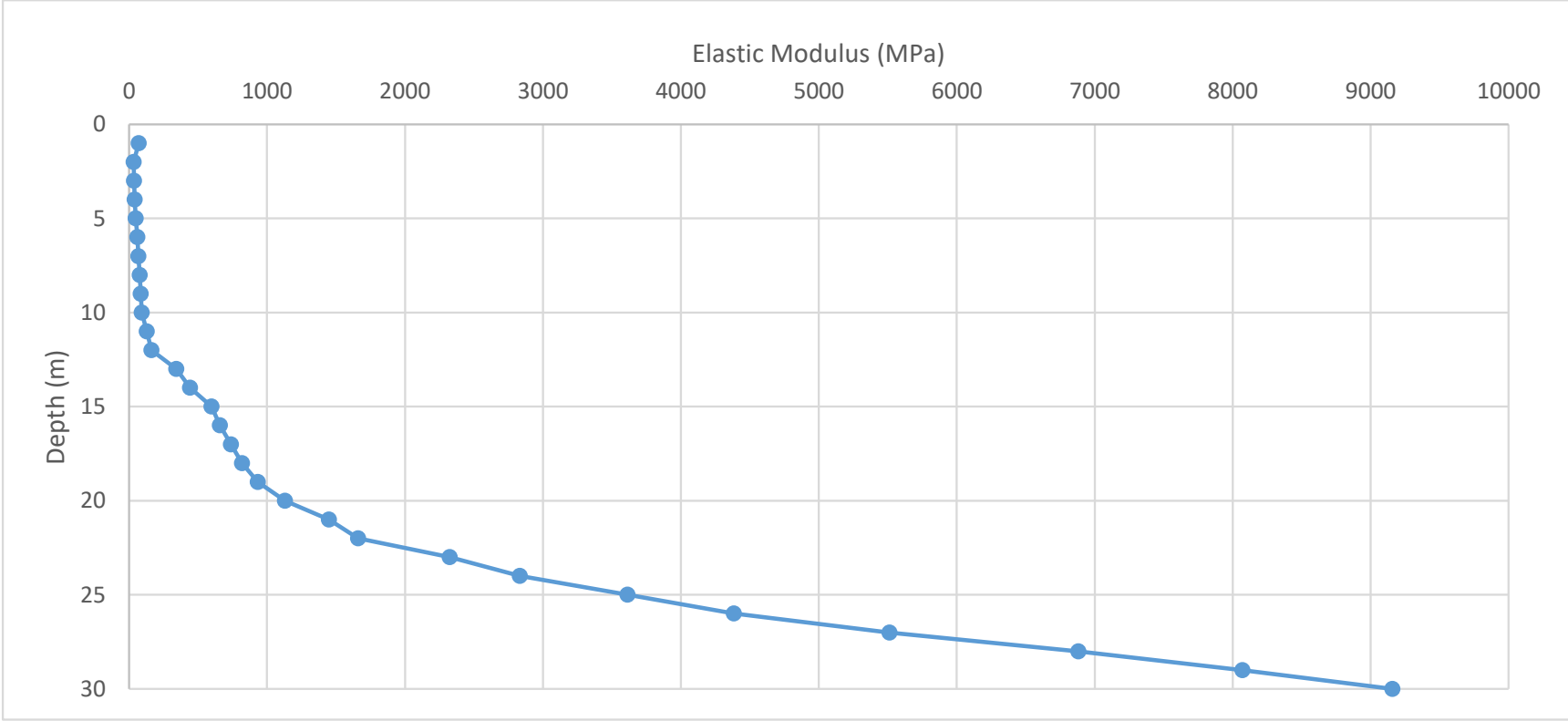

Soil Testing Services

**Project No. :** K22-1175-101

**Project:** DOWNHOLE SEISMIC TESTS FOR INSTALLATION OF 5 MGD DESALINATION PLANT AT IBRAHIM HYDERI, KARACHI

**Borehole No. :** DHST-01

# Elastic Modulus vs Depth Profile



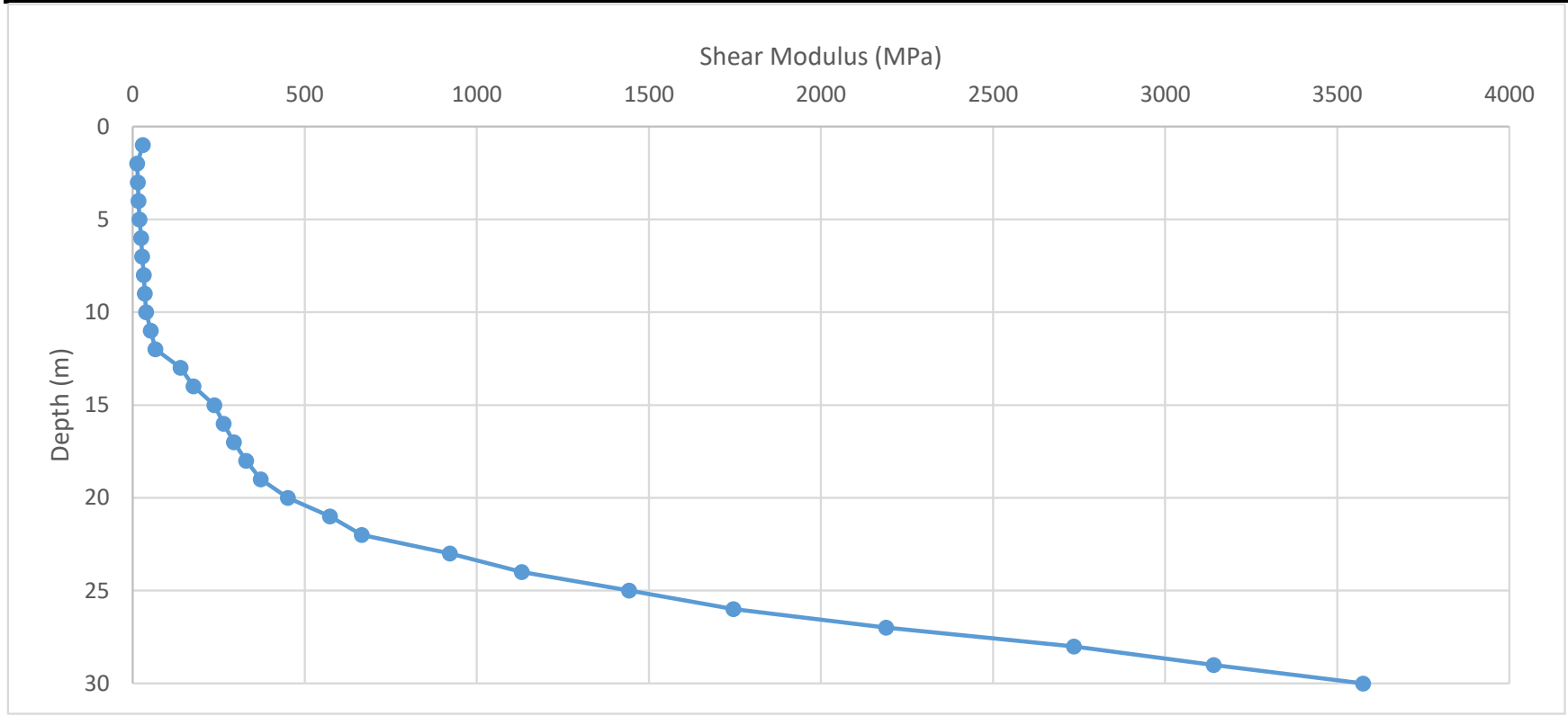

