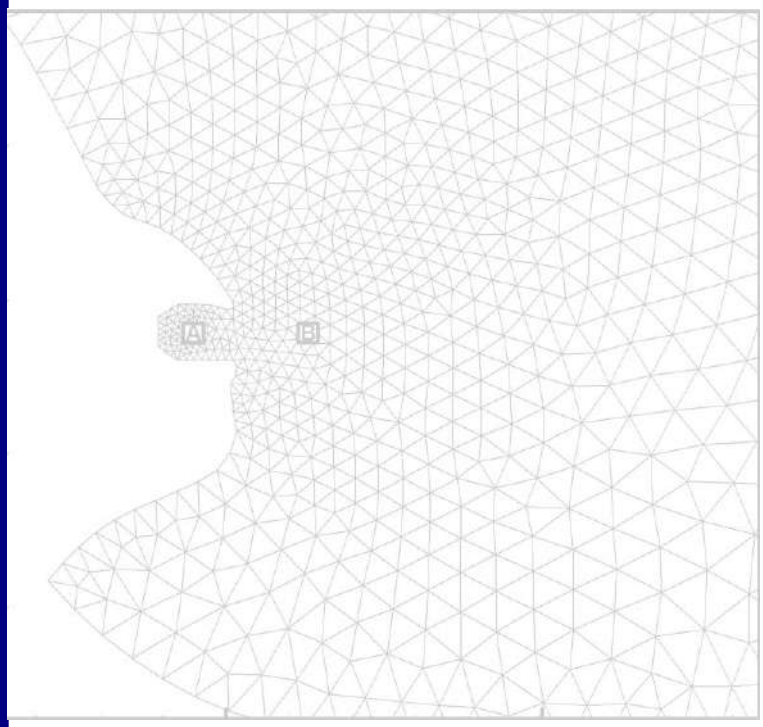
# DPR FOR THE DEVELOPMENT OF INDUSTRIAL LAND BY UTILIZATION OF DREDGED MATERIAL AT PRATAPPUR & FATEPUR, PARADIP FOR IDCO, GoO



**Final Report**

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# CHAPTER 1

## PROJECT BACKGROUND

Indian Oil provides precious petroleum fuels to every part of the country through its network of over 60,000 plus customer touch-points, surmounting the challenges of tough terrain, climate, and accessibility. The marketing network is bolstered by 70.05 MMTPA of Refining Capacity and more than 17,000 KM of cross-country pipelines. Moreover, Indian Oil R&D Centre at Faridabad, one of Asia's finest in downstream petroleum R&D, offers a competitive advantage to the Corporation through world-class technology process solutions and innovative products. Indian Oil R&D has also been instrumental in pioneering path-breaking research to leverage the potential of Hydrogen and other cleaner fuels for the sustainable progress of the nation.

Paradip Refinery, was commissioned in 2016, is situated in Paradip, Jagatsinghpur district in the State of Odisha. Situated on the Eastern Coast this Refinery caters to the petroleum products demand and is strategically located for export of petroleum products to South-East Asian countries. This refinery is spread over approximately 3,345 acres of land and is situated approximately 5 km southwest from the Paradip Port.

Paradip Refinery is Indian Oil's first refinery with a single Atmospheric Column for processing 15.0 Million Metric Tonnes Per Annum. The crude receipt is by 3 nos. Single Point Mooring (SPM) is located around 30 km inside the sea to facilitate Crude delivery by VLCC. The refinery is designed to process 100% High Sulphur Crude and TAN of 0.5.

Several first-time technological features has been installed at Paradip Refinery including Flue Gas Desulphurization facilities for firing high Sulphur Vacuum Residue & Vapor Recovery system from jetty loading to meet the stringent emission norms of SOx and Volatile organic emissions despite processing heavy high Sulphur Crude. The refinery is in a synergic partnership with the environment as this is a zero effluent discharge refinery with strictly monitored and controlled stack emissions that are uplinked on real-time basis to the server of Central Pollution Control Board.

The refinery consists of an Alkylation unit to produce octane-rich low-benzene MS blend components. The refinery configuration also consists of "INDMAX" unit that is indigenous IOCL technology. It is capable of producing a high yield of LPG and propylene. The refinery can produce various petroleum products like gasoline, diesel, kerosene, and aviation turbine fuel, Propylene, Sulphur, and Petroleum Coke. The refinery is also designed

to produce total Premium Quality Gasoline variants for export. Major units are AVU, Coker, CCRU, VGO Hydro-treater, Sulfur Recovery unit, Diesel hydro-treater, and Sulphuric Acid Regeneration Unit (SARU).

On the petrochemical front, Paradip produces various grades of PP from its Polypropylene unit. To expand IOCL's petrochemical footprint, ERU (Ethylene Recovery Unit) and MEG (Mono Ethylene Glycol) units were installed.

The Aerial view of the existing plant as shown in Figure 1.1.



Figure 1.1 Aerial view of IOCL Paradip Plant

In order to address their increasing production into petrochemical domain, Indian Oil Corporation Limited (IOCL) has planned to establish a Petrochemical Complex at Paradip. The proposed site for the project is at Pratappur as shown in Figure 1.2.




Figure 1.2 A schematic of present and proposed IOCL complex

The identified land site spread over 705 acres, requires to be filled up to an approximate elevation of +5.45m above CD, and the net volume of fill is estimated at 7.9 Million Cubic meters, excluding the quantities required for densification, ground improvement, bunding and wastages. Hence, IOCL had approached Odisha Industrial Infrastructure Development Corporation, an organisation under the Government of Odisha, for extending assistance to scout the fill materials from the adjacent sea. In turn, IDCO had nominated Dredging Corporation of India, Limited (DCIL) for dredging at a suitable location in the sea and transporting the dredged materials for reclamation in the low-lying area allotted to IOCL. Before carrying out the dredging and reclamation work, it is necessary to select suitable dredging areas and pipeline routes, bathymetry and topographic surveys, geotechnical and geophysical investigations, as well as environmental studies such as EIA and EMP for the marine environment. A "Detailed Project Report" (DPR) must be prepared after the site investigations to obtain statutory clearances, if any, NOC from the concerned departments of the State Government of Odisha and the Government of India.

Considering the expertise available with the National Technology Centre for Ports, Waterways, and Coasts (NTCPWC) of the Indian Institute of Technology Madras (IITM) for carrying out similar types of studies and preparation of the detailed project reports (DPR),

DCIL had awarded the work of DPR for the Development of Industrial land by utilization of Dredged Material at Pratappur & Fatepur, Paradip for IDCO, GoO vide work order no DCI/IWD/NTCPWC/2023/02 dated 15.12.2023.

## 1.1 OBJECTIVE AND SCOPE OF THE STUDY

The main objectives of the study is to prepare DPR for the Development of Industrial land by utilization of Dredged Material at Pratappur & Fatepur, Paradip.

### 1.1.1 THE SCOPE OF THE STUDY IN PREPARATION OF DPR INTER-ALIA COVERS

- To carry out the bathymetry survey at the proposed area of 6kmx11.5km at 100m line intervals.
- To carry out the Sub-bottom profiler survey at 200m line intervals.
- To carry out a topographic survey between the boundary to the edge of the proposed borrow area for the selection of suitable pipeline routes and to assess the gradient from the borrow area to the reclamation area (30sqkms).
- To carry out the geotechnical investigation at the proposed 24 marine boreholes in the borrow area of about 6km x 11.5km to assess the suitability of ill material for the reclamation area and to assess the required quantity.
- To prepare the Detailed Project Report (DPR) inter-alia covering;
    a. Identification of borrow areas based on the suitability of soil.
    b. Selection of suitable pipeline route.
    c. Total estimate fill quantity
    d. Methodology of Dredging and Reclamation
    e. Pre and Post-impacts of dredging and reclamation and mitigation measures.
- To complete the entire requisite to fill the form-1 application to the state Environmental Impact Assessment Authority (SEIMAA) for obtaining TOR.
- To prepare EIA/EMP reports as per SEIMAA and MoEF for obtaining environmental clearances from the concerned authority.
- To prepare the CRZ map reflecting the HTL/LTL line for the proposed project site.
- Presentation before SEIMAA or in front of statutory/regulatory body for getting NOC clearances.
- To assist the client in obtaining NOC from the state pollution control board.
- To conduct numerical modeling including hydrodynamic modeling and sediment transport model.

## 1.2 DEVELOPMENT OF ALL WEATHER, MULTI-CARGO, GREENFIELD, CAPTIVE JETTY(IES) FOR HANDLING CAPACITY 52 MTPA IN JATADHARI MUHAN RIVER, DIST. JAGATSINGHPUR, ODISHA BY JSW-USL ADJACENT TO THE PROPOSED RECLAMATION AREA.

In the vicinity of the proposed new IOCL complex, JSW – Utkal Steel Limited (JSW-USL) is proposing to develop an all weather Multi-cargo Greenfield port. The proposed project envisages the development of all-weather Multi-cargo, Greenfield Captive Jetty(ies), adjacent to the proposed Integrated Steel Plant (ISP) of JSW-USL, on the riverfront of the Jathadhari River in Ersama Tehsil of Jagatsinghpur District of Odisha. The proposed captive jetty(ies) would cater to the import and export requirements of the demands of the ISP consisting of the steel plant (13.2 MTPA), 900 MW power plant using dual fuel (coal and natural gas from furnaces) and 10 MTPA cement plant. The Integrated steel plant (ISP) is envisaged to be established with an annual capacity of 13.2 MTPA with a provision for expansion in future. The raw material including Coal Bearing Raw Material (CBRM), Flux and Clinker requirement for the ISP will be 24.93 MTPA. The list of various raw materials required for ISP proposed to be handled in the captive jetty(ies) is given as below:

| | |
|---|---|
| Coal-bearing Raw Material (CBRM) | 16.50 MTPA |
| Flux (limestone, quartzite etc.) | 3.13 MTPA |
| Clinker | 5.30 MTPA |
| Total | 24.93 MTPA |

In addition, the finished products from the ISP namely steel (in pellet form or in any other form) and cement shall be shipped using the captive jetty(ies). Hence the total traffic as per initial estimates will be about 52 MTPA and details are as follows:

| | |
|---|---|
| Inward Traffic | 24.93 MTPA |
| Outward Traffic | 27.00 MTPA |
| Total | 51.93 MTPA |

The length of the waterfront proposed being developed including the berthing facilities, depends largely on the annual throughput, parcel size and the cargo handling rates. For the proposed all-weather multi-cargo, green field captive jetty(ies) of 52 MTPA handling capacity, the total length of berths proposed to be developed is about 3400 m. A total 10 Nos. of berths are proposed as part of the initial development.

Considering an average berth length of 340 m, a total berth length of 3400 m for cargo handling, and an additional 3 berths for port crafts are provisioned for the later stage of development. As part of the proposed development, there will be 2 berths for Capesize vessels, 5 berths for Panamax vessels and 3 berths for Handymax vessels. The other three berths shall be earmarked for the port crafts and other requirements in the later years of development.

In order for development of the proposed Greefield port, JSW-USL intends to carry out reclamation of land using about 30 Million cu.m of dredged material from their proposed navigational and berth areas. JSW-USL already secured all statutory clearnaces including CRZ Clearance for these activities.

## 1.3 ORGANIZATION OF THE REPORT

This report is presented in modular form to cater for simpler and clearer understanding. This part of the report is the main text, capturing and summarizing the major aspects of the study. The overall structure of the report is given in Table :

Table 1.1 Overall structure of the report

| SI.NO | DESCRIPTION |
|---|---|
| 1 | Project Background |
| 2 | Project Site Environment |
| 3 | Detailed Site Investigation |
| 4 | Geotechnical Investigation |
| 5 | Dredging and Reclamation Plan |
| 6 | EIA Study |
| 7 | Model study on Hydrodynamic and Wave condition |
| 8 | Project Cost |
| 9 | Discussion and Recommendation |
| 10 | Conclusion |

# CHAPTER 2

# PROJECT SITE ENVIRONMENT

The analysis of the prevailing environmental aspects of the project site is essential for a better understanding of the site that will help in the proposed development and modification of the site. Hence, overall environmental data on the location, connectivity, meteorological parameters, oceanographic conditions, geotechnical aspects, and basic details of the project site are presented for better appreciation.

## 2.1 PROJECT SITE LOCATION

Pratappur is a small village/hamlet in Kujang Tehsil in Jagatsinghapur District of Odisha State, India. It is located 39 km east from the district headquarters in Jagatsinghpur and 79 km from the state capital, Bhubaneswar.

Pratappur is surrounded by Paradip Tehsil towards the east, Marsaghai Tehsil towards the north, Erasama Tehsil towards the south, and Mahakalapada Tehsil towards the north. Pratappur is on the border of Jagatsinghapur District and Kendrapara District. Kendrapara District's Mahakalapada is north towards this place. It is near the Bay of Bengal, with a chance of humidity in the weather.

Odisha is located in the eastern part of the Indian peninsula and lies along the Bay of Bengal to its east, while Chhattisgarh shares its border to the west and northwest. Odisha, with a geographical area of 155,842 square kilometers, accounts for 4.7% of the geographical area of India. The coastal districts are Balasore, Cuttack, Puri, Jagatsinghapur, and Ganjam, which have a coastline of 480 km in length, representing 8% of the coastline of India

In the months of June to September, the southwest monsoon occurs, followed by the northeast monsoon in October- December. The later period is often indicated as the post-monsoon period. January-February is the winter period and March-May is usually the hot weather period.

### 2.1.1 ROAD CONNECTIVITY

Paradip is connected via road with Cuttack and Chandikhole, which are two of the major cities in Odisha.

- Cuttack and Paradip are connected by SH-12 (2 lanes).
- Cuttack and Chandikhole are connected by NH-5A (4 lanes).

All-important destinations in India whether on the North, West, or East could be accessed through any of the above-mentioned Highways as shown in Figure 2.1.




Figure 2.1 Road Map of the site

### 2.1.2 RAIL CONNECTIVITY

Paradip rail network is a part of the East Coast Railway System and is connected to the hinterland via Cuttack by a broad gauge rail link. Cuttack is approximately 90 km from Paradip and connects to the Howrah-Chennai main line. The Howrah-Chennai line connects Paradip to Kolkata (with a route length of about 500 km) to the north and Chennai to the south (with a route length of about 1,340 km). The current rail connectivity to Paradip Port is shown in Figure 2.2.




Figure 2.2 Railway Map of the site

## 2.2 METEOROLOGICAL CONDITIONS

The meteorological conditions in the Pratappur region are described in the following paragraphs:

### 2.2.1 WIND

Windrose of Paradeep shows that dominant wind blows from the SSW much of the time - about 22.08% of all hourly wind directions. Approximately 13.01% (max) of the time the wind blows from the SSW at speeds are more than 5 m/s. Further, at Paradip much of the time winds blow at speeds between 5 and 12.17 m/s - which is 34.85% of the time. About 0.65% of the time winds were CALM i.e. wind speeds less than 0.5m/s. The average wind speed in Paradip is 4.4 m/s with the maximum wind speed of around 12 m/s.

*The Monthly wind rose below showing how wind speed and direction are typically distributed in Paradip, shown in* Figure 2.3

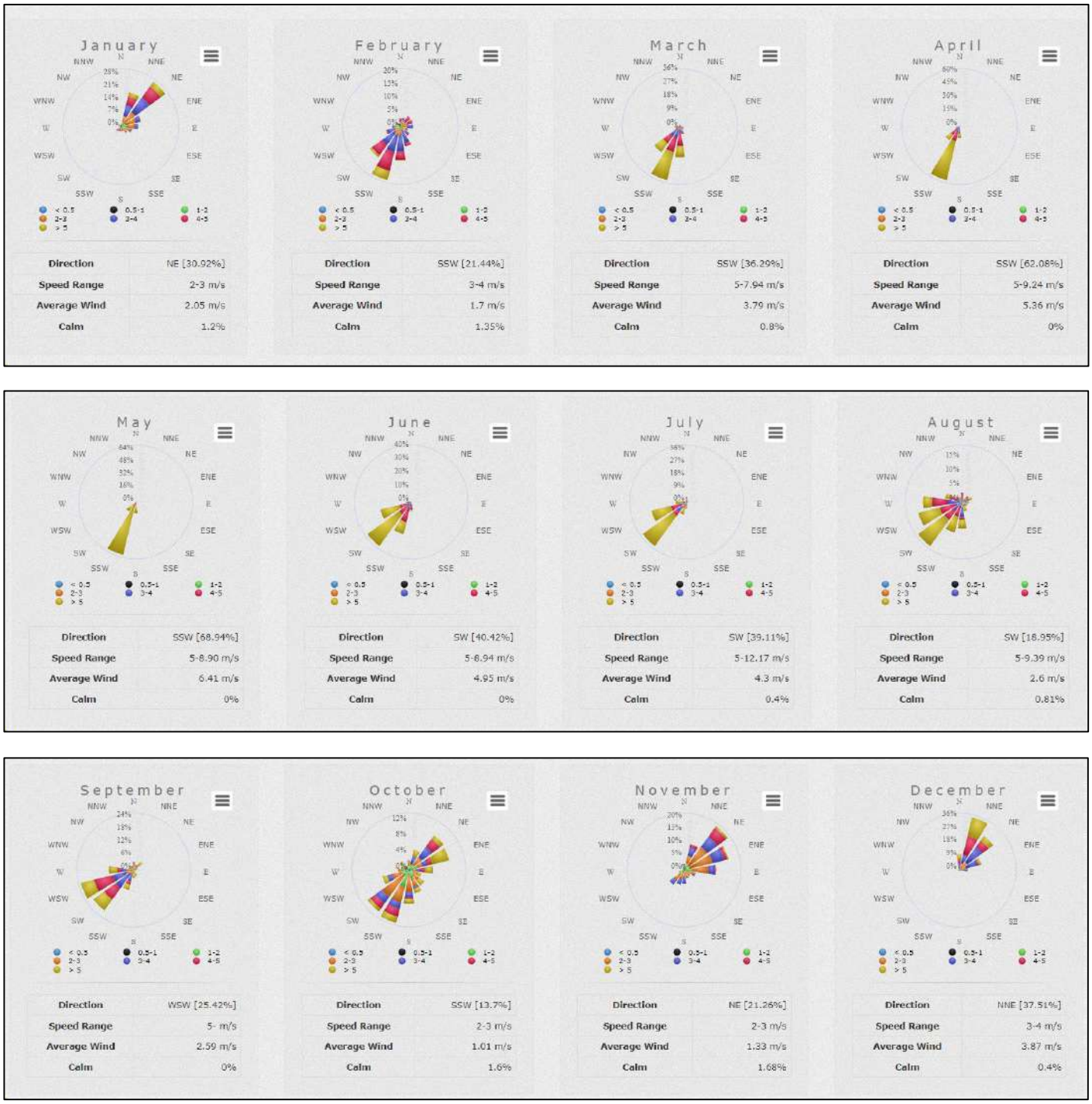



Figure 2.3 Monthly windrose diagram for Paradip

### 2.2.2 TEMPERATURE

The average temperature of Paradip is around 27°C although it varies from around 21°C during Winter (January) to 30°C during the Monsoon (June). The hottest month of the year is June with temperatures varying from 25.8°C to 33.3°C. The coolest month of the year is

January, with temperatures varying from 17.8°C to 25.5°C. The Table 2.1 and Figure 2.4 shows the minimum, maximum, and average °C Temperature by month in Paradip.

Table 2.1 Monthly Temperature

| Month | Temperature, °C | | |
|---|---|---|---|
| | Minimum | Maximum | Average |
| January | 17.8 | 25.5 | 21.4 |
| February | 19.8 | 28.7 | 23.9 |
| March | 23.4 | 30.0 | 26.8 |
| April | 25.2 | 31.6 | 28.3 |
| May | 27.2 | 31.9 | 29.4 |
| June | 25.8 | 33.3 | 29.5 |
| July | 26.1 | 30.4 | 28.3 |
| August | 26.1 | 31.2 | 28.3 |
| September | 26.0 | 30.1 | 28.0 |
| October | 23.6 | 31.2 | 27.7 |
| November | 21.9 | 29.4 | 25.8 |
| December | 17.1 | 25.9 | 22.3 |

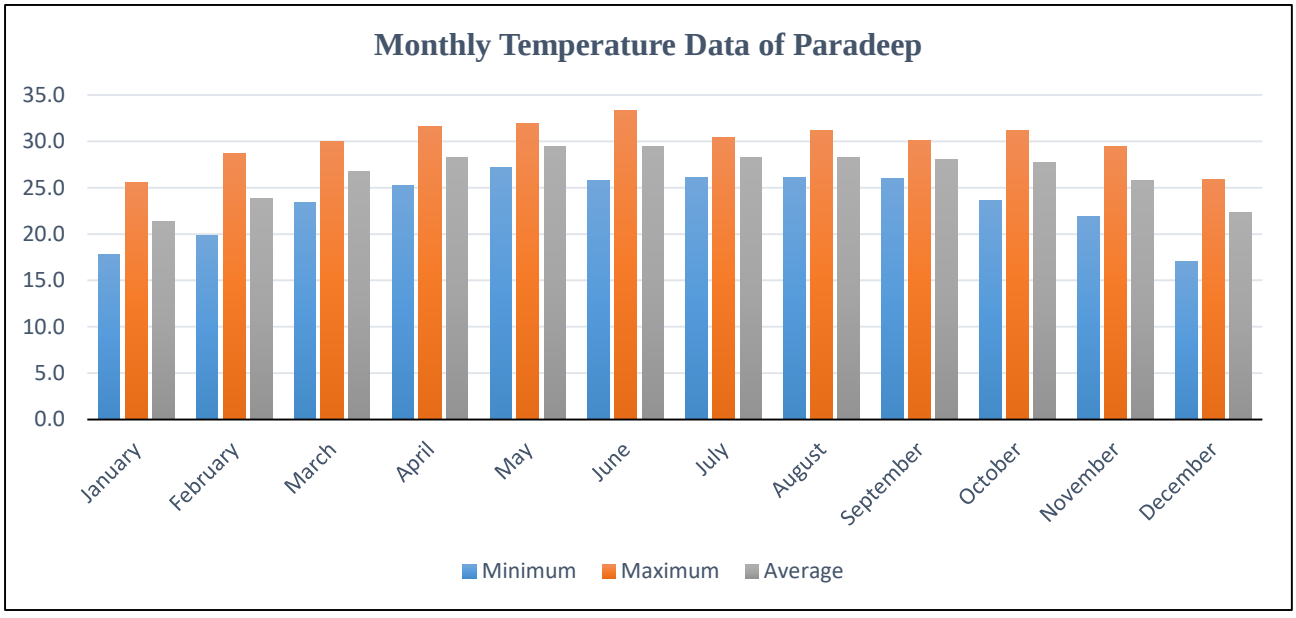



Figure 2.4 Monthly Temperatures values in Paradeep

### 2.2.3 HUMIDITY

The average Relative Humidity of Paradip is around 80% although it varies from around 69% during Winter (December) to 87% during the Monsoon (July). The most humid month of the year is July with humidity varying from 76.9% to 98.6%. The least humid month of the year is December, with humidity varying from 44.4% to 97.0%.

The table 2.2 below shows the minimum, maximum, and average percentage Relative Humidity over the year in Paradip.

Table 2.2 Percentage of Relative Humidity

| Month | Relative Humidity, % | | |
|---|---|---|---|
| | Minimum | Maximum | Average |
| January | 49.8 | 94.1 | 72.3 |
| February | 56.1 | 96.9 | 80.9 |
| March | 56.5 | 96.1 | 82.3 |
| April | 65.4 | 94.0 | 81.9 |
| May | 69.6 | 93.5 | 82.6 |
| June | 62.4 | 94.1 | 82.4 |
| July | 76.9 | 98.6 | 86.9 |
| August | 68.4 | 95.8 | 85.2 |
| September | 74.2 | 96.3 | 85.0 |
| October | 49.0 | 98.6 | 78.2 |
| November | 49.9 | 94.3 | 74.6 |
| December | 44.4 | 97.0 | 69.0 |

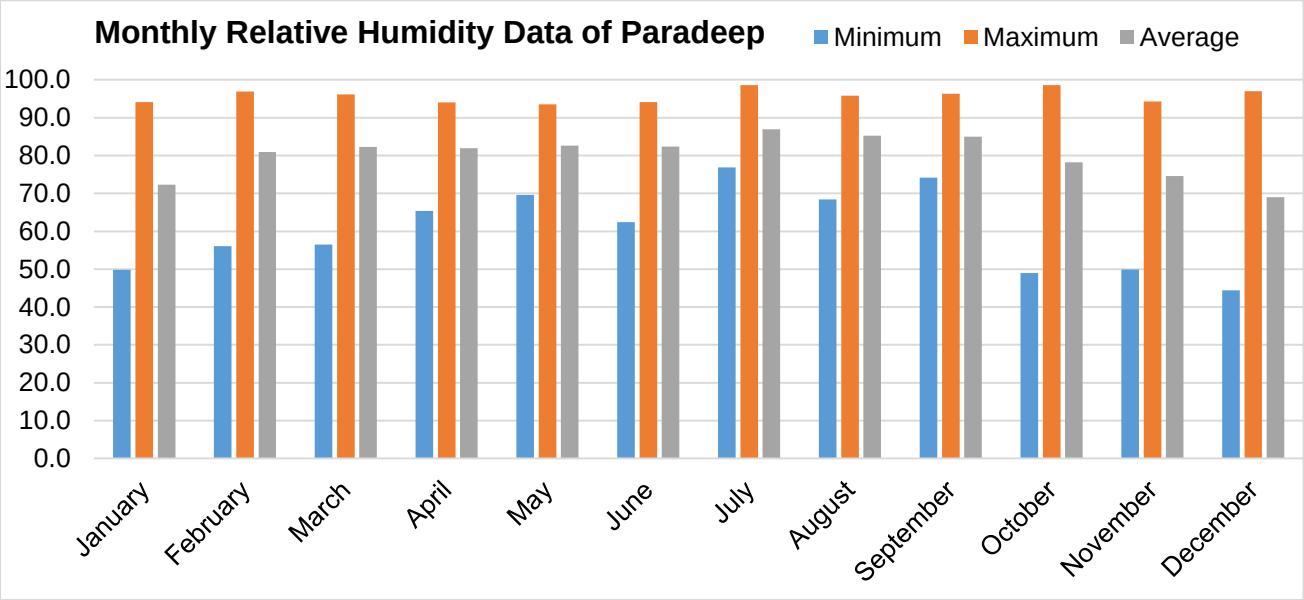



Figure 2.5 Monthly Relative Humidity values in Paradeep

### 2.2.4 RAINFALL

Annual average rainfall at Paradip is about 1,400 mm per annum, about 75% of which is received during the South-Western Monsoon season, i.e., between June and September. October contributed about 8% of the annual rainfall as presented in table 2.3.

Table 2.3 Average Monthly Distribution of Rainfall

| Month | Average Monthly Distribution of Rainfall | | |
|---|---|---|---|
| | Minimum Rainfall (mm) | Maximum Rainfall (mm) | Average Rainfall (mm) |
| January | 0.0 | 27.7 | 10.0 - 12.0 |
| February | 6.1 | 76.7 | 36.0 - 40.0 |
| March | 15.0 | 177.4 | 48.0 - 50.0 |
| April | 16.0 | 67.2 | 38.0 - 42.0 |
| May | 4.2 | 139.9 | 42.0 - 44.0 |
| June | 81.6 | 451.6 | 235.0 - 245.0 |
| July | 135.3 | 577.6 | 268.0 - 276.0 |
| August | 235.8 | 362.4 | 308.0 - 316.0 |
| September | 15.3 | 331.4 | 245.0 - 255.0 |
| October | 15.3 | 331.4 | 116.0 - 120.0 |
| November | 0.0 | 41.1 | 12.0 - 14.0 |
| December | 0.0 | 134.2 | 36.0 - 40.0 |

## 2.3 OCEANOGRAPHY

### 2.3.1 TIDES

In nature, the tides at Paradip occur twice a day and have a tidal range that is comparable to the Chart Datum (CD), as follows:

| | |
|---|---|
| Highest High Water Level (HHWL) | + 3.50 m |
| Lowest Low Water Level (LLWL) | + 0.40 m |
| Mean High Water Springs (MHWS) | + 2.58 m |
| Mean Low Water Springs (MLWS) | + 0.71 m |
| Mean High Water Neaps (MHWN) | + 2.02 m |
| Mean Low Water Neaps (MLWN) | + 1.32 m |

The levels listed above are calculated using chart datum, which is approximately the same level as the Lowest Astronomical Tide.

### 2.3.2 WAVES

Wave characteristics off the Paradip Coast, Odisha, India have been studied from the IMD data. Predominant directions of the waves (frequencies > 10%) are SW, SSW, S, N, and NE with frequencies in decreasing order. A large number of waves possess wave heights of 0.9 m and periods and 9 sec. On about 4% of days in a year, waves with heights ranging from 3.75 to 4.75 m and periods > 17 sec prevail which coincides with the time severe stormy weather (wind speeds > 62.5 km/hr) occurs in the Bay of Bengal. The frequency distribution of waves from different directions during a year has been found to be closely related to the frequency distribution of surface wind directions off Paradip Coast.

### 2.3.3 CYCLONE

Paradip Port is a cyclone-prone area and is affected by cyclones developing in the Bay of Bengal. Figure 2.6 provides tracks of all cyclones that have crossed the coast of Odisha during the last 100 years. During cyclonic conditions, wind speeds may exceed 260 kmph as recorded during the 1999 super cyclone.

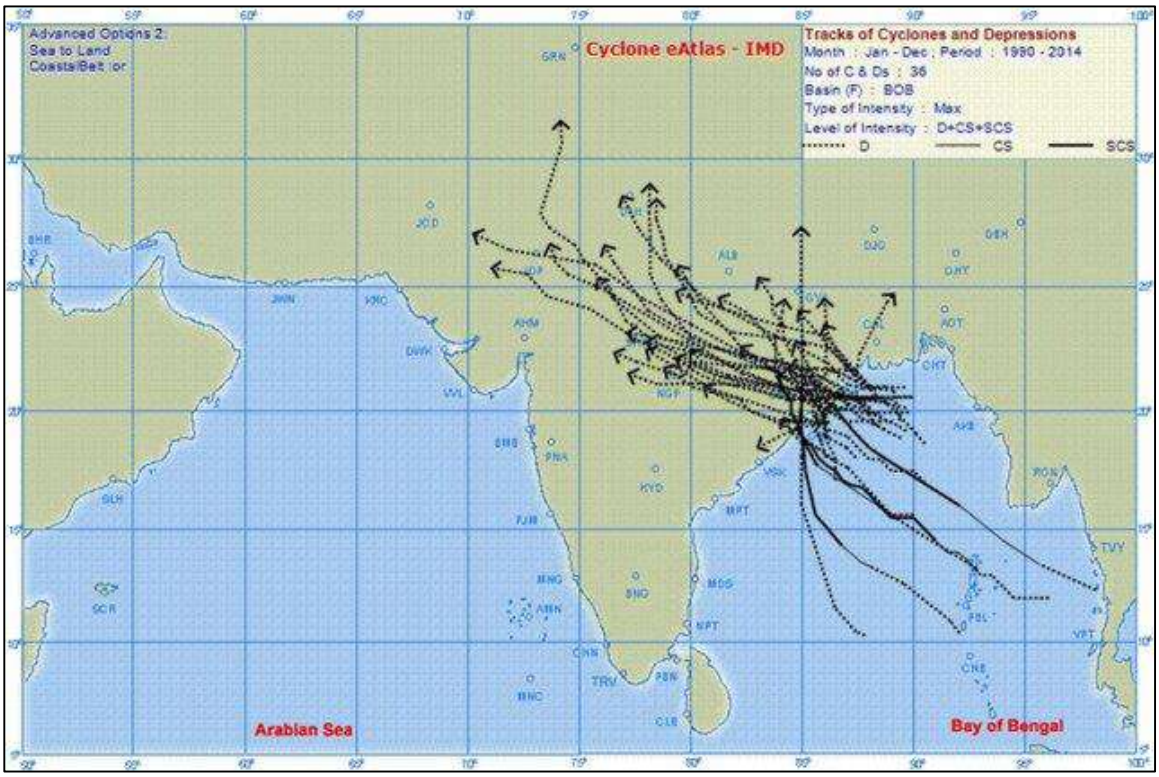



Figure 2.6 Tracklines for the cyclones crossed Odisha

# CHAPTER 3

# DETAILED SITE INVESTIGATIONS

## 3.1 HYDROGRAPHIC STUDY

- The bathymetry survey was conducted at the survey area of 6kmx11.5km in WGS 84 spheroid with UTM coordinates (Zone 45) and the entire survey was carried out with a line spacing of 100m intervals as per requirements.
- The Bathymetry Survey was carried out during the period between 29th December 2023 and 14th January 2024 involving a total area of 11500m x 600m.
- The detailed bathymetry report and survey chart are attached in Annexure I.

## 3.2 SUB BOTTOM PROFILE STUDY

- The sub-bottom profiling survey was carried out by the area covering 11500m x 6000m at a line spacing of 100m by using a SyQwest StrataBox HD 3510 sub-bottom Profiler manufactured in the USA. CODA SEISMIC PLUS was the adopter for the entire data processing and data interpretation. The final outputs from the CODA were taken to generate vertical cross-sections and an isopach map.
- During the sub-bottom profile survey, the sedimentary formation is the primary component of the sub-seabed off Paradip within the surveyed area. The thickness and compactness of the sediment vary at different locations. The minimum sediment thickness has been calculated and mapped between 2.6m and 19.5m based on acoustic impedance and multiples. It has been observed that a second layer exists below 1 to 2m from the seabed, starting beyond 3km from the shore and extending towards the seaward end of the survey limit. An ancient seabed may be present in the presence of this second layer. There are no significant hard formations or strata found within the range of signal penetration in general.
- The detailed Sub-bottom profile report and chart are attached in Annexure II.

## 3.3 TOPOGRAPHIC SURVEY

- The topographical survey was carried out using an Unmanned Aerial Vehicle (UAV) (Drone) & RTK DGPS. The Drone survey was carried out from 18-03-2024 to 09-04-2024 and the RTK survey was carried out from 03-06-2024 to 09-06-2024.
- The Topography survey was carried out by the area covering 30sq.km by using a Model V & DJI Mavic 3 Enterprise.
- Spectra SP85 DGPS has been used for the level transfer and ground control points.

- The total of the surveyed project area is approximately 30 sq.km.
- The topographic survey of the project area has carried out through UAV (unmanned aerial vehicle) image processing and DGPS survey. The topographic contour mapping is done at the 50 m interval.
- The detailed Topography report and survey chart are attached in Annexure III.

# CHAPTER 4

## GEOTECNICAL INVESTIGATIONS

The geotechnical investigations report was carried out by Comacoe in the year 2019 was received from the client, and the salient features are summarized in this chapter. The full report is provided in Annexure IV. The locations of the boreholes is shown in Figure 4.1 and borehole locations marked on the proposed layout which is shown in Figure 4.2.

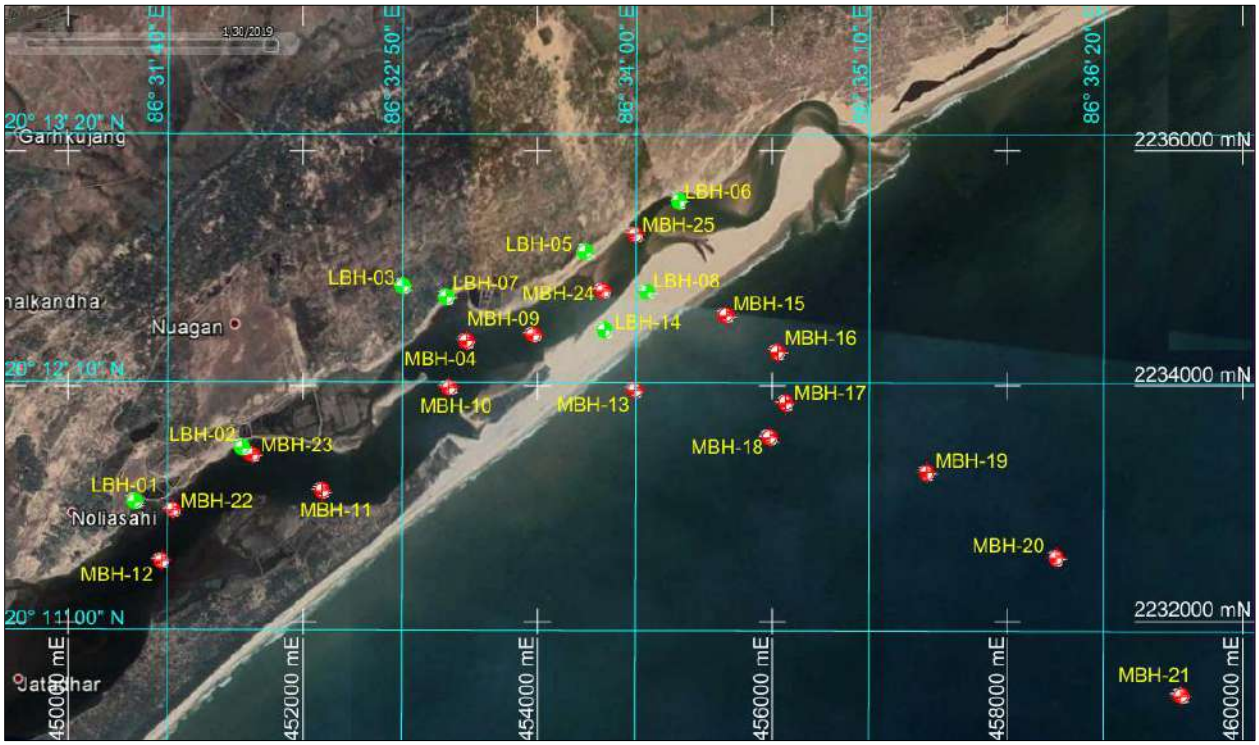



Figure 4.1 Borehole location for entire area

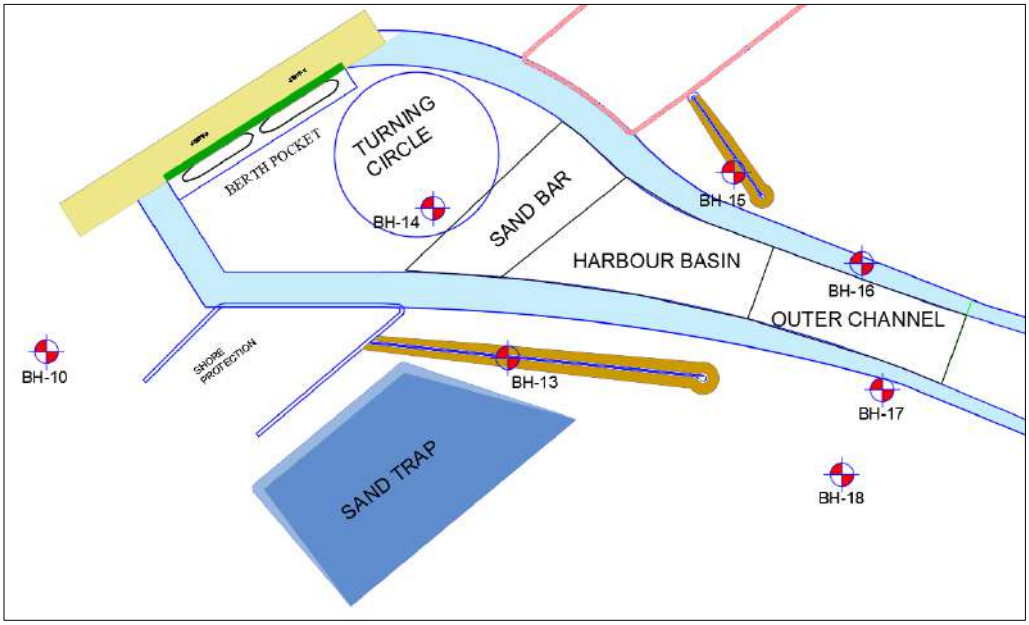



Figure 4.2 Marine Borehole locations at dredging area

The proposed layout includes seven boreholes, with detailed soil properties provided below. These descriptions provides an in-depth understanding of the soil characteristics at each borehole location.

The subsea bed stratigraphy encountered in the proposed dredging area is as follows:

At the proposed breakwater locations on the southern and northern sides, the top layer predominantly consists of medium dense and dense sand. Borehole MBH-13, taken from these locations, shows that the dredging depths include a mix of medium dense sand, very dense sand, clay pockets, and stiff clay. The Standard Penetration Test (SPT) value at these depths reaches a maximum of 55, indicating significant soil resistance.

Further investigation at borehole MBH-15 indicates that the dredging depths are characterized by medium dense sand, very dense sand, fine sand with traces of clay pockets, and sand with traces of clay pockets. The maximum SPT value recorded at this site is 41, which also suggests considerable soil resistance.

In the outer channel, the top layer comprises fine sand and silty sand with clay pockets. Borehole MBH-16 indicates that the dredging depths here include silty fine sand with traces of clay pockets, sandy silty clay, and dense sand. The maximum SPT value for this location is 35, indicating moderate soil resistance.

Borehole MBH-17 presents a different profile, with dredging depths showing medium silty sand, fine sand with traces of clay pockets, and very dense sand. The maximum SPT value recorded at this location is 28, reflecting relatively lower soil resistance compared to the other boreholes in the proposed dredging area.

Across the proposed dredging area, the average density of soil samples is found to be 17.8 kN/m$^3$. The soils exhibit a specific gravity of 2.6, and the average angle of friction is calculated to be 30.54 degrees. These parameters provide critical insights into the soil properties and are essential for planning and executing the dredging operations effectively.

The Stratigraphy of borehole are given in Table 4.1 to Table 4.7

Table 4.1 Stratigraphy of borehole MBH-10

| BH.No | Drill Depth (m) wrt C.D | | Layer Thickness | Description of Strata |
|---|---|---|---|---|
| | From | To | | |
| MBH-10 | 6.00 | 6.45 | 0.45 | Loose, Silty Fine SAND with traces of shell fragments. |
| | 6.45 | 15.50 | 9.05 | Medium Dense, Fine to Medium SAND. |
| | 15.50 | 18.45 | 2.95 | Medium Dense, Silty Clayey SAND/ Sandy CLAY. |
| | 18.45 | 31.95 | 13.50 | Medium Dense, silty Fine SAND |
| | 31.95 | 46.45 | 14.50 | Dense to very dense, Silty Fine SAND |

Table 4.2 Stratigraphy of borehole MBH-13

| BH.No | Drill Depth (m) wrt C.D | | Layer Thickness | Description of Strata |
|---|---|---|---|---|
| | From | To | | |
| MBH-13 | 3.20 | 4.70 | 1.50 | Loose to medium-dense sand |
| | 4.70 | 12.70 | 8.00 | Dense sand |
| | 12.70 | 17.20 | 4.50 | Stiff to very stiff clay |
| | 17.20 | 21.20 | 4.00 | Medium dense sand |
| | 21.20 | 26.20 | 5.00 | Medium dense sand |
| | 26.20 | 30.15 | 3.95 | Stiff clay |

Table 4.3 Stratigraphy of borehole LBH-14

| BH.No | Drill Depth (m) wrt C.D | | Layer Thickness | Description of Strata |
|---|---|---|---|---|
| | From | To | | |
| LBH-14 | 0.00 | 0.45 | 0.45 | Very Loose, Silty Fine SAND. |
| | 0.45 | 4.95 | 4.50 | Loose, Silty Fine SAND. |
| | 4.95 | 9.45 | 4.50 | Loose to medium dense, Silty Fine SAND. |
| | 9.45 | 25.95 | 16.50 | Medium Dense, Silty Fine SAND |
| | 25.95 | 30.45 | 4.50 | Dense, Silty Fine SAND |

Table 4.4 Stratigraphy of borehole MBH-15

| BH.No | Drill Depth (m) wrt C.D | | Layer Thickness | Description of Strata |
|---|---|---|---|---|
| | From | To | | |
| MBH-15 | 2.30 | 5.30 | 3.00 | Medium dense to dense sand |
| | 5.30 | 8.30 | 3.00 | Medium dense to dense sand |
| | 8.30 | 12.30 | 4.00 | Medium dense to dense sand |
| | 12.30 | 16.30 | 4.00 | Stiff to very stiff clay |
| | 16.30 | 24.30 | 8.00 | Medium dense sand |
| | 24.30 | 29.75 | 5.45 | Stiff to very stiff clay |

Table 4.5 Stratigraphy of borehole MBH-16

| BH.No | Drill Depth (m) wrt C.D | | Layer Thickness | Description of Strata |
|---|---|---|---|---|
| | From | To | | |
| MBH-16 | 8.20 | 12.70 | 4.50 | Medium dense to dense sand |
| | 12.70 | 18.90 | 6.20 | Stiff clay |
| | 18.90 | 22.20 | 3.30 | Medium dense sand |
| | 22.20 | 29.65 | 7.45 | Stiff to very stiff clay |

Table 4.6 Stratigraphy of borehole MBH-17

| BH.No | Drill Depth (m) wrt C.D | | Layer Thickness | Description of Strata |
|---|---|---|---|---|
| | From | To | | |
| MBH-17 | 12.40 | 14.35 | 1.95 | Loose to Medium Dense, Silty Fine SAND. |
| | 14.35 | 18.85 | 4.50 | Soft to Very stiff, Sandy Silty CLAY, sand pockets and gravels. |
| | 18.85 | 24.85 | 6.00 | Medium Dense to Dense, Silty Fine SAND |
| | 24.85 | 27.85 | 3.00 | Stiff, Sandy SILT / Sandy CLAY with traces of fine Gravels. |
| | 27.85 | 29.45 | 1.60 | Medium Dense, Silty SAND / Sandy SILT. |

Table 4.7 Stratigraphy of borehole MBH-18

| BH.No | Drill Depth (m) wrt C.D | | Layer Thickness | Description of Strata |
|---|---|---|---|---|
| | From | To | | |
| MBH-18 | 12.80 | 14.75 | 1.95 | Very soft clay |
| | 14.75 | 19.25 | 4.50 | Medium dense sand |
| | 19.25 | 25.25 | 6.00 | Medium dense sand |
| | 25.25 | 28.25 | 3.00 | Stiff clay |
| | 28.25 | 29.85 | 1.60 | Dense sand |

Subsurface profiles of soils in borehole investigations provide a detailed vertical section of the soil layers encountered below the ground surface. These profiles are created using drilling boreholes and systematically recording the types, thicknesses, and depths of various soil strata. The Subsurface profiles are shown in Figure 4.3 to Figure 4.5.

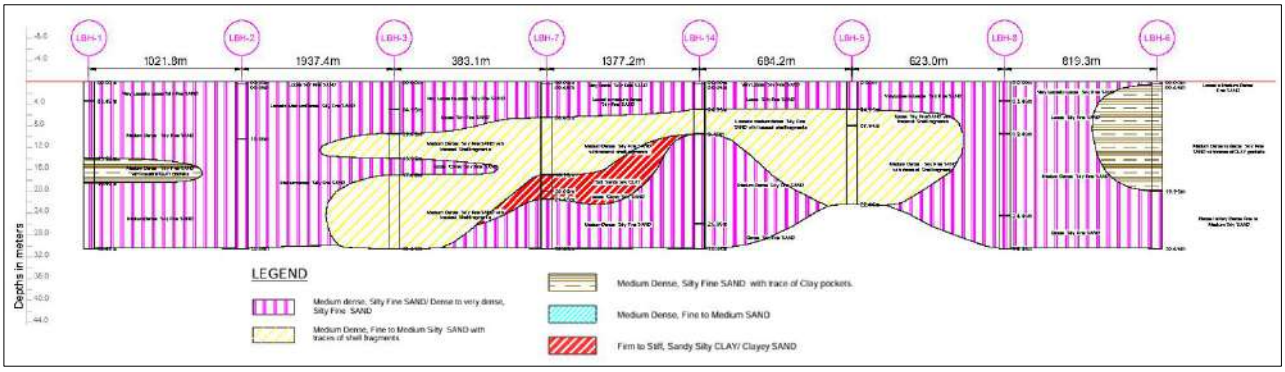



Figure 4.3 Subsurface Soil Profile for Land Boreholes LBH 1 to LBH 3, LBH 5 to LBH 8 and LBH 14

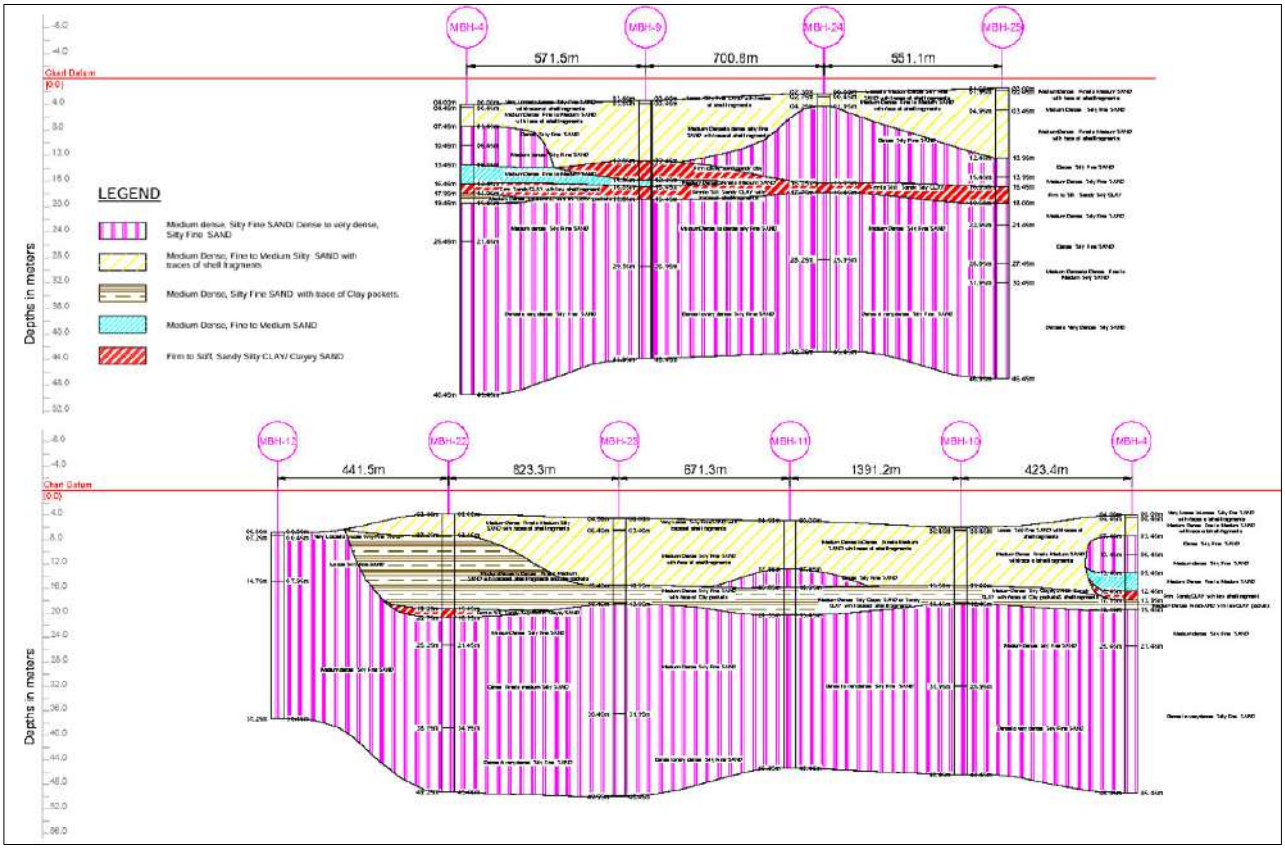



Figure 4.4 Subsurface Soil Profile for Marine Boreholes MBH 4, MBH 9 to MBH 12 and MBH 22 MBH 25

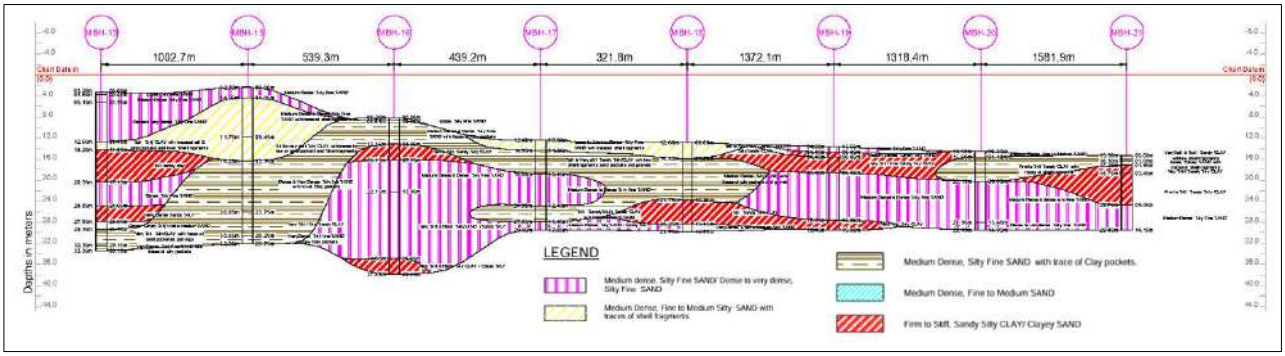



Figure 4.5 Subsurface Soil Profile for Marine Boreholes MBH 13 and MBH 15 to MBH 21

The detailed Report are attached in Annexure IV.

# CHAPTER 5

# RECLAMATION PLAN

## 5.1 INTRODUCTION

It is proposed to develop the land for IDCO (Odisha Industrial Infrastructure Development Corporation) from the dredging activity in the Port areas demarcated for the development of JSW-USL Port. The land area to be developed is about 780 acres in which various hindrances and water bodies are present. Setting aside the sensitive areas and water bodies including buffer zones, it is proposed to develop a total extent of 705 acres (or) 285.30 hectares. The existing and updated proposed land area is shown in Figure 5.1.

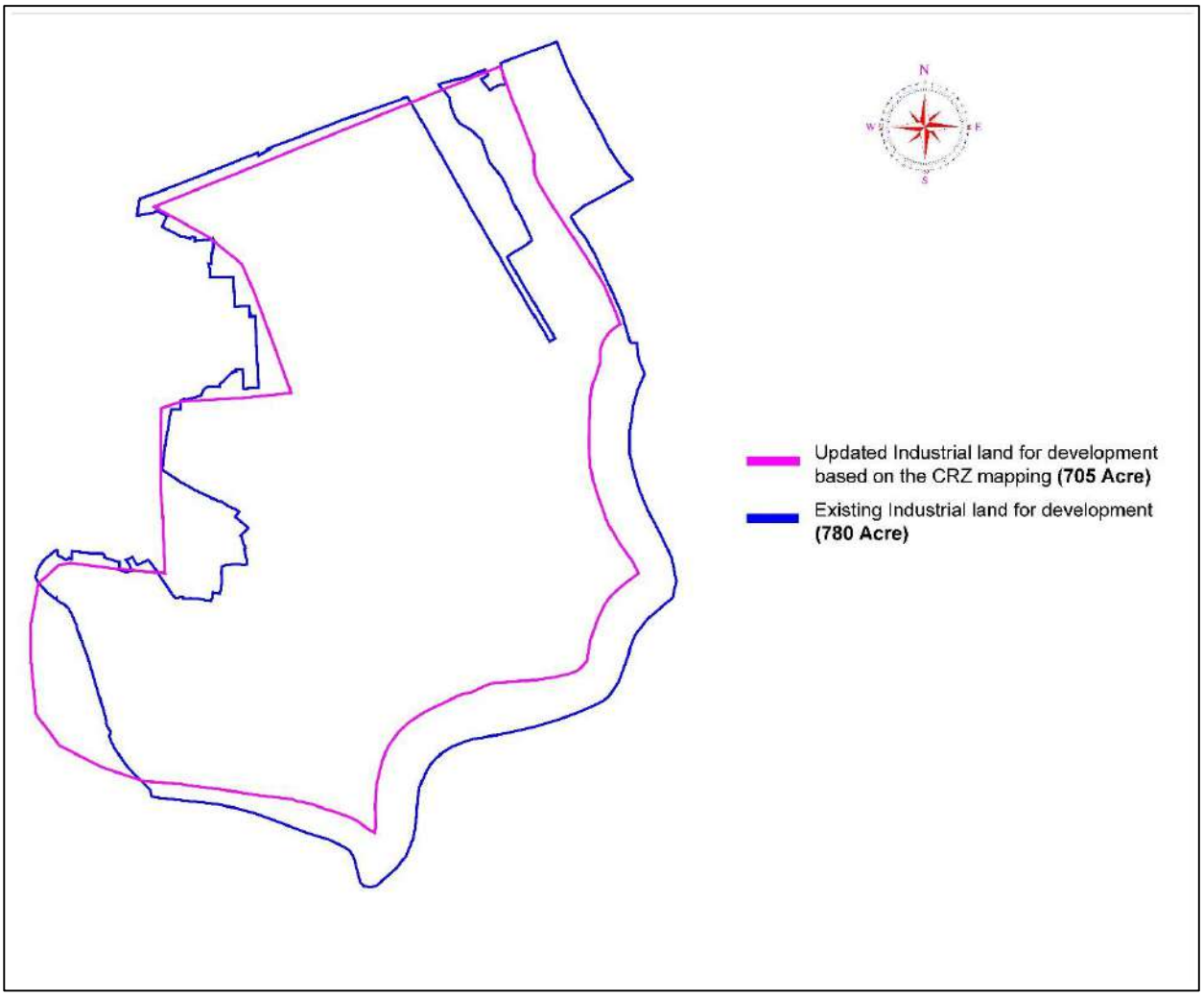



Figure 5.1 The existing and updated proposed land area for development

The present elevation of this ground varies from 0.95m to 4.78m (w.r.t Chart Datum). The average elevation is about 2.66m. It is proposed to develop this land by utilizing dredge spoils from the proposed basin and Navigational areas of JSW Port for which environmental

clearance is already available (**EC22A033OR177049).** After development, this land is required to be at an elevation of 5.45m above CD in order to match the requirements of the eventual user, IOCL. The approximate quantity of dredged spoil required for this development is about 10.92 million cu. meters. This parcel of land is about 10 km from the proposed basin area of JSW Port. The general arrangement layout of the proposed developmental area and proposed JSW Port are shown in Figure 5.2.

This developmental work would have the following major activities:

1. Dredging using a combination of suitable and capable Dredgers.
2. Creation of reclamation bund/ embankment to an elevation of 5.45 m above CD.
3. Laying Discharge pipelines and return water pipelines from the proposed dredging area to the area to be developed.
4. Finishing the land development by Levelling, Consolidation, Compaction etc. in layers to the required quality.

The dredging is to be performed using dredgers of suitable type and capacity dredgers such as CSD, TSHD etc. with supporting crafts and equipment. The dredge spoils shall be transported by means of suitable pipelines to the development site. A return pipeline along the same route adjacent to the discharge pipeline for the purpose of draining out surplus from the reclamation area. A reclamation bund/embankment is to be constructed for retaining the dredge spoils within the reclamation area itself. The dredged spoils dumped into the reclamation area shall be properly levelled, compacted /consolidated within the boundary in layers of approved thickness by suitable means and equipment including Dozers, Earthmovers and Vibrators in layers. After depositing the dredge spoil within the bund area, it has to be levelled, consolidated and compacted by suitable means.

During dredging operation, incase, Silty Clay to Clayey Silt Clay encounters and the same is not suitable for dredging and transporting, the same shall be disposed off at the designated locations inside sea etc.

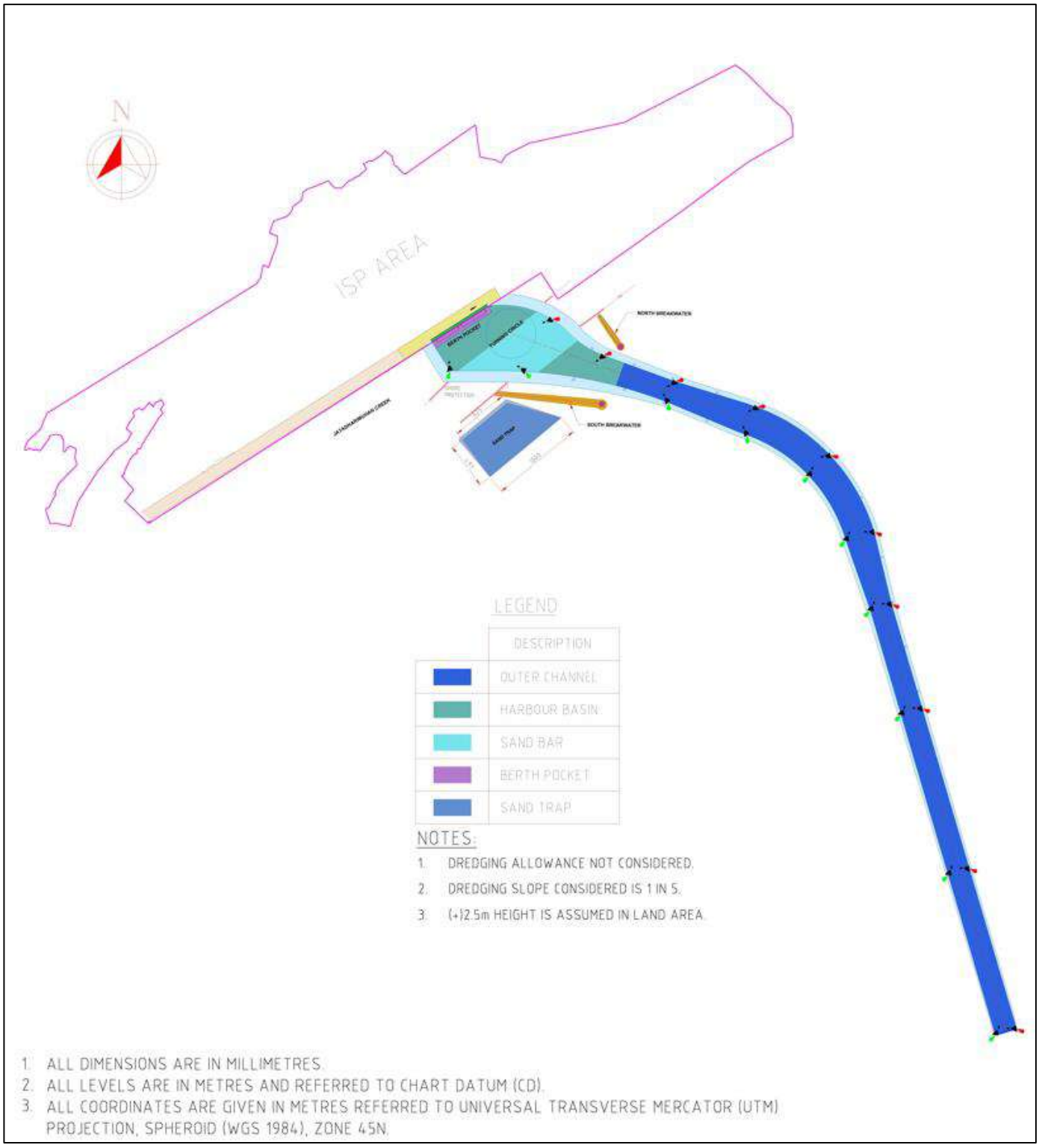



Figure 5.2 General arrangement layout and proposed port JSW-USL

## 5.2 AREAS DEMARCATED FOR THE PROPOSED PORT

Reclamation and dredging are practices most commonly associated with development in the coastal zone, often in areas with intense pressure for competing land uses. Reclamation can include the construction of levees, channels, and canals, as well as the draining and filling of wetlands and other fragile estuarine systems. Dredging activities are primarily associated with the maintenance of existing shipping, navigation, or access channels (maintenance dredging), or capital dredging projects where there is a need for the construction of new or deeper channels. Land reclamation projects are often developed in tandem with capital or maintenance dredging works, with the dredge spoil used to provide fill material for accreted land.

In identifying a suitable dredging area, the presence of sufficient suitable fill is a necessity for a reclamation project. The following factors have been considered:

- Haulage distance from the dredging area to the project location;
- Quantities of fill available; and
- Quality of the fill, including fill mass behaviour and in-situ characteristics.

## 5.3 LOCATION OF PROPOSED RECLAMATION AREA AND DREDGING AREA

The proposed reclamation area is in a low-lying land area of approximately 705 Acres (Based on the reclamation boundary shared). The proposed dredging areas for the filling material are located 6-8km from the reclamation area and the options have been provided for the dredging area selection.

The finished top level of the reclamation area is fixed at +5.45m above CD, in consultation with IOCL & DCIL.

## 5.4 DREDGING AREA FINALISATION BASED ON A MODEL STUDY

Based on the available soil characteristics and suitability and also the cost economics, the dredging area locations for dredging has been determined. The boundaries of the identified dredging area are depicted in Figures 5.3 and 5.4 attached under Annexure V.

The material to be dredged mainly consists of Silty Clay, Silty Clay Sand and Silty Sand.

- The proposed dredge area is shown in Figure 5.3 and 5.4 and the existing Ground/bed levels varies between (-)4.1m and 13.3m with respect to CD.
- Based on the dredging options, quantity has been attached in the Table 5.1 and 5.2.

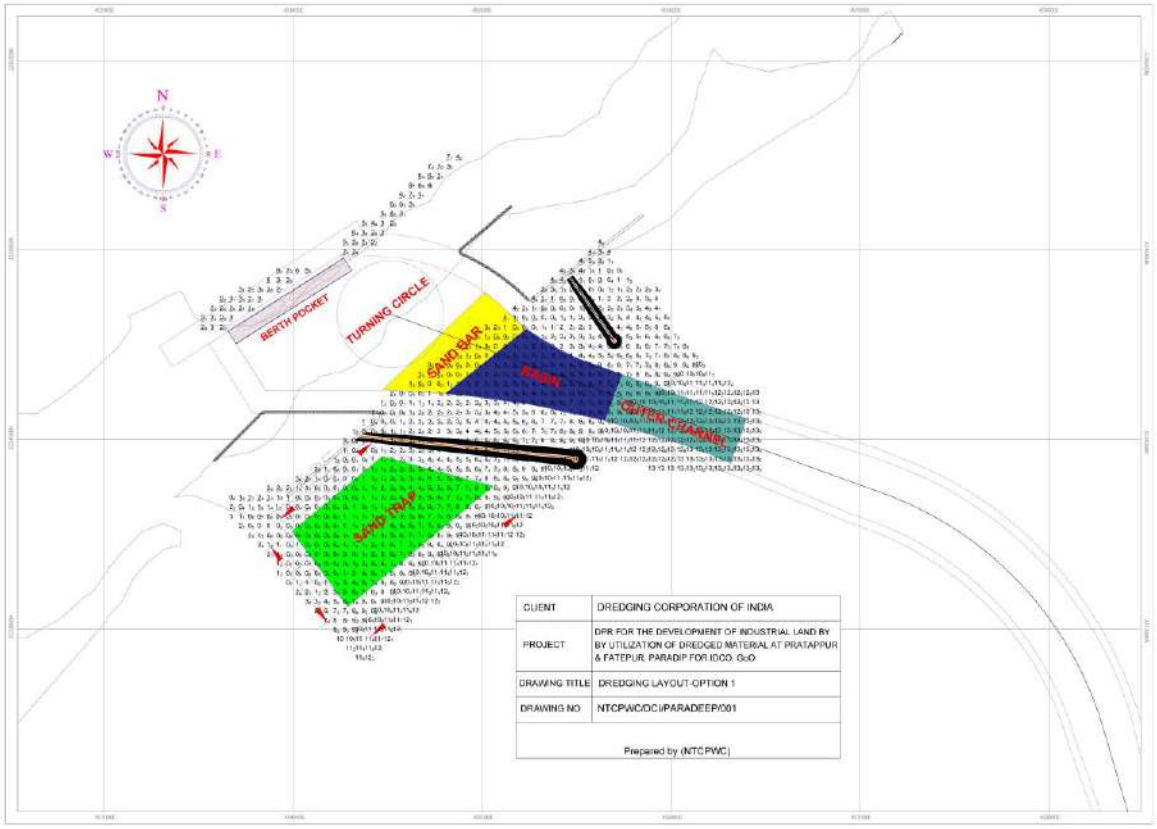



Figure 5.3 Option 1 – Proposed Dredging layout Excluding Inner basin

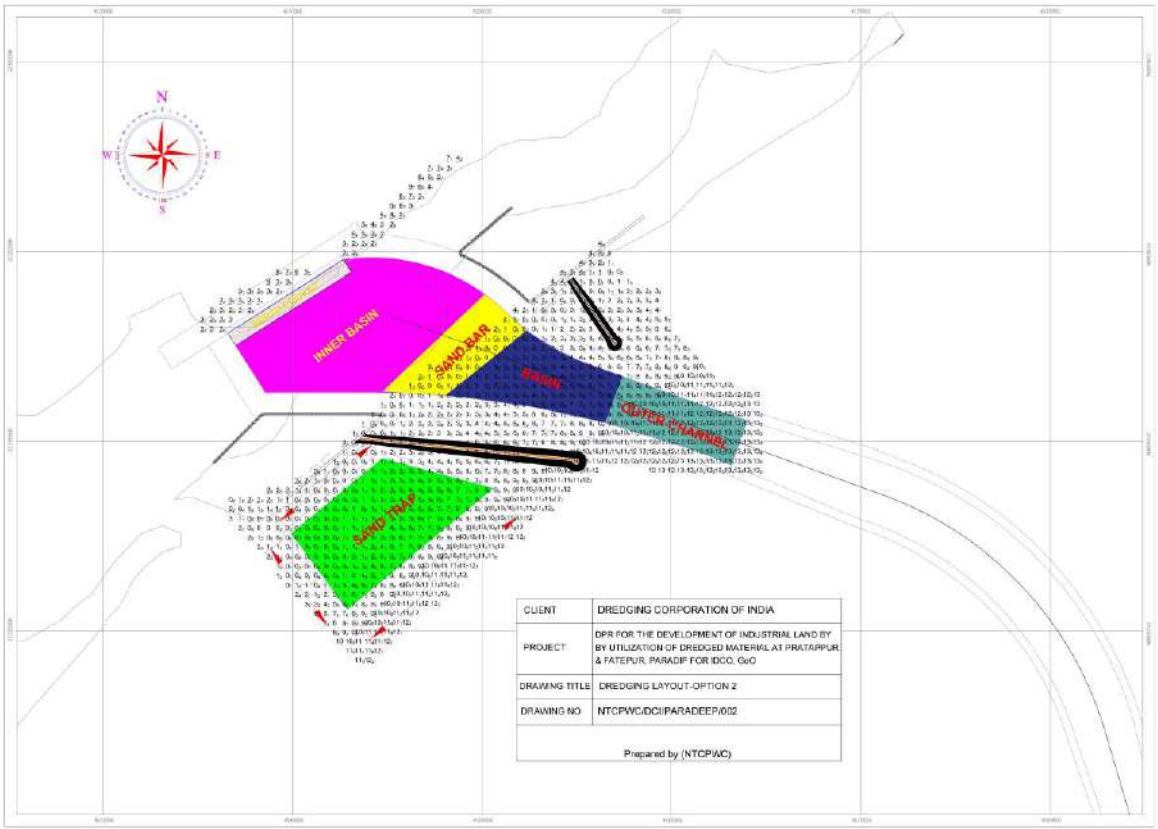



Figure 5.4 Option 2 – Proposed Dredging layout including Inner basin

Table 5.1 The availability of Drede Quantity for Option 1 layout

| Sl No | Location | Areas (m²) provided by JSW | Permissible Depth of dredging (m) provided by JSW-USL | Tentative Existing Average Depth in the proposed dredging area (m) | Depth of cut (m) | Quantity to be dredged (Cu.m) | Likely Dredger Option |
|---|---|---|---|---|---|---|---|
| 1 | Sand Trap | 4,03,424 | 8 | 0 | 8 | 3,22,73,92 | CSD |
| 2 | Sand Bar | 1,71,557 | 18.4 | 0 | 18 | 3,08,08,26 | CSD |
| 3 | Harbour Basin | 2,31,646 | 18.4 | 5 | 13 | 3,01,13,98 | TSHD |
| 4 | Outer Channel | 1,74,417 | 19.3 | 11 | 8.3 | 1,44,51,71 | TSHD |
| | | | | | Total Quantity in (Cu.m) | **1,07,71,987** | |
| | | | | | Total Quantity in (M Cu.m) | **10.77** | |

Table 5.2 The availability of Drede Quantity for Option 2 layout

| Sl. No | Location | Area (m2) | Permissible depth of dredging (m) provided by JSW-USL | Tentative Existing Average Depth in the proposed dredging area (m) | Depth of cut (m) | Quantity to be dredged (Cu.m) | Likely dredger option |
|---|---|---|---|---|---|---|---|
| 1 | Sand Trap | 4,03,424 | 8 | 0 | 5.5 | 22,18,832 | CSD |
| 2 | Sand Bar | 1,71,557 | 18.4 | 0 | 10.5 | 18,01,349 | CSD |
| 3 | Harbour Basin | 2,31,646 | 18.4 | 5 | 5.5 | 12,74,053 | TSHD |
| 4 | Outer channel | 1,74,417 | 19.3 | 11 | 1 | 1,74,417 | TSHD |
| 5 | Inner Basin | 5,74,491 | 18.4 | 1 | 9.5 | 54,57,669 | CSD |
| | | | | | Total Quantity in (Cu.m) | **1,09,26,319** | |
| | | | | | Total Quantity in (M Cu.m) | **10.9** | |

## 5.5 DREDGING METHODOLOGY

This method statement is created based on the information at this point, with the objective of not freezing. The methodology should consider possible alternatives and feasibility of dredging and be modified. Revised by the specialist dredging contractor to be appointed through the EPC tendering process. The final approach has to be developed by the contractors who are experienced and innovative in the field of marine dredging operations.

### 5.5.1 SELECTION OF DREDGING EQUIPMENT

There are a variety of dredgers and means to employ dredgers depending on the specifics of a particular project. No single type of dredger or system of employment will be suitable for all projects.

The selection of dredging equipment for a particular project will depend upon a combination of factors, including:

- Size of the project
- Physical environment in the project site
- Nature of the material to be dredged
- Quantity of the material to be dredged
- Method of disposal of dredged material
- Distance of disposal ground/reclamation from the dredging area
- Availability of equipment

Presently, there are different types of dredgers available in the market. However, only certain types of equipment and dredgers are suitable for the present type of work.

### 5.5.2 THE MAIN EQUIPMENT CONSIDERED FOR THE PROPOSED DREDGING WORKS

- A combination of Cutter Suction Dredger(s) (CSD) with cutter power ranging between 2000KW to 3000KW and Trailing Suction Hopper Dredger(s) (TSHD) with Hopper capacity ranging between 5200 CuM and 7500 CuM can be used for dredging of materials from the designated area and fill in reclamation area through Discharge pipes.
- Booster stations shall be installed at suitable locations for pumping the materials from the designated dredging area to the reclamation area seamlessly.
- In the proposed dredging area, the materials to be dredged are near shore and open sea conditions where the depth of water is varying between 1m and 13m. Hence it is

imperative to deploy a combination of CSD and TSHD(s) of higher capacities for effective dredging in a time-bound manner. The dredged materials are then transported to the reclamation areas through Discharge pipes. The agency to be appointed for executing the job shall be allowed to decide the combinations and capacity of the dredgers, depending upon their availability, in order to complete the work in a time-bound.

### 5.5.3 COMBINATION OF CSDS AND TSHDS

It is recommended that the work can be executed in either of the options elaborated hereunder:

- Option 1 - Two Cutter Suction Dredgers and Two Trailing Suction Hopper Dredgers can be used. By using this combination CSD will dredge in the Sandbar and Sandtrap and TSHD will dredge in the Harbour basin and the Outer channel.
- Option 2 - An alternate option can also be used in which one CSD will dredge in the Inner Basin, By using this combination CSD will dredge in the Sandbar, Sandtrap and the Inner Basin. TSHD will dredge in the Harbour basin and the Outer channel.
- The recommended capacity of the dredgers is as follows.
    1. Cutter suction dredgers – 2000KW to 3000 KW (Cutter power)
    2. Trailing suction dredgers – 5200 cu.m and 7500 cu.m Hopper capacity.

However, the capacity and type of the dredgers and/ or their combination rest with the executing agency, which is responsible for completing the entire project within the stipulated period.

### 5.5.4 DREDGING BY CUTTER SUCTION DREDGER AND TRAILING SUCTION HOPPER DREDGER

The CSD is deployed for dredging and pumping materials through the pipelines directly into the reclamation area. The TSHD is deployed, after the dredging the pipelines are connected to the bow and the materials are disposed to the reclamation area. The pipelines for CSD and TSHD may consist of a combination of floating, submerged and shorelines.

## 5.6 RECLAMATION

The project envisages reclaiming an area of about 705 acres of land to develop an industrial land in Pratappur and Fatepur. The proposed top level of reclamation is +5.45m CD.

To prevent spillage, it is important to allow a long passage for the material to settle down and reduce spillage. It is estimated that the concentration of the dredged material, while discharging to the reclamation area is around 106 g/l. By proper planning and execution, the discharged dredged materials can be retained within the boundaries of the area of reclamation by constructing suitable reclamation bunds as detailed in Figure 5.5. However, the excess water shall be allowed to overflow through the bunds up to the collection champers, where from this surplus water shall be pumped through the return pipelines, positioned at suitable intervals as shown in Figure 5.6. It is estimated that the concentration of the surplus water discharged through the return pipeline shall be in the order of 0.5 g/l. A separate model study for Advection and dispersion was conducted and the results are attached in Annexure VI.

### 5.6.1 SOURCE OF RECLAMATION

The development will need to include a strategy for the reclamation of land to utilise the development of industrial activities. The fill for reclamation work may be obtained from dredging areas. The dredged material will be controlled in order to avoid the build-up of fine material and the potential for the formation of areas of compressible fill within the reclamation.

### 5.6.2 RECLAMATION METHODOLOGY

It is estimated that around 7.9 million m3 of material will be required for reclamation. A sufficient quantity is available in the proposed dredging area.

The reclamation process comprises creating bunds in the reclamation areas of suitable heights to receive the dredged material. Enough resting period will be provided for the subsoil to gain strength after each stage of filling.

### 5.6.3 FORMATION OF RECLAMATION BUND

- The Bund is proposed to be constructed to contain the reclamation using the dredged spoil. The bund shall have the capacity to withhold an approximate quantity of 7.9M Cum of dredged spoil, and also capable of arresting seepage of sand from the reclaimed area spread over 705 acres through the bund.
- Creation of reclamation bund/ embankment to an elevation of 5.45 m above CD.

The typical cross-section of the bund is shown below:

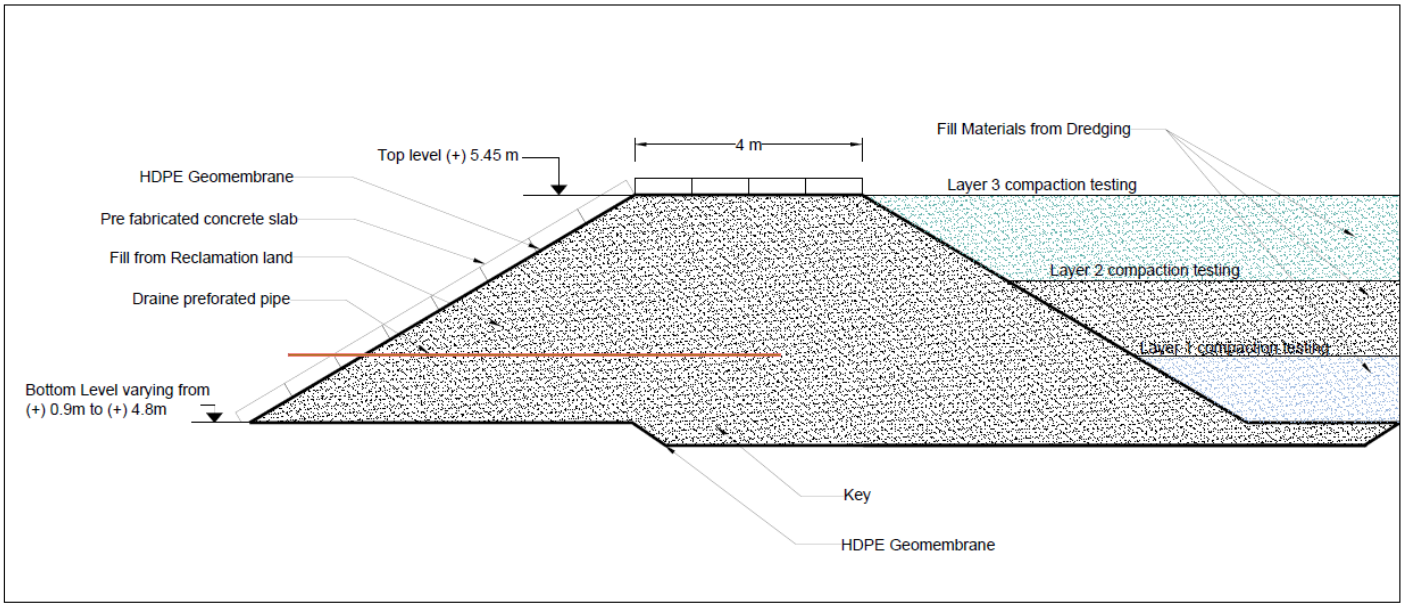



Figure 5.5 Typical cross-section of bund

The salient features of the bund are as follows:

a) The top width of the bund is 4m (approx.)
b) The top level of the bund is +5.45m (approx.) above CD
c) The bed level of the bund varies from +0.9m to +4.8m above CD.
d) HDPE Geo membrane will be provided over the surface of the bund to prevent the movement of reclaimed dredged material.
e) A perforated pipe drain should be provided to drain the rainwater.
f) Bund key shall be provided at the bottom to resist maximum shear.
g) The pre-fabricated concrete slab shall be placed above the Geomembrane layer.
h) The bund shall be formed with soil from reclaimed land.

However, the detailed design and execution of the bund shall be interested to the executing agency.

### 5.6.4 RECLAMATION FILL THROUGH DREDGED MATERIAL

The CSD & TSHD will dispose of the appropriate dredged materials in the reclamation areas. Land-based equipment will be utilized to mobilise the pipelines between the sea and reclamation area before the dredging and reclamation works begin (if deemed necessary). Bund will be constructed around the reclamation area before the filling begins.

### 5.6.5 GROUND IMPROVEMENTS

Compaction increases the shear strength of soils by adding friction from the interlocking of particles. The removal of voids reduces the chance of the soil settling shrinking or expanding and it decreases water seepage that would lead to deleterious shrinking and swelling of soil properties. Hence, the reclaimed area using the dredged spoil transported from the designated area needs to be properly consolidated and compacted.

The engineering properties of granular soil, such as compressibility, shear resistance and resistance against liquefaction, mainly depend on the state of compaction, typically expressed in terms of (relative) density and effective stress.

- vibratory techniques including surface compaction and deep compaction
- dynamic compaction techniques based on (heavy) impact at the surface

Depth compaction trials with the polygonal drum roller indicated an increase of density to a degree of compaction of 95% MDD at a depth of more than 1.30 to 1.50 m. Compaction performance was reported as 500–1500 m3/hr. As a result of the special drum shape, the roller is suitable for granular, mixed and cohesive soils. The finished top level of the reclaimed area is fixed at +5.45 m above CD as recommended by IOCL keeping in view their developmental proposals after interconnecting the existing refinery and proposed additional reclaimed area. The top-level shall be fairly uniform and flat, without any noticeable humps. The strength of the soil for the safe bearing capacity of soil shall be achieved after each stage of filling as per the ISC.

### 5.6.6 SOIL IMPROVEMENT BY VIBRO-COMPACTION

By using power depth vibrators, this method reorganizes the soil particles into a denser arrangement. Settlement will be reduced by vibro compaction. This method is more applicable in the strata that contain silty sand. The dredge material that will be used for reclamation at the industrial land is expected to be silty sand. Vibro-compaction is the method of choice for improving soil.

## 5.7 LAYING DISCHARGE PIPELINES AND RETURN WATER PIPELINES

To determine the Pipeline routing the following aspects have been considered:

- Establish the shortest possible route
- Minimize the number of bends
- Minimize environmental impacts by avoiding protected areas, cultural resources, etc.

Based on the recent Topographic Survey, the pipeline routes have been reviewed and the details are shown in Figure 5.6 and attached in Annexure V.

- The pipeline routes are finalised and the pipeline distance is measured from the shoreline to the reclamation area. The respective routes have been planned to have a combination of Maximum no of three discharge and two return water pipelines.
- The proposed pipeline route will be utilized by both CSD and TSHD dredgers when discharging the material and returning water. The tentative pipeline routes and locations of the booster pump are shown in Figure 5.6.
- However, the actual routing of the pipelines or the location of the booster pumps may vary depending on the site conditions and materials. The tentatively proposed distance of the pipeline ranges between 6.0km to 8.0km.
- The pipeline length was calculated from the shoreline to the reclamation area. To collect the return waters from the reclamation area, a sump has been proposed at the last (bottom) bay of the reclamation area. The return waters will be collected at the sump and the return water pipelines will be connected to it. The return water outlet pipeline has been planned in a parallel way to the intake pipelines.
- The discharge pipeline diameter shall be a maximum of 900mm (Maximum of 3 no’s) and the return pipeline for the water outlet shall be 500mm (Maximum of 2 no’s).

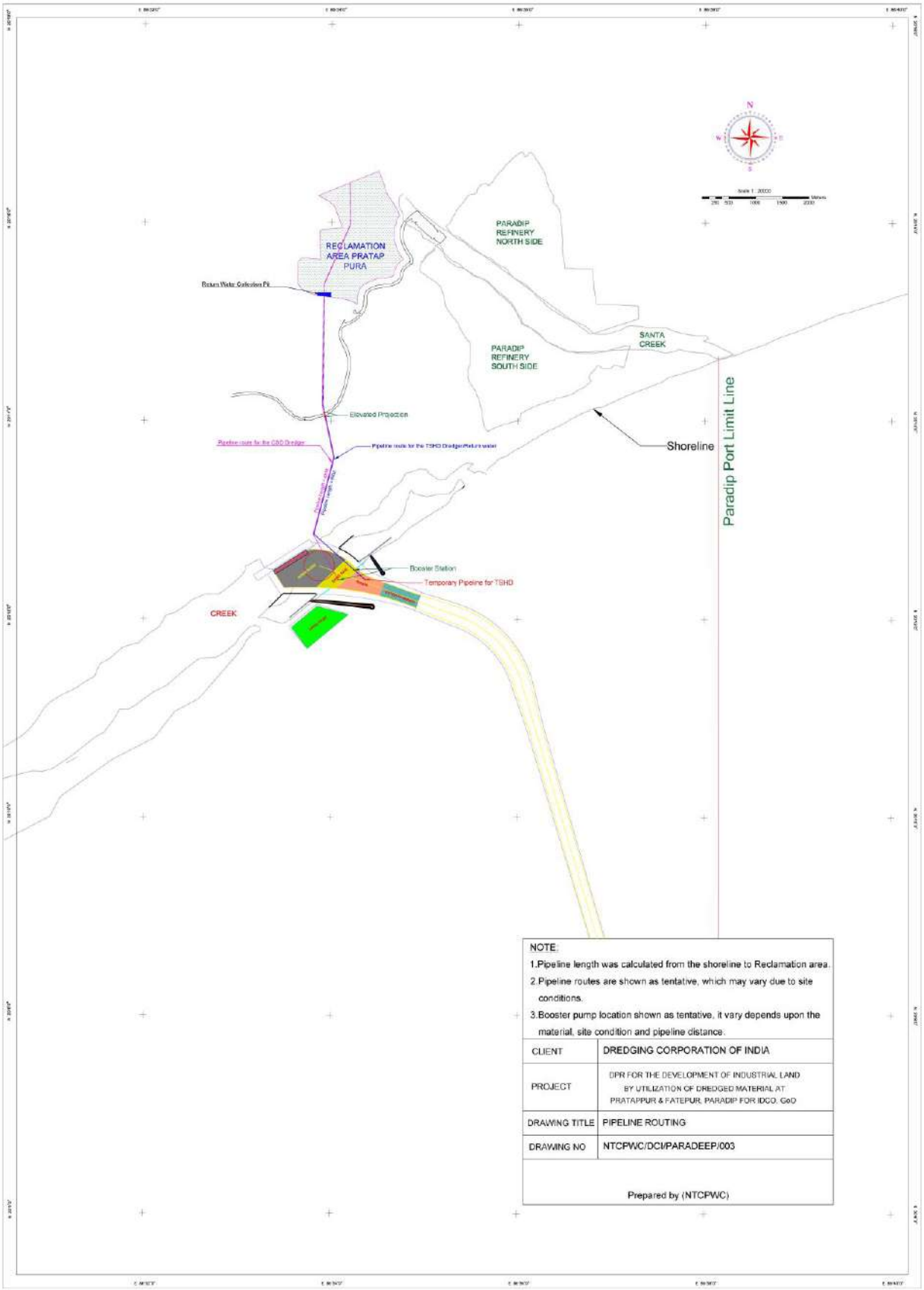



Figure 5.6 Proposed Pipeline Route for dredged material shifting and water outlet return pipeline

## 5.8 TOTAL ESTIMATE FILL QUANTITY

The quantities of Reclamation involved in the projects covered under this report are estimated and tabulated.

### 5.8.1 QUANTITY ESTIMATION

Based on the latest Topography survey, the filling quantity is calculated. The processed XYZ data was used for the Fill quantity estimation. The latest version of Hypack software is used for estimating the required fill quantity. The Hypack estimation methodology is given below:

***TIN-to-Level Calculations***

*TIN-to-Level (reservoir volumes) calculations compute the volume of the material above one or more user-specified levels and the volume of material required to bring any low areas up to the same levels. It also calculates the area of the model that lies above and below the specified levels.*

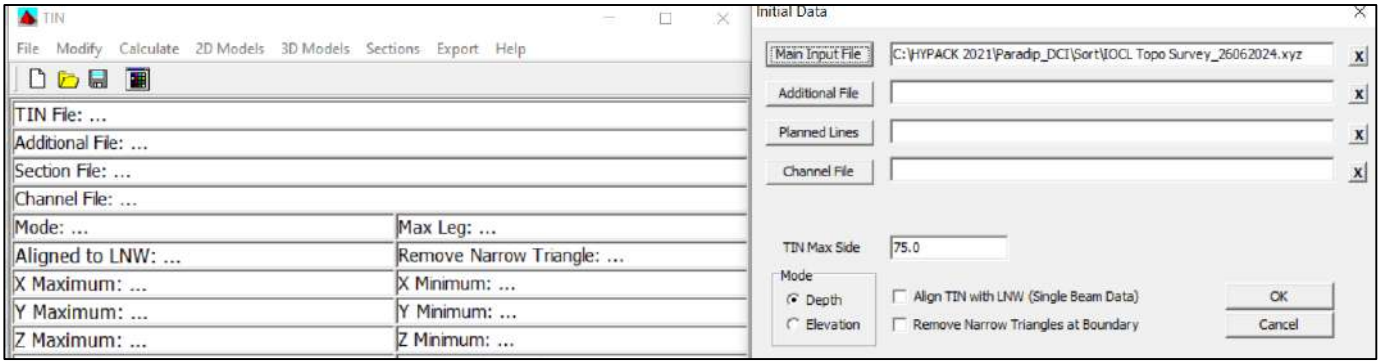
*1. Create the surface model.*

*2. Select CALCULATE-VOLUME and the desired level in the Volume Calculations Control dialog.*

*•The Volume Above shows the number of cubic meters that must be removed to get the channel to the specified level.*

*•The Volume Below is the amount of material that would have to be added to bring the surface up to the design surface or level.*

*•The Area Above and Area Below are the surface areas above and below the specified level.*



```
TIN64 File Version 21.3.0.0
TIN File : C:\HYPACK 2021\Paradip_DCI\Sort\IOCL Topo Survey_26062024.xyz
Mode: Depth
Aligned to LNW: No
Remove Narrow Triangle: No

Max Leg: 75.00
X Maximum: 459100.00
X Minimum: 451400.00
Y Maximum: 2242200.00
Y Minimum: 2232050.00
Z Maximum: 17.91
Z Minimum: 0.00
Z Average: 4.03
Number of Points: 13756
Number of Triangles: 27510

TIN vs Level with Borders Volume Totals
Volume unit: Cubic Meter
TIN File: C:\HYPACK 2021\Paradip_DCI\Sort\IOCL Topo Survey_26062024.xyz

Level: 5.45
Border                          Volume Above    Area Above      Volume Below    Area Below
Reclamation Area5_02082024       7894087.5       2850610.4          296.5           816.1
-------------------------------------------------------------------------------
Total                            7894087.5       2850610.4          296.5           816.1
```

Figure 5.7 Extract of the Volume Calculation

- The estimated fill volume has been calculated based on the recent topography survey. The fill quantity of about 7.9 million cu.m has been dredged from the proposed dredge areas options are provided in this report.

# CHAPTER 6

## EIA AND EMP STUDY

To carry out the Marine EIA study, an extensive survey was made at 21 distinct stations (3 intertidal; 18 estuary, and coastal stations) from January 26th to 29th January 2024. The survey spanned across, strategically positioned at intervals ranging from 4 to 6.5 kilometres (shortest) and 12 to 15 kilometres (longest) from the proposed project site encompassing the Mahanadi River and the coastal waters of Paradeep, Odisha. This comprehensive assessment entails analyses of various parameters such as water quality, sediment attributes, and the biodiversity of biological communities, including plankton, benthos, microbes, and other ecologically sensitive flora and fauna, if any.

The overall report for the Marine EIA study including results and discussions has been attached as Annexure V. However, the conclusion is summarized hereunder.

In the present survey, which lasted for four days, the physico-chemical and biological parameters were analyzed both in the water and sediment samples from predetermined (3 intertidal and 18 coastal stations) locations of Mahanadi estuary and Paradeep coastal waters. As such, the physico-chemical parameters did not show much variation barring a few parameters which showed only marginal variations. The results of various parameters are summarized below:

The diversity indices calculated for the plankton and benthic data in the present study showed undisturbed nature of the environment since diversity values of plankton and benthos were more than 2.5 as has been stated by the Marine ecologist Sanders (1968). The macro benthic conservative species Armandia sp., Glycera longipinnis, Goniada emerita, Spiochaetopterus costarum, Nereis sp.were predominantly occurred in the Mahanadi river Paradeep coastal waters which reflect the stable nature of the ecosystem.

Further, the results of physico-chemical and biological parameters indicated that the water is well oxygenated and nutrients are adequate supporting fairly good plankton population, the base in the food chain. Not only is that, the metal concentration in coastal water and sediment samples indicates that it is well within the ERM (Effective Range Median) values (Long et al., 1995) which means there is no possibilities of heavy metal contamination in the region.

In short, the results of marine ecological survey made during 26th to 29th January 2024 Mahanadi estuary and Paradeep coastal waters and careful perusal of the available

informationsuggested that the water quality parameters are within the safe level and did not indicate any alarming impact on the existing biological components. The analysis on other ecologically sensitive organisms reflected the patchy occurrence of a few groups especially seaweeds from the nearby regions. The discharges occurring from the proposed facility will result in only marginal impacts on biota but such impacts are confined to a limited period since most of the marine organisms are capable of recouping themselves quickly to its original form and thus there will not be any pronounced change to the biotic community. Further, the present marine survey was done only short period, continuous monitoring is also needed even after commissioning of this proposed facility with a view to ascertain the temporal variations in the physico – chemical and biological components of this environment, if any.

The detailed report is attached in Annexure-VI.

# CHAPTER 7

## MODEL STUDY ON HYDRODYNAMIC AND WAVE CONDITION

Mathematical models are used to predict the bed level change based on the hydrodynamic parameters that exist over the region of inspection. In order to pursue the mathematical model studies of hydrodynamics and siltation, the in-house developed hydrodynamic model used is Ocirc employed, the details of which are discussed in *Annexure A*. The model domain can be discretized with triangular elements to obtain numerical solutions to the hydrodynamic equations and compute the changes in the bed levels due to the tidal flow using sediment load balance in the water column.

Based on hydrodynamic modelling results, the dredging activities within the study domain have not significantly altered current conditions, suggesting that the natural flow patterns remain largely unaffected. Across two cases examined, the average siltation inside the proposed borrow area ranges from 0.02-0.08 m/N-N per cycle which is more or less consistent with the existing scenario described in the first modelling report.

The dredge quantity estimate for Case-I for one year in the sand trap area is 0.29 Mm3/year, the sand bar is 0.16 Mm3/ year, the harbour basin is 0.28 Mm3/ year and the outer channel is 0.21 Mm3/ year. For Case-II the dredge quantity estimate for one year in the sand trap area is 0.19 Mm3/year, the sand bar is 0.21 Mm3/ year, the harbour basin is 0.31 Mm3/ year, the outer channel is 0.25 Mm3/ year and inner basin is 0.55 Mm3/ year. The total dredge quantity estimates for a year for Case-I and Case-II are 0.94 Mm3 and 1.51 Mm3.