Soil Testing Services

**Project No. :** K22-1175-101

**Project:** DOWNHOLE SEISMIC TESTS FOR INSTALLATION OF 5 MGD DESALINATION PLANT AT IBRAHIM HYDERI, KARACHI

**Borehole No. :** DHST-01

# Shear Modulus vs Depth Profile



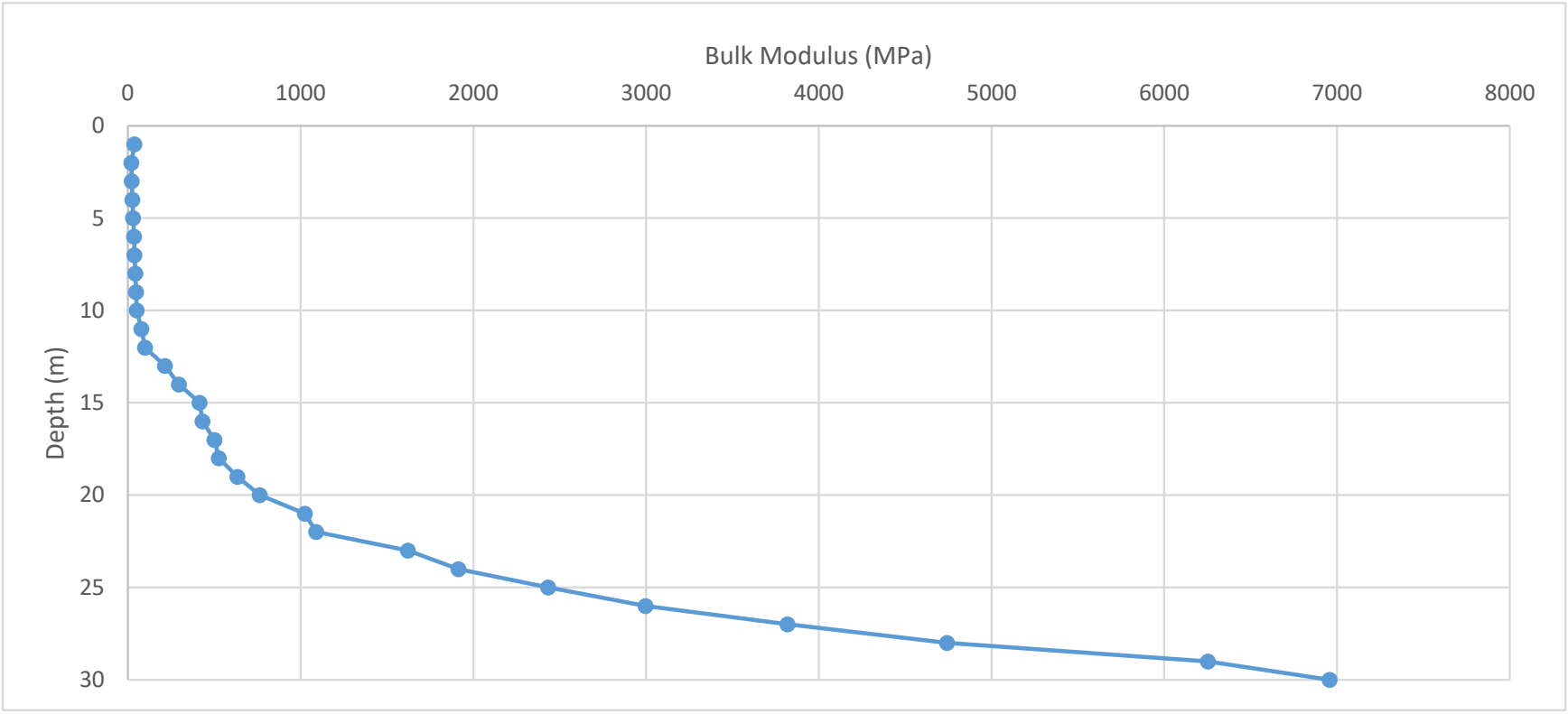

Soil Testing Services

**Project No. :** K22-1175-101

**Project:** DOWNHOLE SEISMIC TESTS FOR INSTALLATION OF 5 MGD DESALINATION PLANT AT IBRAHIM HYDERI, KARACHI

**Borehole No. :** DHST-01

# Bulk Modulus vs Depth Profile

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