As has been ascertained from the mathematical model studies there is no impact on adjacent creek area and proposed harbor areas.

As per the dispersion study, dumping at the proposed location alone does not cause any impact on the adjacent creek area and proposed harbour area. Overall, the study suggests that dredging activities and the disposal of return slurry have no noticeable impact on study area, as evidenced by the minimal changes in current and siltation pattern observed across different scenarios.

The detailed modelling report is attached in Annexure-VII.

# CHAPTER 8

# PROJECT COST

## 8.1 COST ESTIMATE

Ministry of Ports, Shipping and Waterways issued the Dredging Guidelines for Major Ports in June 2021 and requested Major ports to be followed by Major Ports to follow these guidelines for ensure implementation of dredging projects for cost effectiveness and delivery of projects as per schedule, this document shall be reference guidelines but is not exhaustive.

NTCPWC has worked out the dredging unit rate as per the Dredging Guidelines, 2021. As per Chapter 6 of Dredging Guidelines, 2021,– Standardized procedure for dredging estimate, the dredging unit rate shall be arrived as follows:

$$\text{Dredging unit rate } R = \frac{\textbf{Total Cost of Dredging Plant and its operation (C)}}{\textbf{Total Quantity to be dredged (V)(Estimated)}}$$

Where C = C1 + C2 + C3 + C4 + C5 + C6 + C7

| Sl.No. | Cost Item | Guideline | Remarks |
|---|---|---|---|
| 1 | **C1, Depreciation + Interest (D+i) on capital equipment** | As per CIRIA manual (or) Obtained from Dredging contractors by a Rate Tender. | Rate Tender could be done annually. Such rates shall not exceed CIRIA value of capital equipment. |
| 2 | **C2, Maintenance + Repair (M+R) for deployment period** | As per CIRIA manual (or) Obtained from Dredging contractors by a Rate Tender. | For the days of operation excepting any idle times. Such rates shall not exceed 80% CIRIA rates for Indian Conditions. |
| 3 | **C3, Fuel + Lube oil costs** | To be worked out using method stated in this manual (or) to be obtained as part of Rate Tender. | |
| 4 | **C4, Insurance** | 1.6% of c1 | |
| 5 | **C5, Manning Costs** | To be worked out using method stated in this manual (or) to be obtained as part of Rate Tender. | |
| 6 | **C6, Idle time charges** | Simply c1, only for those idle days. | When c6 is applied, c1, c2, c3 will not be applied. |

| | | | |
|---|---|---|---|
| 7 | **C7, Mob and Demob** | 10% of project cost for capital dredging. 7.5% of project cost for Maintenance Dredging. (75% for Mob & 25% for Demob) | This shall not be treated as Mobilization advance. This is a provision in estimate for cost incurred by contractor during all pre & post dredging activities. |
| **Note:** c1 & c2 may be considered to be included costs of support crafts which are least for maintenance dredging. In case of capital dredging, they need to be considered separately depending of dredging plan. | | | |

**Remarks:** In addition, the Cost of dumping / reclamation pipelines, Machineries to be used in the Reclamation site, Multicat / Pontoons to be used, Survey team & Survey vessel and Overhead and Profit components have also been considered while computation of the Dredging unit rate.

The dredging rates were arrived at using a combination of Trailing suction Hopper Dredgers of 5200 cu.m and 7500 cu.m hopper capacity along with 2000KW and 3000 kW power cutter motor Cutter Suction Dredgers and their ancillary equipment. The Overall amount for Dredging in the proposed borrow area and disposal of the same at the proposed reclamation area was assessed based on the fuel price of Rs. 50,000 per MT, i.e. Fuel Price (VLSFO) = 607 USD/MT & 1 USD = 81.97INR as on 20.07.2024. (Source of fuel price: Netpas Bunker)

Table 8.1 Cost Estimate for Option 1

| Sl No | Location | Areas ($m^2$) provided by JSW-USL | Permissible Depth of dredging (m) provided by JSW-USL | Tentative Existing Average Depth in the proposed dredging area (m) | Depth of cut (m) | Quantity to be dredged (Cu.m) | Likely Dredger Option |
|---|---|---|---|---|---|---|---|
| 1 | Sand Trap | 4,03,424 | 8 | 0 | 8 | 3,22,73,92 | CSD |
| 2 | Sand Bar | 1,71,557 | 18.4 | 0 | 18 | 3,08,08,26 | CSD |
| 3 | Harbour Basin | 2,31,646 | 18.4 | 5 | 13 | 3,01,13,98 | TSHD |
| 4 | Outer Channel | 1,74,417 | 19.3 | 11 | 8.3 | 1,44,51,71 | TSHD |
| | | | | | Total Quantity in (Cu.m) | **1,07,71,987** | |
| | | | | | Total Quantity in (M Cu.m) | **10.77** | |

The overall dredging and reclamation cost has been assessed as **Rs. 1,351.91 crores** by using combination of Trailing suction Hopper Dredgers of 5200 cu.m and 7500 cu.m hopper capacity alongwith 2000KW and 3000 kW power cutter motor Cutter Suction Dredgers and its ancillary equipment. The detailed calculations are attached as Annexure VIII.

Table 8.2 Abstract of Capital cost for Option I

| S.No. | Description | Project cost (Rs in Crs) |
|---|---|---|
| 1 | Dredging in the burrow area, as mentioned above and disposing of in the proposed reclamation area including Mobilization and Demobilization of the equipment. | 1,250.04 |
| 2. | Formation of Reclamation bund including levelling, providing HDPE Geomembrane, perforated pipe drain and key, and protecting the top layer with Pre-fabricated concrete slab. | 62.50 |
| | Sub Total | 1312.54 |
| | Contingencies, supervision, Project Management Consultancy and Miscellaneous @ 3% of total cost. | 39.37 |
| | Total Project Cost | **1,351.91** |

Table 8.3 Cost Estimate for Option II

| Sl. No | Location | Area (m2) | Permissible depth of dredging (m) provided by JSW-USL | Tentative Existing Average Depth in the proposed dredging area (m) | Depth of cut (m) | Quantity to be dredged (Cu.m) | Likely dredger option |
|---|---|---|---|---|---|---|---|
| 1 | Sand Trap | 4,03,424 | 8 | 0 | 5.5 | 22,18,832 | CSD |
| 2 | Sand Bar | 1,71,557 | 18.4 | 0 | 10.5 | 18,01,349 | CSD |
| 3 | Harbour Basin | 2,31,646 | 18.4 | 5 | 5.5 | 12,74,053 | TSHD |
| 4 | Outer channel | 1,74,417 | 19.3 | 11 | 1 | 1,74,417 | TSHD |
| 5 | Inner Basin | 5,74,491 | 18.4 | 1 | 9.5 | 54,57,669 | CSD |
| | | | | | Total Quantity in (Cu.m) | **1,09,26,319** | |
| | | | | | Total Quantity in (M Cu.m) | **10.9** | |

The overall dredging and reclamation cost has been assessed as **Rs. 1,344.19 crores** by using a combination of Trailing Suction Hopper Dredgers of 5200 cu.m and 7500 cu.m hopper capacity along with 2000kW and 3000 kW power cutter motor Cutter Suction Dredgers and its ancillary equipment. The detailed calculations are attached as Annexure VIII.

Table 8.4 Abstract of Capital for Option II

| S.No. | Description | Project cost (Rs in Crs) |
|---|---|---|
| 1 | Dredging in the burrow area, as mentioned above and disposing of in the proposed reclamation area including Mobilization and Demobilization of the equipment. | 1,242.54 |
| 2. | Formation of Reclamation bund including levelling, providing HDPE Geomembrane, perforated pipe drain and key, and protecting the top layer with Pre-fabricated concrete slab. | 62.50 |
| | Sub Total | 1305.04 |
| | Contingencies, supervision, Project Management Consultancy and Miscellaneous @ 3% of total cost. | 39.15 |
| | Total Project Cost | **1,344.19** |

# CHAPTER 9

# DISCUSSION AND RECOMMENDATION

## 9.1 PROJECT HIGHLIGHTS

- The proposed land is to be developed by using dredged material from the proposed JSW-USL Port. The total extent of land to be developed is about 705 Acres. The existing average elevation of the area is about +2.66m CD and the proposed developed elevation is +5.45m CD.
- The identified dredge area is in close vicinity to the proposed reclamation area is expected to result in an optimal cost for reclamation works.
- No hard strata are found in the dredge area upto 25m below the sea bed as ascertained from the field measurements and sub-bottom profiler study.
- The proposed reclamation is to be carried out by pumping the dredged matieral to the land area to be developed. The pipeline routes are planned without causing any hinderances to the nearby habitat area.
- The pipeline diameter shall be a maximum of 900mm (3 no's) and the return pipeline for the water outlet shall be 500mm (2 no's).
- The Bund is proposed to be constructed to accommodate the dredging quantity of around 7.9M Cum.
- Based on hydrodynamic modelling results, the dredging activities within the study domain has not significantly altered current conditions, suggesting that the natural flow patterns remain largely unaffected.
- The hydrodynamic study also confirms that there is no visible change in the current patterns, magnitudes, siltation etc., in all the options of borrow pit configurations and all dredging and reclamation plans are viable. However, both options are approved by MOEF&CC and EC is available except for the additional length of discharge pipelines. The study also confirms that both options of borrow pit configurations do not cause any impact on the structures proposed by JSW-USL.
- The identified routing of the pipeline shall not cause any hindrances to the proposed activity inside the JSW-USL area.
- The analysis reveals consistent siltation rates with no significant variation observed after deepening the dredging pit area for reclamation purposes. The

siltation study suggests that the dredging activities for land reclamation are not anticipated to substantially alter the siltation rates in the area.

## 9.2 BENEFITS OF USAGE OF MATERIALS FROM THE DESIGNATED PORT LIMIT OF JSW UTKAL STEEL LIMITED

- In view of the proposed JSW-USL Port development and creation of its navigational areas and berth pockets by dredging, the most environmentally friendly option is to dredge the material from the nearby sea. This will preserve the valuable minerals available in the vicinity of the proposed project site or disturbing any other site.
- Both the area namely, the water front and backup to both JSW UTKAL STEEL LIMITED and IOCL were allotted only by IDCO for development of infrastructure facilities by the individual organisations. JSW Utkal Steel Limited already obtained necessary statutory clearances for their project including the dredging within their designated port limits. Eventhough, an overall estimated dredging quantity of about 30million Cu.m is contemplated in the developmental proposal of JSW Utkal Steel Limited, they are planning to use about 20million Cu.m of dredged spoil for development of land in their airmarked permises, the balance 10million Cu.m is proposed to be disposed of in the offshore dumping area. This extra quantity of materials dredged can be gainfully utilized in reclaiming the airmarked permises of IOCL, thereby also minimizing environmental disturbance at the offshore location.
- The identified locations for dredging for the purpose of reclamation of the designated area of IOCL, are very close to the proposed dredging area, whichis within the port limit of IOCL and it would be the least cost of transporation mode for laying of pipeline for disposal and return pipeline for surplus water and thereby, reduces the cost of infrastructure development of IOCL. Similarly, the dredging is proposed to carried out the purpose of reclamation, within the designated portlimit and proposed dredging area for manuvarability of vessels, there would a considerable cost savings for JSW Utkal Steel Limited also.
- Since all the environmental related issues including EIA and EMP have already examined and studied in detail by JSW Utkal Steel Limited, dredging within their designated port limits will not result any environmental hazards.

## 9.3 RECOMMENDATION

- In order to reduce the time required for initiating the entire EC process to a considerable extent, it is recommended that
  - ✓ EC is available with JSW for the Construction of Captive Jetty & Dredging & Reclamation works of 30 Million Cum.
  - ✓ NOC from JSW-USL & MOU between JSW Utkal Steel Limited and IDCO for dredging, transportation & utilization of dredged materials from JSW-USL Port Area and through JSW-USL ISP are required for utilizing existing EC of JSW-USL to cater to the Dredging & Reclamation requirement of IDCO for the following purposes:
    - i. To accommodate the requirement of about 7.9 Million Cum.
    - ii. Laying of Dredged Slurry pipelines and return lines to & from the Reclamation area of IDCO from the shoreline through the JSW-USL site, for a short period of 10 months, without causing any major hindrances.
  - ✓ Affidavit by IDCO for dredging, transportation & utilisation of dredged materials in strict compliance with the conditions stipulated in EIA & CRZ Clearances awarded to JSW-USL.

In the meantime, IDCO may be requested to obtain the required CRZ clearances well before the commencement of activities for Dredging & Reclamation.

## CONCLUSION

- After detailed field investigations and model study, it is concluded that the identified location for dredging and transporting the material for reclamation purposes listed in chapter 5, above are feasible options and are the best-suited location for the intended purpose with the least cost.
- Both the options for dredging and reclamation for a quantity of 7.9 million cubic meters are confirmed feasible and they do not have any adverse impact on the environment and also proposed JSW-USL developments.
- The identified pipeline routing locations are also the most suitable ones with no major impact on the existing/proposed adjacent structures/activities. Therefore, the locations can be adopted depending on the selected alternative dredging area.
- The total cost of the project is in the range of Rs. 1345 crores to Rs. 1350 crores, excluding GST involving dredging of about 10.77 to 10.9 Million Cu.m and reclaiming the site of development to the tune of 705 Acres.

for NTCPWC, IITM

[Prof K. Murali]

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# ANNEXURE I

# HYDROGRAPHIC STUDY REPORT

## Contents

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# 1 FIELD SURVEYS

Field surveys play a crucial role in gathering data, helping to understand the actual conditions of the site. In this project, the following field study were conducted to identify suitable borrow locations for land reclamation.

- Bathymetry Survey
- Sub-bottom Profiler Survey
- Topography Survey
- Geo Technical Investigation

NTCPWC deployed the team to carry out the Bathymetry and Sub-bottom profile study, the data collection was started on December 2023.

The Details and Results of the field surveys are elaborated in this report.

## 1.1 BATHYMETRY SURVEY

### 1.1.1 METHODOLOGY

#### 1.1.1.1 GENERAL

The survey works was conducted in accordance with the specifications and scope of work. The bathymetry survey was conducted in WGS 84 spheroid with UTM coordinates (Zone 45) and was supplemented by geographical coordinates indicating the latitude and longitude.

#### 1.1.1.2 SURVEY VESSEL

The Survey vessel was hired to conduct the Bathymetry survey. The survey equipment was mobilized to the Survey vessel on 29th December 2023 and necessary checks were performed to minimize the errors. The equipment was fitted in the survey vessel and necessary offset values were given in Hypack Software. Survey vessel ‘NAMO NARAYANA’ with high maneuverability and sufficient deck space was used for carrying out the surveys.

#### 1.1.1.3 SURVEY PLANNED LINES

The entire survey was carried out with a line spacing of 100m intervals as per requirements. The qualified and experienced surveyors of NTCPWC carried out this survey work. Total Survey Line km’s = 696 Line km’s (Area of 11500m x 6000m)

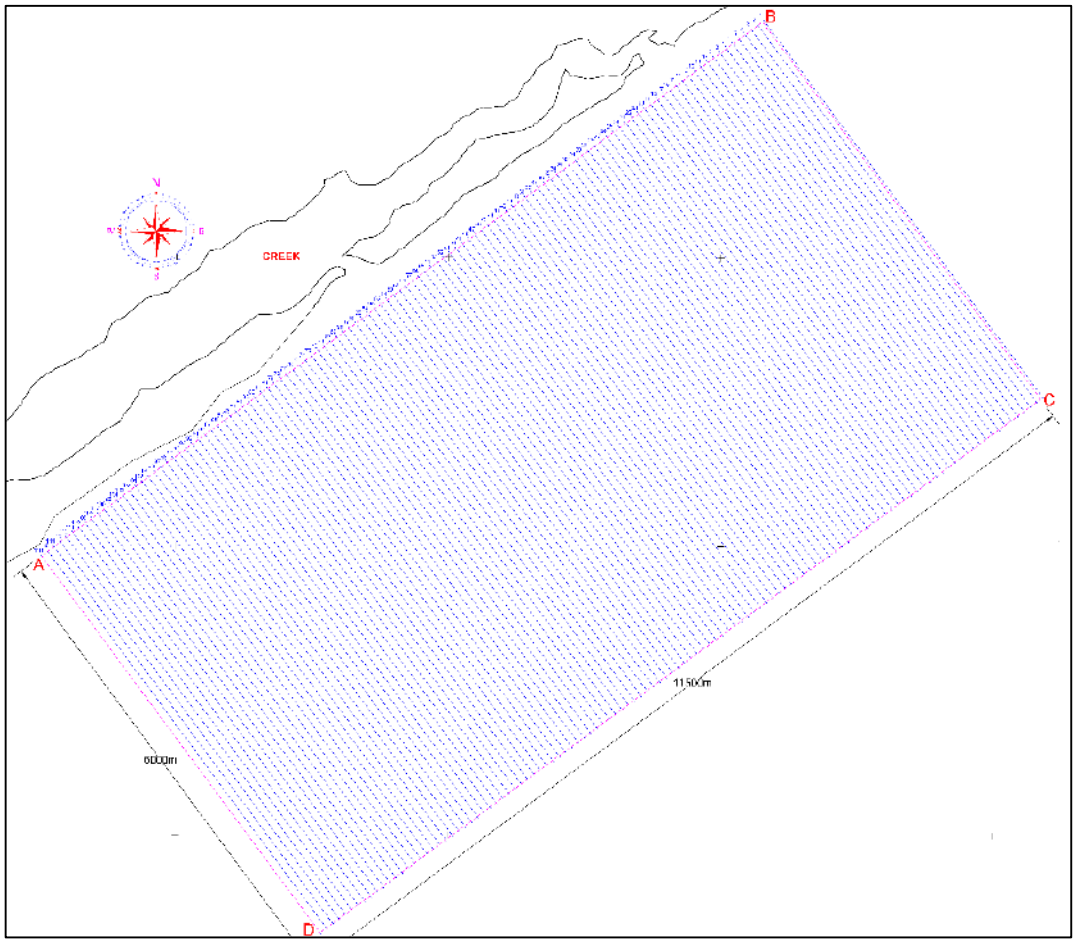



**Figure 1 Survey Line Details**

### 1.1.2 EQUIPMENT, SOFTWARE SUMMARY & DATA LOGGING SYSTEM

- 1 x Teledyne Odom Echotrac E20 Echosounder
- 1 x Dual frequency transducer 33 kHz and 210 kHz and vessel mounting pole
- 1 x R632 Hemisphere Receiver Modular GNSS Receiver
- 1 x Teledyne TSS Motion Sensor for sea swell compensation
- 1 x laptop for Navigational visualization
- 1 x Hypack Survey for data collection, visualization, storage, and processing software.
- 2 x Computer Interface, 12V Power Supply

The Bathymetry survey has been done using Odom Echotrac E20 Dual frequency echo-sounder, IN ADDITION, R632 Hemisphere DGNSS/beacon receiver for acquiring the bathymetric data. The necessary inputs were given in HYPACK data collection software before the commencement of the survey. The recorded data includes the date, time, depth, latitude, longitude, X coordinate, and Y coordinate. The data was obtained and then processed using Hypack software and corrected using tide collected from Paradip Port Authority.

### 1.1.2.1 Geodesy Parameters

The bathymetry survey was conducted in WGS 84 Datum; Grid co-ordinates in terms of Universal Transverse Mercator (UTM) Projection. Details of the Spheroid and Grid system as provided in Table 1.

Table 1.1 Geodetic Parameters and Conversion

| GEODETIC PARAMETERS | |
|---|---|
| Datum | WGS 84 |
| Ellipsoid | WGS 84 |
| Grid | UTM North |
| Semi-Major Axis (a) | 6378137.000 meters |
| Zone | Zone 45 (84E-90E) |
| Inverse Flattening (1/f) | 298.2572236 |
| **PROJECTION PARAMETERS** | |
| Grid Projection | Universal Transverse Mercator |
| Central Meridian (CM) | 87.0° East |
| Origin Latitude (False Lat.) | 00.0° |
| Delta Scale | 0.0 |
| False Easting (FE) | 500000.0 m |
| False Northing (FN) | 0.0 m |
| Scale Factor on CM | 0.99960 |
| Units | Meters |

### 1.1.2.2 TELEDYNE ODOM ECHOTRAC E20 ECHOSOUNDER

Single Beam Echo Sounder (SBES) was used to carrying out the bathymetry survey at paradip. The Teledyne Odom Hydrographic Echotrac E20 (Fig. 2) is a professional grade echo sounding, which used for this survey. This echo sounder is a Recorder, Digitizer, Transceiver, utilizes multiple processors including two dedicated Digital Signal Processors (DSPs), which work in concert to accomplish specific analysis while communicating effectively on a real-time basis in order to assure accurate measurements even under difficult sea conditions and also for all types of seabed. E20 has a provision of selectable two simultaneously transmitted frequencies, a) 200 kHz High Band and b) 33 kHz Low Band. The E20 has an Ethernet port that outputs with the 16-bit

samples of the acoustic data for further processing or visualization. Temporary fixing of the E20 transducer in a vertical pole fixed over the side of the survey vessel of 1.0 meters below the waterline was maintained during the execution of the bathymetry survey.

Both high and low channels frequency agility, enabled to precisely match the transceiver to the transducer. This ability minimizes near-surface noise caused by transducer ringing while increasing echo return strength. Processing of the survey data were undertaken by the processor to ensure the data recorded does not have any offset errors. During processing of bathymetric data, the following checks performed:

- Draft measurements were correct for Single Beam Echo Sounder system.
- Correct vessel offsets applied to the correct sensors.
- Lead line measurement was performed to cross verify the depth.




**Figure 2 Odom Echotrach E20 Echosounder**

The processing of survey data consists of two main functions: rejection of outliers, then statistical combination of the remaining soundings into binned survey data. The Hypack processing software designed to provide the tools a surveyor needs to perform efficient processing of the large amount of data collected while maintaining good quality control of the final output.

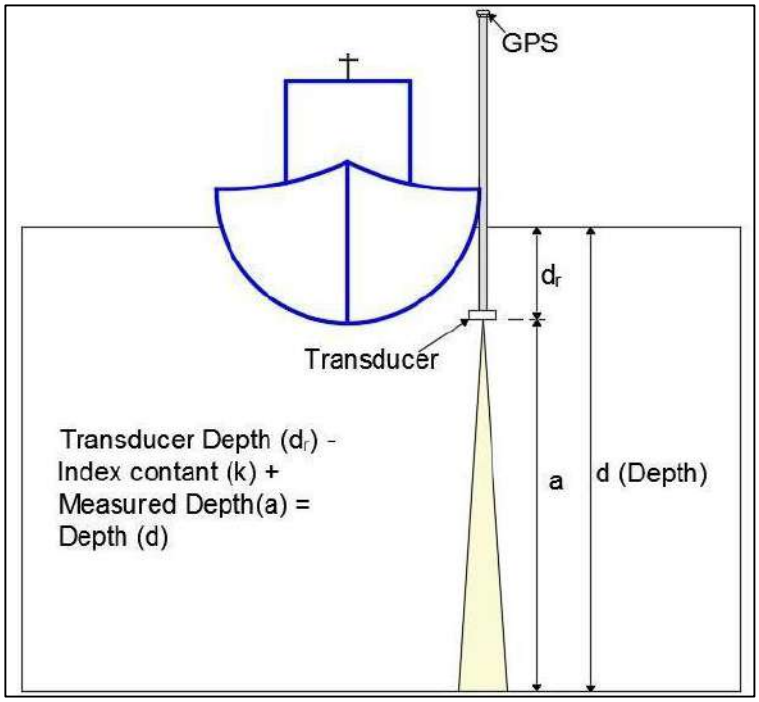
During processing the very high-resolution ping-by-ping data converted into a binned bathymetric chart - typically, 1m binging used in shallow water surveys. The bathymetry records from individual lines can be re-examined to look at specific features at higher resolution, if

required.

Immediate feedback on survey results is important so that the surveyor quality check the data as it comes in and ensure the required accuracy standards maintained. Data quality control tools are important part of the software provided with bin-by-bin measure of the data density, distribution and confidence, both on-line and in post processing.

The processed data from each line was added to the survey window sheet, giving confidence that coverage is complete and that overlapping data from different lines matches well. The on-line display of the bathymetry also allowed the surveyor to immediately identify the features of interest for a more detailed.

Proper mounting of the transducer is a crucial part of the installation of any "Bathymetry survey". Temporary installation of the transducer mounted over-the-side 1.0 meters below the waterline. Draft is the correction value added to the measured depth to adjust for the difference between the depth of the transducer and the water's surface (a +dr– k) where "a" is the measured depth, "dr"equals the draft (depth of the transducer below the water surface). Index constant "k" is system delays originating in both transducer and echo sounder circuitry. In the accompanying illustration, "d" is equal to the depth of the seabed below the water's surface **(Figure 3)**.




The depth is computed according to the general formula shown below

$$d = ½ (v * t) - k + dr$$

d =depth from water's surface

v =average speed of sound in the water column

t =measured elapsed time of signal travel from the transducer to seabed and back to the Transducer

k =system index constant

dr=difference from referenced water surface to transducer (draft)

Echotrac E20 Single beam system shown in **Figure 3.** Processing of the survey data were undertaken at the office. The processor ensured that sufficient checks conducted to ensure the data recorded without offset errors.

### 1.1.2.3 HORIZONTAL CONTROL

R632 GNSS receiver processes and supports more than 1,100 channels and offers flexible and scalable simultaneous tracking of every modern and planned GNSS constellation and signal including GPS, GLONASS, BeiDou, Galileo, QZSS, IRNSS, SBAS and Atlas L-band.

The R632 combines Hemisphere's Athena GNSS engine and Atlas L-band correction technologies with status LEDs and a WebUI. It also comes equipped with UHF (400 MHz and 900 MHz) radio, cellular modem, Bluetooth and Wi-Fi.

Hemisphere R632 comes with GNSS dual antenna receiver is one way to provide heading. GNSS1 can be used to determine the position and GNSS2 is used for Heading. Both the receiver and antennas are connected with system via IP connection. GPS heading and GNSS heading can be determined by comparing the position of the two antennas. There is a minimum distance required between 2 antennas for an accurate heading to be generated.

The RTCM correction stream from an MSK source can be passed to other DGNSS receivers using the Repeat RTCM function. The positioning data received have high reliability and integrity. The system was calibrated prior to mobilize the system in the field.




**Figure 3 Hemisphere R632 Receiver**

### 1.1.2.4 SMC IMU 008 MOTION SENSOR

The SMC motion sensors consists of separate axial measurement component groups converting signals from actual movements via accelerometers and gyroscopes into output data of angles and attitude. The output parameters are presented in a digital output string via RS422 or RS232. Each separate axial group consists of gyroscopes, accelerometers and temperature sensors. All data from the different sensor elements is processed and filtered in the motion sensor's CPU. The signal from the gyroscopes are combined with the signal from the accelerometers to provide the output of acceleration values and angle values from the motion sensor with limited influence of accelerations. Heave, surge and sway is calculated by integrating the acceleration in the X, Y and Z-axis. The zero point for heave, surge and sway will be the average of the output over a time of 4 cycles. The calculations of the distances are optimized for continues motion. In the calibration process which is individual for every motion sensor the g-values from the accelerometers and angle rate are from the gyros are calibrated over the stated temperature range. SMC are using a 3 axis calibration machine that is equipped with a temperature chamber.



**Figure 4 SMC IMU 008 Motion Sensor**

### 1.1.2.5 HYPACK NAVIGATION SOFTWARE

HYPACK 2023 navigational software used, which is a user-friendly, for marine navigation, positioning and surveying activities. HYPACK hydrographic survey software solutions used for data collection and processing which enable real time imaging (during survey), terrain modeling,

and statistical reporting (after processing).

#### 1.1.2.6 DATA PROCESSING AND REPORTING

On completion of bathymetry, the data was post processed using a combination of software packages, i.e. Hypack & AutoCAD 2023. Initially the data was examined for depth and position correctness in Hypack single beam editor module. Here digitally generated profiles were examined and compared to analogue records.

If during the survey the echo sounder digitizer briefly loses lock, a zero is recorded which shows as a full height spike on the digital profile. Any zero spikes were manually removed, the track of the survey vessel was also examined, and position spikes, which resulted from brief loss of differential corrections, were removed. The appropriate tidal data given by PPA was used to reduce the soundings with respect to the Charted Datum. This reduced and quality-controlled bathymetric data, which was then imported into AutoCAD for chart plotting.

The survey data logged in RAW file format was processed in HYPACK software and converted into xyz (Easting, Northing and Elevation) file with 100x100 meter grid spacing. The XYZ file has been used to prepare the final survey chart. Finally, the data is presented in drawing (*.dwg) using AutoCAD for windows.

#### 1.1.2.7 TIDAL CORRECTIONS

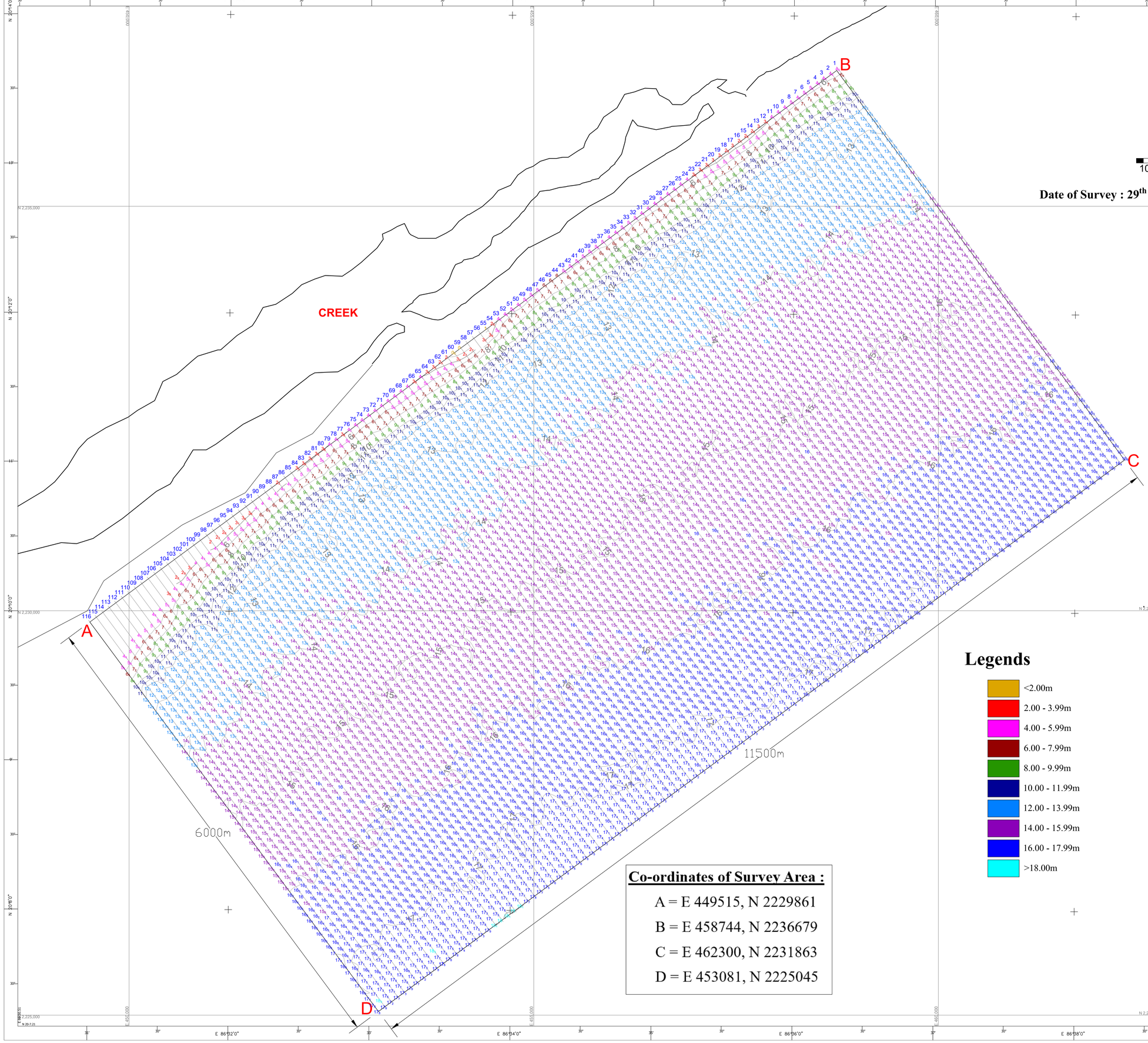
The tide data were received from the Paradip Port Authority. It was measured at 12-minute intervals. The same data was used to correct the soundings for the bathymetry survey.

#### 1.1.2.8 PROGRESS REPORT

During the field survey data collection, the surveyors conveyed the Daily Progress Report (DPR) to the NTCPWC office in Chennai, and the same was submitted to DCI.

### 1.1.3 RESULT

- The Bathymetry Survey was carried out during the period between 29th December 2023 and 14th January 2024 involving a total area of 11500m x 600m.
- The bathymetry survey has been completed with a survey line spacing of 100m.
- The bathymetry survey chart is attached below.




N
E
S
W

Scale 1 : 15000

100 200 400 600 800 Meters

**Date of Survey : 29th December 2023 to 14th January 2024**

GEODETIC PARAMETERS :

| | |
|---|---|
| Ellipsoid | : WGS84 |
| Geodetic Datum | : WGS84 |
| Semi major axis | : 6378137.00m |
| Inverse flattening | : 298.2572236 |
| Projection | : Universal Transverse Mercator |
| Central Meridian (CM) | : 87° E ( Zone 45) |
| False Easting | : 500000m |
| False Northing | : 0m |
| Scale factor at CM | : 0.99960 |

**Notes:**

1) Survey was carried out from 29th December 2023 to 14th January 2024.
2) Position Fixing was controlled from Hemisphere R632 Positioning System.
3) TELEDYNE E20 Single beam echosounder was deployed to carry out the entire survey.
4) Tide values during the survey are taken from Paradip Port.
5) SMC-008 Heave sensor was used for the survey.
6) Grid Size: 100 m x 100 m.
7) Survey area co-ordinates were confirmed by the client.

## Legends

- <2.00m
- 2.00 - 3.99m
- 4.00 - 5.99m
- 6.00 - 7.99m
- 8.00 - 9.99m
- 10.00 - 11.99m
- 12.00 - 13.99m
- 14.00 - 15.99m
- 16.00 - 17.99m
- >18.00m

**Co-ordinates of Survey Area :**

A = E 449515, N 2229861

B = E 458744, N 2236679

C = E 462300, N 2231863

D = E 453081, N 2225045

Natural Scale 1 : 15000

10 20 40 60 80 Meters

CONSULTANT:

NATIONAL TECHNOLOGY CENTRE FOR PORTS, WATERWAYS AND COASTS (NTCPWC)
IIT MADRAS, CHENNAI-600 036.

CLIENT:

DREDGING CORPORATION OF INDIA LIMITED

PROJECT:

DPR FOR THE DEVELOPMENT OF INDUSTRIAL LAND BY UTILIZATION OF DREDGED MATERIAL AT PRATAPPUR & FATEPUR, PARADIP FOR IDCO, GoO

TITLE:

BATHYMETRY SURVEY MAP

| | | | |
|---|---|---|---|
| Paper Size | : A0 | Surveyed by | : Mr.Arun & Mr.Santhosh |
| Survey Period | : January-2024 | Processed by | : Mr.Arun |
| Drawn by | : Mr.Arun | Checked by | : Mr.V.Maheshvaran |
| Drawing Number | : 001-DCI-PARADIP | Date | : 23/01/2024 |

Approved by
Dr. J.SRIGANESH (NTCPWC)

# ANNEXURE II

# SUB-BOTTOM PROFILE REPORT

## Contents

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# 1 SUB-BOTTOM PROFILER SURVEY

To study the characteristics of sub-seabed for dredging and land reclamation for Paradip Petrochemical Project, covering an area of 11.5km along the coast and 6.0km into the sea. Accordingly, the sub-bottom profiler surveys were conducted between 04.01.2024 and 19.01.2024. The location map of the survey line details is shown in **Figure. 1.**

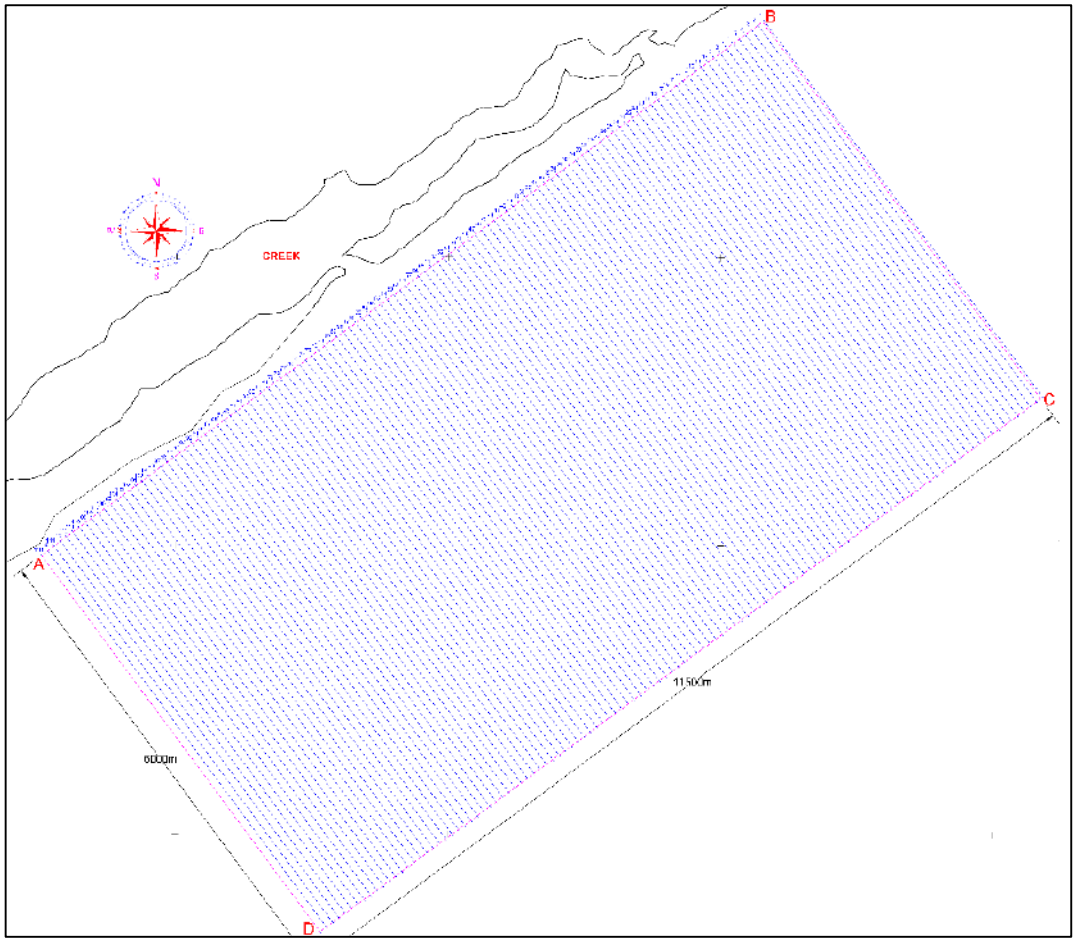



**Figure 1 Survey Line Details**

This report describes about working methodology, introduction to the instruments, some technical aspects followed oceanographic studies, results derived from the field studies and some site facts to help the client to reach a reliable solution in order to meet the further requirements on dredging solutions.

## 1.1.1 METHODOLOGY

### 1.1.1.1 COORDINATE SYSTEMS

The WGS-84 coordinate system was followed for the entire data acquisition, data processing, and preparation of reports and drawings.

### 1.1.1.2 DETAILS OF GEODETIC PARAMETERS

Table 1.1 Geodetic and Projection parameters

| GEODETIC PARAMETERS | |
|---|---|
| Datum | WGS 84 |
| Ellipsoid | WGS 84 |
| Grid | UTM North |
| Semi-Major Axis (a) | 6378137.000 meters |
| Zone | Zone 45 (84E-90E) |
| Inverse Flattening (1/f) | 298.2572236 |
| **PROJECTION PARAMETERS** | |
| Grid Projection | Universal Transverse Mercator |
| Central Meridian (CM) | 87.0° East |
| Origin Latitude (False Lat.) | 00.0° |
| Delta Scale | 0.0 |
| False Easting (FE) | 500000.0 m |
| False Northing (FN) | 0.0 m |
| Scale Factor on CM | 0.99960 |
| Units | Meters |

### 1.1.1.3 SURVEY PLANNED LINES

The survey was executed with the same bathymetry survey line file and line spacing of 100m intervals as per the requirements. This survey work is carried out by the qualified and experienced surveyors of NTCPWC. Total Survey Line km's = 696 Line km's (Area of 11500m x 6000m)

### 1.1.1.4 SURVEY VESSEL

The different configuration of instrument installed/towed onboard are shown below.

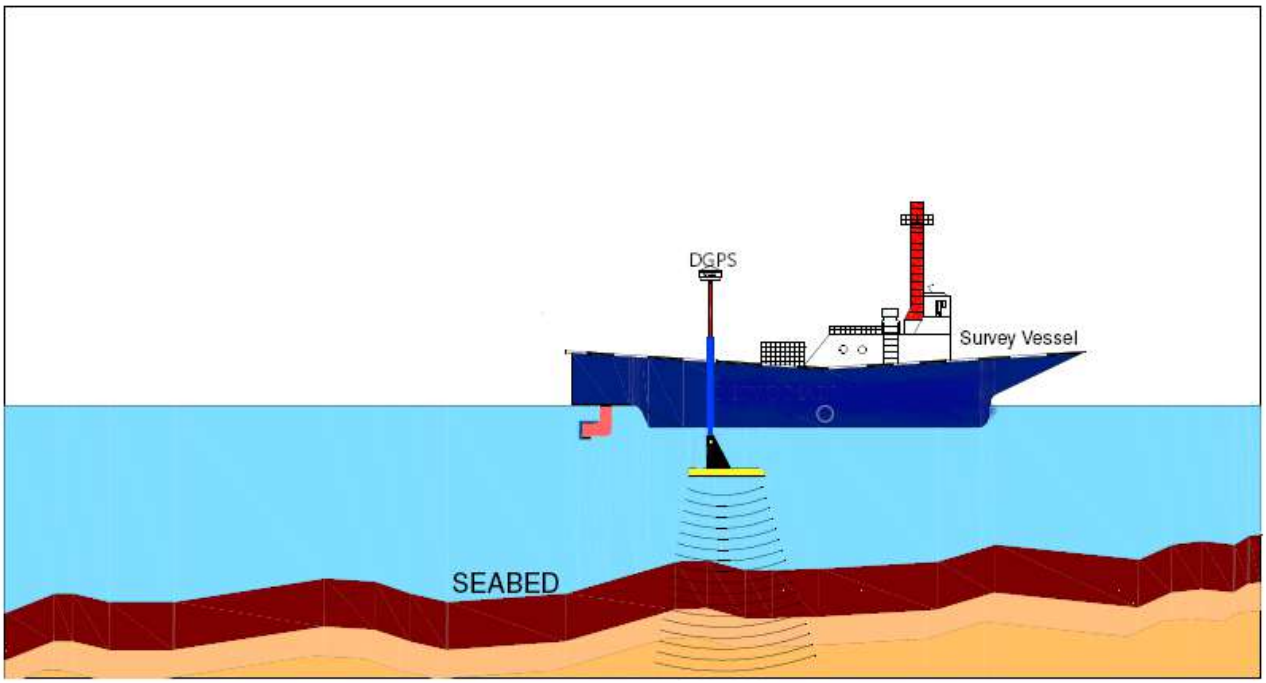



**Figure 2 Survey Vessel**

### 1.1.2 SUB-BOTTOM PROFILING SURVEY

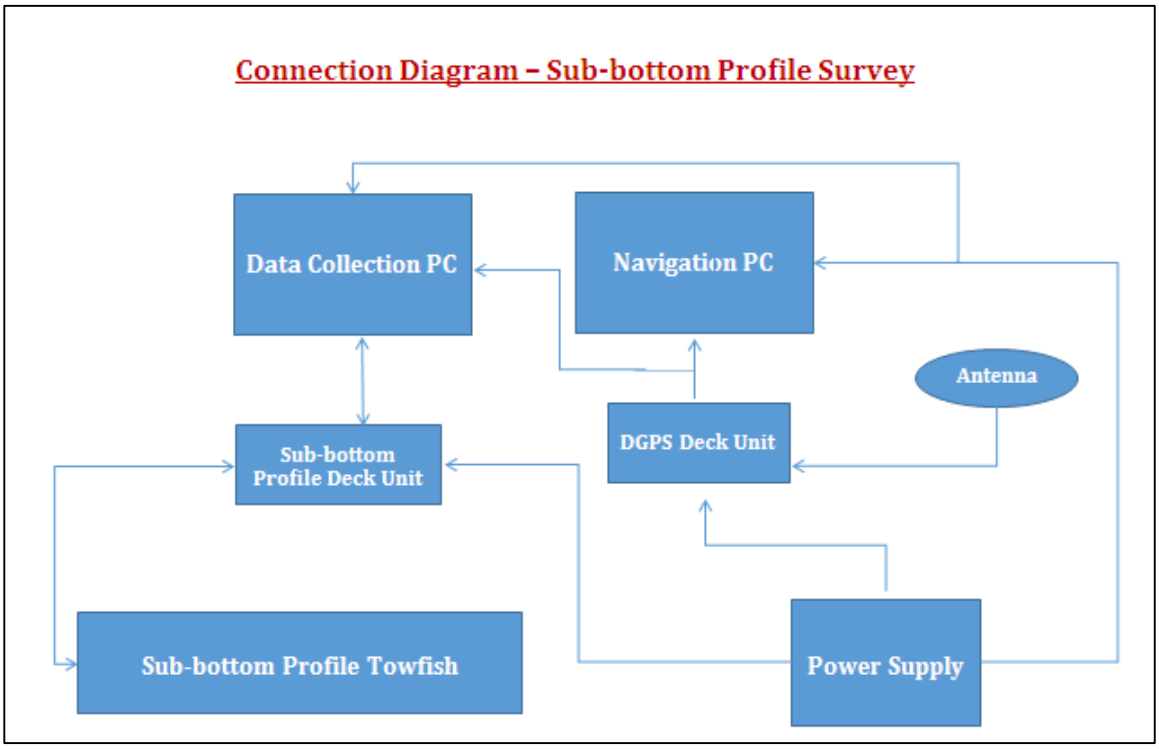
#### 1.1.2.1 SURVEY AREA

The sub-bottom profiling survey was carried out by the area of covering 11500m X 6000m at a line spacing of 100m by using SyQwest StrataBox HD 3510 sub-bottom Profiler manufactured in USA. The planned lines for sub-bottom profiling survey is presented in Fig. 1.

***Sequence of Survey*** **:** During data acquisition, the transducer was mounted at 1m below the water surface on the starboard side. The tow-fish cable was connected to the transmitter unit and the connections between transmitter and receiver were established by co-axial cables. The Stratabox HD Acquisition software was used for data acquisition. The sub-bottom/seismic data was recorded at the reputation pulse of 126 ms with required transmission power and receiving gain and stored in SEG-Y (Society of Exploration Geophysics) format. The DGPS data was also given into the data acquisition system through serial communication (RS 232). The entire system was powered by 100 AH battery reserved on the survey boat.

#### 1.1.2.2 CONNECTION DIAGRAM

The connection diagram of the sub-bottom profile survey, Towfish, deck unit, DGPS, and navigation systems are shown below.




***Data processing:*** CODA SEISMIC PLUS was adopter for entire data processing and data interpretation. The recorded data in the form of SEG-Y was imported to the CODA and seismic records were processed. The sub-bottom layers were interpreted and digitized using several geophysical techniques. The final outputs from the CODA were taken to generate vertical cross-sections and an isopach map.

### 1.1.2.3 SYQWEST STRATABOX HD 3510 SUB-BOTTOM PROFILER

The StrataBoxHD ™ 3510 is a portable high-resolution marine sediment imaging instrument capable of delivering 15cm of marine sediment strata resolution with bottom penetration of up to 40 meters. It is designed exclusively for inshore and coastal geophysical marine survey upto 800 meters of water depth. The specifications are mentioned hereunder:

- *Geographic Position Input : NMEA Compatible*
- *Depth Accuracy : +/- 0.5% of depth*
- *Strata Resolution : 6 cm with up to 40 meters bottom penetration @10Khz*
  *15 cm with up to 40 meters bottom penetration @3.5Khz*
- *Draft Offset : 0 to 30 feet (10 meters)*
- *Depth Resolution : 0.1 foot (0.1 meters)*
- *Sound Velocity : 4600 - 5250 ft/sec (1400 - 1600 mt/sec)1 mt/sec int.*
- *Data Output : NMEA 0183; DPT, DBT, PMC; ODEC*

- *StrataBox I/F : Ethernet via RJ-45*
- *Transmit Rate : Up to 10 Hz, depth and operator mode dependent*
- *Transmit Output Power : 300 Watts (pulsed), 1000 Watts capable*

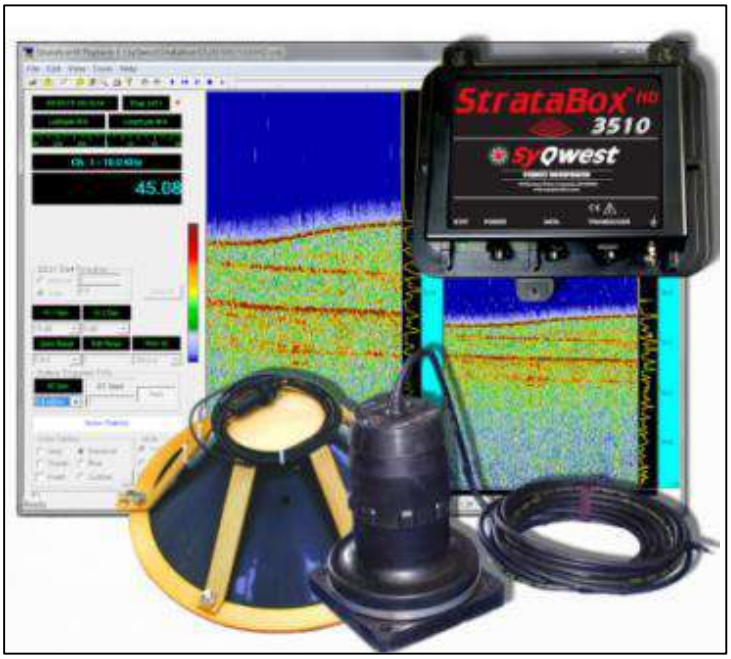



**Figure 3 SyQwest Strata Box HD 3510**

### 1.1.2.4 HORIZONTAL POSITIONING SYSTEM

The survey vessel was equipped with DGPS system for Precise Dynamic Positioning to give the real time position to sub-bottom profiling record. The DGPS system was setup to operate on UTM North Grid, Zone 45, WGS-1984 ellipsoid coordinate.

**Mobile Station:** The horizontal positioning acquired using Mobile unit TRIMBLE SPS 351 Beacon Receiver. It combines high-performance GPS reception with a DGPS-capable receiver in a lightweight, durable housing and comes with a separate antenna. The unit performs continuous RAIM calculations which enhance the integrity of the position data. The GPS receiver also contains technology enabling SBAS e.g. WAAS and EGNOS or Beacon real time differential capabilities. When used with a Real- time Kinematic (RTK) Base station, the GPS receiver provides RTK positioning for high-accuracy, centimeter-level applications. A standard R4 GPS receiver provides the following features: • 10 Hz (10 positions per second) output rate •12 GPS (C/A-code L1, C/A code L2 (for the Omni STAR XP/HP and RTK models)) tracking channels, code carrier channels Sub meter differential accuracy (RMS), assuming at least five satellites and a PDOP (Position Dilution of Precision) of less than four (when used with Satellite Based Augmentation Systems (SBAS) correction).

***The detailed specification of SPS 351 is:***

- SBAS such as WAAS (Wide Area Augmentation System) differential correction
- Highly versatile multifunctional display unit
- Beacon differential correction
- Large number of input and output ports to support highly complex and integrated bridge systems
- Channel management capability
- Easy access to standardized and proprietary text messages Fully upgradable to support future features.
- NMEA-0183 output: GGA, GLL, GRS, GST, GSA, GSV, MSS, RMC, VTG, ZDA (the default NMEA messages are GGA, GSA, VTG, and RMC).

The confidence checks on DGPS systems were performed before commencement and after completion of surveys. The DGPS correction age (latency) and positional Dilution of Precision (PDOP) were confirmed that within allwable limits.




**Figure 4 Trimble SPS 351**

### 1.1.3 RESULT

The sub-bottom profile survey data indicates that the sedimentary formation is the predominant composition of the sub-seabed off Paradip within the surveyed area. The thickness and compactness of the sediment vary at different locations. Based on acoustic impedance and the limitation of multiples, the minimum sediment thickness has been interpreted and mapped between 2.6m and 19.5m. It has been observed that a second layer exists below 1 to 2m from the seabed, starting beyond 3km from the shore and extending towards the seaward end of the survey limit. This second layer may indicate the presence of an ancient seabed. In general, there are no significant hard formations or strata observed within the range of signal penetration.

The typical sub-bottom profiling plates are as shown in below:

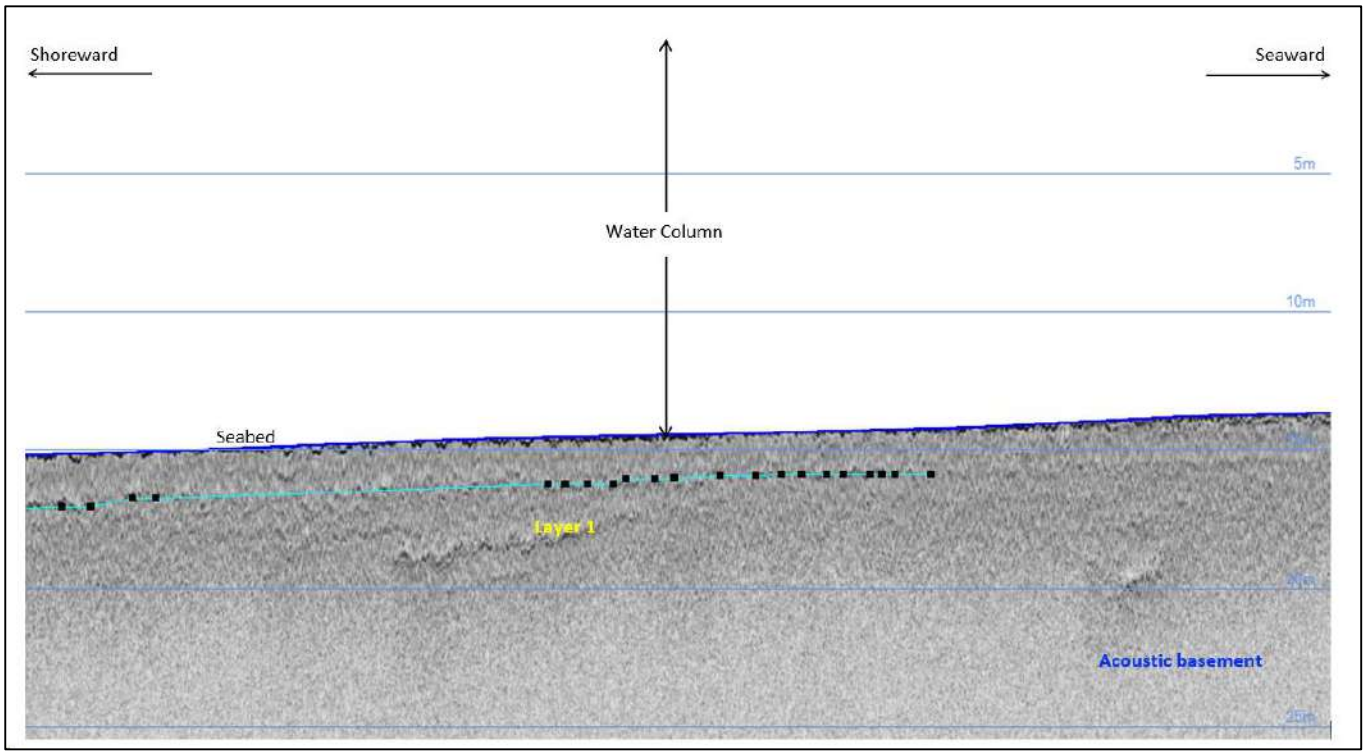



**Plate No: 01 - Typical Sub-bottom Profile Record Showing Vertical Sub-stracta Along Line No 07**

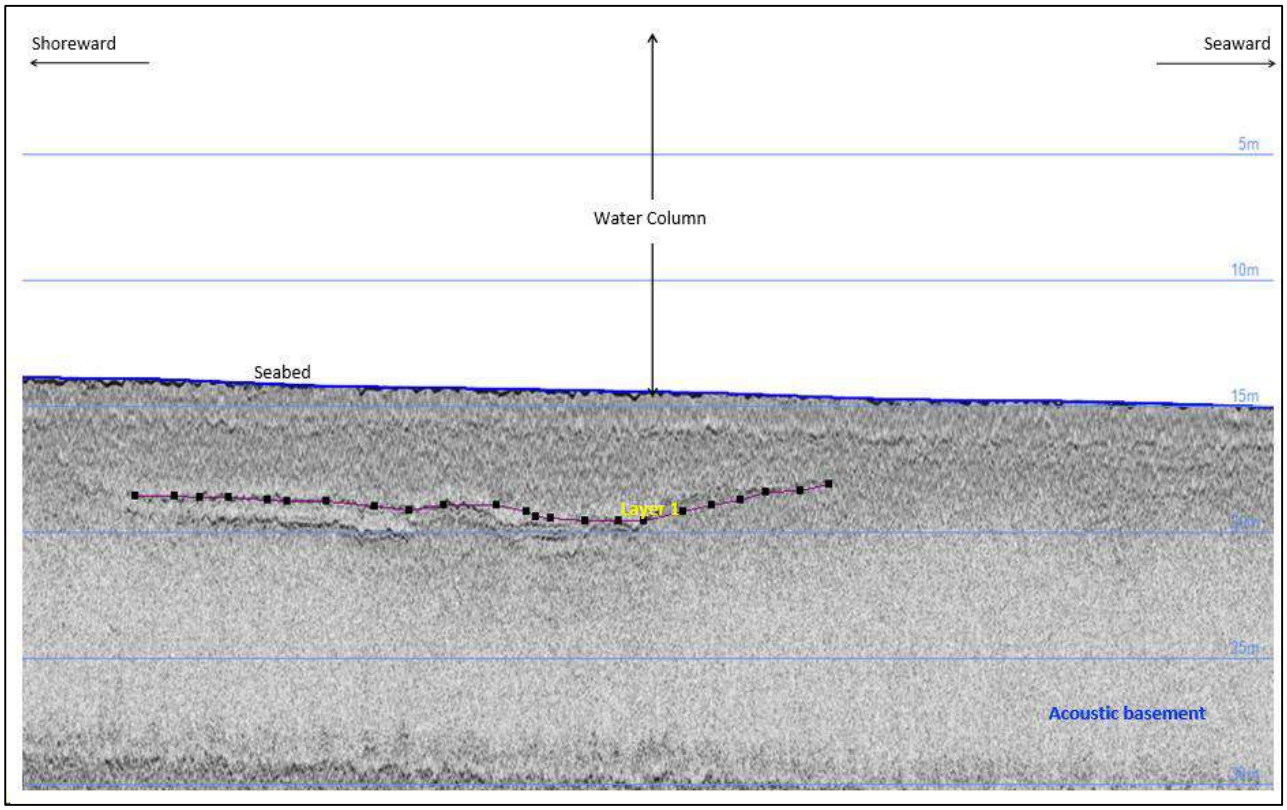



**Plate No: 02 - Typical Sub-bottom Profile Record Showing Vertical Sub-stracta Along Line No 25**

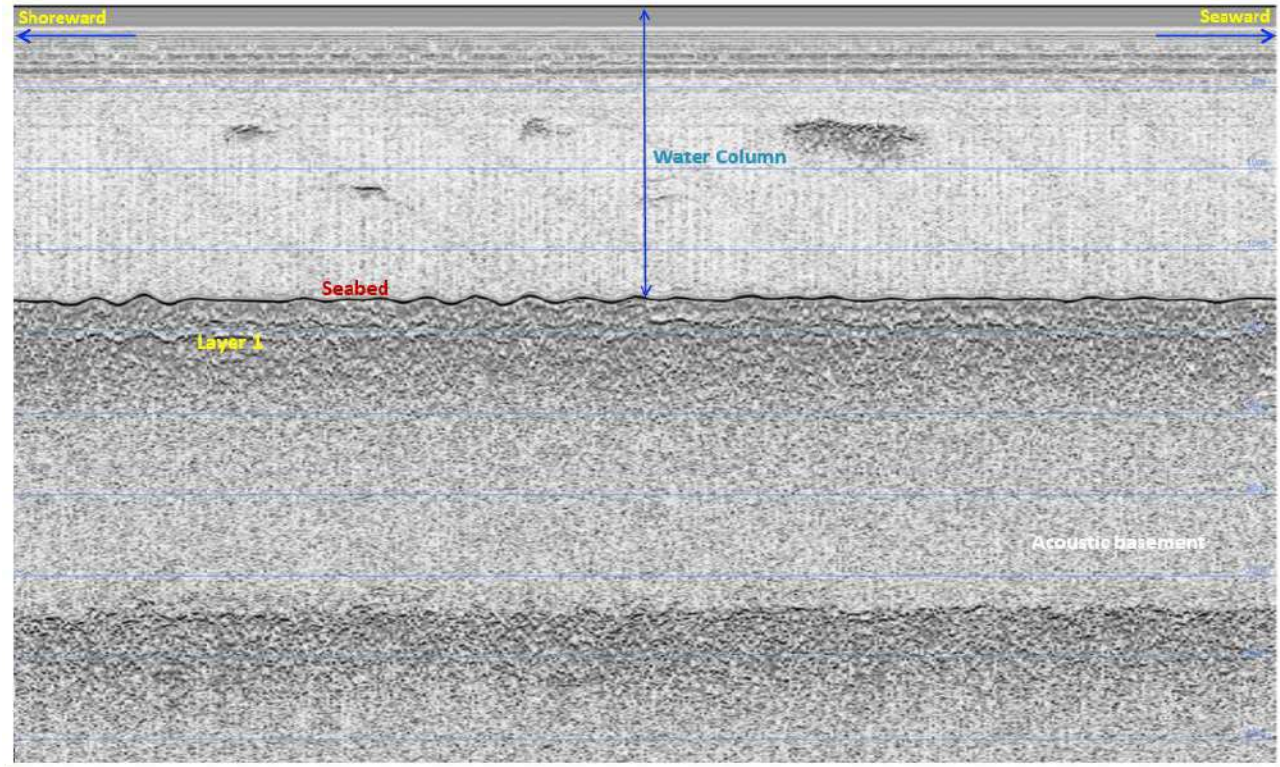



**Plate No: 03 - Typical Sub-bottom Profile Record Showing Vertical Sub-stracta Along Line No 58**

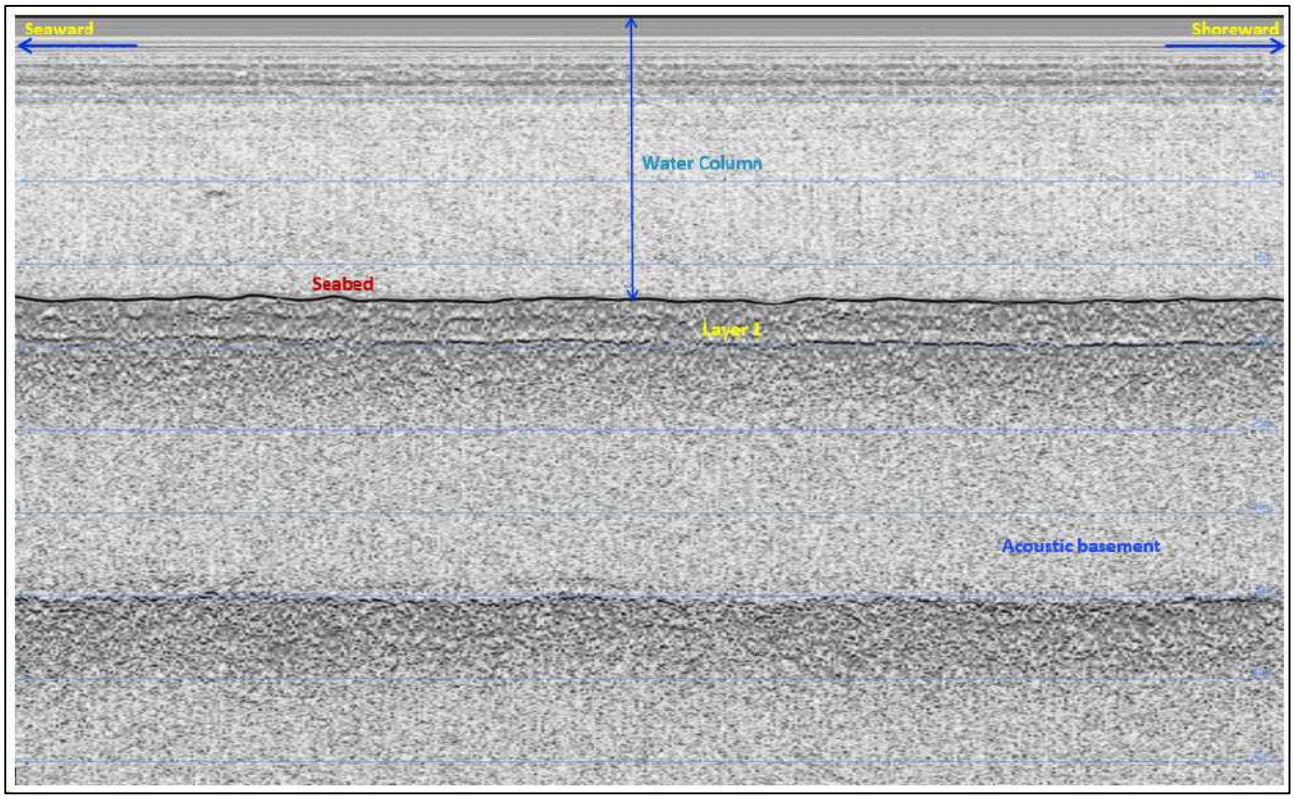



**Plate No: 04 - Typical Sub-bottom Profile Record Showing Vertical Sub-stracta Along Line No 93**

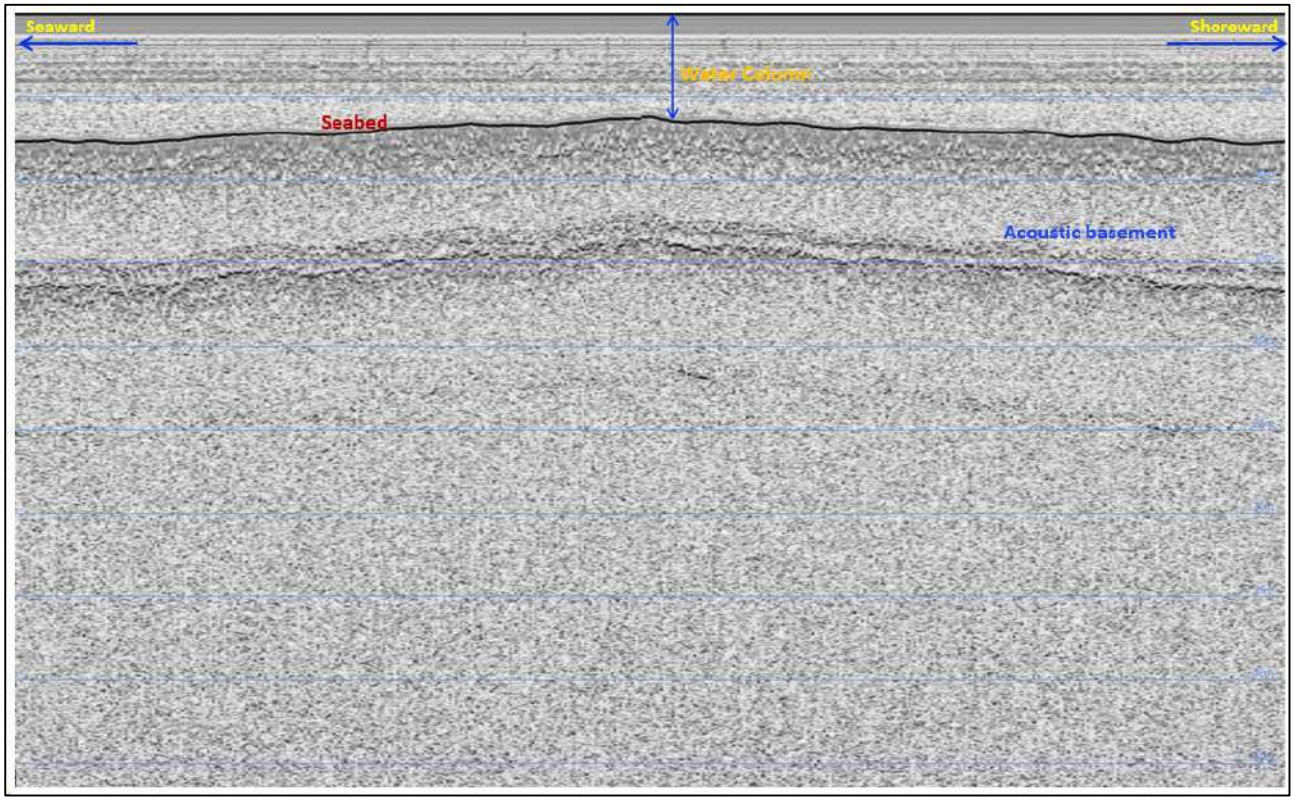



**Plate No: 05 - Typical Sub-bottom Profile Record Showing Vertical Sub-stracta Along Line No 107**

The geographical descriptions of each sub-bottom layer/acoustic boundary and remarks are tabulated below;

Table 1.2 Geographical descriptions

| | |
|---|---|
| **Transect 1/CH 01** | Along this transect, the seabed varies from 4.97m to 16.65m w.r.t. Chart Datum. The acoustic basement varies from 14.09m to 33.32m. The minimum sediment thickness varies between 8.97m and 17.26m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 02/CH 02** | Along this transect, the seabed varies from 4.86m to 16.75m w.r.t. Chart Datum. The acoustic basement varies from 14.7m to 33.13m. The minimum sediment thickness varies between 9.61m and 17.14m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 03/CH 03** | Along this transect, the seabed varies from 4.98m to 16.84m w.r.t. Chart Datum. The acoustic basement varies from 15.54m to 33.34m. The minimum sediment thickness varies between 9.98m and 17.01m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 04/CH 04** | Along this transect, the seabed varies from 4.97m to 16.77m w.r.t. Chart Datum. The acoustic basement varies from 16.54m to 33.32m. The minimum sediment thickness varies between 10.96m and 17m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 05/CH 05** | Along this transect, the seabed varies from 5.25m to 16.82m w.r.t. Chart Datum. The acoustic basement varies from 18.02m to 33.11m. The minimum sediment thickness varies between 11.62m and 16.75m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 06/CH 06** | Along this transect, the seabed varies from 5.33m to 16.38m w.r.t. Chart Datum. The acoustic basement varies from 20.71m to 33.78m. The minimum sediment thickness varies between 11.59m and 17m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 07/CH 07** | Along this transect, the seabed varies from 4.89m to 16.78m w.r.t. Chart Datum. The acoustic basement varies from 21.93m to 33.89m. The minimum sediment thickness varies between 10.99m and 16.64m.<br>***Note:*** *No significant hard strata presented between seabed and* |

| | |
|---|---|
| | *acoustic basement.* |
| **Transect 08/CH 08** | Along this transect, the seabed varies from 5.19m to 16.81m w.r.t. Chart Datum. The acoustic basement varies from 22.62m to 33.51m. The minimum sediment thickness varies between 9.23m and 16.33m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 09/CH 09** | Along this transect, the seabed varies from 4.62m to 16.86m w.r.t. Chart Datum. The acoustic basement varies from 33.51m to 33.06m. The minimum sediment thickness varies between 8.08m and 16.54m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 10/CH 10** | Along this transect, the seabed varies from 4.21m to 16.81m w.r.t. Chart Datum. The acoustic basement varies from 13.38m to 33.83m. The minimum sediment thickness varies between 6.02m and 17.42m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 11/CH 11** | Along this transect, the seabed varies from 4.07m to 16.70m w.r.t. Chart Datum. The acoustic basement varies from 12.93m to 34.54m. The minimum sediment thickness varies between 8.39m and 17.98m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 12/CH 12** | Along this transect, the seabed varies from 3.69m to 16.92m w.r.t. Chart Datum. The acoustic basement varies from 13.99m to 34.3m. The minimum sediment thickness varies between 10.21m and 17.71m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 13/CH 13** | Along this transect, the seabed varies from 3.29m to 16.75m w.r.t. Chart Datum. The acoustic basement varies from 15.37m to 34.06m. The minimum sediment thickness varies between 11.04m and 17.66m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 14/CH 14** | Along this transect, the seabed varies from 3.15m to 16.95m w.r.t. Chart Datum. The acoustic basement varies from 18.27m to 34.2m. The minimum sediment thickness varies between 11.31m and 17.45m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 15/CH 15** | Along this transect, the seabed varies from 3.05m to 17.13m w.r.t. Chart Datum. The acoustic basement varies from 19.09m to |

| | |
|---|---|
| | 34.33m. The minimum sediment thickness varies between 11.72m and 17.58m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 16/CH 16** | Along this transect, the seabed varies from 2.91m to 16.85m w.r.t. Chart Datum. The acoustic basement varies from 18.27m to 34.19m. The minimum sediment thickness varies between 10.29m and 17.39m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 17/CH 17** | Along this transect, the seabed varies from 3.17m to 17.07m w.r.t. Chart Datum. The acoustic basement varies from 16.81m to 34.06m. The minimum sediment thickness varies between s9.06m and 17.2m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 18/CH 18** | Along this transect, the seabed varies from 3.04m to 17.16m w.r.t. Chart Datum. The acoustic basement varies from 19.28m to 34.13m. The minimum sediment thickness varies between 11.11m and 17.45m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 19/CH 19** | Along this transect, the seabed varies from 3.29m to 17.04m w.r.t. Chart Datum. The acoustic basement varies from 22.12m to 34.22m. The minimum sediment thickness varies between 12.89m and 17.71m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 20/CH 20** | Along this transect, the seabed varies from 3.01m to 16.92m w.r.t. Chart Datum. The acoustic basement varies from 22.71m to 34.08m. The minimum sediment thickness varies between 12.95m and 17.23m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 21/CH 21** | Along this transect, the seabed varies from 3.47m to 16.98m w.r.t. Chart Datum. The acoustic basement varies from 23.4m to 33.99m. The minimum sediment thickness varies between seabed and acoustic basement varies between 13.38m and 17.2m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 22/CH 22** | Along this transect, the seabed varies from 3.9m to 16.96m w.r.t. Chart Datum. The acoustic basement varies from 24.08m to 33.76m. The minimum sediment thickness varies between 13.11m and 16.97m.<br>***Note:*** *No significant hard strata presented between seabed and* |

| | |
|---|---|
| | *acoustic basement.* |
| **Transect 23/CH 23** | Along this transect, the seabed varies from 3.97m to 16.95m w.r.t. Chart Datum. The acoustic basement varies from 23.94m to 33.62m. The minimum sediment thickness varies between 13.24m and 16.91m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 24/CH 24** | Along this transect, the seabed varies from 4.28m to 17.1m w.r.t. Chart Datum. The acoustic basement varies from 22.62m to 33.56m. The minimum sediment thickness varies between 11.94m and 16.9m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 25/CH 25** | Along this transect, the seabed varies from 4.63m to 17.06m w.r.t. Chart Datum. The acoustic basement varies from 20.87m to 33.85m. The minimum sediment thickness varies between s10.56m and 17.11m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 26/CH 26** | Along this transect, the seabed varies from 4.78m to 17.02m w.r.t. Chart Datum. The acoustic basement varies from 19.99m to 33.11m. The minimum sediment thickness varies between 10.52m and 16.47m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 27/CH 27** | Along this transect, the seabed varies from 5.06m to 17.44m w.r.t. Chart Datum. The acoustic basement varies from 18.29m to 32.39m. The minimum sediment thickness varies between 11.07m and 15.84m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 28/CH 28** | Along this transect, the seabed varies from 5.21m to 17.59m w.r.t. Chart Datum. The acoustic basement varies from 15.54m to 32.22m. The minimum sediment thickness varies between 8.25m and 15.29m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 29/CH 29** | Along this transect, the seabed varies from 4.98m to 17.1m w.r.t. Chart Datum. The acoustic basement varies from 13.39m to 32.18m. The minimum sediment thickness varies between 6.01m and 15.5m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 30/CH 30** | Along this transect, the seabed varies from 4.47m to 17.63m w.r.t. Chart Datum. The acoustic basement varies from 13.05m to |

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| | 32.32m. The minimum sediment thickness varies between 6.76m and 15.22m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 31/CH 31** | Along this transect, the seabed varies from 5.05m to 17.49m w.r.t. Chart Datum. The acoustic basement varies from 12.82m to 32.44m. The minimum sediment thickness varies between 7.63m and 15.78m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 32/CH 32** | Along this transect, the seabed varies from 5.30m to 17.11m w.r.t. Chart Datum. The acoustic basement varies from 10.26m to 32.36m. The minimum sediment thickness varies between 4.72m and 15.46m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 33/CH 33** | Along this transect, the seabed varies from 5.27m to 17.01m w.r.t. Chart Datum. The acoustic basement varies from 7.57m to 32.39m. The minimum sediment thickness varies between 1.64m and 15.42m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 34/CH 34** | Along this transect, the seabed varies from 5.31m to 17.2m w.r.t. Chart Datum. The acoustic basement varies from 10.38m to 32.72m. The minimum sediment thickness varies between 5.56m and 16.01m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 35/CH 35** | Along this transect, the seabed varies from 5.06m to 17.01m w.r.t. Chart Datum. The acoustic basement varies from 14.39m to 33.11m. The minimum sediment thickness varies between 9.93m and 16.35m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 36/CH 36** | Along this transect, the seabed varies from 5.09m to 17.53m w.r.t. Chart Datum. The acoustic basement varies from 13.68m to 33.14m. The minimum sediment thickness varies between 9.18m and 16.17m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 37/CH 37** | Along this transect, the seabed varies from 5.07m to 17.09m w.r.t. Chart Datum. The acoustic basement varies from 12.95m to 33.18m. The minimum sediment thickness varies between 8.65m and 16.44m.<br>***Note:*** *No significant hard strata presented between seabed and* |

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| | *acoustic basement.* |
| **Transect 38/CH 38** | Along this transect, the seabed varies from 5.6m to 17.03m w.r.t. Chart Datum. The acoustic basement varies from 11.99m to 33.16m. The minimum sediment thickness varies between 7.33m and 16.3m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 39/CH 39** | Along this transect, the seabed varies from 5.52m to 17.45m w.r.t. Chart Datum. The acoustic basement varies from 11.51m to 33.17m. The minimum sediment thickness varies between 6.44m and 16.55m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 40/CH 40** | Along this transect, the seabed varies from 5.72m to 17.33m w.r.t. Chart Datum. The acoustic basement varies from 12.51m to 33.73m. The minimum sediment thickness varies between 7.35m and 17.24m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 41/CH 41** | Along this transect, the seabed varies from 5.81m to 17.36m w.r.t. Chart Datum. The acoustic basement varies from 14.81m to 34.24m. The minimum sediment thickness varies between 9.38m and 17.51m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 42/CH 42** | Along this transect, the seabed varies from 5.8m to 17.36m w.r.t. Chart Datum. The acoustic basement varies from 14.97m to 34.13m. The minimum sediment thickness varies between 8.69m and 17.3m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 43/CH 43** | Along this transect, the seabed varies from 5.58m to 17.49m w.r.t. Chart Datum. The acoustic basement varies from 15.23m to 34.09m. The minimum sediment thickness varies between8.15m and 17.36m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 44/CH 44** | Along this transect, the seabed varies from 6.05m to 17.15m w.r.t. Chart Datum. The acoustic basement varies from 18.07m to 34.41m. The minimum sediment thickness varies between 8.66m and 17.32m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 45/CH 45** | Along this transect, the seabed varies from 6.29m to 17.21m w.r.t. Chart Datum. The acoustic basement varies from 18.03m to |

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| | 34.74m. The minimum sediment thickness varies between 8.65m and 17.75m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 46/CH 46** | Along this transect, the seabed varies from 6.36m to 117.59m w.r.t. Chart Datum. The acoustic basement varies from 16.23m to 34.67m. The minimum sediment thickness varies between 7.98m and 17.77m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 47/CH 47** | Along this transect, the seabed varies from 5.8m to 17.17m w.r.t. Chart Datum. The acoustic basement varies from 12.32m to 34.39m. The minimum sediment thickness varies between 6.37m and 18.06m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 48/CH 48** | Along this transect, the seabed varies from 5.45m to 17.25m w.r.t. Chart Datum. The acoustic basement varies from 13.6m to 34.65m. The minimum sediment thickness varies between 7.63m and 17.76m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 49/CH 49** | Along this transect, the seabed varies from 5.49m to 17.43m w.r.t. Chart Datum. The acoustic basement varies from 14.9m to 34.79m. The minimum sediment thickness varies between 8.92m and 18.04m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 50/CH 50** | Along this transect, the seabed varies from 5.01m to 17.34m w.r.t. Chart Datum. The acoustic basement varies from 15.06m to 35.47m. The minimum sediment thickness varies between 10.19m and 18.62m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 51/CH 51** | Along this transect, the seabed varies from 5.41m to 17.21m w.r.t. Chart Datum. The acoustic basement varies from 15m to 32.03m. The minimum sediment thickness varies between seabed and acoustic basement varies between 10.19m and 14.98m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 52/CH 52** | Along this transect, the seabed varies from 4.89m to 17.4m w.r.t. Chart Datum. The acoustic basement varies from 15.67m to 32.53m. The minimum sediment thickness varies between 8.2m and 15.56m.<br>***Note:*** *No significant hard strata presented between seabed and* |

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| | *acoustic basement.* |
| **Transect 53/CH 53** | Along this transect, the seabed varies from 4.74m to 17.2m w.r.t. Chart Datum. The acoustic basement varies from 16.35m to 33.47m. The minimum sediment thickness varies between 8.09m and 16.06m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 54/CH 54** | Along this transect, the seabed varies from 3.07m to 17.36m w.r.t. Chart Datum. The acoustic basement varies from 16.91m to 34.24m. The minimum sediment thickness varies between seabed and acoustic basement varies between 8.1m and 16.89m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 55/CH 55** | Along this transect, the seabed varies from 1.12m to 17.22m w.r.t. Chart Datum. The acoustic basement varies from 17.37m to 34.96m. The minimum sediment thickness varies between 8.3m and 17.65m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 56/CH 56** | Along this transect, the seabed varies from 3.36m to 17.29m w.r.t. Chart Datum. The acoustic basement varies from 16.69m to 34.47m. The minimum sediment thickness varies between 7.53m and 17.07m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 57/CH 57** | Along this transect, the seabed varies from 5.93m to 17.29m w.r.t. Chart Datum. The acoustic basement varies from 15.78m to 33.68m. The minimum sediment thickness varies between 7.2m and 16.37m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 58/CH 58** | Along this transect, the seabed varies from 2.07m to 17.57m w.r.t. Chart Datum. The acoustic basement varies from 13.56m to 33.93m. The minimum sediment thickness varies between 6.44m and 16.48m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 59/CH 59** | Along this transect, the seabed varies from 1.27m to 17.14m w.r.t. Chart Datum. The acoustic basement varies from 11.17m to 34.07m. The minimum sediment thickness varies between 5.27m and 16.78m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 60/CH 60** | Along this transect, the seabed varies from 0.65m to 17.36m w.r.t. Chart Datum. The acoustic basement varies from 7.58m to |

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| | 34.31m. The minimum sediment thickness varies between 3.92m and 17.3m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 61/CH 61** | Along this transect, the seabed varies from 2.18m to 17.53m w.r.t. Chart Datum. The acoustic basement varies from 4.28m to 34.63m. The minimum sediment thickness varies between 1.98m and 17.48m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 62/CH 62** | Along this transect, the seabed varies from 2.71m to 17.74m w.r.t. Chart Datum. The acoustic basement varies from 11.09m to 35.07m. The minimum sediment thickness varies between 4.54m and 17.93m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 63/CH 63** | Along this transect, the seabed varies from 3.43m to 17.39m w.r.t. Chart Datum. The acoustic basement varies from 5.83m to 34.87m. The minimum sediment thickness varies between 2.29m and 17.65m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 64/CH 64** | Along this transect, the seabed varies from 3.57m to 17.39m w.r.t. Chart Datum. The acoustic basement varies from 10.15m to 31.83m. The minimum sediment thickness varies between 4.73m and 15.27m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 65/CH 65** | Along this transect, the seabed varies from 4.19m to 17.7m w.r.t. Chart Datum. The acoustic basement varies from 12.96m to 31.92m. The minimum sediment thickness varies between 5.99m and 15.11m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 66/CH 66** | Along this transect, the seabed varies from 4.08m to 17.46m w.r.t. Chart Datum. The acoustic basement varies from 11.28m to 32.37m. The minimum sediment thickness varies between 7.15m and 15.58m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 67/CH 67** | Along this transect, the seabed varies from 4.25m to 17.27m w.r.t. Chart Datum. The acoustic basement varies from 10.74m to 32.34m. The minimum sediment thickness varies between 7.15m and 15.53m.<br>***Note:*** *No significant hard strata presented between seabed and* |

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| | *acoustic basement.* |
| **Transect 68/CH 68** | Along this transect, the seabed varies from 4.46m to 17.41m w.r.t. Chart Datum. The acoustic basement varies from 10.42m to 34.64m. The minimum sediment thickness varies between 6.02m and 17.48m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 69/CH 69** | Along this transect, the seabed varies from 4.72m to 17.47m w.r.t. Chart Datum. The acoustic basement varies from 12.5m to 34.49m. The minimum sediment thickness varies between 7.03m and 17.27m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 70/CH 70** | Along this transect, the seabed varies from 4.21m to 17.73m w.r.t. Chart Datum. The acoustic basement varies from 11.41m to 34.8m. The minimum sediment thickness varies between 8.74m and 17.45m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 71/CH 71** | Along this transect, the seabed varies from 4.13m to 17.31m w.r.t. Chart Datum. The acoustic basement varies from 10.01m to 34.65m. The minimum sediment thickness varies between 6.56m and 18.26m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 72/CH 72** | Along this transect, the seabed varies from 4.71m to 17.65m w.r.t. Chart Datum. The acoustic basement varies from 9.67m to 34.47m. The minimum sediment thickness varies between 7.86m and 18.25m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 73/CH 73** | Along this transect, the seabed varies from 4.37m to 17.67m w.r.t. Chart Datum. The acoustic basement varies from 10.55m to 33.35m. The minimum sediment thickness varies between 6.2m and 18.09m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 74/CH 74** | Along this transect, the seabed varies from 4.21m to 17.83m w.r.t. Chart Datum. The acoustic basement varies from 9.67m to 35.19m. The minimum sediment thickness varies between 5.33m and 17.59m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 75/CH 75** | Along this transect, the seabed varies from 4.55m to 17.71m w.r.t. Chart Datum. The acoustic basement varies from 10.55m to |

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| | 33.35m. The minimum sediment thickness varies between 5.31m and 16.1m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 76/CH 76** | Along this transect, the seabed varies from 4.27m to 17.65m w.r.t. Chart Datum. The acoustic basement varies from 10.98m to 32.23m. The minimum sediment thickness varies between 5.38m and 15.79m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 77/CH 77** | Along this transect, the seabed varies from 3.86m to 17.61m w.r.t. Chart Datum. The acoustic basement varies from 11.4m to 32.43m. The minimum sediment thickness varies between 5.47m and 16.05m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 78/CH 78** | Along this transect, the seabed varies from 4.47m to 17.49m w.r.t. Chart Datum. The acoustic basement varies from 11.58m to 32.54m. The minimum sediment thickness varies between 5.18m and 16.07m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 79/CH 79** | Along this transect, the seabed varies from 4.34m to 17.47m w.r.t. Chart Datum. The acoustic basement varies from 11.48m to 32.81m. The minimum sediment thickness varies between 5.15m and 16.07m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 80/CH 80** | Along this transect, the seabed varies from 3.85m to 17.39m w.r.t. Chart Datum. The acoustic basement varies from 11.84m to 33.33m. The minimum sediment thickness varies between 6.19m and 16.36m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 81/CH 81** | Along this transect, the seabed varies from 3.92m to 17.67m w.r.t. Chart Datum. The acoustic basement varies from 10.23m to 33.18m. The minimum sediment thickness varies between 5.05m and 15.87m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 82/CH 82** | Along this transect, the seabed varies from 3.54m to 17.57m w.r.t. Chart Datum. The acoustic basement varies from 10.45m to 32.83m. The minimum sediment thickness varies between 5.08m and 15.84m.<br>***Note:*** *No significant hard strata presented between seabed and* |

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| | *acoustic basement.* |
| **Transect 83/CH 83** | Along this transect, the seabed varies from 3.72m to 17.75m w.r.t. Chart Datum. The acoustic basement varies from 9.05m to 33.52m. The minimum sediment thickness varies between4.44m and 15.63m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 84/CH 84** | Along this transect, the seabed varies from 3.56m to 17.74m w.r.t. Chart Datum. The acoustic basement varies from 8.3m to 33.77m. The minimum sediment thickness varies between 4.1m and 16.12m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 85/CH 85** | Along this transect, the seabed varies from 4.51m to 17.6m w.r.t. Chart Datum. The acoustic basement varies from 10.59m to 32.51m. The minimum sediment thickness varies between 5.81m and 15.15m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 86/CH 86** | Along this transect, the seabed varies from 4.1m to 17.63m w.r.t. Chart Datum. The acoustic basement varies from 12.17m to 33.84m. The minimum sediment thickness varies between 9.67 m and 17.19m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 87/CH 87** | Along this transect, the seabed varies from 2.31m to 17.91m w.r.t. Chart Datum. The acoustic basement varies from 12.48m to 34.81m. The minimum sediment thickness varies between10.13m and 18.22m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 88/CH 88** | Along this transect, the seabed varies from 3.68m to 17.6m w.r.t. Chart Datum. The acoustic basement varies from 14.52m to 36.14m. The minimum sediment thickness varies between 10.26m and 18.88m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 89/CH 89** | Along this transect, the seabed varies from 3.41m to 17.7m w.r.t. Chart Datum. The acoustic basement varies from 14.76m to 36.5m. The minimum sediment thickness varies between10.82m and 19.34m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 90/CH 90** | Along this transect, the seabed varies from 3.47m to 17.52m w.r.t. Chart Datum. The acoustic basement varies from 14.81m to |

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| | 36.8m. The minimum sediment thickness varies between10.82m and 17.92m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 91/CH 91** | Along this transect, the seabed varies from 3.29m to 17.92m w.r.t. Chart Datum. The acoustic basement varies from 16.69m to 36.82m. The minimum sediment thickness varies between 10.82m and 17.7m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 92/CH 92** | Along this transect, the seabed varies from 2.99m to 17.73m w.r.t. Chart Datum. The acoustic basement varies from 20.58m to 36.28m. The minimum sediment thickness varies between 11.81m and 18.95m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 93/CH 93** | Along this transect, the seabed varies from 2.72m to 17.8m w.r.t. Chart Datum. The acoustic basement varies from 23.69m to 35.61m. The minimum sediment thickness varies between 12.17m and 17.94m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 94/CH 94** | Along this transect, the seabed varies from 2.54m to 17.99m w.r.t. Chart Datum. The acoustic basement varies from 24.63m to 35.47m. The minimum sediment thickness varies between 12.31m and 17.99m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 95/CH 95** | Along this transect, the seabed varies from 2.2m to 17.94m w.r.t. Chart Datum. The acoustic basement varies from 24.96m to 35.4m. The minimum sediment thickness varies between 12.37m and 17.53m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 96/CH 96** | Along this transect, the seabed varies from 2.1m to 18.29m w.r.t. Chart Datum. The acoustic basement varies from 25.28m to 35.53m. The minimum sediment thickness varies between12.83m and 17.44m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 97/CH 97** | Along this transect, the seabed varies from 2.32m to 17.97m w.r.t. Chart Datum. The acoustic basement varies from 25.32m to 35.62m. The minimum sediment thickness varies between12.79m and 17.65m.<br>***Note:*** *No significant hard strata presented between seabed and* |

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| | *acoustic basement.* |
| **Transect 98/CH 98** | Along this transect, the seabed varies from 2.18m to 18.05m w.r.t. Chart Datum. The acoustic basement varies from 25.18m to 34.94m. The minimum sediment thickness varies between 12.68m and 17.32m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 99/CH 99** | Along this transect, the seabed varies from 3.74m to 17.76m w.r.t. Chart Datum. The acoustic basement varies from 24.22m to 34.4m. The minimum sediment thickness varies between 12.69m and 17.01m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 100/CH 100** | Along this transect, the seabed varies from 3.52m to 17.28m w.r.t. Chart Datum. The acoustic basement varies from 16.76m to 34.07m. The minimum sediment thickness varies between 8.89m and 17.31m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 101/CH 101** | Along this transect, the seabed varies from 3.34m to 17.73m w.r.t. Chart Datum. The acoustic basement varies from 9.72m to 33.62m. The minimum sediment thickness varies between 3.46m and 16.49m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 102/CH 102** | Along this transect, the seabed varies from 2.78m to 17.92m w.r.t. Chart Datum. The acoustic basement varies from 8.1m to 33.82m. The minimum sediment thickness varies between 2.58m and 16.82m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 103/CH 103** | Along this transect, the seabed varies from 2.66m to 17.77m w.r.t. Chart Datum. The acoustic basement varies from 7.25m to 34.05m. The minimum sediment thickness varies between 2.82m and 17.69m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 104/CH 104** | Along this transect, the seabed varies from 2.85m to 17.77m w.r.t. Chart Datum. The acoustic basement varies from 7.05m to 33.55m. The minimum sediment thickness varies between 3.63m and 15.9m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 105/CH 105** | Along this transect, the seabed varies from 3.17m to 17.81m w.r.t. Chart Datum. The acoustic basement varies from 6.92m to |

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| | 34.51m. The minimum sediment thickness varies between 3.93m and 16.73m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 106/CH 106** | Along this transect, the seabed varies from 3.65m to 18.25m w.r.t. Chart Datum. The acoustic basement varies from 6.85m to 34.68m. The minimum sediment thickness varies between 3.7m and 16.86m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 107/CH 107** | Along this transect, the seabed varies from 4.67m to 17.68m w.r.t. Chart Datum. The acoustic basement varies from 7.32m to 34.57m. The minimum sediment thickness varies between 2.57m and 16.61m.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 108/CH 108** | Along this transect, the seabed varies from 4.39m to 17.78m w.r.t. Chart Datum. The acoustic basement varies from 7.35m to 33.88m. The minimum sediment thickness varies between 1.14m and 16.52<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 109/CH 109** | Along this transect, the seabed varies from 4.4m to 17.47m w.r.t. Chart Datum. The acoustic basement varies from 7.26m to 33.64m. The minimum sediment thickness varies between1.73m and 16.56.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 110/CH 110** | Along this transect, the seabed varies from 4.66m to 17.75m w.r.t. Chart Datum. The acoustic basement varies from 7.75m to 33.22m. The minimum sediment thickness varies between 2.07m and 15.87.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 111/CH 111** | Along this transect, the seabed varies from 4.39m to 17.9m w.r.t. Chart Datum. The acoustic basement varies from 8.22m to 33.07m. The minimum sediment thickness varies between 2.25m and 15.41.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 112/CH 112** | Along this transect, the seabed varies from 4.25m to 17.91m w.r.t. Chart Datum. The acoustic basement varies from 8.72m to 32.83m. The minimum sediment thickness varies between2.76m and 15.41.<br>***Note:*** *No significant hard strata presented between seabed and* |

| | |
|---|---|
| | *acoustic basement.* |
| **Transect 113/CH 113** | Along this transect, the seabed varies from 4.18m to 17.71m w.r.t. Chart Datum. The acoustic basement varies from 8.66m to 32.73m. The minimum sediment thickness varies between 3.44m and 15.47.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 114/CH 114** | Along this transect, the seabed varies from 4.57m to 17.71m w.r.t. Chart Datum. The acoustic basement varies from 8.01m to 32.68m. The minimum sediment thickness varies between 3.41m and 15.44.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 115/CH 115** | Along this transect, the seabed varies from 4.44m to 18.11m w.r.t. Chart Datum. The acoustic basement varies from 7.41m to 33.04m. The minimum sediment thickness varies between 3.01m and 15.25.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |
| **Transect 116/CH 116** | Along this transect, the seabed varies from 5.62m to 17.81m w.r.t. Chart Datum. The acoustic basement varies from 9.94m to 32.51m. The minimum sediment thickness varies between 3.94m and 15.46.<br>***Note:*** *No significant hard strata presented between seabed and acoustic basement.* |

# ANNEXURE III

# TOPOGRAPHICAL SURVEY REPORT

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# 1 INTRODUCTION

The combination of Differential Global Positioning System (DGPS) and Drone has been carried out at Paradip for Topographic survey. DGPS improves GPS accuracy by correcting errors, and transmitting the corrected values to the drone, which flies at a specific height. Both Drone and DGPS can make topographic survey faster and more precise, especially over large or hard-to-reach areas. This teamwork saves time and money, and the data can be viewed easily using mapping software. This report details and elaborates Topographic survey method using DGPS and drones at Paradip. The survey location as shown in Figure 1.



Figure 1 Topographical Survey Area

The project summary has been mentioned in the below table.

Table 1.1 Project Summary

| | |
|---|---|
| **Name of the Project** | Implementation of Topographic Survey at Odisha For IOCL Pradip Site |
| **DGPS Instrument** | Spectra SP85 |
| **UAV Model** | Model V & DJI Mavic 3 Enterprise |
| **Sensor** | Daylight RGB camera (24.3 megapixels) |
| **Flying Height** | 80 meters Above Ground Level (AGL) |
| **Ground Sample Distance** | 2 cm per pixel |
| **UAV Image Processing Software** | Agisoft, Bentley Context Capture, Auto CAD, Google Earth, and Global Mapper. |
| **Deliverables** | Project Report |

## 2 PROJECT WORKFLOW

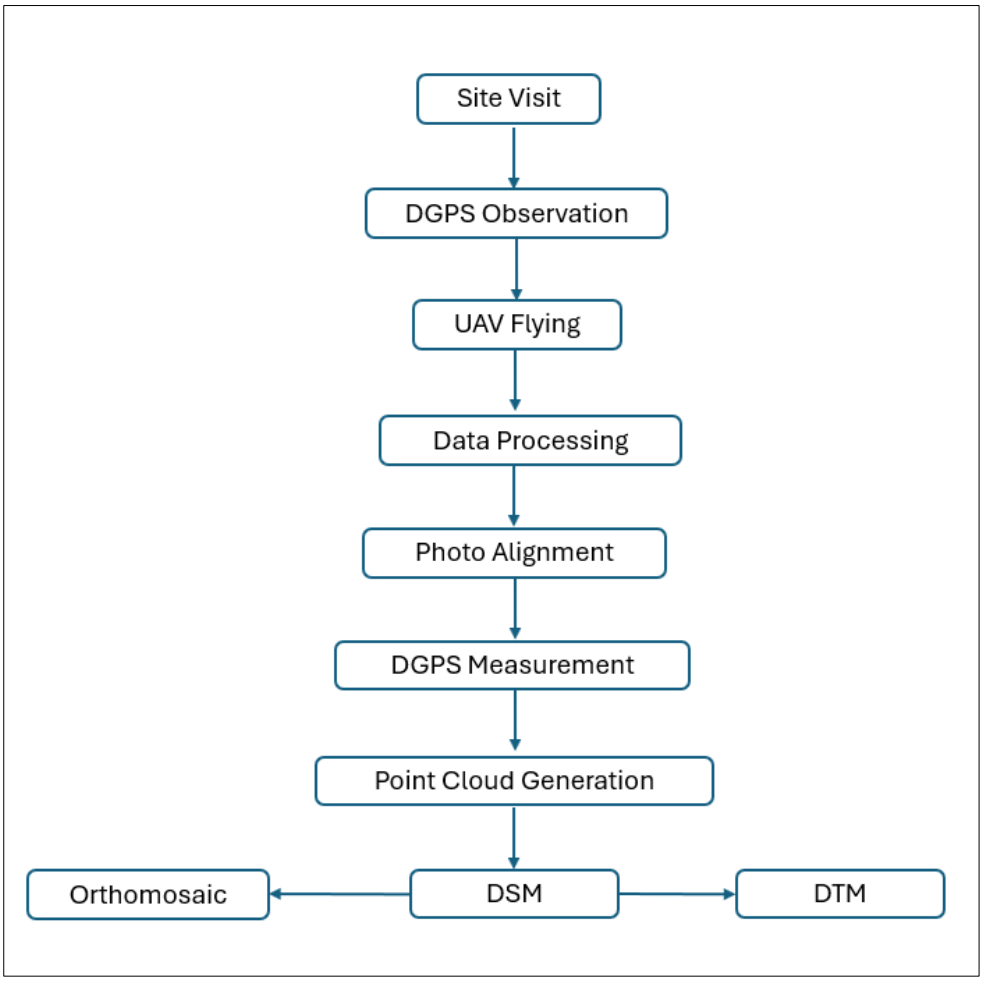



Figure 2 Project Workflow

# 3 TOPOGRAPHICAL SURVEY

## 3.1 DGPS Survey

DGPS (Differential Global Positioning System) is a satellite-based navigation technology that boosts GPS accuracy by correcting for signal errors. It works by comparing GPS signals received from satellites with signals from fixed-ground reference stations. These corrections, transmitted to DGPS receivers, refine position calculations, achieving high accuracy levels ranging from centimeter to millimeter precision. Widely applied in land surveying, agriculture, marine, and aviation, DGPS enhances efficiency and reliability in navigation tasks. When integrated with drone surveying, it improves aerial mapping accuracy. As technology advances, DGPS systems are expected to further evolve, promising even greater precision and reliability in various applications.

## 3.2 Survey Area

The survey area comprises 705 acres of land area adjacent to IOCL Refinery Plant in Paradip. The tpographic survery has been completed using Drone Survey and the Bench Mark details are shifted from Paradip Port w.r.to Charted Datum. TheBM details provided by Paradip Port is elaborated below.

## 3.3 Benchmark details

The Bench mark details were provided by Paradip Port with respect o CD. Is is located 200 meters North West from main road of Paradip port Office gate close to ATG hut situated near to Marine Jettyinside Paradip Port. The station comprises of brass plate with “NHO Dheradun” engraved on it and ‘LBM Darshak 2023-24’written adjacent in red paint. The height of the BM is shown in below Table.

Table 2 Bench mark details at Paradip

| Sl.No | BM Detail | Elevation (m) |
|---|---|---|
| 1 | LGM DSK 2023-24 | + 5.0501m above chart datum |

## 3.4 DGPS Data Processing

GCP are reference points on the ground with known global coordinates established and it is used for accurately geo-referencing the UAV images during processing. All the observed GCP points were processed with base point using DGPS Post Processing software and the processed coordinates were used for image alignment to improve the positional accuracy of the UAV data product i.e., Orthomosaic, DSM, DTM and 3-Model.

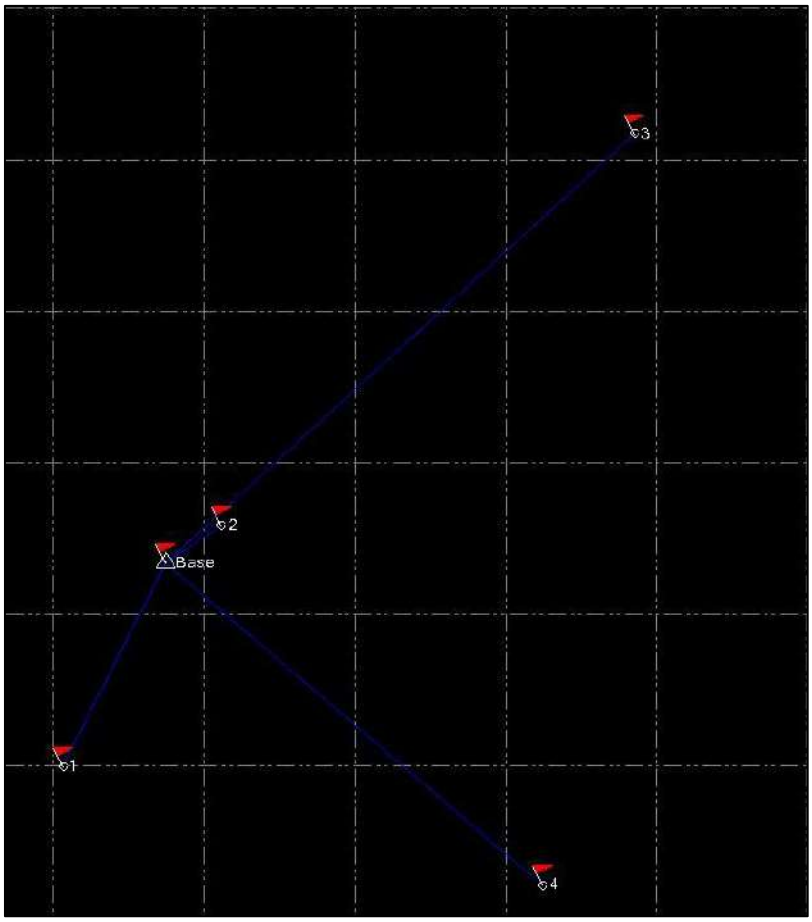



Figure 3 DGPS data processing

### 3.5 UAV/Drone Survey

The selection of UAV has been varied depends on the application and terrain. For example, Land Use and Land Cover (LU/ LC) mapping for a plain terrain fixed-wing UAV are most suitable for capture the nadir image in a short time. At the same time, the mapping area is located in a hilly region, multi-copter is most suitable to capture the nadir images, but it will take additional time compared to the fixed wing. For small AOI, multi-copter UAV with low endurance will be sufficient.

### 3.6 Ground Control Station (GCS)

A GCS is a land-based control Centre for UAV and payloads. It is used to configure, monitor, and control the flight parameters of UAV in real-time. The major role of the GCS software is used to plan the flying pattern. It provides a map screen where the user can define a home location, waypoints for the flight, setting camera overlaps, setting flying height, battery level monitoring and see the progress of the mission. The real-time location of the UAV is monitored using a mobile phone with the help of a location finder path and track the location of the UAV even at the failure of radio communication. Figure 7 shows the GCS display of UAV Nadir photo

acquisition of the proposed reclamation site. The flight pattern is created in two directions North-South and East-West respectively.




Figure 4 Flying pattern

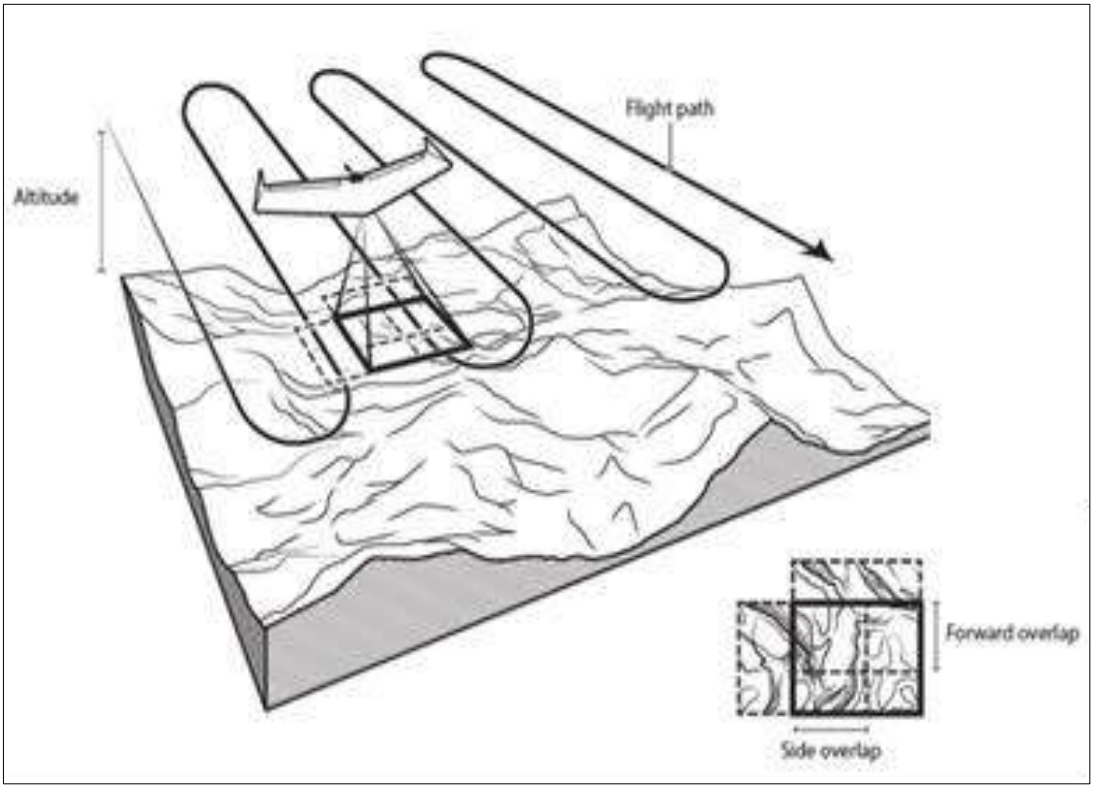



Figure 5 Typical Image for Flying pattern

### 3.7 UAV Image Processing

UAV (Unmanned Aerial Vehicle) image processing involves analysing aerial images captured by drones for various applications. Drones equipped with cameras capture images, which undergo pre-processing steps like correction and enhancement. Algorithms extract features like buildings and vegetation for analysis, aiding tasks such as land use classification and change detection. Applications include agriculture, environmental monitoring, and disaster management, offering rapid data acquisition and cost-effectiveness. Challenges include processing complexity and regulatory constraints. Advancements in technology promise to enhance capabilities, paving the way for improved analysis and decision-making in diverse fields.

### 3.8 Image Geo-tagging

The nadir images do not have any GPS information details such as Latitude, Longitude and Altitude. All the acquired nadir images are geo-tagged (combining positional information (POS) to the corresponding images) using an open-source python script. The POS with corresponding images is verified using the Google Earth Pro open-source software. After the Geo-tagging, GPS information was added in the image properties details.

### 3.9 Ground Control Points (GCP) Optimization

UAV acquired high-resolution aerial images along with GPS location. To obtain the survey-grade positional accuracy of the end product, the pre-defined GCP points were placed on the permanent structure on the ground. These locations were surveyed using a DGPS instrument and accurate position details are derived in XYZ format before the UAV survey. Reconstruct the aligned UAV images through the GCP to provide precise horizontal and vertical positional accuracy.

### 3.10 Digital Surface Model (DSM)

A Digital Surface Model (DSM) is a detailed representation of the Earth's surface, capturing its topography, terrain features, and elevation data. It provides a digital representation of the Earth's surface, including natural and man-made structures like buildings, trees, and mountains. DSMs are commonly used in various applications such as urban planning, environmental assessment, and infrastructure development. By accurately depicting the Earth's surface in digital form, DSMs help analysts and planners make informed decisions about land use, flood risk management, and transportation planning. They are generated using remote sensing technologies like LiDAR (Light Detection and Ranging) or photogrammetry.

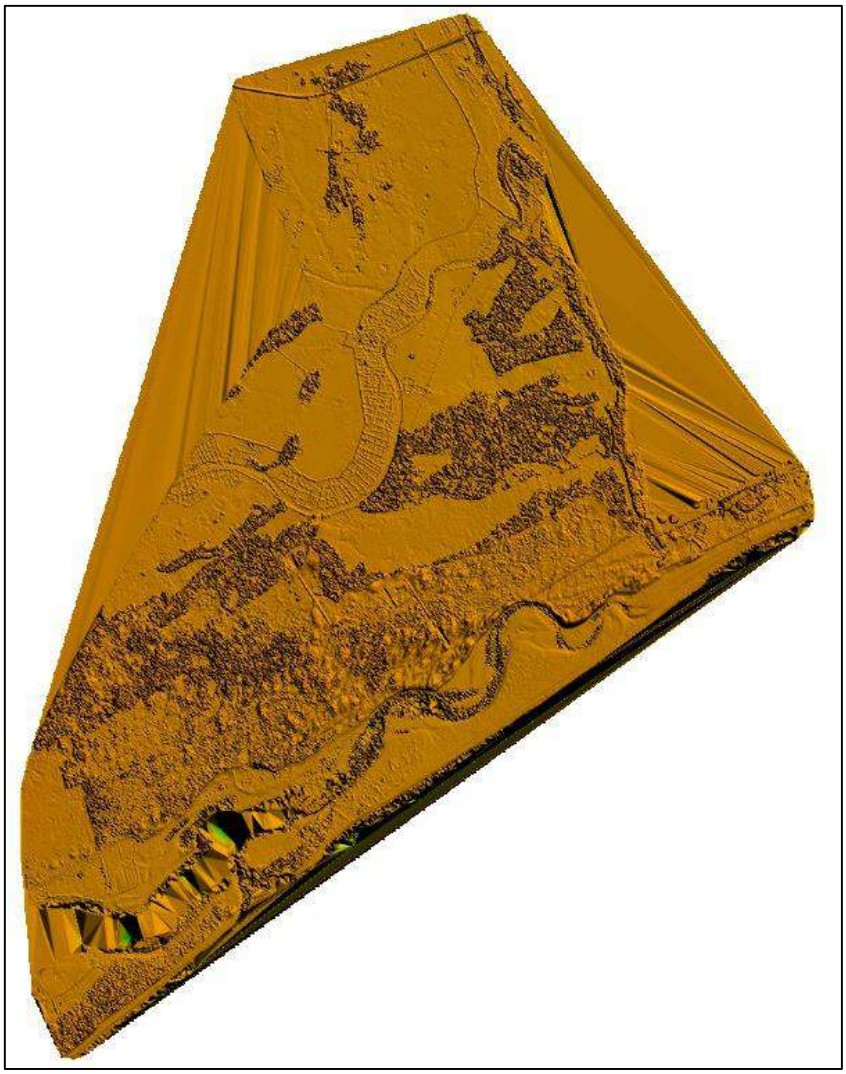


Figure 6 Digital Surface Model

### 3.11 Digital Terrain Model (DTM)

A Digital Terrain Model (DTM) is a digital representation of the bare Earth's surface, devoid of any above-ground features such as buildings, vegetation, or infrastructure. It provides detailed elevation data, depicting the natural landscape including valleys, hills, and other terrain features. DTMs are essential in various fields such as geology, hydrology, and civil engineering for tasks like slope analysis, drainage modeling, and site suitability assessments. Like DSMs, DTMs are created using remote sensing technologies such as LiDAR or photogrammetry, enabling accurate depiction of ground elevation. By providing precise elevation information, DTMs facilitate informed decision-making in land management, environmental planning, and infrastructure design.

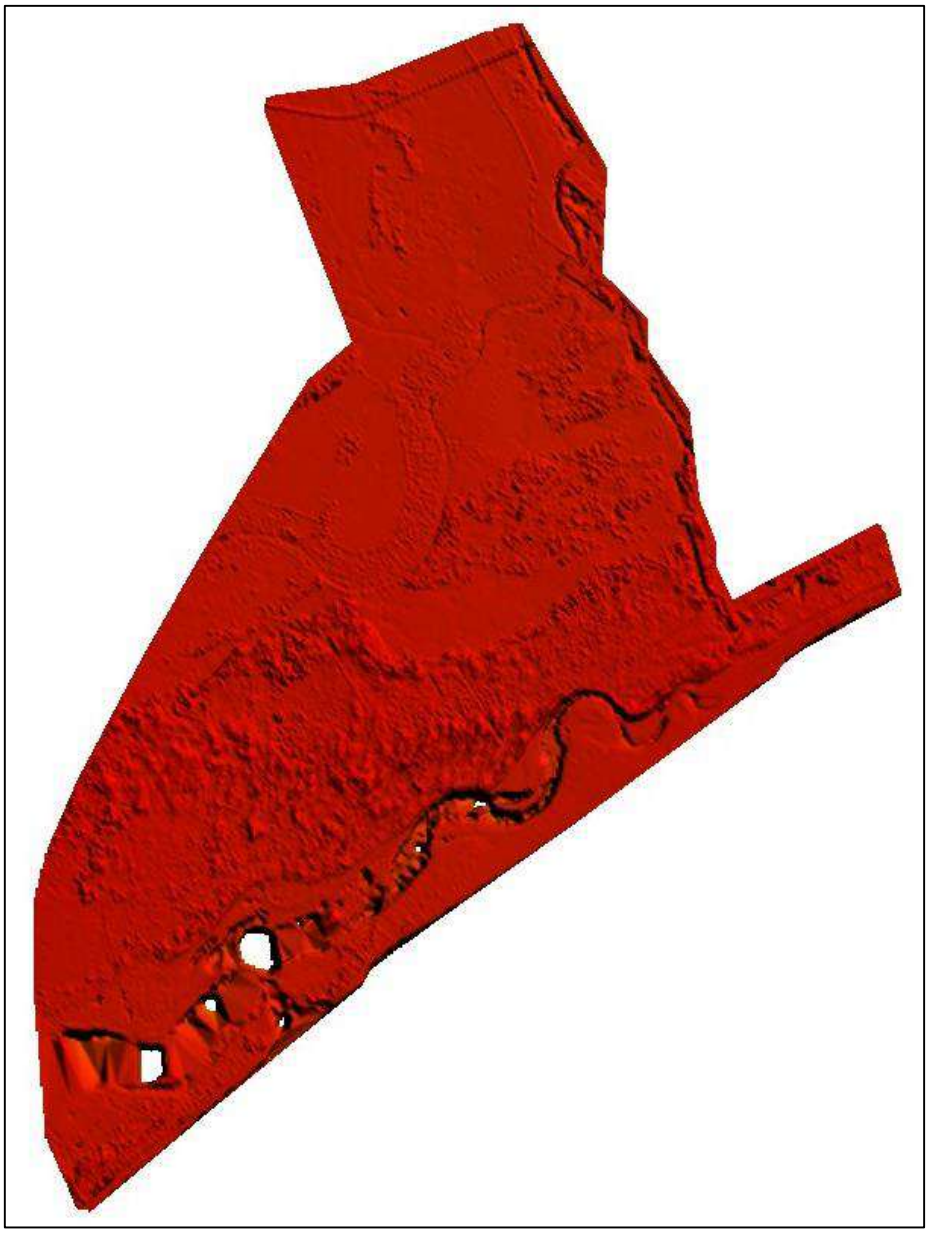


Figure 7 Digital Terrain Model

### 3.12 Ortho mosaic Image

An orthophoto, short for orthorectified photograph, is a georeferenced aerial or satellite image that has been corrected for distortion caused by terrain relief, sensor perspective, and camera tilt. Unlike regular aerial photographs, orthophotos have uniform scale and true geometric properties, making them suitable for accurate measurements and mapping applications. They are widely used in fields such as urban planning, agriculture, forestry, and environmental monitoring. Orthophotos are created by combining aerial or satellite imagery with digital elevation models (DEMs) or Digital Terrain Models (DTMs) to remove perspective distortions and ensure consistent scale across the entire image. This correction process enables precise interpretation and analysis of features on the Earth's surface.

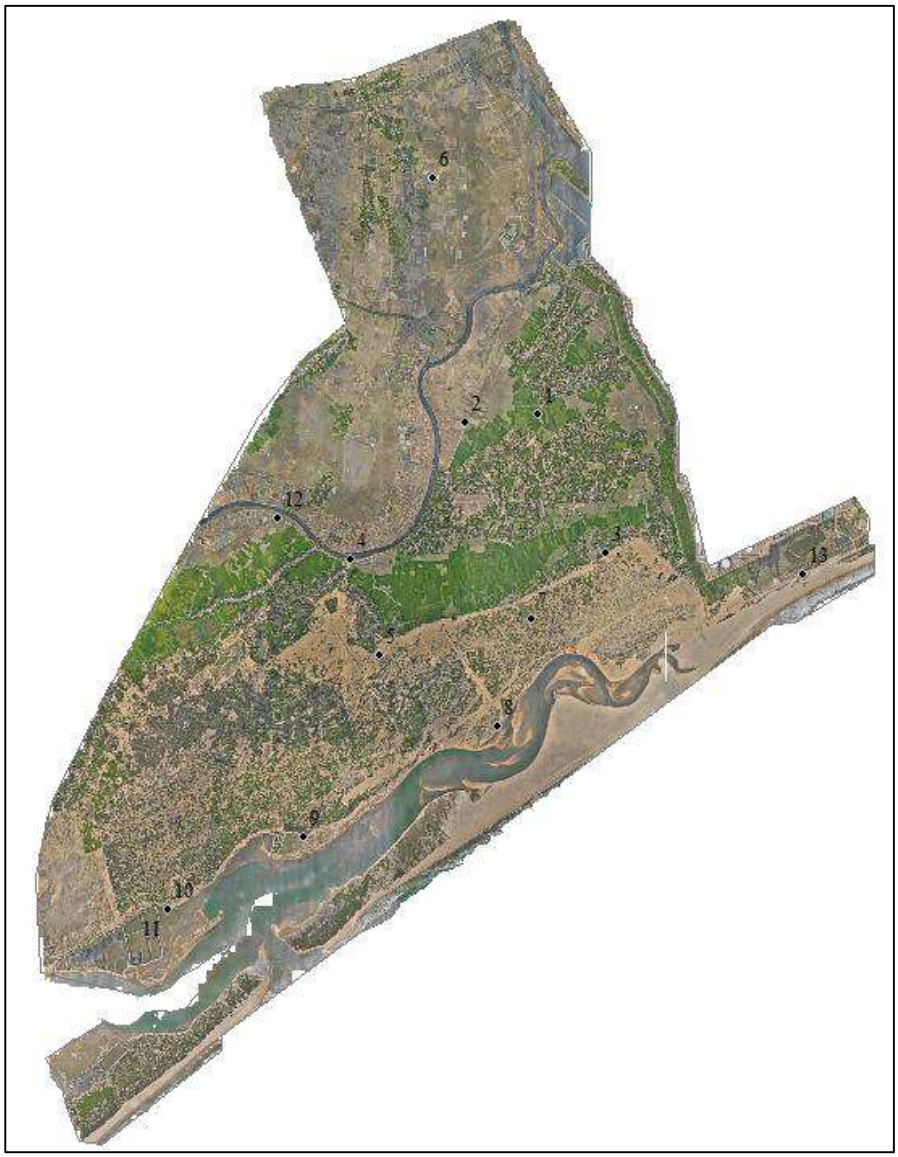



Figure 8 Ortho mosaic Map

## 4 CONCLUSION

In conclusion, topographical survey at the Pradip site in Odisha, by deploying drone and DGPS surveys, has furnished precise and detailed data crucial for future planning and development. Overcoming terrain challenges, the topographic survey has furnished with accuracy and reliability of the survey.

**********

452000E 454000E 456000E 458000E

2242000N 2240000N 2238000N 2236000N 2234000N 2232000N

E 86°3'40" E 86°3'60" E 86°3'60" E 86°3'40"

N 20°16'0" N 20°16'0" N 20°14'0" N 20°14'0" N 20°12'0" N 20°12'0"

N

W E

S

Scale 1 : 10000

100 200 400 600 800 Meters

**Date of Survey :** 18th March 2024 to 09th April 2024 & 03rd June 2024 to 09th June 2024.

CRZ AREA

RECLAMATION AREA PRATAP PURA

PARADIP REFINERY NORTH SIDE

PARADIP REFINERY SOUTH SIDE

SANTA CREEK

Return Water Collection Pit

CREEK

Elevated Projection

SHORELINE

Pipeline route for the CSD Dredger

Pipeline Length = 8KM

Pipeline Length = 6KM

Pipeline route for the TSHD Dredger/Return water

CREEK

Temporary Pipeline for TSHD

SHORELINE

**LEGEND :**

$0_5\ 1_6$ Depths in above Chart datum

$0_5\ 1_2$ Depths in below Chart datum

GEODETIC PARAMETERS :

| | |
|---|---|
| Ellipsoid | : WGS84 |
| Geodetic Datum | : WGS84 |
| Semi major axis | : 6378137.00m |
| Inverse flattening | : 298.2572236 |
| Projection | : Universal Transverse Mercator |
| Central Meridian (CM) | : 87° E ( Zone 45) |
| False Easting | : 500000m |
| False Northing | : 0m |
| Scale factor at CM | : 0.99960 |

**Notes:**

1) Survey was carried out by UAV from 18th March to 09th April 2024, using RTK DGPS from 03rd June 2024 to 09th June 2024.
2) Grid Size: 50 m x 50 m.
3) Survey area co-ordinates were given by the client.
4) The benchmark given by Paradip Port Trust is 5.0501m C.D.
5) IOCL BM=6.7511m with respect to Port BM.
6) Pipeline length was calculated from the shoreline to the Reclamation area.
7) Pipeline routes are shown as tentative, which may vary due to site conditions.

CONSULTANT:

NATIONAL TECHNOLOGY CENTRE FOR PORTS WATERWAYS AND COASTS (NTCPWC)
IIT MADRAS, CHENNAI-600 036.

CLIENT:

DREDGING CORPORATION OF INDIA LIMITED

PROJECT:

DPR FOR THE DEVELOPMENT OF INDUSTRIAL LAND BY UTILIZATION OF DREDGED MATERIAL AT PRATAPPUR & FATEPUR, PARADIP FOR IDCO, GoO

TITLE:

TOPOGRAPHICAL SURVEY MAP

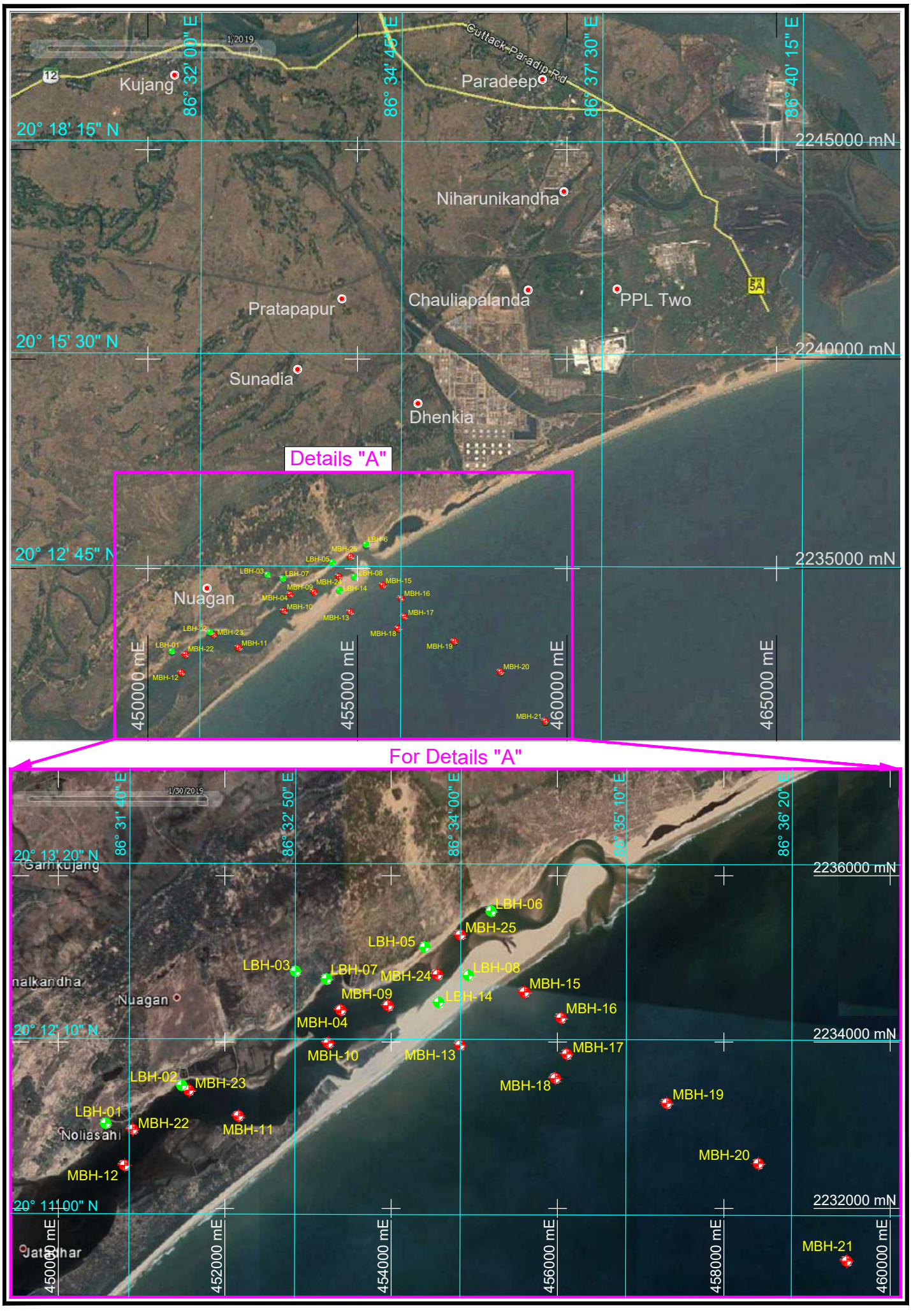
| | | | |
|---|---|---|---|
| Paper Size | : A0 | Surveyed by | : Saran |
| Survey Period | : June 2024 | Processed by | : Ram singh yadav |
| Drawn by | : Arun | Checked by | : Maheshvaran |
| Drawing Number | : DCI-TOPO-01-R5 | Date | : 02/08/2024 |

Approved by
Dr. J.SRIGANESH (NTCPWC)

# ANNEXURE IV

# GEOTECHNICAL INVESTIGATIONS

# LOCATION MAP



# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **LBH-01** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 450590.18** | **N: 2233025.63** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E: 450569.0** | **N: 2233024.0** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **30.45m below Ground Level.** | **Drilling Period** | **27/03/2019 to 29/03/2019** | | |

| LBH Depth (M) GL | Drill Depth wrt G.L. | Sample Type | Sample No | Standard Penetration Test (SPT) 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00-0.45 | 0.00-0.45 | SPT-1 | 1 | 1 | 2 | 2 | 4 | 100 | | - | - | - | Very Loose to Loose, Grayish Brown(10YR 5/2), Sity Fine **SAND.** |
| 1.50-1.95 | 1.50-1.95 | SPT-2 | 2 | 2 | 3 | 3 | 6 | 100 | | - | - | - | |
| 3.00-3.45 | 3.00-3.45 | SPT-3 | 3 | 3 | 4 | 4 | 8 | 100 | | - | - | - | |
| 4.50-4.95 | 4.50-4.95 | SPT-4 | 4 | 4 | 5 | 6 | 11 | 100 | | - | - | - | Medium Dense, Dark grayish Brown(10YR 4/2), Silty Fine **SAND**. |
| 6.00-6.45 | 6.00-6.45 | SPT-5 | 5 | 5 | 5 | 6 | 11 | 100 | | - | - | - | |
| 7.50-7.95 | 7.50-7.95 | SPT-6 | 6 | 4 | 7 | 6 | 13 | 100 | | - | - | - | |
| 9.00-9.45 | 9.00-9.45 | SPT-7 | 7 | 5 | 6 | 8 | 14 | 100 | | - | - | - | |
| 10.50-10.95 | 10.50-10.95 | SPT-8 | 8 | 5 | 7 | 7 | 14 | 100 | | - | - | - | |
| 12.00-12.45 | 12.00-12.45 | SPT-9 | 9 | 4 | 6 | 8 | 14 | 100 | | - | - | - | |
| 13.50-13.95 | 13.50-13.95 | SPT-10 | 10 | 7 | 9 | 10 | 19 | 100 | | - | - | - | |
| 15.00-15.45 | 15.00-15.45 | SPT-11 | 11 | 9 | 9 | 12 | 21 | 100 | | - | - | - | Medium Dense, Greenish Gray(10YR 6/1), Silty Fine **SAND** with trace to few of clay pockets. |
| 16.50-16.95 | 16.50-16.95 | SPT-12 | 12 | 10 | 10 | 12 | 22 | 100 | | - | - | - | |
| 18.00-18.45 | 18.00-18.45 | SPT-13 | 13 | 6 | 6 | 8 | 14 | 100 | | - | - | - | |
| 19.50-19.95 | 19.50-19.95 | SPT-14 | 14 | 6 | 7 | 9 | 16 | 100 | | - | - | - | Medium Dense, Brownish(10YR 4/3), Silty Fine **SAND.** |
| 21.00-21.45 | 21.00-21.45 | SPT-15 | 15 | 7 | 7 | 9 | 16 | 100 | | - | - | - | |
| 22.50-22.95 | 22.50-22.95 | SPT-16 | 16 | 8 | 9 | 9 | 18 | 100 | | - | - | - | |
| 24.00-24.45 | 24.00-24.45 | SPT-17 | 17 | 6 | 9 | 8 | 17 | 100 | | - | - | - | |
| 25.50-25.95 | 25.50-25.95 | SPT-18 | 18 | 10 | 13 | 15 | 28 | 100 | | - | - | - | |
| 27.00-27.45 | 27.00-27.45 | SPT-19 | 19 | 8 | 10 | 12 | 22 | 100 | | - | - | - | |
| 28.50-28.95 | 28.50-28.95 | SPT-20 | 20 | 10 | 12 | 12 | 24 | 100 | | - | - | - | Medium Dense, Dark grayish Brown(10YR 4/2), Silty Fine SAND. |
| 30.00-30.45 | 30.00-30.45 | SPT-21 | 21 | 11 | 11 | 14 | 25 | 100 | | - | - | - | |

**Borehole LBH-01 Terminated at 30.45m Below Ground Level.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | Drill Rig | Dando-250 | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite/Gaurgum |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 1 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **LBH-02** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 451504.72** | **N: 2233435.56** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E: 451483.00** | **N: 2233481.00** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **30.45m below Ground Level.** | **Drilling Period** | **29/03/2019 to 31/03/2019** | | |

| LBH Depth (M) GL | Drill Depth wrt G.L. | Sample Type | Sample No | Standard Penetration Test (SPT) 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00-0.45 | 0.00-0.45 | SPT-1 | 1 | 1 | 1 | 2 | 3 | 100 | | - | - | - | Very Loose, Grayish Brown(10YR 5/2), Silty Fine **SAND**. |
| 1.50-1.95 | 1.50-1.95 | SPT-2 | 2 | 2 | 3 | 3 | 6 | 100 | | - | - | - | Loose, Grayish Brown(10YR 5/2), Silty Fine **SAND**. |
| 3.00-3.45 | 3.00-3.45 | SPT-3 | 3 | 2 | 4 | 3 | 7 | 100 | | - | - | - | |
| 4.50-4.95 | 4.50-4.95 | SPT-4 | 4 | 3 | 3 | 4 | 7 | 100 | | - | - | - | |
| 6.00-6.45 | 6.00-6.45 | SPT-5 | 5 | 3 | 5 | 4 | 9 | 100 | | - | - | - | |
| 7.50-7.95 | 7.50-7.95 | SPT-6 | 6 | 4 | 4 | 4 | 8 | 100 | | - | - | - | |
| 9.00-9.45 | 9.00-9.45 | SPT-7 | 7 | 5 | 6 | 6 | 12 | 100 | | - | - | - | Medium Dense, Dark grayish Brown(10YR 4/2), Silty Fine **SAND** with traces of shell fragments. |
| 10.50-10.95 | 10.50-10.95 | SPT-8 | 8 | 5 | 6 | 5 | 11 | 100 | | - | - | - | Medium Dense, Grayish Brown(10YR 5/2), Silty Fine **SAND**. |
| 12.00-12.45 | 12.00-12.45 | SPT-9 | 9 | 4 | 6 | 7 | 13 | 100 | | - | - | - | Medium Dense, Dark grayish Brown(10YR 5/2), Silty Fine **SAND** with traces of shell fragments. |
| 13.50-13.95 | 13.50-13.95 | SPT-10 | 10 | 6 | 8 | 8 | 16 | 100 | | - | - | - | |
| 15.00-15.45 | 15.00-15.45 | SPT-11 | 11 | 9 | 11 | 13 | 24 | 100 | | - | - | - | Medium Dense, Yellowish Brown(10YR 5/6), Silty Fine **SAND**. |
| 16.50-16.95 | 16.50-16.95 | SPT-12 | 12 | 8 | 12 | 11 | 23 | 100 | | - | - | - | |
| 18.00-18.45 | 18.00-18.45 | SPT-13 | 13 | 6 | 8 | 9 | 17 | 100 | | - | - | - | |
| 19.50-19.95 | 19.50-19.95 | SPT-14 | 14 | 5 | 6 | 7 | 13 | 100 | | - | - | - | Medium Dense, Gray(10YR 6/1), Silty Fine **SAND**. |
| 21.00-21.45 | 21.00-21.45 | SPT-15 | 15 | 7 | 7 | 9 | 16 | 100 | | - | - | - | |
| 22.50-22.95 | 22.50-22.95 | SPT-16 | 16 | 9 | 8 | 9 | 17 | 100 | | - | - | - | Medium Dense, Dark Gray(10YR 4/1), Silty Fine **SAND**. |
| 24.00-24.45 | 24.00-24.45 | SPT-17 | 17 | 11 | 11 | 12 | 23 | 100 | | - | - | - | |
| 25.50-25.95 | 25.50-25.95 | SPT-18 | 18 | 10 | 13 | 13 | 26 | 100 | | - | - | - | Medium Dense, Dark Grayish Brown(10YR 5/2), Silty Fine **SAND**. |
| 27.00-27.45 | 27.00-27.45 | SPT-19 | 19 | 9 | 11 | 13 | 24 | 100 | | - | - | - | |
| 28.50-28.95 | 28.50-28.95 | SPT-20 | 20 | 9 | 10 | 13 | 23 | 100 | | - | - | - | |
| 30.00-30.45 | 30.00-30.45 | SPT-21 | 21 | 11 | 13 | 13 | 26 | 100 | | - | - | - | |

**Borehole LBH-02 Terminated at 30.45m Below Ground Level.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | VST | Vane Shear Test | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite/Gaurgum |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 1 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **LBH-03** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 452927.54** | **N: 2234236.44** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E: 452852.0** | **N: 2234852.0** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **30.45m below Ground Level.** | **Drilling Period** | **31/03/2019 to 02/04/2019** | | |

| LBH Depth (M) GL | Drill Depth wrt G.L. | Sample Type | Sample No | Standard Penetration Test (SPT) 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00-0.45 | 0.00-0.45 | SPT-1 | 1 | 1 | 1 | 2 | 3 | 100 | | - | - | - | Very Loose to Loose, Yellowish Brown(10YR 5/6), Silty Fine **SAND**. |
| 1.50-1.95 | 1.50-1.95 | SPT-2 | 2 | 2 | 3 | 3 | 6 | 100 | | - | - | - | |
| 3.00-3.45 | 3.00-3.45 | SPT-3 | 3 | 2 | 3 | 4 | 7 | 100 | | - | - | - | |
| 4.50-4.95 | 4.50-4.95 | SPT-4 | 4 | 3 | 4 | 3 | 7 | 100 | | - | - | - | |
| 6.00-6.45 | 6.00-6.45 | SPT-5 | 5 | 5 | 6 | 8 | 14 | 100 | | - | - | - | Loose, Dark yellowish Brown(10YR 4/6), Silty Fine **SAND**. |
| 7.50-7.95 | 7.50-7.95 | SPT-6 | 6 | 3 | 4 | 5 | 9 | 100 | | - | - | - | |
| 9.00-9.45 | 9.00-9.45 | SPT-7 | 7 | 5 | 4 | 5 | 9 | 100 | | - | - | - | |
| 10.50-10.95 | 10.50-10.95 | SPT-8 | 8 | 8 | 11 | 12 | 23 | 100 | | - | - | - | Medium Dense, Dark yellowish Brown( 10YR 4/6), Silty Medium to Fine **SAND** with traces of shell fragments. |
| 12.00-12.45 | 12.00-12.45 | SPT-9 | 9 | 6 | 8 | 9 | 17 | 100 | | - | - | - | Medium Dense, dark grayish Brown(10YR 4/2), Silty Fine **SAND** with trace of shell fragments. |
| 13.50-13.95 | 13.50-13.95 | SPT-10 | 10 | 6 | 7 | 9 | 16 | 100 | | - | - | - | |
| 15.00-15.45 | 15.00-15.45 | SPT-11 | 11 | 3 | 3 | 4 | 7 | 100 | | - | - | - | Medium, Greenish Gray(10GY 6/1), Sandy **Clayey Silt**. |
| 16.50-17.00 | 16.50-17.00 | UDS-1 | 12 | - | - | - | - | 100 | | - | - | - | |
| 18.00-18.45 | 18.00-18.45 | SPT-12 | 13 | 6 | 8 | 7 | 15 | 100 | | - | - | - | Medium Dense, Olive Gray(5Y 4/2), Silty Fine **SAND** with few of shell fragments. |
| 19.50-19.95 | 19.50-19.95 | SPT-13 | 14 | 6 | 9 | 9 | 18 | 100 | | - | - | - | |
| 21.00-21.45 | 21.00-21.45 | SPT-14 | 15 | 5 | 8 | 9 | 17 | 100 | | - | - | - | |
| 22.50-22.95 | 22.50-22.95 | SPT-15 | 16 | 7 | 9 | 9 | 18 | 100 | | - | - | - | Medium Dense, Brownish(10YR 4/3), Silty Fine **SAND**. |
| 24.00-24.45 | 24.00-24.45 | SPT-16 | 17 | 6 | 8 | 11 | 19 | 100 | | - | - | - | |
| 25.50-25.95 | 25.50-25.95 | SPT-17 | 18 | 8 | 8 | 9 | 17 | 100 | | - | - | - | |
| 27.00-27.45 | 27.00-27.45 | SPT-18 | 19 | 9 | 10 | 11 | 21 | 100 | | - | - | - | Medium Dense, Brownish(10YR 4/3), Silty Fine **SAND** with traces of shell fragments. |
| 28.50-28.95 | 28.50-28.95 | SPT-19 | 20 | 8 | 12 | 11 | 23 | 100 | | - | - | - | |
| 30.00-30.45 | 30.00-30.45 | SPT-20 | 21 | 7 | 10 | 12 | 22 | 100 | | - | - | - | Medium Dense, yellowish Brown(10YR 5/6), Silty Fine **SAND** . |

**Borehole LBH-03 Terminated at 30.45m Below Ground Level.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | VST | Vane Shear Test | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite/Gaurgum |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 1 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-04** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 453395.0** | **N: 2234385.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E: 453401.0** | **N: 2234393.0** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **45.45m below Bed Level.** **C.D. Depth:-** **-4.00 mtrs.** | **Drilling Period** | **22/05/2019 to 25/05/2019** | | |

| Drill Depth(M) wrt C.D. | Drill Depth wrt B.L. | Sample Type | Sample No | Standard Penetration 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.00-4.45 | 0.00-0.45 | SPT-1 | 1 | 3 | 4 | 4 | 8 | 32 | | - | - | - | Loose, Dark Grayish to Brownish(10Y-5GY 4/2), Silty Fine **SAND** with traces of shell fragments. |
| 5.50-5.95 | 1.50-1.95 | SPT-2 | 2 | 12 | 14 | 15 | 29 | 52 | | - | - | - | Medium Dense, Light Olive Brown(2.5Y 5/4), Fine to Medium **SAND** with trace of shell fragments. |
| 7.00-7.45 | 3.00-3.45 | SPT-3 | 3 | 10 | 12 | 16 | 28 | 24 | | - | - | - | |
| 8.50-8.95 | 4.50-4.95 | SPT-4 | 4 | 16 | 20 | 22 | 42 | 30 | | - | - | - | Dense, Light Yellowish Brown(2.5Y 6/3), Silty Fine **SAND**. |
| 10.00-10.45 | 6.00-6.45 | SPT-5 | 5 | 19 | 26 | 19 | 45 | 44 | | - | - | - | |
| 11.50-11.95 | 7.50-7.95 | SPT-6 | 6 | 12 | 14 | 13 | 27 | 60 | | - | - | - | Medium Dense, Pale Olive(5Y 6/4), Silty Fine **SAND**. |
| 13.00-13.45 | 9.00-9.45 | SPT-7 | 7 | 10 | 14 | 14 | 28 | 52 | | - | - | - | |
| 14.50-14.95 | 10.50-10.95 | SPT-8 | 8 | 13 | 15 | 16 | 31 | 54 | | - | - | - | Medium Dense, Grayish Brown(2.5Y 5/2), Fine to Medium Silty **SAND**. |
| 16.00-16.45 | 12.00-12.45 | SPT-9 | 9 | 9 | 17 | 13 | 30 | 48 | | - | - | - | |
| 16.50 | 12.50 | -- | -- | -- | -- | -- | -- | -- | | - | - | - | Firm, Dark Greenish Gray(10GY 4/1), Sandy **CLAY** with few shell fragments. (12.50 to 15.0m) |
| 17.50-17.95 | 13.50-13.95 | SPT-10 | 10 | 3 | 3 | 4 | 7 | 35 | | - | - | - | |
| 19.00-19.45 | 15.00-15.45 | SPT-11 | 11 | 8 | 8 | 12 | 20 | 43 | | - | - | - | Medium Dense, Dark Grayish, Fine **SAND** with few **CLAY** pockets. Sandy CLAY/Clayey SAND. |
| 20.50-20.95 | 16.50-16.95 | SPT-12 | 12 | 8 | 12 | 13 | 25 | 42 | | - | - | - | Medium Dense, Greenish Gray(Gley-1 5/1), Silty Fine **SAND.** |
| 22.00-22.45 | 18.00-18.45 | SPT-13 | 13 | 12 | 15 | 17 | 32 | 55 | | - | - | - | Medium Dense to Dense, Light Brownish Grey(2.5Y 6/2), Fine to Medium **SAND**. |
| 23.50-23.95 | 19.50-19.95 | SPT-14 | 14 | 6 | 14 | 14 | 28 | 32 | | - | - | - | Medium Dense, Pale Olive(5Y 6/4), Silty Fine **SAND**. |
| 25.00-25.45 | 21.00-21.45 | SPT-15 | 15 | 10 | 10 | 20 | 30 | 50 | | - | - | - | |
| 26.50-26.95 | 22.50-22.95 | SPT-16 | 16 | 12 | 15 | 17 | 32 | 63 | | - | - | - | Dense, Light Yellowish Brown(2.5Y 6/4), Silty Fine **SAND**. |
| 28.00-28.45 | 24.00-24.45 | SPT-17 | 17 | 13 | 17 | 20 | 37 | 46 | | - | - | - | |
| 29.50-29.95 | 25.50-25.95 | SPT-18 | 18 | 17 | 19 | 26 | 45 | 53 | | - | - | - | Dense, Brownish(10YR 5/3), Fine to Medium, Silty **SAND**. |
| 31.00-31.45 | 27.00-27.45 | SPT-19 | 19 | 15 | 21 | 22 | 43 | 55 | | - | - | - | |
| 32.50-32.95 | 28.50-28.95 | SPT-20 | 20 | 20 | 22 | 25 | 47 | 48 | | - | - | - | Dense, Olive Yellow(2.5Y 6/6), Silty Fine **SAND**. |
| 34.00-34.45 | 30.00-30.45 | SPT-21 | 21 | 13 | 15 | 21 | 36 | 52 | | - | - | - | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | Drill Rig | Swanskar | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 2 | |

## FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-04** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 453395.0** | **N: 2234385.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | | | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **45.45m below Bed Level.** **C.D. Depth:-** **-4.00 mtrs.** | **Drilling Period** | **22/05/2019 to 25/05/2019** | | |

| Drill Depth(M) wrt C.D. | Drill Depth wrt B.L. | Sample Type | Sample No | Standard Penetration 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 35.50-35.95 | 31.50-31.95 | SPT-22 | 22 | 17 | 20 | 20 | 40 | 46 | | - | - | - | Dense, Light Yellowish Brown(2.5Y 6/4), Silty Fine **SAND**. |
| 37.00-37.45 | 33.00-33.45 | SPT-23 | 23 | 14 | 17 | 17 | 34 | 51 | | - | - | - | |
| 38.50-38.95 | 34.50-34.95 | SPT-24 | 24 | 14 | 18 | 24 | 42 | 48 | | - | - | - | Dense, Light Olive Brown(2.5Y 5/4), Fine to Medium Silty **SAND**. |
| 40.00-40.45 | 36.00-36.45 | SPT-25 | 25 | 20 | 24 | 27 | 51 | 51 | | - | - | - | |
| 41.50-41.95 | 37.50-37.95 | SPT-26 | 26 | 21 | 22 | 23 | 45 | 46 | | - | - | - | Dense, Light Yellowish Brown(2.5Y 6/4), Silty Fine **SAND**. |
| 43.00-43.45 | 39.00-39.45 | SPT-27 | 27 | 23 | 23 | 26 | 49 | 54 | | - | - | - | |
| 44.50-44.95 | 40.50-40.95 | SPT-28 | 28 | 20 | 22 | 29 | 51 | 52 | | - | - | - | Dense to Very Dense, Light Olive Brown(2.5Y 5/4), Fine to Medium Silty **SAND**. |
| 46.00-46.45 | 42.00-42.45 | SPT-29 | 29 | 25 | 26 | 31 | 57 | 46 | | - | - | - | |
| 47.50-47.95 | 43.50-43.95 | SPT-30 | 30 | 20 | 21 | 25 | 46 | 44 | | - | - | - | |
| 49.00-49.45 | 45.00-45.45 | SPT-31 | 31 | 22 | 25 | 28 | 53 | 49 | | - | - | - | |

**Borehole MBH-04 Terminated at 45.45m Below Bed Level.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | Drill Rig | Swanskar | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 2 of 2 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **LBH-05 A** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 4544707.00** | **N: 2235142.00** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E: 454406.90** | **N: 2235142.04** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **30.45m below Ground Level.** | **Drilling Period** | **03/04/2019 to 05/04/2019** | | |

| LBH Depth (M) GL | Drill Depth wrt G.L. | Sample Type | Sample No | Standard Penetration Test (SPT) 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00-0.45 | 0.00-0.45 | SPT-1 | 1 | 1 | 2 | 2 | 4 | 100 | | - | - | - | Very Loose to Loose, Dark Grayish Brown(10YR 4/2), Silty Fine **SAND**. |
| 1.50-1.95 | 1.50-1.95 | SPT-2 | 2 | 1 | 4 | 5 | 9 | 100 | | - | - | - | |
| 3.00-3.45 | 3.00-3.45 | SPT-3 | 3 | 4 | 5 | 6 | 11 | 100 | | - | - | - | |
| 4.50-4.95 | 4.50-4.95 | SPT-4 | 4 | 3 | 3 | 4 | 7 | 100 | | - | - | - | |
| 6.00-6.45 | 6.00-6.45 | SPT-5 | 5 | 5 | 6 | 5 | 11 | 100 | | - | - | - | Loose to medium dense, Dark grayish Brown(10YR 4/2), Sillty Fine **SAND** with traces of shell fragments. |
| 7.50-7.95 | 7.50-7.95 | SPT-6 | 6 | 4 | 4 | 5 | 9 | 100 | | - | - | - | |
| 9.00-9.45 | 9.00-9.45 | SPT-7 | 7 | 6 | 8 | 9 | 17 | 100 | | - | - | - | Medium Dense, Yellowish Brown(10YR 5/6), Silty Fine **SAND** with traces of shell fragments. |
| 10.50-10.95 | 10.50-10.95 | SPT-8 | 8 | 6 | 9 | 9 | 18 | 100 | | - | - | - | |
| 12.00-12.45 | 12.00-12.45 | SPT-9 | 9 | 5 | 8 | 7 | 15 | 100 | | - | - | - | Medium Dense, Grayish(5/1), Silty Fine **SAND** with traces of shell fragments. |
| 13.50-13.95 | 13.50-13.95 | SPT-10 | 10 | 6 | 6 | 8 | 14 | 100 | | - | - | - | |
| 15.00-15.45 | 15.00-15.45 | SPT-11 | 11 | 6 | 7 | 8 | 15 | 100 | | - | - | - | |
| 16.50-16.95 | 16.50-16.95 | SPT-12 | 12 | 9 | 8 | 9 | 17 | 100 | | - | - | - | |
| 18.00-18.45 | 18.00-18.45 | SPT-13 | 13 | 8 | 9 | 9 | 18 | 100 | | - | - | - | |
| 19.50-19.95 | 19.50-19.95 | SPT-14 | 14 | 10 | 10 | 9 | 19 | 100 | | - | - | - | |
| 21.00-21.45 | 21.00-21.45 | SPT-15 | 15 | 10 | 10 | 11 | 21 | 100 | | - | - | - | Medium Dense, Yellowish Brown(10YR 5/6), Silty Fine **SAND**. |
| 22.50-22.95 | 22.50-22.95 | SPT-16 | 16 | 8 | 9 | 12 | 21 | 100 | | - | - | - | |
| 24.00-24.45 | 24.00-24.45 | SPT-17 | 17 | 9 | 11 | 10 | 21 | 100 | | - | - | - | |
| 25.50-25.95 | 25.50-25.95 | SPT-18 | 18 | 10 | 12 | 13 | 25 | 100 | | - | - | - | |
| 27.00-27.45 | 27.00-27.45 | SPT-19 | 19 | 11 | 12 | 14 | 26 | 100 | | - | - | - | |

**Borehole LBH-05 A Terminated at 27.45m Below Ground Level.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | VST | Vane Shear Test | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite/Gaurgum |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 1 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **LBH-06A** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 455186.0** | **N: 2235662.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E: 455206.0** | **N: 2235546.0** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **30.45m below Bed Level.** **C.D. Depth:-** **-1.00 mtrs.** | **Drilling Period** | **29/05/2019 to 31/05/2019** | | |

| Drill Depth wrt C.D | Drill Depth wrt B.L. | Sample Type | Sample No | Standard Penetration 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.00-1.45 | 0.00-0.45 | SPT-1 | 1 | 5 | 5 | 4 | 9 | 60 | | - | - | - | Loose to Medium Dense, Light Olive Brown(2.5Y 5/4), Fine **SAND.** |
| 2.50-2.95 | 1.50-1.95 | SPT-2 | 2 | 4 | 8 | 10 | 18 | 62 | | - | - | - | Medium Dense, Dark Grayish Brown(2.5Y 4/2) to Grayish Brown(2.5Y 5/2), Silty Fine **SAND**. |
| 4.00-4.45 | 3.00-3.45 | SPT-3 | 3 | 7 | 9 | 13 | 22 | 46 | | - | - | - | |
| 5.50-5.95 | 4.50-4.95 | SPT-4 | 4 | 12 | 12 | 17 | 29 | 42 | | - | - | - | Medium Dense, Light Yellowish Brown(10YR 6/4), Fine to Medium Silty **SAND**. |
| 7.00-7.45 | 6.00-6.45 | SPT-5 | 5 | 15 | 14 | 19 | 33 | 34 | | - | - | - | Dense, Light Yellowish Brown(10YR 6/4), Fine to Medium **SAND**. |
| 8.50-8.95 | 7.50-7.95 | SPT-6 | 6 | 15 | 18 | 18 | 36 | 38 | | - | - | - | |
| 10.00-10.45 | 9.00-9.45 | SPT-7 | 7 | 17 | 20 | 22 | 42 | 22 | | - | - | - | |
| 11.50-11.95 | 10.50-10.95 | SPT-8 | 8 | 21 | 19 | 20 | 39 | 30 | | - | - | - | Dense, Olive(5Y 5/3), Silty Fine **SAND**. |
| 13.00-13.35 | 12.00-12.45 | SPT-9 | 9 | 12 | 15 | 15 | 30 | 67 | | - | - | - | Medium Dense to Dense, Olive Gray(5Y 5/2), Silty **SAND**/ Sandy **SILT**. |
| 14.50-14.95 | 13.50-13.95 | SPT-10 | 10 | 10 | 15 | 16 | 31 | 56 | | - | - | - | |
| 16.00-16.45 | 15.00-15.45 | SPT-11 | 11 | 10 | 10 | 11 | 21 | 49 | | - | - | - | Medium Dense, Grayish(5Y 5/1),Silty Clayey **SAND** with traces of **CLAY** pockets. |
| 17.50-17.95 | 16.50-16.95 | SPT-12 | 12 | 8 | 9 | 11 | 20 | 45 | | - | - | - | Medium Dense, Grayish(5Y 6/1), Silty Fine **SAND** with traces of **CLAY** pockets |
| 19.00-19.45 | 18.00-18.45 | SPT-13 | 13 | 10 | 13 | 14 | 27 | 35 | | - | - | - | Medium Dense, Olive(5Y 4/4), Silty Fine **SAND** with traces of **CLAY** pockets. |
| 20.50-20.95 | 19.50-19.95 | SPT-14 | 14 | 12 | 14 | 18 | 32 | 25 | | - | - | - | Medium Dense to Dense, Olive Gray(5Y 5/2), Silty Fine **SAND**. |
| 22.00-22.45 | 21.00-21.45 | SPT-15 | 15 | 17 | 18 | 17 | 35 | 37 | | - | - | - | Dense, Light Yellowish Brown(2.5Y 6/3) to Yellowish(2.5Y 7/8), Silty Fine **SAND**. |
| 23.50-23.95 | 22.50-22.95 | SPT-16 | 16 | 16 | 19 | 21 | 40 | 55 | | - | - | - | |
| 25.00-25.45 | 24.00-24.45 | SPT-17 | 17 | 18 | 20 | 20 | 40 | 26 | | - | - | - | |
| 26.50-26.95 | 25.50-25.95 | SPT-18 | 18 | 20 | 20 | 15 | 35 | 35 | | - | - | - | Dense, Olive Yellow(2.5Y 6/6), Fine to Medium Silty **SAND**. |
| 28.00-28.45 | 27.00-27.45 | SPT-19 | 19 | 20 | 19 | 23 | 42 | 33 | | - | - | - | Dense, Light Olive Brown(2.5Y 5/4), Fine to Medium Silty **SAND**. |
| 29.50-29.95 | 28.50-28.95 | SPT-20 | 20 | 17 | 20 | 26 | 46 | 34 | | - | - | - | |
| 31.00-31.45 | 30.00-30.45 | SPT-21 | 21 | 20 | 24 | 28 | 52 | 32 | | - | - | - | Dense to Very Dense, Light Olive Brown(2.5Y 5/4), Fine to Medium Silty **SAND**. |

**Borehole LBH-06A Terminated at 30.45m Below Bed Level.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | Drill Rig | Swanskar | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 1 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **LBH-07-Opt.1** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 453224.00** | **N: 2234760.00** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E: 453223.96** | **N: 2234760.04** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **30.45m below Ground Level.** | **Drilling Period** | **10/03/2019 to 11/03/2019** | | |

| LBH Depth (M) GL | Drill Depth wrt G.L. | Sample Type | Sample No | Standard Penetration Test (SPT) 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00-0.45 | 0.00-0.45 | SPT-1 | 1 | 1 | 1 | 2 | 3 | 100 | | - | - | - | Very Loose, BrownISH(10YR 4/3), Sity Fine **SAND.** |
| 1.50-1.95 | 1.50-1.95 | SPT-2 | 2 | 1 | 3 | 4 | 7 | 100 | | - | - | - | Loose to Medium Dense,Yellowish Brown(10YR 5/6), Silty Fine **SAND.** |
| 3.00-3.45 | 3.00-3.45 | SPT-3 | 3 | 3 | 4 | 4 | 8 | 100 | | - | - | - | |
| 4.50-4.95 | 4.50-4.95 | SPT-4 | 4 | 3 | 5 | 5 | 10 | 100 | | - | - | - | |
| 6.00-6.45 | 6.00-6.45 | SPT-5 | 5 | 4 | 5 | 7 | 12 | 100 | | - | - | - | |
| 7.50-7.95 | 7.50-7.95 | SPT-6 | 6 | 6 | 7 | 8 | 15 | 100 | | - | - | - | Medium Dense, Yellowish Brown(10YR 5/6), Silty Fine **SAND** with traces of shell fragements. |
| 9.00-9.45 | 9.00-9.45 | SPT-7 | 7 | 8 | 9 | 11 | 20 | 100 | | - | - | - | Medium Dense, Yellowish Brown(10YR 5/6), Silty Fine to Medium **SAND.** |
| 10.50-10.95 | 10.50-10.95 | SPT-8 | 8 | 6 | 8 | 9 | 17 | 100 | | - | - | - | Medium Dense, Dark grayish Brown(10YR 4/2), Silty Fine **SAND** with traces of shell fragments. |
| 12.00-12.45 | 12.00-12.45 | SPT-9 | 9 | 5 | 7 | 9 | 16 | 100 | | - | - | - | |
| 13.50-13.95 | 13.50-13.95 | SPT-10 | 10 | 6 | 7 | 9 | 16 | 100 | | - | - | - | |
| 15.00-15.45 | 15.00-15.45 | SPT-11 | 11 | 7 | 7 | 9 | 16 | 100 | | - | - | - | Medium Dense, Dark Grayish Brown(10YR 4/2), Silty Fine **SAND.** |
| 16.50-16.95 | 16.50-16.95 | SPT-12 | 12 | 8 | 9 | 9 | 18 | 100 | | - | - | - | |
| 18.00-18.45 | 18.00-18.45 | SPT-13 | 13 | 3 | 3 | 4 | 7 | 100 | | - | - | - | Soft, Greenish Gray(5GY 6/1), Sandy silty **CLAY**. |
| 19.50-20.00 | 19.50-20.00 | UDS-1 | 14 | - | - | - | - | 100 | | - | - | - | |
| 21.00-21.45 | 21.00-21.45 | SPT-14 | 15 | 3 | 4 | 4 | 8 | 100 | | - | - | - | Loose, Greenish Gray(5GY 6/1), Clayey Silty **SAND.** |
| 22.50-22.95 | 22.50-22.95 | SPT-15 | 16 | 6 | 8 | 8 | 16 | 100 | | - | - | - | Medium Dense, Olive Gray(5Y 4/2), Silty Fine **SAND**. |
| 24.00-24.45 | 24.00-24.45 | SPT-16 | 17 | 7 | 8 | 9 | 17 | 100 | | - | - | - | |
| 25.50-25.95 | 25.50-25.95 | SPT-17 | 18 | 9 | 9 | 10 | 19 | 100 | | - | - | - | Medium Dense, Brownish (10YR 4/3), Silty Fine **SAND**. |
| 27.00-27.45 | 27.00-27.45 | SPT-18 | 19 | 8 | 9 | 11 | 20 | 100 | | - | - | - | |
| 28.50-28.95 | 28.50-28.95 | SPT-19 | 20 | 9 | 10 | 12 | 22 | 100 | | - | - | - | Medium Dense, Dark Yellowish Brown (10YR 4/4), Silty Fine **SAND.** |
| 30.00-30.45 | 30.00-30.45 | SPT-20 | 21 | 10 | 12 | 12 | 24 | 100 | | - | - | - | |

**Borehole LBH-07-Opt.1Terminated at 30.45m Below Ground Level.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | VST | Vane Shear Test | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite/Gaurgum |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 1 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **LBH-08** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 454929.00** | **N: 2234802.00** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E: 454928.97** | **N: 2234802.04** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **30.45m below Ground Level.** | **Drilling Period** | **08/04/2019 to 09/04/2019** | | |

| LBH Depth (M) GL | Drill Depth wrt G.L. | Sample Type | Sample No | Standard Penetration Test (SPT) 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00-0.45 | 0.00-0.45 | SPT-1 | 1 | 1 | 2 | 1 | 3 | 100 | | - | - | - | Very Loose to Loose, Yellowish Brown(10YR 5/6), Silty Fine **SAND**. |
| 1.50-1.95 | 1.50-1.95 | SPT-2 | 2 | 2 | 2 | 3 | 5 | 100 | | - | - | - | |
| 3.00-3.45 | 3.00-3.45 | SPT-3 | 3 | 2 | 3 | 3 | 6 | 100 | | - | - | - | |
| 4.50-4.95 | 4.50-4.95 | SPT-4 | 4 | 3 | 3 | 4 | 7 | 100 | | - | - | - | Loose, Yellowish Brown(10YR 5/6), Silty Fine to Medium **SAND**. |
| 6.00-6.45 | 6.00-6.45 | SPT-5 | 5 | 3 | 4 | 3 | 7 | 100 | | - | - | - | Loose, Dark Grayish Brown(10YR 4/2), Silty Fine **SAND.** |
| 7.50-7.95 | 7.50-7.95 | SPT-6 | 6 | 3 | 3 | 5 | 8 | 100 | | - | - | - | Loose, Yellowish Brown(10YR 5/6), Silty Fine **SAND.** |
| 9.00-9.45 | 9.00-9.45 | SPT-7 | 7 | 4 | 4 | 5 | 9 | 100 | | - | - | - | |
| 10.50-10.95 | 10.50-10.95 | SPT-8 | 8 | 5 | 6 | 7 | 13 | 100 | | - | - | - | Medium Dene,Dark Grayish Brown(10YR 4/2), Silty Fine **SAND.** |
| 12.00-12.45 | 12.00-12.45 | SPT-9 | 9 | 7 | 8 | 8 | 16 | 100 | | - | - | - | Medium Dense, Dark Yellowish Brown (10YR 4/4), Silty Fine **SAND.** |
| 13.50-13.95 | 13.50-13.95 | SPT-10 | 10 | 8 | 7 | 9 | 16 | 100 | | - | - | - | |
| 15.00-15.45 | 15.00-15.45 | SPT-11 | 11 | 9 | 10 | 10 | 20 | 100 | | - | - | - | |
| 16.50-16.95 | 16.50-16.95 | SPT-12 | 12 | 10 | 11 | 13 | 24 | 100 | | - | - | - | |
| 18.00-18.45 | 18.00-18.45 | SPT-13 | 13 | 10 | 12 | 13 | 25 | 100 | | - | - | - | |
| 19.50-20.00 | 19.50-20.00 | SPT-14 | 14 | 8 | 9 | 10 | 19 | 100 | | - | - | - | |
| 21.00-21.45 | 21.00-21.45 | SPT-15 | 15 | 9 | 11 | 10 | 21 | 100 | | - | - | - | |
| 22.50-22.95 | 22.50-22.95 | SPT-16 | 16 | 10 | 10 | 12 | 22 | 100 | | - | - | - | |
| 24.00-24.45 | 24.00-24.45 | SPT-17 | 17 | 12 | 12 | 13 | 25 | 100 | | - | - | - | |
| 25.50-25.95 | 25.50-25.95 | SPT-18 | 18 | 13 | 15 | 15 | 30 | 100 | | - | - | - | Dense, Yellowish Brown (10YR 5/6), Silty Fine **SAND**. |
| 27.00-27.45 | 27.00-27.45 | SPT-19 | 19 | 14 | 16 | 17 | 33 | 100 | | - | - | - | |
| 28.50-28.95 | 28.50-28.95 | SPT-20 | 20 | 14 | 16 | 18 | 34 | 100 | | - | - | - | |
| 30.00-30.45 | 30.00-30.45 | SPT-21 | 21 | 16 | 17 | 19 | 36 | 100 | | - | - | - | |

**Borehole LBH-08Terminated at 30.45m Below Ground Level.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | VST | Vane Shear Test | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite/Gaurgum |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 1 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-09** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 453964.0** | **N: 2234439.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E:453962** | **N:2234445** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **40.45m below Bed Level.** **C.D. Depth:-** **-3.40 mtrs.** | **Drilling Period** | **20/05/2019 to 22/05/2019** | | |

| Drill Depth(M) wrt C.D. | Drill Depth wrt B.L. | Sample Type | Sample No | Standard Penetration 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.40-3.85 | 0.00-0.45 | SPT-1 | 1 | 2 | 3 | 4 | 7 | 42 | | - | - | - | Loose, Dark Grayish Olive(10Y-5GY 4/2), Silty Fine **SAND** with traces of shell fragments. |
| 4.90-5.35 | 1.50-1.95 | SPT-2 | 2 | 5 | 8 | 8 | 16 | 48 | | - | - | - | Medium Dense, Dark Grayish Olive(10Y-5GY 4/2), Silty Fine **SAND** with trace of shell fragments. |
| 6.40-6.85 | 3.00-3.45 | SPT-3 | 3 | 14 | 13 | 15 | 28 | 60 | | - | - | - | Medium Dense, Light Olive Brown(2.5Y 5/4), Fine to Medium Silty **SAND** with trace of shell fragments. |
| 7.90-8.35 | 4.50-4.95 | SPT-4 | 4 | 10 | 14 | 15 | 29 | 52 | | - | - | - | |
| 9.40-9.85 | 6.00-6.45 | SPT-5 | 5 | 12 | 19 | 22 | 41 | 45 | | - | - | - | Medium Dense to Dense, Grayish Brown(2.5Y 5/2), Silty Fine **SAND**. |
| 10.90-11.35 | 7.50-7.95 | SPT-6 | 6 | 14 | 22 | 20 | 42 | 52 | | - | - | - | |
| 12.40-12.85 | 9.00-9.45 | SPT-7 | 7 | 12 | 15 | 15 | 30 | 60 | | - | - | - | Medium Dense to Dense, Brownish(10YR 5/3), Fine to Medium Silty **SAND**. |
| 13.90-14.35 | 10.50-10.95 | SPT-8 | 8 | 10 | 14 | 18 | 32 | 51 | | - | - | - | |
| 15.40-15.85 | 12.00-12.45 | SPT-9 | 9 | 14 | 15 | 13 | 28 | 64 | | - | - | - | Medium Dense, Light Olive Brown(2.5Y 5/3), Silty Fine **SAND**. |
| 16.40-16.90 | 13.00-13.50 | -- | -- | -- | -- | -- | -- | -- | | - | - | - | Firm, Dark Grayish(10GY 3/1), Clayey **SAND** / Sandy **CLAY**. |
| 16.90-17.35 | 13.50-13.95 | SPT-10 | 10 | 8 | 9 | 14 | 23 | 48 | | - | - | - | Medium Dense, Light Olive Brown(2.5Y 5/4), Fine to Medium Silty **SAND** with traces of clay pockets. |
| 18.40-18.85 | 15.00-15.45 | SPT-11 | 11 | 4 | 5 | 5 | 10 | 100 | | - | - | - | Firm to Stiff, Very Dark Greenish Gray(10GY 3/1), Sandy **CLAY** with traces of shell fragments. |
| 19.90-20.35 | 16.50-16.95 | SPT-12 | 12 | 9 | 12 | 12 | 24 | 70 | | - | - | - | (16.20mtrs onwards) Medium Dense, Light Brownish Gray(10YR 6/2), Fine to Medium Silty **SAND** with traces of **CLAY** pockets. |
| 21.40-21.85 | 18.00-18.45 | SPT-13 | 13 | 12 | 14 | 20 | 34 | 48 | | - | - | - | Medium Dense to Dense, Light Olive Brown(2.5Y 5/4), Silty Fine **SAND**. |
| 22.90-23.35 | 19.50-19.95 | SPT-14 | 14 | 15 | 15 | 16 | 31 | 42 | | - | - | - | |
| 24.40-24.85 | 21.00-21.45 | SPT-15 | 15 | 17 | 16 | 19 | 35 | 35 | | - | - | - | Dense, Light Yellowish Brown(2.5Y 6/3), Fine to Medium Silty **SAND**. |
| 25.90-26.35 | 22.50-22.95 | SPT-16 | 16 | 10 | 12 | 16 | 28 | 61 | | - | - | - | Medium Dense, Light Yellowish Brown(2.5Y 6/4), Silty Fine **SAND**. |
| 27.40-27.85 | 24.00-24.45 | SPT-17 | 17 | 11 | 16 | 16 | 32 | 64 | | - | - | - | Medium Dense to Dense, Pale Brown (10YR 6/3), Silty Fine **SAND**. |
| 28.90-29.35 | 25.50-25.95 | SPT-18 | 18 | 14 | 14 | 16 | 30 | 62 | | - | - | - | |
| 30.40-30.85 | 27.00-27.45 | SPT-19 | 19 | 12 | 18 | 20 | 38 | 38 | | - | - | - | Dense, Light yellowish Brown(10YR 6/4), Fine to Medium, Silty **SAND**. |
| 31.90-32.35 | 28.50-28.95 | SPT-20 | 20 | 12 | 15 | 19 | 34 | 60 | | - | - | - | Dense, Light Olive Brown(2.5Y 6/4), Fine to Medium, Silty **SAND**. |
| 33.40-33.85 | 30.00-30.45 | SPT-21 | 21 | 15 | 15 | 16 | 31 | 52 | | - | - | - | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | Drill Rig | Swanskar | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 2 | |

## FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-09** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 453964.0** | **N: 2234439.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E:453962** | **N:2234445** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **40.45m below Bed Level.** **C.D. Depth:-** **-3.40 mtrs.** | **Drilling Period** | **20/05/2019 to 22/05/2019** | | |

| Drill Depth(M) wrt C.D. | Drill Depth wrt B.L. | Sample Type | Sample No | Standard Penetration 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 35.40-35.85 | 32.00-32.45 | SPT-22 | 22 | 12 | 18 | 20 | 38 | 48 | | - | - | - | Dense, Light Yellowish Brown(2.5Y 6/4), Silty Fine **SAND**. |
| 36.90-37.35 | 33.50-33.95 | SPT-23 | 23 | 17 | 17 | 25 | 42 | 42 | | - | - | - | Dense, Yellowish(2.5Y 7/6), Silty Fine **SAND**. |
| 38.40-38.85 | 35.00-35.45 | SPT-24 | 24 | 15 | 20 | 20 | 40 | 58 | | - | - | - | |
| 39.90-40.35 | 36.50-36.95 | SPT-25 | 25 | 18 | 18 | 19 | 37 | 70 | | - | - | - | Dense, Light Olive Brown(2.5Y 5/4), Fine to Medium Silty **SAND**. |
| 41.40-41.85 | 38.00-38.45 | SPT-26 | 26 | 22 | 23 | 22 | 45 | 51 | | - | - | - | |
| 43.40-43.85 | 40.00-40.45 | SPT-27 | 27 | 24 | 21 | 22 | 43 | 43 | | - | - | - | |

**Borehole MBH-09 Terminated at 40.45m Below Bed Level.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | Drill Rig | Swanskar | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 2 of 2 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-10** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 453245.0** | **N: 2233989.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E:453245** | **N:2233986** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **40.45m below Bed Level.** **C.D. Depth:-** **-6.00 mtrs.** | **Drilling Period** | **18/05/2019 to 20/05/2019** | | |

| Drill Depth(M) wrt C.D. | Drill Depth wrt B.L. | Sample Type | Sample No | Standard Penetration 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6.00-6.45 | 0.00-0.45 | SPT-1 | 1 | 1 | 2 | 2 | 4 | 67 | | - | - | - | Loose, Very Dark Grayish Gray(5GY 3/1), Silty Fine **SAND** with traces of shell fragments. |
| 7.50-7.95 | 1.50-1.95 | SPT-2 | 2 | 3 | 6 | 7 | 13 | 65 | | - | - | - | Medium Dense, Dark Greenish Gray(5GY 4/1), Fine **SAND** with trace of shell fragments. |
| 9.00-9.45 | 3.00-3.45 | SPT-3 | 3 | 6 | 6 | 10 | 16 | 35 | | - | - | - | Medium Dense, Light Yellowish Brown(10YR 6/4), Fine to Medium **SAND** with trace of shell fragments. |
| 10.50-10.95 | 4.50-4.95 | SPT-4 | 4 | 4 | 8 | 7 | 15 | 32 | | - | - | - | |
| 12.00-12.45 | 6.00-6.45 | SPT-5 | 5 | 10 | 13 | 15 | 28 | 60 | | - | - | - | Medium Dense, Olive Yellow(5Y 6/6), Silty Fine **SAND**. |
| 13.50-13.95 | 7.50-7.95 | SPT-6 | 6 | 6 | 10 | 12 | 22 | 35 | | - | - | - | |
| 15.00-15.45 | 9.00-9.45 | SPT-7 | 7 | 4 | 10 | 14 | 24 | 62 | | - | - | - | Medium Dense, Grayish Brown(2.5Y 5/2), Silty Fine **SAND**. |
| 16.50-16.95 | 10.50-10.95 | SPT-8 | 8 | 7 | 9 | 9 | 18 | 69 | | - | - | - | Medium Dense, Grayish Brown(2.5Y 5/2), Silty **Clayey SAND**/ **Sandy CLAY** with traces of Clay pockets & shell fragments. |
| 18.00-18.45 | 12.00-12.45 | SPT-9 | 9 | 7 | 8 | 8 | 16 | 60 | | - | - | - | |
| 19.50-19.95 | 13.50-13.95 | SPT-10 | 10 | 6 | 10 | 13 | 23 | 70 | | - | - | - | Medium Dense, Grayish Brown(2.5Y 5/2), Silty Fine **SAND**. |
| 21.00-21.45 | 15.00-15.45 | SPT-11 | 11 | 9 | 12 | 11 | 23 | 70 | | - | - | - | Medium Dense, Yellowish Brown(10YR 5/6), Fine to Medium Silty **SAND** with trace of shell fragments. |
| 22.50-22.95 | 16.50-16.95 | SPT-12 | 12 | 7 | 11 | 14 | 25 | 75 | | - | - | - | |
| 24.00-24.45 | 18.00-18.45 | SPT-13 | 13 | 9 | 14 | 15 | 29 | 70 | | - | - | - | |
| 25.50-25.95 | 19.50-19.95 | SPT-14 | 14 | 6 | 10 | 13 | 23 | 60 | | - | - | - | Medium Dense, Grayish Brown(2.5Y 5/2), Silty Fine **SAND**. |
| 27.00-27.45 | 21.00-21.45 | SPT-15 | 15 | 9 | 12 | 13 | 25 | 66 | | - | - | - | |
| 28.50-28.95 | 22.50-22.95 | SPT-16 | 16 | 12 | 14 | 15 | 29 | 72 | | - | - | - | Medium Dense to Dense, Light Olive Brown(2.5Y 5/6), Silty Fine **SAND**. |
| 30.00-30.45 | 24.00-24.45 | SPT-17 | 17 | 15 | 15 | 14 | 29 | 60 | | - | - | - | |
| 31.50-31.95 | 25.50-25.95 | SPT-18 | 18 | 13 | 16 | 15 | 31 | 52 | | - | - | - | |
| 33.00-33.45 | 27.00-27.45 | SPT-19 | 19 | 9 | 12 | 18 | 30 | 48 | | - | - | - | Medium Dense to Dense, Olive Yellow(2.5Y 6/6), Fine to Medium Silty **SAND**. |
| 34.50-34.95 | 28.50-28.95 | SPT-20 | 20 | 14 | 17 | 17 | 34 | 55 | | - | - | - | Dense, Light yellowish Brown(2.5Y 6/4), Medium grained, Silty **SAND**. |
| 36.00-36.45 | 30.00-30.45 | SPT-21 | 21 | 13 | 17 | 19 | 36 | 62 | | - | - | - | Dense, Brownish(10YR 5/3), Medium to Coarse **SAND**. |
| 37.50-37.95 | 31.50-31.95 | SPT-22 | 22 | 15 | 15 | 17 | 32 | 49 | | - | - | - | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | Drill Rig | Swanskar | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 2 | |

## FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-10** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 453245.0** | **N: 2233989.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E:453245** | **N:2233986** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **40.45m below Bed Level.** **C.D. Depth:-** **-6.00 mtrs.** | **Drilling Period** | **18/05/2019 to 20/05/2019** | | |

| Drill Depth(M) wrt C.D. | Drill Depth wrt B.L. | Sample Type | Sample No | Standard Penetration 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39.00-39.45 | 33.00-33.45 | SPT-23 | 23 | 17 | 18 | 20 | 38 | 66 | | - | - | - | Dense, Brownish(10YR 5/3), Medium grained **SAND**. |
| 40.50-40.95 | 34.50-34.95 | SPT-24 | 24 | 12 | 15 | 18 | 33 | 61 | | - | - | - | Dense, Light Yellowish Brown(2.5Y 6/4), Medium to Fine Silty **SAND**. |
| 42.00-42.45 | 36.00-36.45 | SPT-25 | 25 | 10 | 16 | 21 | 37 | 55 | | - | - | - | |
| 43.50-43.95 | 37.50-37.95 | SPT-26 | 26 | 13 | 19 | 23 | 42 | 42 | | - | - | - | |
| 45.00-45.45 | 39.00-39.45 | SPT-27 | 27 | 18 | 21 | 25 | 46 | 66 | | - | - | - | Dense to Very Dense, Light Yellowish Brown(2.5Y 6/4), Fine to Medium Silty **SAND**. |
| 46.00-46.45 | 40.00-40.45 | SPT-28 | 28 | 21 | 23 | 24 | 47 | 48 | | - | - | - | |

**Borehole MBH-10 Terminated at 40.45m Below Bed Level.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | Drill Rig | Swanskar | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 2 of 2 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-11** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 452159.0** | **N: 2233120.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E: 452165.0** | **N: 2233112.0** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **40.45m below Bed Level.** **C.D. Depth:-** **-4.90 mtrs.** | **Drilling Period** | **31/05/2019 to 02/06/2019** | | |

| CBH Depth (M) BL | Drill Depth wrt B.L. | Sample Type | Sample No | Standard Penetration 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.90-5.35 | 0.00-0.45 | SPT-1 | 1 | 6 | 8 | 9 | 17 | 56 | | - | - | - | Medium Dense, Dark Grayish Brown(2.5Y 4/2), Silty Fine **SAND** with traces of **CLAY** pockets. |
| 6.40-6.85 | 1.50-1.95 | SPT-2 | 2 | 8 | 11 | 12 | 23 | 67 | | - | - | - | Medium Dense, Light Olive Brown(2.5Y 5/4), Silty Fine **SAND**. |
| 7.90-8.35 | 3.00-3.45 | SPT-3 | 3 | 9 | 12 | 16 | 28 | 58 | | - | - | - | Medium Dense, Light Yellowish Brown(2.5Y 6/4), Fine to Medium Silty **SAND**. |
| 9.40-9.85 | 4.50-4.95 | SPT-4 | 4 | 10 | 11 | 13 | 24 | 40 | | - | - | - | Medium Dense to Dense, Light Olive Brown(2.5Y 5/4), Fine to Medium **SAND** with traces of shell fragments. |
| 10.90-11.35 | 6.00-6.45 | SPT-5 | 5 | 12 | 14 | 18 | 32 | 55 | | - | - | - | |
| 12.40-12.85 | 7.50-7.95 | SPT-6 | 6 | 11 | 15 | 15 | 30 | 53 | | - | - | - | |
| 13.90-14.35 | 9.00-9.45 | SPT-7 | 7 | 14 | 15 | 17 | 32 | 78 | | - | - | - | Dense, Grayish Brown(2.5Y 5/2), Fine to Medium Silty **SAND** with traces of Shell fragments. |
| 15.40-15.85 | 10.50-10.95 | SPT-8 | 8 | 12 | 17 | 18 | 35 | 64 | | - | - | - | Dense, Light Olive Brown(2.5Y 5/3), Silty Fine **SAND**. |
| 16.90-17.35 | 12.00-12.45 | SPT-9 | 9 | 8 | 6 | 8 | 14 | 72 | | - | - | - | Medium Dense, Dark Grayish Brown(2.5Y4/2), Silty Clayey **SAND** or Sandy **CLAY.** |
| 18.40-18.85 | 13.50-13.95 | SPT-10 | 10 | 8 | 8 | 9 | 17 | 67 | | - | - | - | |
| 19.90-20.35 | 15.00-15.45 | SPT-11 | 11 | 12 | 14 | 16 | 30 | 64 | | - | - | - | Medium Dense, Olive Brown(2.5Y 4/3), Fine to Medium Silty **SAND** with traces of Shell fragments. |
| 21.40-21.85 | 16.50-16.95 | SPT-12 | 12 | 14 | 14 | 18 | 32 | 70 | | - | - | - | Medium Dense to Dense, Grayish Brown(2.5Y 5/2) to Light Brownish Gray(2.5Y 6/2), Silty Fine SAND. |
| 22.90-23.35 | 18.00-18.45 | SPT-13 | 13 | 12 | 14 | 19 | 33 | 68 | | - | - | - | |
| 24.40-24.85 | 19.50-19.95 | SPT-14 | 14 | 15 | 15 | 14 | 29 | 56 | | - | - | - | |
| 25.90-26.35 | 21.00-21.45 | SPT-15 | 15 | 12 | 14 | 17 | 31 | 58 | | - | - | - | Dense, Light Gray(5Y 7/2), Silty Fine **SAND**. |
| 27.40-27.85 | 22.50-22.95 | SPT-16 | 16 | 14 | 16 | 18 | 34 | 56 | | - | - | - | |
| 28.90-29.35 | 24.00-24.45 | SPT-17 | 17 | 17 | 20 | 19 | 39 | 52 | | - | - | - | |
| 30.40-30.85 | 25.50-25.95 | SPT-18 | 18 | 14 | 16 | 19 | 35 | 55 | | - | - | - | Dense, Brownish Yellow(10YR 6/6), Silty Fine **SAND** traces of Medium sand. |
| 31.90-32.35 | 27.00-27.45 | SPT-19 | 19 | 16 | 14 | 18 | 32 | 48 | | - | - | - | |
| 33.40-33.85 | 28.50-28.95 | SPT-20 | 20 | 14 | 15 | 15 | 30 | 56 | | - | - | - | Dense, Pale Olive(5Y 6/4), Silty Fine **SAND**. |
| 34.90-35.35 | 30.00-30.45 | SPT-21 | 21 | 17 | 16 | 19 | 35 | 58 | | - | - | - | |
| 36.40-36.85 | 31.50-31.95 | SPT-22 | 22 | 20 | 19 | 20 | 39 | 52 | | - | - | - | Dense, Light Olive Brown(2.5Y 5/6), Fine to Medium Silty **SAND**. |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | Drill Rig | Swanskar | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 2 | |

## FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-11** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 452159.0** | **N: 2233120.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E: 452165.0** | **N: 2233112.0** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **40.45m below Bed Level.** **C.D. Depth:-** **-4.90 mtrs.** | **Drilling Period** | **31/05/2019 to 02/06/2019** | | |

| CBH Depth (M) BL | Drill Depth wrt B.L. | Sample Type | Sample No | Standard Penetration 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 37.90-38.35 | 33.00-33.45 | SPT-23 | 23 | 20 | 21 | 21 | 42 | 48 | | - | - | - | Dense, Light Olive Brown(2.5Y 5/6), Fine to Medium Silty **SAND**. |
| 39.40-39.85 | 34.50-34.95 | SPT-24 | 24 | 22 | 23 | 25 | 48 | 62 | | - | - | - | |
| 40.90-41.35 | 36.00-36.45 | SPT-25 | 25 | 25 | 20 | 18 | 38 | 53 | | - | - | - | Dense to Very Dense, Pale Olive(5Y 6/4), Silty Fine **SAND**. |
| 42.90-43.35 | 38.00-38.45 | SPT-26 | 26 | 24 | 21 | 21 | 42 | 60 | | - | - | - | |
| 44.90-45.35 | 40.00-40.45 | SPT-27 | 27 | 20 | 20 | 27 | 47 | 50 | | - | - | - | |

**Borehole MBH-11 Terminated at 40.45m Below Bed Level.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | Drill Rig | Swanskar | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 2 of 2 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-12** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 450797.0** | **N: 2232520.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E:450806** | **N:2232515** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **39.45m below Bed Level.** **C.D. Depth:-** **-6.80 mtrs.** | **Drilling Period** | **30.04.19 to 02.05.19** | | |

| Drill Depth(M) wrt C.D. | Drill Depth wrt B.L. | Sample Type | Sample No | Standard Penetration 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6.80-7.25 | 0.00-0.45 | SPT-1 | 1 | 1 | 2 | 1 | 3 | 32 | | - | - | - | Very Loose to Loose, Yellowish Brown(10YR 5/6), Silty Fine **SAND**. |
| 8.30-8.75 | 1.50-1.95 | SPT-2 | 2 | 3 | 2 | 4 | 6 | 62 | | - | - | - | |
| 9.80-10.25 | 3.00-3.45 | SPT-3 | 3 | 3 | 3 | 3 | 6 | 35 | | - | - | - | Loose, Dark Yellowish Brown(10YR 4/6), Silty Fine **SAND** with trace of shell fragments. |
| 11.30-11.75 | 4.50-4.95 | SPT-4 | 4 | 3 | 4 | 5 | 9 | 28 | | - | - | - | |
| 12.80-13.25 | 6.00-6.45 | SPT-5 | 5 | 3 | 4 | 4 | 8 | 52 | | - | - | - | |
| 14.30-14.75 | 7.50-7.95 | SPT-6 | 6 | 4 | 3 | 5 | 8 | 38 | | - | - | - | Loose, Light Olive Brown(2.5YR 5/4), Silty Fine **SAND**. |
| 15.80-16.25 | 9.00-9.45 | SPT-7 | 7 | 5 | 6 | 6 | 12 | 34 | | - | - | - | Medium Dense, Light Olive Brown(2.5Y 5/4), Silty Fine **SAND**. |
| 17.30-17.75 | 10.50-10.95 | SPT-8 | 8 | 6 | 7 | 8 | 15 | 42 | | - | - | - | |
| 18.80-19.25 | 12.00-12.45 | SPT-9 | 9 | 6 | 8 | 8 | 16 | 30 | | - | - | - | |
| 20.30-20.75 | 13.50-13.95 | SPT-10 | 10 | 8 | 8 | 10 | 18 | 34 | | - | - | - | |
| 21.80-22.25 | 15.00-15.45 | SPT-11 | 11 | 7 | 7 | 9 | 16 | 30 | | - | - | - | |
| 23.30-23.75 | 16.50-16.95 | SPT-12 | 12 | 8 | 9 | 10 | 19 | 46 | | - | - | - | Medium Dense, Olive Brown(2.5Y 4/4), Silty Fine **SAND.** |
| 24.80-25.25 | 18.00-18.45 | SPT-13 | 13 | 8 | 8 | 9 | 17 | 48 | | - | - | - | |
| 26.30-26.75 | 19.50-19.95 | SPT-14 | 14 | 8 | 7 | 9 | 16 | 42 | | - | - | - | |
| 27.80-28.25 | 21.00-21.45 | SPT-15 | 15 | 9 | 9 | 10 | 19 | 38 | | - | - | - | |
| 29.30-29.75 | 22.50-22.95 | SPT-16 | 16 | 10 | 9 | 10 | 19 | 30 | | - | - | - | |
| 30.80-31.25 | 24.00-24.45 | SPT-17 | 17 | 11 | 11 | 11 | 22 | 42 | | - | - | - | Medium Dense, Yellowish Brown(10YR 5/6), Silty Fine **SAND**. |
| 32.30-32.75 | 25.50-25.95 | SPT-18 | 18 | 10 | 11 | 12 | 23 | 32 | | - | - | - | |
| 33.80-34.25 | 27.00-27.45 | SPT-19 | 19 | 11 | 12 | 11 | 23 | 40 | | - | - | - | |
| 35.30-35.75 | 28.50-28.95 | SPT-20 | 20 | 11 | 11 | 14 | 25 | 28 | | - | - | - | |
| 36.80-37.25 | 30.00-30.45 | SPT-21 | 21 | 12 | 13 | 14 | 27 | 28 | | - | - | - | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | Drill Rig | Swanskar | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 2 | |

## FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-12** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 450797.0** | **N: 2232520.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | | | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **39.45m below Bed Level.** **C.D. Depth:-** **-6.80 mtrs.** | **Drilling Period** | **30.04.19 to 02.05.19** | | |

| Drill Depth(M) wrt C.D. | Drill Depth wrt B.L. | Sample Type | Sample No | Standard Penetration 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 38.30-38.75 | 31.50-31.95 | SPT-22 | 22 | 12 | 12 | 13 | 25 | 32 | | - | - | - | Medium Dense, Yellowish Brown(10YR 5/6), Silty Fine **SAND**. |
| 39.80-40.25 | 33.00-33.45 | SPT-23 | 23 | 13 | 13 | 15 | 28 | 24 | | - | - | - | |
| 41.30-41.75 | 34.50-34.95 | SPT-24 | 24 | 15 | 16 | 16 | 32 | 26 | | - | - | - | Dense, Light Olive Brown(2.5Y 5/4), Silty Fine **SAND.** |
| 42.80-43.25 | 36.00-36.45 | SPT-25 | 25 | 16 | 17 | 16 | 33 | 28 | | - | - | - | |
| 44.30-44.75 | 37.50-37.95 | SPT-26 | 26 | 17 | 18 | 19 | 37 | 30 | | - | - | - | |
| 45.80-46.25 | 39.00-39.45 | SPT-27 | 27 | 18 | 18 | 20 | 38 | 26 | | - | - | - | |

**Borehole MBH-12 Terminated at 39.45m Below Bed Level.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | Drill Rig | Swanskar | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 2 of 2 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-13** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 454838.0** | **N: 2233973.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E: 454828.1** | **N: 2233964.8** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **26.95m below Bed Level.** **SBL** **(-)3.20m below CD** | **Drilling Period** | **22/02/2019 to 23/02/2019** | | |

| BH Depth (M) SBL | Drill Depth wrt C.D. | Sample Type | Sample No | Standard Penetration Test (SPT) 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00-0.45 | 3.20-3.65 | SPT-1 | 1 | 6 | 3 | 3 | 6 | 43 | | - | - | - | Loose, Olive brown(2.5Y 4/3), Silty fine **SAND**. |
| 1.50-1.95 | 4.70-5.15 | SPT-2 | 2 | 6 | 7 | 8 | 15 | 33 | | - | - | - | Medium Dense, Olive brown(2.5Y 4/3), Silty fine **SAND**. |
| 3.00-3.45 | 6.20-6.65 | SPT-3 | 3 | 8 | 17 | 20 | 37 | 43 | | - | - | - | Dense, Olive gray(5Y 4/2), Silty fine **SAND**. |
| 4.50-4.95 | 7.70-8.15 | SPT-4 | 4 | 13 | 24 | 31 | 55 | 68 | | - | - | - | Very Dense, Yellowish brown(10YR 5/4), Silty fine to medium **SAND**. |
| 6.00-6.45 | 9.20-9.65 | SPT-5 | 5 | 3 | 13 | 28 | 41 | 34 | | - | - | - | Dense, Dark greenish gray(10Y 4/1), Silty fine **SAND**. |
| 7.50-7.95 | 10.70-11.15 | SPT-6 | 6 | 8 | 18 | 16 | 34 | 62 | | - | - | - | |
| 9.00-9.45 | 12.20-12.65 | SPT-7 | 7 | 15 | 20 | 20 | 40 | 33 | | - | - | - | Dense, Dark greenish gray(10Y 4/1), Silty fine **SAND** with traces of Shell fragments. |
| 10.50-11.00 | 13.70-14.20 | UDS-1 | 8 | - | - | - | - | 100 | | - | - | - | Soft, Dark greenish gray(10GY 5/1), Silty **CLAY** with traces of silt & sand pockets and fewof Shell fragments. |
| 12.00-12.50 | 15.20-15.70 | UDS-2 | 9 | - | - | - | - | 100 | | - | - | - | Stiff to very stiff, Light olive gray(2.5Y 6/2), Sandy **CLAY**. |
| 13.50-13.95 | 16.70-17.15 | SPT-8 | 10 | 13 | 15 | 18 | 33 | 100 | | - | - | - | |
| 15.00-15.45 | 18.20-18.65 | SPT-9 | 11 | 11 | 17 | 20 | 37 | 100 | | - | - | - | Dense, greenish gray(5GY 6/1), Silty fine **SAND**. |
| 16.50-16.95 | 19.70-20.15 | SPT-10 | 12 | 13 | 19 | 20 | 39 | 33 | | - | - | - | |
| 18.00-18.45 | 21.20-21.65 | SPT-11 | 13 | 15 | 20 | 22 | 42 | 44 | | - | - | - | |
| 19.50-19.95 | 22.70-23.15 | SPT-12 | 14 | 14 | 24 | 27 | 51 | 40 | | - | - | - | Very Dense, Yellowish brown(10YR 5/4), Sandy **SILT**. |
| 21.00-21.45 | 24.20-24.65 | SPT-13 | 15 | 13 | 27 | 29 | 56 | 48 | | - | - | - | |
| 22.50-22.95 | 25.70-26.15 | SPT-14 | 16 | 8 | 16 | 19 | 35 | 53 | | - | - | - | Dense, Yellowish brown(10YR 5/6), Clayey Silty fine to medium **SAND**. |
| 24.00-24.45 | 27.20-27.65 | SPT-15 | 17 | 8 | 15 | 16 | 31 | 100 | | - | - | - | Very Stiff, Grayish brown(2.5Y 5/2), Silty **CLAY** with trace to few sand pockets. |
| 25.50-25.95 | 28.70-29.15 | SPT- 16 | 18 | 7 | 16 | 14 | 30 | 86 | | - | - | - | Very Stiff, Light greenish gray(10GY 7/1) becoming Yellowish, Silty **CLAY** with traces of sand pockets & partings. |
| 26.50-26.95 | 29.70-30.15 | SPT-17 | 19 | 26 | 27 | 35 | 62 | 56 | | - | - | - | Very Dense, Light greenish gray(10GY 7/1), Silty fine **SAND** with traces clay pockets. |

**Borehole MBH-13 Terminated at 26.95m Below Seabead Level(30.15m below CD)**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | Drill Rig | Dando-250 | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite/Gaurgum |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 1 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **LBH-14** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 454572.00** | **N: 2234478.00** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E: 454572.00** | **N: 2234478.00** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **30.45m below Ground Level.** | **Drilling Period** | **06/04/2019 to 07/04/2019** | | |

| LBH Depth (M) GL | Drill Depth wrt G.L. | Sample Type | Sample No | Standard Penetration Test (SPT) 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00-0.45 | 0.00-0.45 | SPT-1 | 1 | 1 | 2 | 2 | 4 | 100 | | - | - | - | Very Loose, yellowish Brown(10YR 5/6), Silty Fine **SAND**. |
| 1.50-1.95 | 1.50-1.95 | SPT-2 | 2 | 2 | 3 | 3 | 6 | 100 | | - | - | - | Loose, yellowish Brown(10YR 5/6), Silty Fine **SAND**. |
| 3.00-3.45 | 3.00-3.45 | SPT-3 | 3 | 3 | 3 | 3 | 6 | 100 | | - | - | - | |
| 4.50-4.95 | 4.50-4.95 | SPT-4 | 4 | 4 | 4 | 3 | 7 | 100 | | - | - | - | |
| 6.00-6.45 | 6.00-6.45 | SPT-5 | 5 | 4 | 4 | 5 | 9 | 100 | | - | - | - | Loose to Medium Dense, Dark Grayish Brown(10YR 4/2), Silty Fine **SAND**.(**6.00-7.50m**) traces of shell fragments. |
| 7.50-7.95 | 7.50-7.95 | SPT-6 | 6 | 4 | 5 | 6 | 11 | 100 | | - | - | - | |
| 9.00-9.45 | 9.00-9.45 | SPT-7 | 7 | 4 | 6 | 5 | 11 | 100 | | - | - | - | |
| 10.50-10.95 | 10.50-10.95 | SPT-8 | 8 | 5 | 5 | 7 | 12 | 100 | | - | - | - | Medium Dense, yellowish Brown(10YR 5/6), Silty Fine **SAND**. |
| 12.00-12.45 | 12.00-12.45 | SPT-9 | 9 | 8 | 8 | 7 | 15 | 100 | | - | - | - | |
| 13.50-13.95 | 13.50-13.95 | SPT-10 | 10 | 10 | 10 | 11 | 21 | 100 | | - | - | - | Medium Dense, yellowish Brown(10YR 5/6), Silty Fine to Medium **SAND** with traces of shell fragments. |
| 15.00-15.45 | 15.00-15.45 | SPT-11 | 11 | 11 | 12 | 12 | 24 | 100 | | - | - | - | Medium Dense, Dark Grayish Brown(10YR 4/2), Silty Fine to Medium **SAND**. |
| 16.50-16.95 | 16.50-16.95 | SPT-12 | 12 | 11 | 12 | 11 | 23 | 100 | | - | - | - | |
| 18.00-18.45 | 18.00-18.45 | SPT-13 | 13 | 6 | 7 | 8 | 15 | 100 | | - | - | - | Medium Dense, Dark Grayish Brown(10YR 5/6), Silty Fine **SAND.** |
| 19.50-20.00 | 19.50-20.00 | SPT-14 | 14 | 9 | 9 | 10 | 19 | 100 | | - | - | - | |
| 21.00-21.45 | 21.00-21.45 | SPT-15 | 15 | 9 | 10 | 11 | 21 | 100 | | - | - | - | |
| 22.50-22.95 | 22.50-22.95 | SPT-16 | 16 | 10 | 10 | 12 | 22 | 100 | | - | - | - | |
| 24.00-24.45 | 24.00-24.45 | SPT-17 | 17 | 12 | 12 | 13 | 25 | 100 | | - | - | - | Medium Dense, Yellowish Brown(10YR 5/6), Silty Fine **SAND**. |
| 25.50-25.95 | 25.50-25.95 | SPT-18 | 18 | 13 | 14 | 14 | 28 | 100 | | - | - | - | |
| 27.00-27.45 | 27.00-27.45 | SPT-19 | 19 | 13 | 15 | 16 | 31 | 100 | | - | - | - | Dense, Yellowish Brown(10YR 5/6), Silty Fine SAND. |
| 28.50-28.95 | 28.50-28.95 | SPT-20 | 20 | 14 | 16 | 18 | 34 | 100 | | - | - | - | |
| 30.00-30.45 | 30.00-30.45 | SPT-21 | 21 | 14 | 16 | 19 | 35 | 100 | | - | - | - | |

**Borehole LBH-14Terminated at 30.45m Below Ground Level.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | VST | Vane Shear Test | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite/Gaurgum |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 1 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-15** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 455610.0** | **N: 2234607.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E: 455603.3** | **N: 2234600.9** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **27.45m below Bed Level.** **SBL** **2.30m below CD** | **Drilling Period** | **20/02/2019 to 22/02/2019** | | |

| BH Depth (M) SBL | Drill Depth wrt C.D. | Sample Type | Sample No | Standard Penetration Test (SPT) 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00-0.45 | 2.30-2.75 | SPT-1 | 1 | 3 | 6 | 8 | 14 | 45 | | - | - | - | Medium Dense, Light yellowish brown(2.5Y 6/3), Silty fine **SAND**. |
| 1.50-1.95 | 3.80-4.25 | SPT-2 | 2 | 7 | 8 | 10 | 18 | 37 | | - | - | - | |
| 3.00-3.45 | 5.30-5.75 | SPT-3 | 3 | 11 | 20 | 21 | 41 | 44 | | - | - | - | Dense, Light yellowish brown(2.5Y 6/3), Silty fine **SAND**. |
| 4.50-4.95 | 6.80-7.25 | SPT-4 | 4 | 9 | 15 | 19 | 34 | 40 | | - | - | - | |
| 6.00-6.45 | 8.30-8.75 | SPT-5 | 5 | 11 | 18 | 21 | 39 | 42 | | - | - | - | Dense, Dark greenish gray(10GY 4/1), Silty fine **SAND** with traces of Shell fragments. |
| 7.50-7.95 | 9.80-10.25 | SPT-6 | 6 | 10 | 12 | 16 | 28 | 44 | | - | - | - | Medium Dense, Dark greenish gray(10GY 4/1), Silty fine **SAND** with traces of Shell fragments. |
| 9.00-9.45 | 11.30-11.75 | SPT-7 | 7 | 11 | 17 | 19 | 36 | 35 | | - | - | - | |
| 10.50-10.95 | 12.80-13.25 | SPT-8 | 8 | 4 | 6 | 10 | 16 | 100 | | - | - | - | Stiff, Dark greenish gray(10GY 4/1), Silty **CLAY** with traces to few of sand pockets and Shell fragments. |
| 12.00-12.45 | 14.30-14.75 | SPT-9 | 9 | 10 | 9 | 16 | 25 | 100 | | - | - | - | Very Stiff, Greenish gray(10GY 6/1), Sandy **CLAY**. |
| 13.50-13.95 | 15.80-16.25 | SPT-10 | 10 | 5 | 4 | 5 | 9 | 20 | | - | - | - | Stiff, Brownish(10YR 5/3), Clayey **SAND**/Sandy **CLAY**. |
| 15.00-15.45 | 17.30-17.75 | SPT-11 | 11 | 11 | 14 | 12 | 26 | 56 | | - | - | - | Medium Dense, Dark yellowish brown(10YR 4/6), Fine to Medium Silty **SAND**. |
| 16.50-16.95 | 18.80-19.25 | SPT-12 | 12 | 12 | 16 | 20 | 36 | 44 | | - | - | - | Dense, Dark Yellowish brown(10YR 4/6), Fine to Medium Silty **SAND**. |
| 18.00-18.45 | 20.30-20.75 | SPT-13 | 13 | 10 | 24 | 32 | 56 | 36 | | - | - | - | Very Dense, Dark yellowish brown(10YR 4/6), Silty fine **SAND**. |
| 19.50-19.95 | 21.80-22.25 | SPT-14 | 14 | 23 | 37 | 45 | 82 | 60 | | - | - | - | |
| 21.00-21.45 | 23.30-23.75 | SPT-15 | 15 | 14 | 17 | 30 | 47 | 42 | | - | - | - | Very Dense, Dark yellowish brown(10YR 4/6), Silty fine **SAND** with few of Clay pockets. |
| 22.50-22.95 | 24.80-25.25 | SPT-16 | 16 | 7 | 11 | 19 | 30 | 100 | | - | - | - | Very Stiff, Light Yellowish brown(2.5Y 6/3), Silty **CLAY**. |
| 24.00-24.45 | 26.30-26.75 | SPT-17 | 17 | 11 | 13 | 18 | 31 | 100 | | - | - | - | Very Stiff, Dark yellowish brown(10YR 4/6), Sandy **CLAY**. |
| 25.50-25.95 | 27.80-28.25 | SPT-18 | 18 | 6 | 11 | 17 | 28 | 100 | | - | - | - | |
| 27.00-27.45 | 29.30-29.75 | SPT-19 | 19 | 24 | 28 | 30 | 58 | 44 | | - | - | - | Very Dense, Light Greenish grey(10GY 7/1), Silty fine **SAND** with few Clay pockets. |

**Borehole MBH-15 Terminated at 27.45m Below Seabead Level(29.75m below CD)**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | Drill Rig | Dando-250 | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite/Gaurgum |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 1 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-16** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 456046.0** | **N: 2234291.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E: 456043.1** | **N: 2234288.7** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **21.45m below Bed Level.** **SBL** **8.20m below CD** | **Drilling Period** | **16/02/2019 to 17/02/2019** | | |

| BH Depth (M) SBL | Drill Depth wrt C.D. | Sample Type | Sample No | Standard Penetration Test (SPT) 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00-0.45 | 8.20-8.65 | SPT-1 | 1 | 3 | 3 | 6 | 9 | 40 | | - | - | - | Loose, Light Olive Brown(2.5Y 5/4), Silty Fine **SAND**. |
| 1.50-1.95 | 9.70-10.15 | SPT-2 | 2 | 11 | 15 | 16 | 31 | 46 | | - | - | - | Dense, Yellowish Brown(10YR 5/4), Silty Fine **SAND**. |
| 3.00-3.45 | 11.20-11.65 | SPT-3 | 3 | 9 | 14 | 15 | 29 | 53 | | - | - | - | Medium Dense, Greenish Gray(GLEY 6/1), Silty Fine **SAND**. |
| 4.50-4.95 | 12.70-13.15 | SPT-4 | 4 | 9 | 15 | 20 | 35 | 35 | | - | - | - | Dense, Dark Greenish Gray(GLEY 4/1), Silty Fine **SAND**. with traces of **CLAY** pockets. |
| 6.00-6.45 | 14.20-14.65 | SPT-5 | 5 | 3 | 3 | 3 | 6 | 33 | | - | - | - | Soft, Dark Greenish Gray(GLEY 4/1), Sandy Silty **CLAY** with few shell fragments. |
| 7.50-7.95 | 15.70-16.15 | SPT-6 | 6 | 6 | 7 | 11 | 18 | 84 | | - | - | - | Very Stiff, Light yellowish brown(2.5Y 6/3), Sandy Silty **CLAY**. |
| 9.00-9.45 | 17.20-17.65 | SPT-7 | 7 | 4 | 8 | 10 | 18 | 100 | | - | - | - | Very stiff, Light Yellowish Brown(2.5Y 6/3), Clayey Silty **SAND** / Sandy Silty **CLAY** with traces of gravels. (9.00-10.70mtrs) |
| 10.50-10.95 | 18.70-19.15 | SPT-8 | 8 | 4 | 5 | 8 | 13 | 90 | | - | - | - | Medium Dense, Yellowish Brown(10YR 5/4), Silty Fine **SAND**. |
| 12.00-12.45 | 20.20-20.65 | SPT-9 | 9 | 12 | 16 | 21 | 37 | 46 | | - | - | - | Dense, Brownish Yellow(10YR 6/6), Fine to Medium **SAND**. |
| 13.50-13.95 | 21.70-22.15 | SPT-10 | 10 | 10 | 9 | 16 | 25 | 70 | | - | - | - | Medium Dense to Dense, Brownish Yellow(10YR 6/6), Silty Fine **SAND**. |
| 15.00-15.45 | 23.20-23.65 | SPT-11 | 11 | 10 | 14 | 16 | 30 | 44 | | - | - | - | Very Stiff to Hard, Brownish Yellow(10YR 6/6), Silty **SAND** / Sandy **SILT**. |
| 16.50-16.95 | 24.70-25.15 | SPT-12 | 12 | 15 | 18 | 20 | 38 | 48 | | - | - | - | |
| 18.00-18.45 | 26.20-26.65 | SPT-13 | 13 | 6 | 7 | 11 | 18 | 40 | | - | - | - | (18.00-18.20)Medium Dense, Brownish Yellow(10YR 6/6), Silty **SAND**. |
| | | | | | | | | | | | | | (18.20-18.45)Very Stiff, Brownish Yellow(10YR 6/6), Sandy **SILT**. |
| 19.50-19.95 | 27.70-28.15 | SPT-14 | 14 | 9 | 13 | 20 | 33 | 100 | | - | - | - | Hard, Brownish Yellow(10YR 6/6), Sandy Silty **CLAY**. |
| 21.00-21.45 | 29.20-29.65 | SPT-15 | 15 | 7 | 9 | 15 | 24 | 100 | | - | - | - | Very Stiff, Brownish Yellow(10YR 6/6) Sandy Clayey **SILT**. |

**Borehole MBH-16 Terminated at 21.450m Below Seabead Level(29.65m below CD)**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Rahul | Drill Rig | Dando-250 | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite/Gaurgum |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 1 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-17** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 456110.0** | **N: 2233853.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E: 456112.8** | **N: 2233855.0** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **17.05m below Bed Level.** **SBL** **12.40m below CD** | **Drilling Period** | **18/02/2019 to 19/02/2019** | | |

| BH Depth (M) SBL | Drill Depth wrt C.D. | Sample Type | Sample No | Standard Penetration Test (SPT) 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00-0.45 | 12.40-12.85 | SPT-1 | 1 | 6 | 8 | 12 | 20 | 54 | | - | - | - | Loose to Medium Dense, Yellowish Brown(10YR 5/4), Silty Fine **SAND** with traces of shell fragments. |
| 1.50-1.95 | 13.90-14.35 | SPT-2 | 2 | 7 | 11 | 17 | 28 | 62 | | - | - | - | Medium Dense, Dark Grayish(GLEY 4/1), Silty Fine **SAND** with traces of shell fragments. |
| 3.00-3.45 | 15.40-15.85 | SPT-3 | 3 | 2 | 2 | 3 | 5 | 94 | | - | - | - | Soft, Dark Greenish Gray(GLEY 4/1), Sandy Silty **CLAY** with few shell fragments. |
| 4.50-4.95 | 16.90-17.35 | SPT-4 | 4 | 5 | 7 | 7 | 14 | 100 | | - | - | - | (4.50-6.30mtrs) Stiff, Light Yellowish Brown(2.5Y 6/3), Silty **CLAY**. |
| 6.00-6.45 | 18.40-18.85 | SPT-5 | 5 | 3 | 6 | 11 | 17 | 100 | | - | - | - | (6.30- 7.50mtrs) Very Stiff, Light Yellowish Brown(2.5Y 6/3) Sandy **SILT** with Gravels. |
| 7.50-7.95 | 19.90-20.35 | SPT-6 | 6 | 8 | 8 | 9 | 17 | 67 | | - | - | - | Medium Dense, Light Yellowish Brown(2.5Y 6/3), Silty Fine **SAND**. |
| 9.00-9.45 | 21.40-21.85 | SPT-7 | 7 | 23 | 33 | 37 | 70 | 64 | | - | - | - | Very Dense to Dense, Brownish Yellowish(10YR 7/6), Silty Fine **SAND**. |
| 10.50-10.95 | 22.90-23.35 | SPT-8 | 8 | 17 | 18 | 20 | 38 | 60 | | - | - | - | |
| 12.00-12.45 | 24.40-24.85 | SPT-9 | 9 | 17 | 21 | 30 | 51 | 60 | | - | - | - | Dense, Brownish Yellow(10YR 6/6), Fine **SAND**. |
| 13.50-13.95 | 25.90-26.35 | SPT-10 | 10 | 9 | 16 | 25 | 41 | 67 | | - | - | - | Hard, Brownish Yellow(10YR 6/6), Sandy **SILT**. |
| 15.00-15.45 | 27.40-27.85 | SPT-11 | 11 | 5 | 8 | 12 | 20 | 100 | | - | - | - | Stiff, Brownish Yellow(10YR 6/6), Sandy **SILT** / Sandy **CLAY** with traces of fine Gravels. |
| 16.60-17.05 | 29.00-29.45 | SPT-12 | 12 | 6 | 10 | 13 | 23 | 46 | | - | - | - | Medium Dense, Brownish Yellow(10YR 6/6), Silty **SAND** / Sandy **SILT**. |

**Borehole MBH-17 Terminated at 17.05m Below Seabead Level(29.45m below CD)**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Rahul | Drill Rig | Dando-250 | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite/Gaurgum |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 1 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-18** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 455975.0** | **N: 2233567.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E: 455974.6** | **N: 2233564.3** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **16.95m below Bed Level.** **SBL** **12.80m below CD** | **Drilling Period** | **12/02/2019 to 12/02/2019** | | |

| BH Depth (M) SBL | Drill Depth wrt C.D. | Sample Type | Sample No | Standard Penetration Test (SPT) 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00-1.00 | 12.80-13.80 | UDS-1 | 1 | - | - | - | - | 60 | | - | - | - | Very soft, Dark Greenish Gray(10Y 4/1), Silty **CLAY**. |
| 1.00-.1.45 | 13.80-14.25 | SPT-1 | 2 | - | - | - | - | 57 | | - | - | - | |
| 2.00-3.00 | 14.80-15.80 | UDS-2 | 3 | - | - | - | - | 54 | | - | - | - | Soft, Light Yellowish Brown(2.5Y 6/3), Silty Clayey **SAND**/ Silty Sandy **CLAY**. |
| 3.00-3.45 | 15.80-16.25 | SPT-2 | 4 | 5 | 8 | 11 | 19 | 100 | | - | - | - | Medium Dense, Light Yelowish Brown(2.5Y 6/3), Silty Fine **SAND** with traces of gravels. |
| 4.50-4.95 | 17.30-17.75 | SPT-3 | 5 | 5 | 6 | 9 | 15 | 90 | | - | - | - | Medium Dense, Olive Yellow(2.5Y 6/6), Silty **SAND** with traces of clay pockets. |
| 6.00-6.45 | 18.80-19.25 | SPT-4 | 6 | 4 | 8 | 13 | 21 | 70 | | - | - | - | Medium Dense, Olive Yellow(2.5Y 6/6) to light gray(2.5Y 7/1), Silty Fine **SAND**. |
| 7.50-7.95 | 20.30-20.75 | SPT-5 | 7 | 8 | 8 | 11 | 19 | 54 | | - | - | - | |
| 9.00-9.45 | 21.80-22.25 | SPT-6 | 8 | 8 | 13 | 14 | 27 | 56 | | - | - | - | Medium Dense, Light Greenish Gray(10Y 8/1), Fine to Medium, Silty **SAND**. |
| 10.50-10.95 | 23.30-23.75 | SPT-7 | 9 | 10 | 15 | 15 | 30 | 30 | | - | - | - | |
| 12.00-12.45 | 24.80-25.25 | SPT-8 | 10 | 15 | 18 | 18 | 36 | 42 | | - | - | - | Dense, Yellowish(10YR 7/6), Sandy **SILT**/ Silty **SAND**. |
| 13.50-13.95 | 26.30-26.75 | SPT-9 | 11 | 11 | 16 | 26 | 42 | 54 | | - | - | - | |
| 15.00-15.45 | 27.80-28.25 | SPT-10 | 12 | 5 | 7 | 9 | 16 | 75 | | - | - | - | Stiff, Yellowish(10YR 7/6), Sandy Silty **CLAY.** |
| 16.50-16.95 | 29.30-29.75 | SPT-11 | 13 | 29 | 39 | 48 | 87 | 78 | | - | - | - | Very Dense, Yellowish Brown(10YR 5/4), Fine to Medium Silty**SAND**. |

**Borehole MBH-18 Terminated at 16.95m Below Seabead Level(29.75m below CD)**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Rahul | Drill Rig | Dando-250 | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite/Gaurgum |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 1 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-19** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 457311.0** | **N: 2233270.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E: 457313.4** | **N: 2233263.5** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **15.80m below Bed Level.** **SBL** **13.65m below CD** | **Drilling Period** | **15/02/2019 to 16/02/2019** | | |

| BH Depth (M) SBL | Drill Depth wrt C.D. | Sample Type | Sample No | Standard Penetration Test (SPT) 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00-1.00 | 13.65-14.65 | UDS-1 | 1 | - | - | - | - | 30 | | - | - | - | Loose, Grayish (7.5Y 6/1), Silty Fine **SAND**. |
| 1.50-1.95 | 15.15-15.60 | SPT-1 | 2 | 3 | 5 | 6 | 11 | 78 | | - | - | - | Medium Dense, Light Greenish Gray(10GY 5/1), Clayey Silty **SAND.** |
| 3.00-3.45 | 16.65-17.10 | SPT-2 | 3 | 5 | 5 | 8 | 13 | 100 | | - | - | - | Stiff, Yellowish Brown(10YR 6/4), Silty **CLAY**. |
| 4.50-4.95 | 18.15-18.60 | SPT-3 | 4 | 7 | 11 | 12 | 23 | 100 | | - | - | - | Very Stiff, Pale Yellow(2.5Y 7/3), Fine Sandy Silty **CLAY.** |
| 6.00-6.45 | 19.65-20.10 | SPT-4 | 5 | 3 | 4 | 5 | 9 | 100 | | - | - | - | Medium Dense to Dense, Yellow(10YR 7/6), Silty Fine **SAND**. |
| 7.50-7.95 | 21.15-21.60 | SPT-5 | 6 | 8 | 13 | 20 | 33 | 50 | | - | - | - | |
| 9.00-9.45 | 22.65-23.10 | SPT-6 | 7 | 38 | 37 | 25 | 62 | 70 | | - | - | - | Very Dense, Yellowish(10YR 7/6), Fine to Medium, Silty **SAND.** |
| 10.50-10.95 | 24.15-24.60 | SPT-7 | 8 | 11 | 12 | 20 | 32 | 52 | | - | - | - | Dense, Light Yellowish Brown(10YR 6/4), Silty Fine **SAND.** |
| 12.00-12.45 | 25.65-26.10 | SPT-8 | 9 | 14 | 17 | 22 | 39 | 62 | | - | - | - | Dense, Light Yellowish Brown(10YR 6/4), Fine to Medium, Silty **SAND**. |
| 13.50-13.95 | 27.15-27.60 | SPT-9 | 10 | 15 | 18 | 18 | 36 | 46 | | - | - | - | |
| 15.35-15.80 | 29.00-29.45 | SPT-10 | 11 | 5 | 8 | 12 | 20 | 90 | | - | - | - | Very Stiff, Light Yellowish Brown(10YR 6/4), Silty **CLAY**. |

**Borehole MBH-19 Terminated at 15.80m Below Seabead Level(29.45m below CD)**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Rahul | Drill Rig | Dando-250 | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite/Gaurgum |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 1 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-20** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 458405.0** | **N: 2232535.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E: 458414.2** | **N: 2232537.8** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **14.95m below Bed Level.** **SBL** **14.50m below CD** | **Drilling Period** | **14/02/2019 to 15/02/2019** | | |

| BH Depth (M) SBL | Drill Depth wrt C.D. | Sample Type | Sample No | Standard Penetration Test (SPT) 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00-1.00 | 14.50-15.50 | UDS-1 | 1 | - | - | - | - | 30 | | - | - | - | Loose, Grayish (7.5Y 6/1), Silty Fine **SAND**. |
| 1.00-1.45 | 15.50-15.94 | SPT-1 | 2 | 2 | 4 | 2 | 6 | 100 | | - | - | - | 1.00-1.10m - Loose, Grayish(7.5Y 6/1), Silty Fine **SAND** with traces of shell fragments and clay pockets.<br>1.10-1.45 - Soft, Dark Grayish(10YR 4/1), Silty **CLAY** with traces of shell fragments and Fine **SAND.** |
| 2.50-3.50 | 17.00-18.00 | UDS-2 | 3 | - | - | - | - | 50 | | - | - | - | Soft to Firm, Dark Greenish gray(10GY 4/1), Sandy Silty **CLAY** with Sand partings. |
| 4.00-4.45 | 18.50-18.95 | SPT-2 | 4 | 8 | 8 | 10 | 18 | 67 | | - | - | - | Very Stiff, Light Yellowish Brown (2.5Y 6/4), Silty **CLAY**. (4.00m - 5.65m) |
| 5.50-5.95 | 20.00-20.45 | SPT-3 | 5 | 8 | 9 | 12 | 21 | 100 | | - | - | - | |
| 7.00-7.45 | 21.50-21.95 | SPT-4 | 6 | 8 | 11 | 14 | 25 | 51 | | - | - | - | (5.65m onwards) Medium Dense, Light Yellowish Brown(10YR 6/4), Silty Fine **SAND** with fewClay pockets. |
| 8.50-8.95 | 23.00-23.45 | SPT-5 | 7 | 8 | 18 | 27 | 45 | 61 | | - | - | - | Dense, Light Yellowish Brown(10YR 6/4), Silty Fine **SAND.** |
| 10.00-10.45 | 24.50-24.95 | SPT-6 | 8 | 9 | 17 | 26 | 43 | 65 | | - | - | - | |
| 11.50-11.95 | 26.00-26.45 | SPT-7 | 9 | 9 | 20 | 25 | 45 | 64 | | - | - | - | Dense, Light Yellowish Brown(10YR 6/4), Fine to Medium Silty **SAND.** |
| 13.00-13.45 | 27.50-27.95 | SPT-8 | 10 | 9 | 13 | 17 | 30 | 52 | | - | - | - | Medium Dense, Brownish Yellow(10YR 6/6), Fine to Medium Silty **SAND.** |
| 14.50-14.95 | 29.00-29.45 | SPT-9 | 11 | 10 | 17 | 20 | 37 | 92 | | - | - | - | Hard, Light Yellowish Brown(10YR 6/4), Silty **CLAY**. |

**Borehole MBH-20 Terminated at 14.95m Below Seabead Level(29.45m below CD)**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Rahul | Drill Rig | Dando-250 | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite/Gaurgum |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 1 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-21** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 459484.0** | **N: 2231369.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E: 459478.1** | **N: 2231367.0** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **14.15m below Bed Level.** **SBL** **15.30m below CD** | **Drilling Period** | **13/02/2019 to 14/02/2019** | | |

| BH Depth (M) SBL | Drill Depth wrt C.D. | Sample Type | Sample No | Standard Penetration Test (SPT) 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00-1.00 | 15.30-16.30 | UDS-1 | 1 | - | - | - | - | 95 | | - | - | - | Very Soft to Soft, Dark Greenish Gray(10Y 4/1), Sandy **CLAY** with few shell fragments. |
| 1.50-1.95 | 16.80-17.25 | SPT-1 | 2 | 2 | 4 | 5 | 9 | 91 | | - | - | - | Loose, Dark Greenish Gray(10GY 4/1), Clayey **SAND** with traces of shell fragments. |
| 3.00-3.45 | 18.30-18.75 | SPT-2 | 3 | 7 | 8 | 11 | 19 | 100 | | - | - | - | Very Stiff, Light Yellowish Brown(2.5Y 6/3), Sandy Silty **CLAY**. |
| 4.50-4.95 | 19.80-20.25 | SPT-3 | 4 | 6 | 8 | 9 | 16 | 89 | | - | - | - | Medium Dense, Light Brownish Gray(2.5Y 6/2), Silty Fine **SAND**. |
| 6.00-6.45 | 21.30-21.75 | SPT-4 | 5 | 10 | 13 | 14 | 27 | 56 | | - | - | - | |
| 7.50-7.95 | 22.80-23.25 | SPT-5 | 6 | 10 | 15 | 17 | 32 | 100 | | - | - | - | Dense, Olive Yellow(2.5Y 6/6), Silty Fine **SAND** with traces of few Gravels. |
| 9.00-9.45 | 24.30-24.75 | SPT-6 | 7 | 6 | 14 | 22 | 36 | 45 | | - | - | - | Dense, Olive Yellow(2.5Y 6/6), Fine to Medium Silty **SAND.** |
| 10.50-10.95 | 25.80-26.25 | SPT-7 | 8 | 13 | 27 | 41 | 68 | 89 | | - | - | - | Very Dense, Pale yellow(2.5Y 8/4) to Yellow (2.5Y 8/6), Fine to Medium Silty **SAND**. |
| 12.00-12.45 | 27.30-27.75 | SPT-8 | 9 | 10 | 13 | 14 | 27 | 40 | | - | - | - | Medium Dense to Dense, Dark Yellowish Brown(10YR 4/6), Silty Fine **SAND** with traces of Clay Pockets. |
| 13.70-14.15 | 29.00-29.45 | SPT-9 | 10 | 11 | 25 | 35 | 60 | 100 | | - | - | - | Very Dense, Dark Yellowish Brown(10YR 4/6), Silty Fine **SAND**. |

**Borehole MBH-21 Terminated at 14.15m Below Seabead Level(29.45m below CD)**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Rahul | Drill Rig | Dando-250 | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite/Gaurgum |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 1 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-22** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 450893.0** | **N: 2232951.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E:450879** | **N:2232943** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **45.45m below Bed Level.** **C.D. Depth:-** **-3.80 mtrs.** | **Drilling Period** | **11.05.19 to 13.05.19** | | |

| Drill Depth(M) wrt C.D. | Drill Depth wrt B.L. | Sample Type | Sample No | Standard Penetration 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.80-4.25 | 0.00-0.45 | SPT-1 | 1 | 1 | 2 | 2 | 4 | 74 | | - | - | - | Loose, Dark Grayish Brown(2.5Y 4/2), Silty Fine **SAND.** |
| 5.30-5.75 | 1.50-1.95 | SPT-2 | 2 | 5 | 8 | 9 | 17 | 32 | | - | - | - | Medium Dense, Yellowish Brown(10YR 5/6), Silty Fine **SAND**. |
| 6.80-7.25 | 3.00-3.45 | SPT-3 | 3 | 6 | 8 | 8 | 16 | 22 | | - | - | - | |
| 8.30-8.75 | 4.50-4.95 | SPT-4 | 4 | 6 | 9 | 11 | 20 | 26 | | - | - | - | |
| 9.80-10.25 | 6.00-6.45 | SPT-5 | 5 | 5 | 8 | 9 | 17 | 28 | | - | - | - | |
| 11.30-11.75 | 7.50-7.95 | SPT-6 | 6 | 5 | 8 | 7 | 15 | 64 | | - | - | - | |
| 12.80-13.25 | 9.00-9.45 | SPT-7 | 7 | 8 | 9 | 9 | 18 | 66 | | - | - | - | |
| 14.30-14.75 | 10.50-10.95 | SPT-8 | 8 | 10 | 11 | 14 | 25 | 62 | | - | - | - | Medium Dense, Greenish Gray(10Y 5/1), Silty Fine **SAND** with traces of shell fragments. |
| 15.80-16.25 | 12.00-12.45 | SPT-9 | 9 | 10 | 10 | 11 | 21 | 60 | | - | - | - | Medium Dense, Greenish Gray(10Y 5/1), Silty Fine **SAND** with traces of clay pockets & shell fragments. |
| 17.30-17.75 | 13.50-13.95 | SPT-10 | 10 | 10 | 12 | 13 | 25 | 52 | | - | - | - | Medium Dense, Greenish Gray(10Y 5/1), Silty Fine **SAND** with traces of shell fragments. |
| 18.80-19.25 | 15.00-15.45 | SPT-11 | 11 | 11 | 11 | 13 | 24 | 49 | | - | - | - | |
| 20.30-20.75 | 16.50-16.95 | SPT-12 | 12 | 11 | 12 | 14 | 26 | 42 | | - | - | - | |
| 21.80-22.25 | 18.00-18.45 | SPT-13 | 13 | 12 | 13 | 15 | 28 | 54 | | - | - | - | Medium Dense, Yellowish Brown(10YR 5/6), Silty Fine **SAND** with trace of shell fragments. |
| 23.30-23.75 | 19.50-19.95 | SPT-14 | 14 | 12 | 13 | 16 | 29 | 40 | | - | - | - | |
| 24.80-25.25 | 21.00-21.45 | SPT-15 | 15 | 13 | 13 | 15 | 28 | 66 | | - | - | - | |
| 26.30-26.75 | 22.50-22.95 | SPT-16 | 16 | 13 | 13 | 15 | 28 | 56 | | - | - | - | |
| 27.80-28.25 | 24.00-24.45 | SPT-17 | 17 | 12 | 14 | 16 | 30 | 52 | | - | - | - | Medium Dense to Dense, Yellowish Brown(10YR 5/6), Silty Fine **SAND.** |
| 29.30-29.75 | 25.50-25.95 | SPT-18 | 18 | 13 | 13 | 15 | 28 | 66 | | - | - | - | |
| 30.80-31.25 | 27.00-27.45 | SPT-19 | 19 | 15 | 15 | 16 | 31 | 54 | | - | - | - | |
| 32.30-32.75 | 28.50-28.95 | SPT-20 | 20 | 15 | 16 | 17 | 33 | 62 | | - | - | - | Dense, Yellowish Brown(10YR 5/6), Silty Fine **SAND**. |
| 33.80-34.25 | 30.00-30.45 | SPT-21 | 21 | 13 | 14 | 15 | 29 | 48 | | - | - | - | Medium Dense, Dark Grayish Brown(2.5Y 4/2), Silty Fine **SAND** with traces of shell fragments. |
| 35.30-35.75 | 31.50-31.95 | SPT-22 | 22 | 13 | 14 | 14 | 28 | 50 | | - | - | - | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | Drill Rig | Swanskar | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 2 | |

## FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-22** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 450893.0** | **N: 2232951.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E:450879** | **N:2232943** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **45.45m below Bed Level.** **C.D. Depth:-** **-3.80 mtrs.** | **Drilling Period** | **11.05.19 to 13.05.19** | | |

| Drill Depth(M) wrt C.D. | Drill Depth wrt B.L. | Sample Type | Sample No | Standard Penetration 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 36.80-37.25 | 33.00-33.45 | SPT-23 | 23 | 14 | 15 | 15 | 30 | 46 | | - | - | - | Medium Dense to Dense, Dark Grayish Brown(2.5Y 4/2), Silty Fine **SAND** with traces of shell frgments. |
| 38.30-38.75 | 34.50-34.95 | SPT-24 | 24 | 14 | 15 | 16 | 31 | 42 | | - | - | - | |
| 39.80-40.25 | 36.00-36.45 | SPT-25 | 25 | 15 | 16 | 18 | 34 | 72 | | - | - | - | Dense, Olive Brown(2.5Y 4/4), Silty Fine **SAND**. |
| 41.30-41.75 | 37.50-37.95 | SPT-26 | 26 | 16 | 18 | 19 | 37 | 52 | | - | - | - | |
| 42.80-43.25 | 39.00-39.45 | SPT-27 | 27 | 17 | 19 | 25 | 44 | 64 | | - | - | - | |
| 44.30-44.75 | 40.50-40.95 | SPT-28 | 28 | 19 | 21 | 25 | 46 | 48 | | - | - | - | Dense, Yellowish Brown(10YR 5/6), Silty Fine **SAND**. |
| 45.80-46.25 | 42.00-42.45 | SPT-29 | 29 | 20 | 24 | 27 | 51 | 48 | | - | - | - | Very Dense, Yellowish Brown(10YR 5/6), Silty Fine **SAND**. |
| 47.30-47.75 | 43.50-43.95 | SPT-30 | 30 | 21 | 26 | 26 | 52 | 52 | | - | - | - | |
| 48.80-49.25 | 45.00-45.45 | SPT-31 | 31 | 23 | 27 | 28 | 55 | 46 | | - | - | - | |

**Borehole MBH-22 Terminated at 45.45m Below Bed Level.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | Drill Rig | Swanskar | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite. |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 2 of 2 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-23** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 451569.0** | **N: 2233421.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E:451568** | **N:2233417** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **45.45m below Bed Level.** **C.D. Depth:-** **-4.50 mtrs.** | **Drilling Period** | **15/05/2019 to 17/05/2019** | | |

| Drill Depth(M) wrt C.D. | Drill Depth wrt B.L. | Sample Type | Sample No | Standard Penetration 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.50-4.95 | 0.00-0.45 | SPT-1 | 1 | 1 | 1 | 1 | 2 | 64 | | - | - | - | Very Loose, Dark Grayish Gray(10Y 4/1), Silty Fine **SAND** with traces of shell fragments. |
| 6.00-6.45 | 1.50-1.95 | SPT-2 | 2 | 1 | 2 | 2 | 4 | 60 | | - | - | - | |
| 7.50-7.95 | 3.00-3.45 | SPT-3 | 3 | 4 | 7 | 9 | 16 | 52 | | - | - | - | Medium Dense, Yellowish Brown(10YR 5/6), Silty Fine **SAND** with trace of shell fragments. |
| 9.00-9.45 | 4.50-4.95 | SPT-4 | 4 | 5 | 8 | 10 | 18 | 70 | | - | - | - | |
| 10.50-10.95 | 6.00-6.45 | SPT-5 | 5 | 4 | 7 | 14 | 21 | 64 | | - | - | - | Medium Dense, Greenish Gray(10Y 6/1) become Yellowish Brown(10YR 5/6), Silty Fine to Medium **SAND.** |
| 12.00-12.45 | 7.50-7.95 | SPT-6 | 6 | 7 | 10 | 13 | 23 | 66 | | - | - | - | Medium Dense, Light Olive Brown(2.5Y 5/3), Silty Fine **SAND.** |
| 13.50-13.95 | 9.00-9.45 | SPT-7 | 7 | 9 | 13 | 12 | 25 | 60 | | - | - | - | Medium Dense, Dark Gray(2.5Y 4/1), Silty Fine **SAND**. |
| 15.00-15.45 | 10.50-10.95 | SPT-8 | 8 | 8 | 12 | 14 | 26 | 48 | | - | - | - | |
| 16.50-16.95 | 12.00-12.45 | SPT-9 | 9 | 5 | 6 | 6 | 12 | 46 | | - | - | - | Medium Dense, Greenish Gray(10Y 5/1), Silty Fine **SAND** with traces to few of clay pockets. |
| 18.00-18.45 | 13.50-13.95 | SPT-10 | 10 | 5 | 6 | 7 | 13 | 42 | | - | - | - | |
| 19.50-19.95 | 15.00-15.45 | SPT-11 | 11 | 7 | 10 | 12 | 22 | 39 | | - | - | - | Medium Dense, Dark Gray(2.5Y 4/1), Silty Fine **SAND**. |
| 21.00-21.45 | 16.50-16.95 | SPT-12 | 12 | 8 | 11 | 13 | 24 | 62 | | - | - | - | Medium Dense, Yellowish Brown(10YR 5/6), Silty Fine **SAND** with trace of shell fragments. |
| 22.50-22.95 | 18.00-18.45 | SPT-13 | 13 | 9 | 12 | 14 | 26 | 70 | | - | - | - | Medium Dense, Dark Yellowish Brown(10YR 4/4), Silty Fine **SAND**. |
| 24.00-24.45 | 19.50-19.95 | SPT-14 | 14 | 10 | 13 | 16 | 29 | 74 | | - | - | - | |
| 25.50-25.95 | 21.00-21.45 | SPT-15 | 15 | 10 | 11 | 14 | 25 | 74 | | - | - | - | |
| 27.00-27.45 | 22.50-22.95 | SPT-16 | 16 | 11 | 11 | 14 | 25 | 69 | | - | - | - | Medium Dense, Yellowish Brown(10YR 5/6), Silty Fine **SAND**. |
| 28.50-28.95 | 24.00-24.45 | SPT-17 | 17 | 10 | 12 | 14 | 26 | 72 | | - | - | - | |
| 30.00-30.45 | 25.50-25.95 | SPT-18 | 18 | 11 | 16 | 15 | 31 | 66 | | - | - | - | |
| 31.50-31.95 | 27.00-27.45 | SPT-19 | 19 | 11 | 14 | 14 | 28 | 70 | | - | - | - | |
| 33.00-33.45 | 28.50-28.95 | SPT-20 | 20 | 13 | 14 | 15 | 29 | 68 | | - | - | - | |
| 34.50-34.95 | 30.00-30.45 | SPT-21 | 21 | 12 | 15 | 15 | 30 | 64 | | - | - | - | Medium Dense to Dense, Olive Brown(2.5Y 4/3), Silty Fine **SAND**. |
| 36.00-36.45 | 31.50-31.95 | SPT-22 | 22 | 11 | 15 | 15 | 30 | 60 | | - | - | - | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | Drill Rig | Swanskar | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 2 | |

## FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-23** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 451569.0** | **N: 2233421.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E:451568** | **N:2233417** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **45.45m below Bed Level.** **C.D. Depth:-** **-4.50 mtrs.** | **Drilling Period** | **15/05/2019 to 17/05/2019** | | |

| Drill Depth(M) wrt C.D. | Drill Depth wrt B.L. | Sample Type | Sample No | Standard Penetration 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 37.50-37.95 | 33.00-33.45 | SPT-23 | 23 | 13 | 16 | 18 | 34 | 66 | | - | - | - | Dense, Yellowish Brown(10YR 5/6), Silty Fine **SAND**. |
| 39.00-39.45 | 34.50-34.95 | SPT-24 | 24 | 14 | 16 | 20 | 36 | 60 | | - | - | - | |
| 40.50-40.95 | 36.00-36.45 | SPT-25 | 25 | 14 | 17 | 19 | 36 | 52 | | - | - | - | |
| 42.00-42.45 | 37.50-37.95 | SPT-26 | 26 | 16 | 19 | 21 | 40 | 58 | | - | - | - | |
| 43.50-43.95 | 39.00-39.45 | SPT-27 | 27 | 15 | 22 | 24 | 46 | 58 | | - | - | - | |
| 45.00-45.45 | 40.50-40.95 | SPT-28 | 28 | 16 | 24 | 26 | 50 | 48 | | - | - | - | Dense to Very Dense, Light Olive Brown(2.5Y 5/3), Silty Fine **SAND**. |
| 46.50-46.95 | 42.00-42.45 | SPT-29 | 29 | 17 | 26 | 27 | 53 | 46 | | - | - | - | |
| 48.00-48.45 | 43.50-43.95 | SPT-30 | 30 | 17 | 27 | 29 | 56 | 42 | | - | - | - | |
| 49.50-49.95 | 45.00-45.45 | SPT-31 | 31 | 18 | 27 | 30 | 57 | 30 | | - | - | - | |

**Borehole MBH-23 Terminated at 45.45m Below Bed Level.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | Drill Rig | Swanskar | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 2 of 2 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-24** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 454561.0** | **N: 2234801.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E: 454558.0** | **N: 2234811.0** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **40.45m below Bed Level.** **C.D. Depth:-** **-2.30 mtrs.** | **Drilling Period** | **25/05/2019 to 27/05/2019** | | |

| Drill Depth wrt C.D. | Drill Depth wrt B.L. | Sample Type | Sample No | Standard Penetration 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.30-2.75 | 0.00-0.45 | SPT-1 | 1 | 7 | 8 | 10 | 18 | 52 | | - | - | - | Loose to Medium Dense, Grayish Brown(2.5Y 5/2), Silty Fine **SAND** with traces of shell fragments. |
| 3.80-4.25 | 1.50-1.95 | SPT-2 | 2 | 11 | 13 | 16 | 29 | 47 | | - | - | - | Medium Dense, Yellowish Brown(10YR 5/4), Fine to Medium **SAND** with trace of shell fragments. |
| 5.30-5.75 | 3.00-3.45 | SPT-3 | 3 | 13 | 14 | 18 | 32 | 44 | | - | - | - | Dense, Light Yellowish Brown(2.5Y 6/3), Fine to Medium SAND with traces of shell fragments. |
| 6.80-7.25 | 4.50-4.95 | SPT-4 | 4 | 18 | 20 | 22 | 42 | 46 | | - | - | - | Dense, Light Olive Brown(2.5Y 5/6), Medium grained **SAND**. |
| 8.30-8.75 | 6.00-6.45 | SPT-5 | 5 | 19 | 22 | 21 | 43 | 42 | | - | - | - | |
| 9.80-10.25 | 7.50-7.95 | SPT-6 | 6 | 21 | 16 | 20 | 36 | 50 | | - | - | - | Dense, Light Yellowish Brown(2.5Y 6/3), Fine to Medium Silty **SAND**. |
| 11.30-11.75 | 9.00-9.45 | SPT-7 | 7 | 15 | 18 | 20 | 38 | 48 | | - | - | - | Dense, Grayish Brown(2.5Y 5/2) to Light Yellowish Brown(2.5Y 6/3), Silty Fine **SAND**. |
| 12.80-13.25 | 10.50-10.95 | SPT-8 | 8 | 16 | 16 | 17 | 33 | 51 | | - | - | - | |
| 14.30-14.75 | 12.00-12.45 | SPT-9 | 9 | 12 | 12 | 15 | 27 | 56 | | - | - | - | Medium Dense, Olive(5Y 5/3) to Olive Gray(5Y 5/2), Silty**SAND**. |
| 15.80-16.25 | 13.50-13.95 | SPT-10 | 10 | 13 | 12 | 12 | 24 | 54 | | - | - | - | |
| 17.30-17.75 | 15.00-15.45 | SPT-11 | 11 | 3 | 4 | 6 | 10 | 86 | | - | - | - | Firm to Stiff, Grayish(5Y 4/1), Sandy Silty **CLAY**. (14.70m onwards **CLAY** started) |
| 18.80-19.25 | 16.50-16.95 | SPT-12 | 12 | 7 | 8 | 8 | 16 | 52 | | - | - | - | Medium Dense, Olive Gray(5Y 5/2),Silty Fine **SAND** with few **CLAY** pockets. |
| 20.30-20.75 | 18.00-18.45 | SPT-13 | 13 | 10 | 10 | 12 | 22 | 45 | | - | - | - | Medium Dense, Olive Gray(5Y 5/2), Silty Fine **SAND.** |
| 21.80-22.25 | 19.50-19.95 | SPT-14 | 14 | 13 | 12 | 13 | 25 | 42 | | - | - | - | Medium Dense, Pale Olive(5Y 6/3), Fine to Medium, Silty **SAND**. |
| 23.30-23.75 | 21.00-21.45 | SPT-15 | 15 | 10 | 14 | 14 | 28 | 48 | | - | - | - | |
| 24.80-25.25 | 22.50-22.95 | SPT-16 | 16 | 12 | 15 | 17 | 32 | 54 | | - | - | - | Dense, Pale Yellow(5Y 7/3), Silty Fine **SAND**. |
| 26.30-26.75 | 24.00-24.45 | SPT-17 | 17 | 15 | 14 | 16 | 30 | 50 | | - | - | - | Medium Dense, Pale Yellow(5Y 7/4), Fine to Medium Silty **SAND**. |
| 27.80-28.25 | 25.50-25.95 | SPT-18 | 18 | 11 | 12 | 18 | 30 | 38 | | - | - | - | |
| 29.30-29.75 | 27.00-27.45 | SPT-19 | 19 | 13 | 13 | 20 | 33 | 46 | | - | - | - | Dense, Pale Olive(5Y 6/3), Silty Fine **SAND**. |
| 30.80-31.25 | 28.50-28.95 | SPT-20 | 20 | 15 | 16 | 17 | 33 | 51 | | - | - | - | |
| 32.30-32.75 | 30.00-30.45 | SPT-21 | 21 | 18 | 18 | 20 | 38 | 58 | | - | - | - | Dense, Light Yellowish Brown(2.5Y 6/3), Fine to Medium **SAND**. |
| 33.80-34.25 | 31.50-31.95 | SPT-22 | 22 | 20 | 21 | 24 | 45 | 43 | | - | - | - | Dense, Olive Yellow(2.5Y 6/6), Silty Fine **SAND**. |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | Drill Rig | Swanskar | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 2 | |

## FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-24** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 454561.0** | **N: 2234801.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E: 454558.0** | **N: 2234811.0** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **40.45m below Bed Level.** **C.D. Depth:-** **-2.30 mtrs.** | **Drilling Period** | **25/05/2019 to 27/05/2019** | | |

| Drill Depth wrt C.D. | Drill Depth wrt B.L. | Sample Type | Sample No | Standard Penetration 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 35.30-35.75 | 33.00-33.45 | SPT-23 | 23 | 19 | 25 | 23 | 48 | 50 | | - | - | - | Dense, Olive Yellow(2.5Y 6/6) to Light Yellowish Brown(2.5Y 6/4), Silty Fine **SAND**. |
| 36.80-37.25 | 34.50-34.95 | SPT-24 | 24 | 15 | 23 | 23 | 46 | 60 | | - | - | - | |
| 37.30-37.75 | 36.00-36.45 | SPT-25 | 25 | 21 | 24 | 28 | 52 | 42 | | - | - | - | Very Dense, Light Yellowish Brown(2.5Y 6/4), Silty Fine **SAND**. |
| 40.30-40.75 | 38.00-38.45 | SPT-26 | 26 | 20 | 28 | 30 | 58 | 38 | | - | - | - | Very Dense, Light Olive Brown(2.5Y 5/6), Fine to Medium Silty **SAND**. |
| 42.30-42.75 | 40.00-40.45 | SPT-27 | 27 | 20 | 27 | 32 | 59 | 49 | | - | - | - | |

**Borehole MBH-24 Terminated at 40.45m Below Bed Level.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | Drill Rig | Swanskar | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 2 of 2 | |

# FIELD BOREHOLE LOG

| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-25** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 454846.0** | **N: 2235263.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E: 454834.0** | **N: 2235266.0** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **45.45m below Bed Level.** **C.D. Depth:-** **-1.50 mtrs.** | **Drilling Period** | **27/05/2019 to 29/05/2019** | | |

| Drill Depth wrt C.D. | Drill Depth wrt B.L. | Sample Type | Sample No | Standard Penetration 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.50-1.95 | 0.00-0.45 | SPT-1 | 1 | 5 | 7 | 9 | 16 | 30 | | - | - | - | Medium Dense, Yellowish Brown(10YR 5/6), Fine to Medium Silty **SAND** with traces of shell fragments. |
| 3.00-3.45 | 1.50-1.95 | SPT-2 | 2 | 6 | 8 | 12 | 20 | 42 | | - | - | - | Medium Dense, Dark Grayish Brown(10YR 4/2), Silty Fine **SAND**. |
| 4.50-4.95 | 3.00-3.45 | SPT-3 | 3 | 10 | 13 | 15 | 28 | 44 | | - | - | - | |
| 6.00-6.45 | 4.50-4.95 | SPT-4 | 4 | 12 | 14 | 16 | 30 | 49 | | - | - | - | Medium Dense to Dense, Grayish Brown(2.5Y 5/2), Fine to Medium **SAND** with traces of shell fragments. |
| 7.50-7.95 | 6.00-6.45 | SPT-5 | 5 | 15 | 17 | 20 | 37 | 47 | | - | - | - | |
| 9.00-9.45 | 7.50-7.95 | SPT-6 | 6 | 12 | 20 | 22 | 42 | 69 | | - | - | - | |
| 10.50-10.95 | 9.00-9.45 | SPT-7 | 7 | 17 | 21 | 20 | 41 | 54 | | - | - | - | |
| 12.00-12.45 | 10.50-10.95 | SPT-8 | 8 | 17 | 17 | 16 | 33 | 56 | | - | - | - | Dense, Light Brownish Gray(2.5Y 6/2), Silty Fine **SAND**. |
| 13.50-13.95 | 12.00-12.45 | SPT-9 | 9 | 12 | 13 | 15 | 28 | 48 | | - | - | - | Medium Dense, Olive(5Y 5/4) to Olive Gray(5Y 4/2), Silty Fine **SAND**. |
| 15.00-15.45 | 13.50-13.95 | SPT-10 | 10 | 15 | 15 | 14 | 29 | 54 | | - | - | - | |
| 16.50-16.95 | 15.00-15.45 | SPT-11 | 11 | 16 | 11 | 13 | 24 | 42 | | - | - | - | Medium Dense, Olive Gray(5Y 4/2),Silty Fine **SAND** with traces of **CLAY** pockets. |
| 18.00-18.45 | 16.50-16.95 | SPT-12 | 12 | 7 | 6 | 7 | 13 | 70 | | - | - | - | Firm to Stiff, Dark Greenish Gray(10Y 4/1), Sandy Silty **CLAY**/ Clayey **SAND**. |
| 19.50-19.95 | 18.00-18.45 | SPT-13 | 13 | 9 | 10 | 13 | 23 | 44 | | - | - | - | Medium Dense, Olive(5Y 4/4), Silty Fine **SAND** with traces of **CLAY** pockets. |
| 21.00-21.45 | 19.50-19.95 | SPT-14 | 14 | 10 | 12 | 18 | 30 | 50 | | - | - | - | Medium Dense, Olive Gray(5Y 5/2) to Light Olive Gray(5Y6/2), Silty Fine **SAND**. |
| 22.50-22.95 | 21.00-21.45 | SPT-15 | 15 | 13 | 16 | 17 | 33 | 42 | | - | - | - | |
| 24.00-24.45 | 22.50-22.95 | SPT-16 | 16 | 17 | 20 | 24 | 44 | 47 | | - | - | - | Dense, Olive Gray(5Y 5/2), Fine to Medium Silty **SAND**. |
| 25.50-25.95 | 24.00-24.45 | SPT-17 | 17 | 20 | 24 | 23 | 47 | 52 | | - | - | - | Dense, Olive Gray(5Y 5/2), Silty Fine **SAND**. |
| 27.00-27.45 | 25.50-25.95 | SPT-18 | 18 | 18 | 20 | 18 | 38 | 40 | | - | - | - | Dense, Pale Olive(5Y 6/4), Silty Fine **SAND** traces of Medium sand. |
| 28.50-28.95 | 27.00-27.45 | SPT-19 | 19 | 18 | 19 | 21 | 40 | 60 | | - | - | - | |
| 30.00-30.45 | 28.50-28.95 | SPT-20 | 20 | 12 | 14 | 16 | 30 | 41 | | - | - | - | Medium Dense to Dense, Yellowish Brown(10YR 5/6), Fine to Medium Silty **SAND**. |
| 31.50-31.95 | 30.00-30.45 | SPT-21 | 21 | 15 | 15 | 18 | 33 | 44 | | - | - | - | |
| 33.00-33.45 | 31.50-31.95 | SPT-22 | 22 | 19 | 20 | 21 | 41 | 40 | | - | - | - | Dense, Dark Yellowish Brown(10YR 4/4), Fine to Medium Silty **SAND**. |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | Drill Rig | Swanskar | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 1 of 2 | |

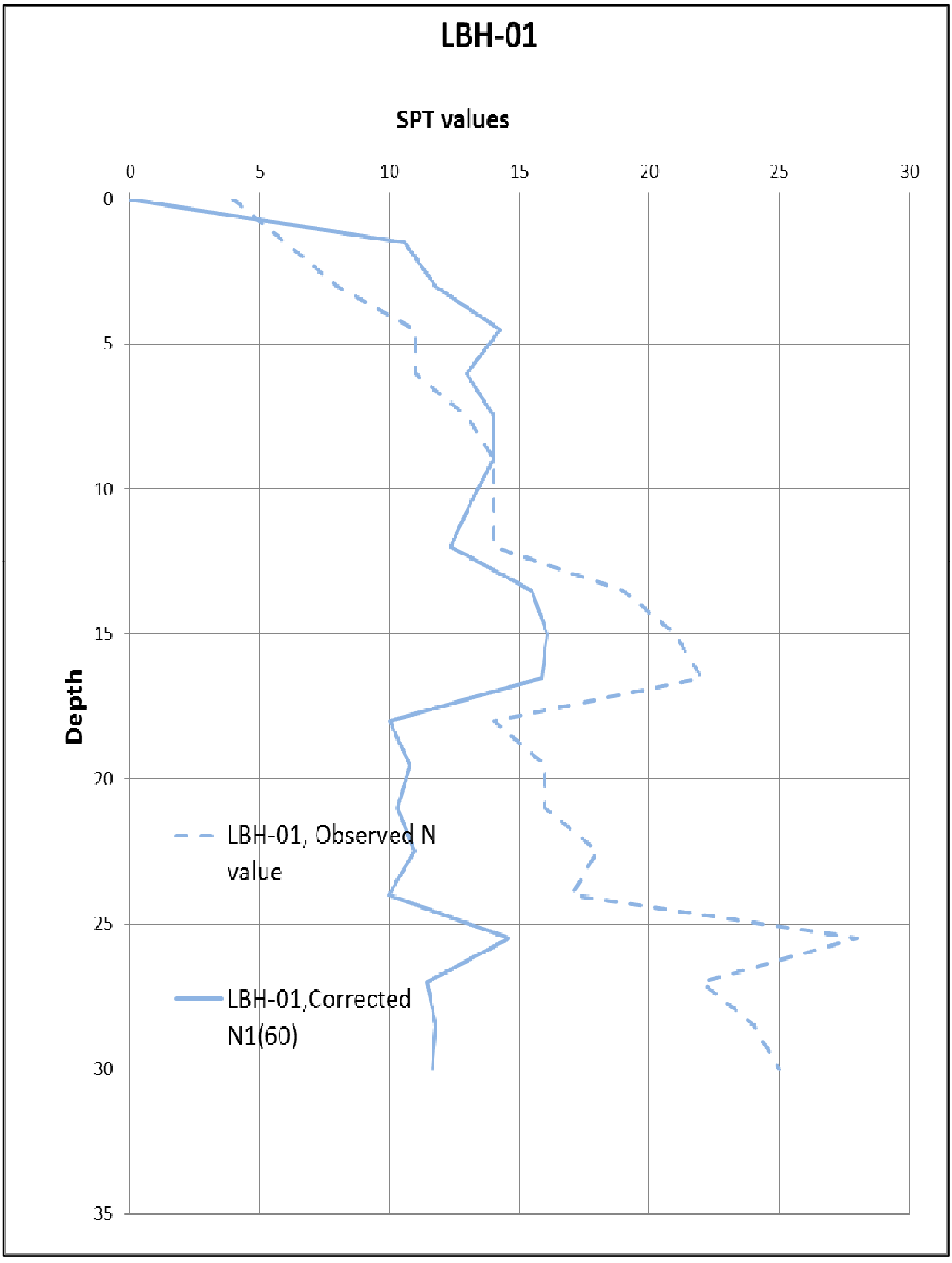
## FIELD BOREHOLE LOG

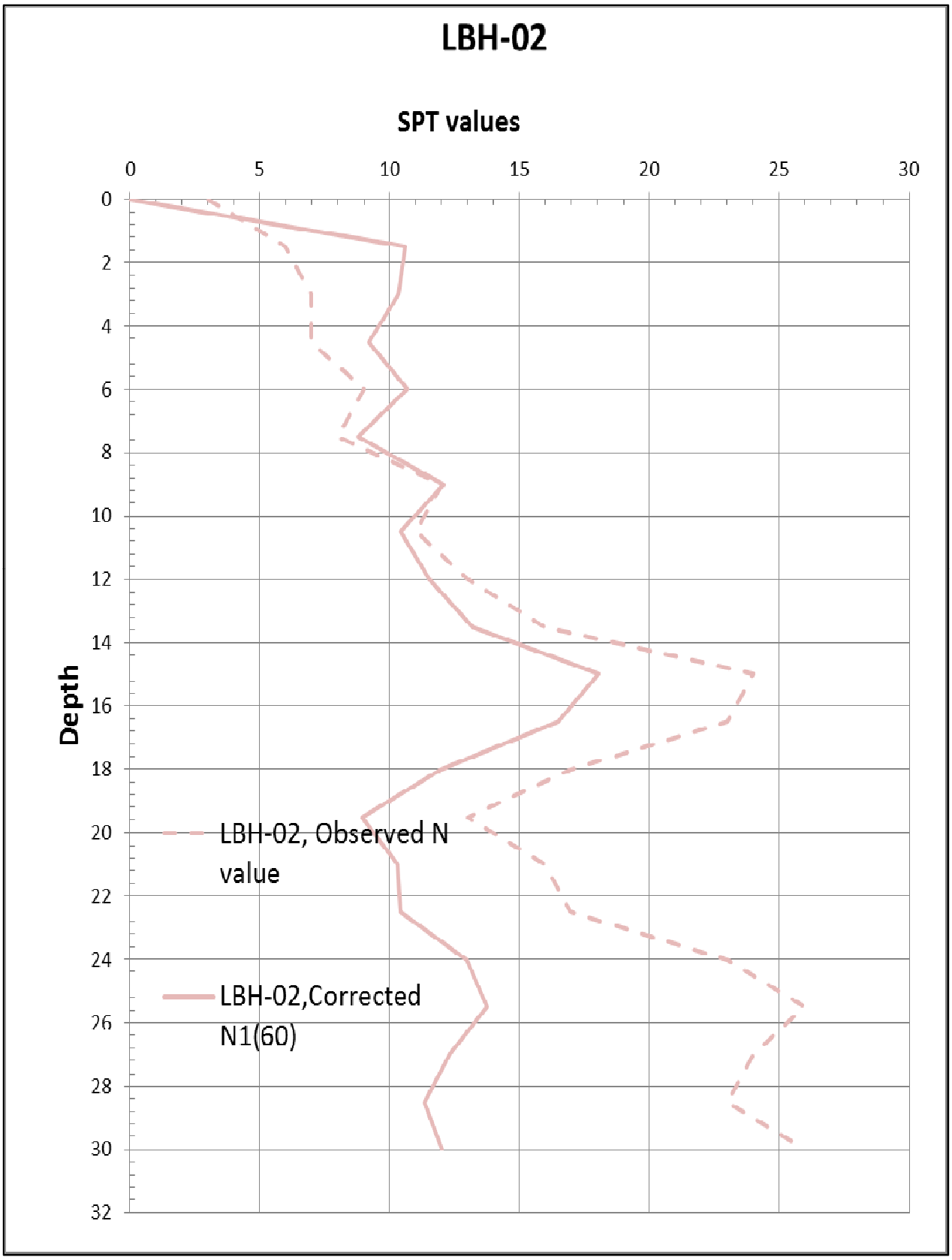
| | | | | | |
|---|---|---|---|---|---|
| **Project Name** | **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.** | **Borehole No** | **MBH-25** | | |
| **Location** | **Jagatsinghpur Dist, Paradip, Odisha.** | **Proposed Coordinates** | **E: 454846.0** | **N: 2235263.0** | **Datum** **WGS1984** |
| **Client** | **JSW UTKAL STEEL LIMITED** | **Positioned Coordinates** | **E: 454834.0** | **N: 2235266.0** | **Zone** **45 N** |
| **Project Code** | **CM 19 01 03** | **Drilling Method** | **Rotary drilling** | | |
| **Termination Depth** | **45.45m below Bed Level.** **C.D. Depth:-** **-1.50 mtrs.** | **Drilling Period** | **27/05/2019 to 29/05/2019** | | |

| Drill Depth wrt C.D. | Drill Depth wrt B.L. | Sample Type | Sample No | Standard Penetration 15 cm | 15 cm | 15 cm | SPT 'N' Value | Sample Recovery (%) | Soil Log | TCR (%) | SCR (%) | RQD (%) | Strata Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 34.50-34.95 | 33.00-33.45 | SPT-23 | 23 | 24 | 22 | 23 | 45 | 50 | | - | - | - | Dense, Light Olive Brown(2.5Y 5/6), Fine to Medium Silty **SAND**. |
| 36.00-36.45 | 34.50-34.95 | SPT-24 | 24 | 25 | 26 | 26 | 52 | 48 | | - | - | - | |
| 37.50-37.95 | 36.00-36.45 | SPT-25 | 25 | 28 | 26 | 28 | 54 | 30 | | - | - | - | Very Dense, Light Olive Brown(2.5Y 5/3), Silty Fine **SAND**. |
| 39.00-39.45 | 37.50-37.95 | SPT-26 | 26 | 24 | 26 | 30 | 56 | 46 | | - | - | - | |
| 40.50-40.95 | 39.00-39.45 | SPT-27 | 27 | 20 | 24 | 26 | 50 | 30 | | - | - | - | Dense to Very Dense, Light Yellowish Brown(2.5Y 6/4), Silty Fine **SAND**. |
| 42.00-42.45 | 40.50-40.95 | SPT-28 | 28 | 28 | 25 | 28 | 53 | 44 | | - | - | - | |
| 43.50-43.95 | 42.00-42.45 | SPT-29 | 29 | 22 | 25 | 24 | 49 | 30 | | - | - | - | Dense to Very Dense, Light Olive Brown(2.5Y 5/4), Fine to Medium Silty **SAND**. |
| 45.00-45.45 | 43.50-43.95 | SPT-30 | 30 | 24 | 28 | 31 | 59 | 42 | | - | - | - | |
| 46.50-46.95 | 45.00-45.45 | SPT-31 | 31 | 21 | 28 | 28 | 56 | 34 | | - | - | - | |

**Borehole MBH-25 Terminated at 45.45m Below Bed Level.**

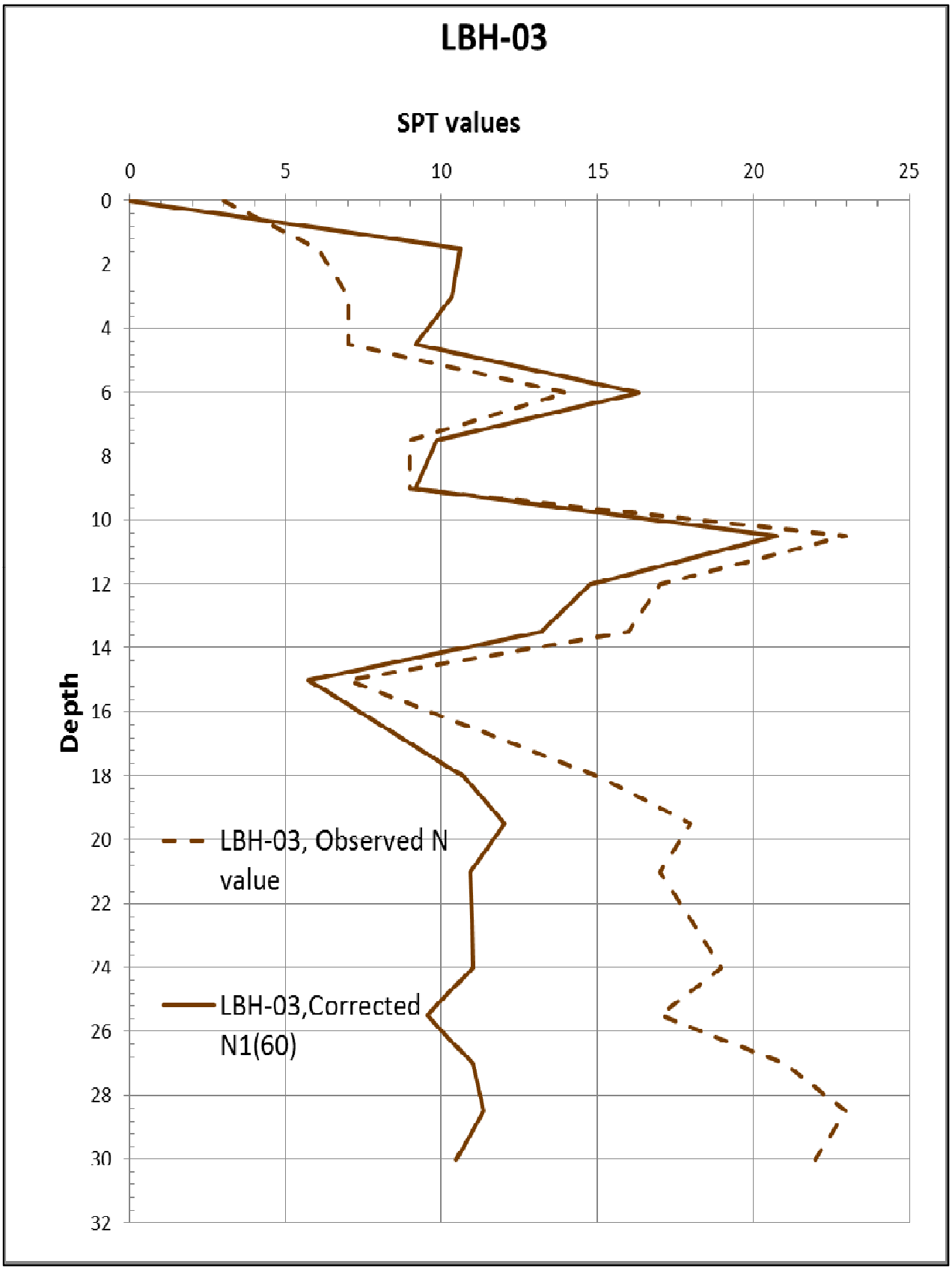
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Logged By | Vijayendra & Ramsundar | Drill Rig | Swanskar | Outer Casing | 150 mm | SBL | Sea Bed Level | SPT | Standard Penetration Test |
| Checked By | Vijayendra Patil | Inner Casing | NX Size | CD | Chart Datum | UDS | UnDisturbed Soil Sample | Drill Mud | Bentonite |
| Soil type | SAND | | SILT | | CLAY | ROCK | | Page 2 of 2 | |

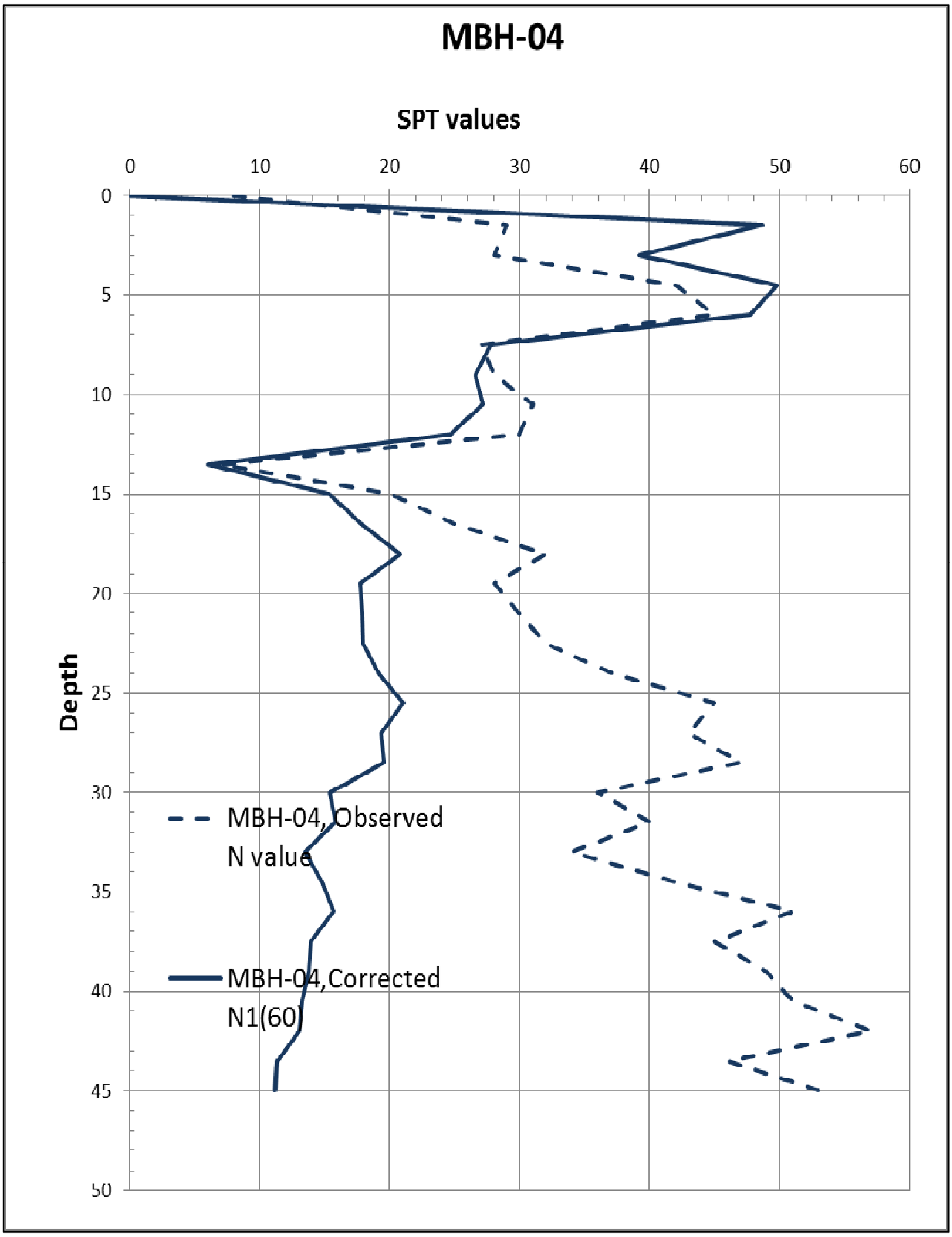

LBH-01
SPT values
0
5
10
15
20
25
30
Depth
0
5
10
15
20
25
30
35
LBH-01, Observed N value
LBH-01,Corrected N1(60)

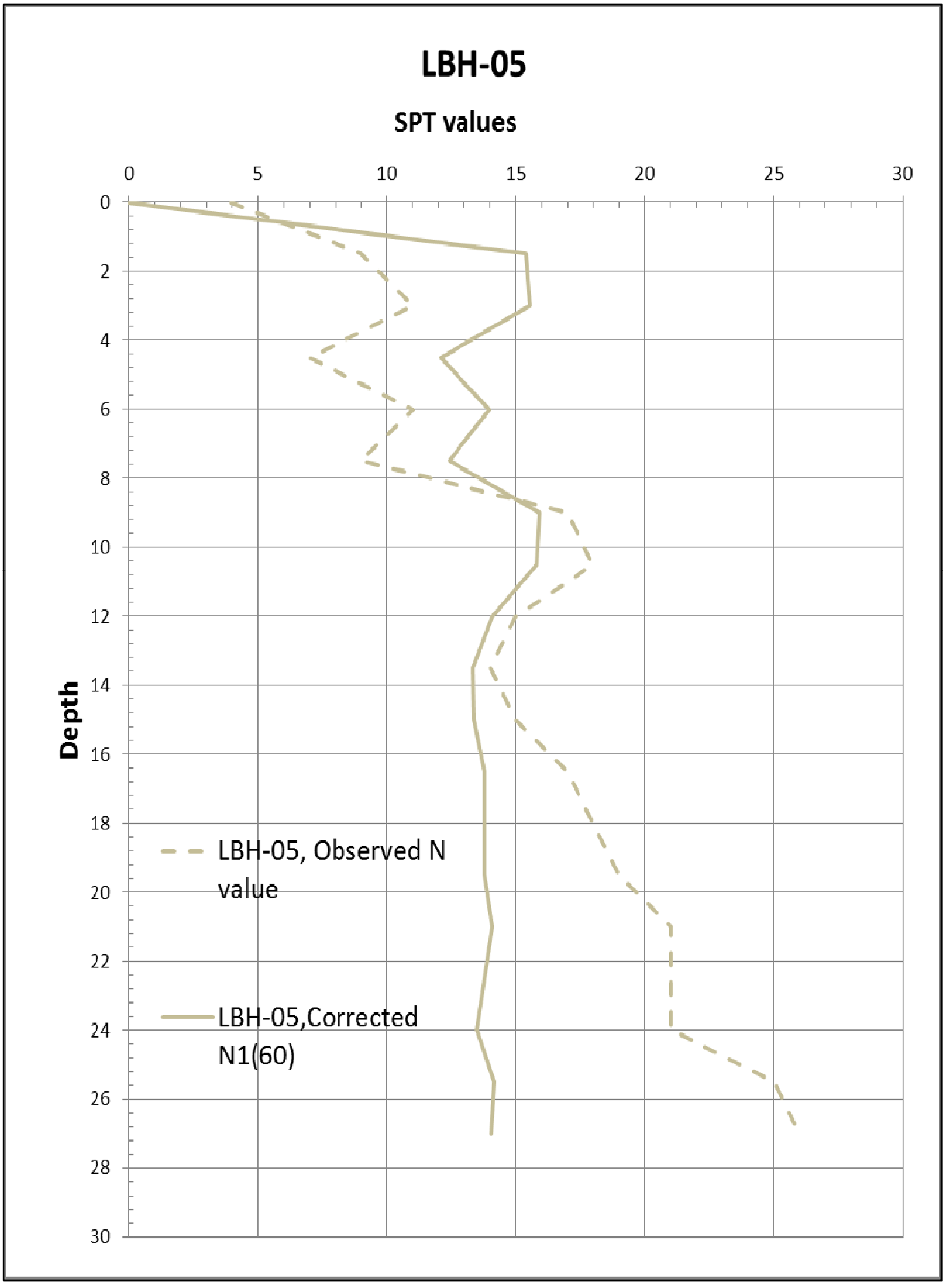





**Annexure 15.3**
**N Value profile**

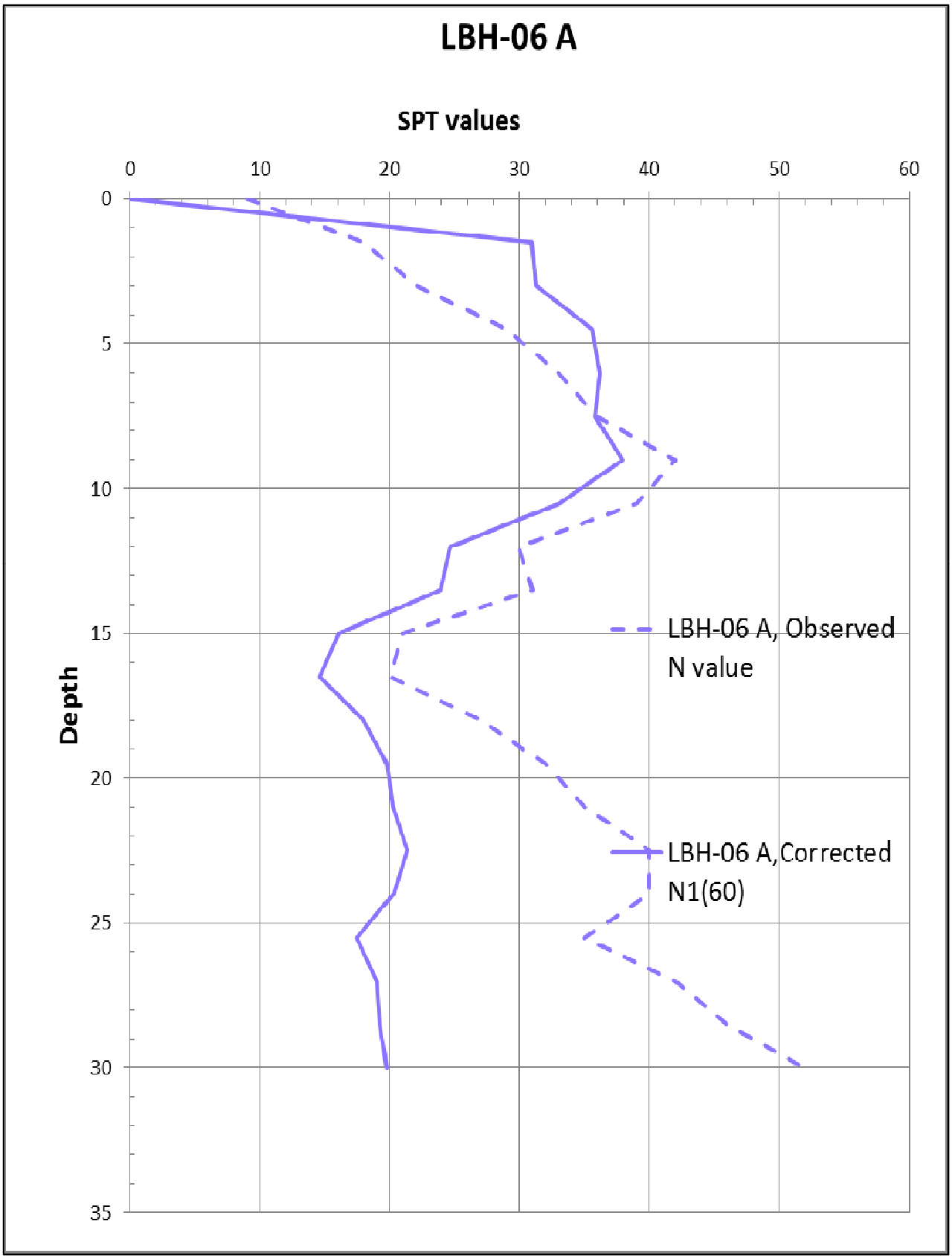

LBH-03
SPT values
0
5
10
15
20
25
Depth
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
LBH-03, Observed N value
LBH-03,Corrected N1(60)

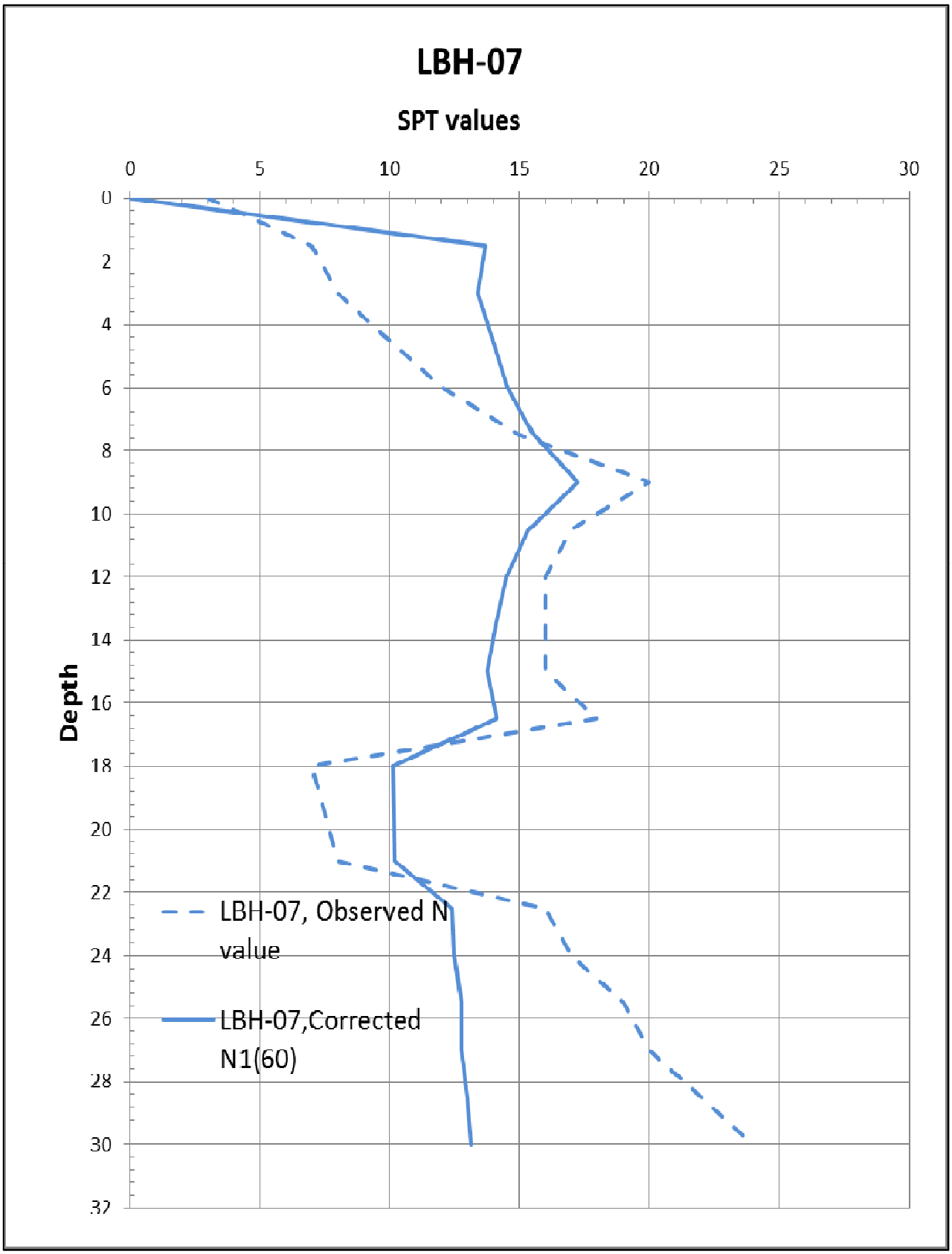

MBH-04
SPT values
0
10
20
30
40
50
60
Depth
0
5
10
15
20
25
30
35
40
45
50
MBH-04, Observed N value
MBH-04,Corrected N1(60)

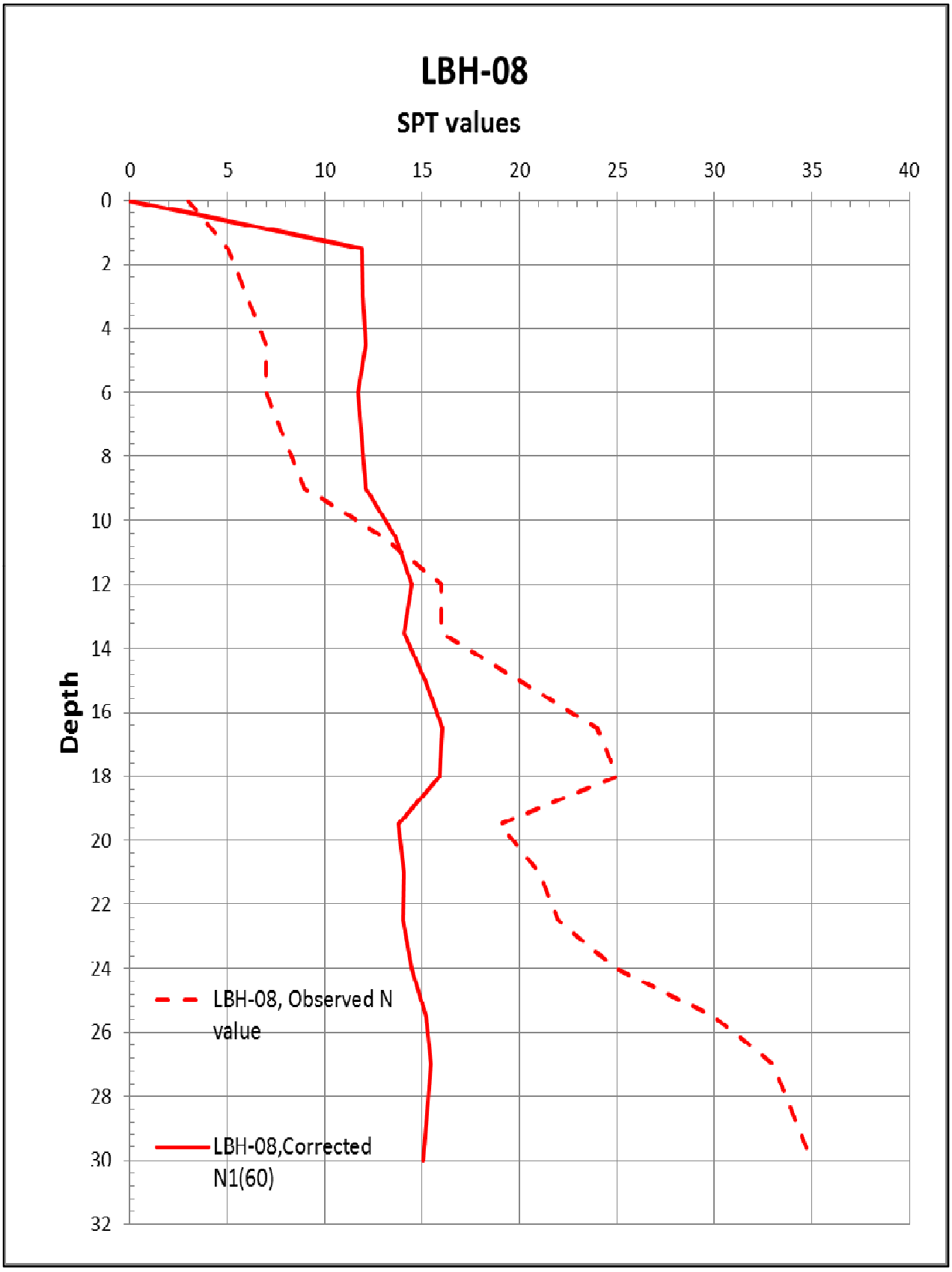


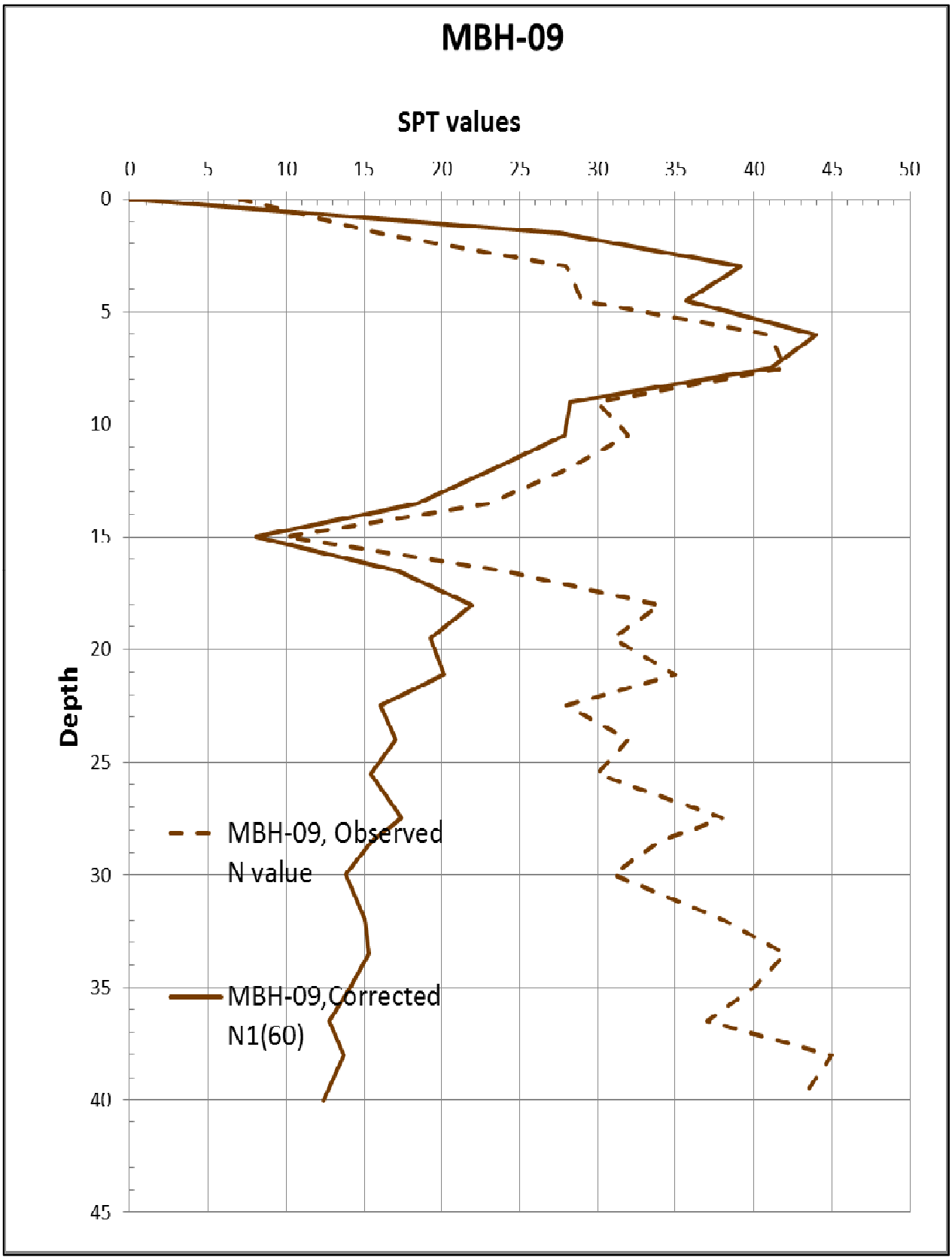


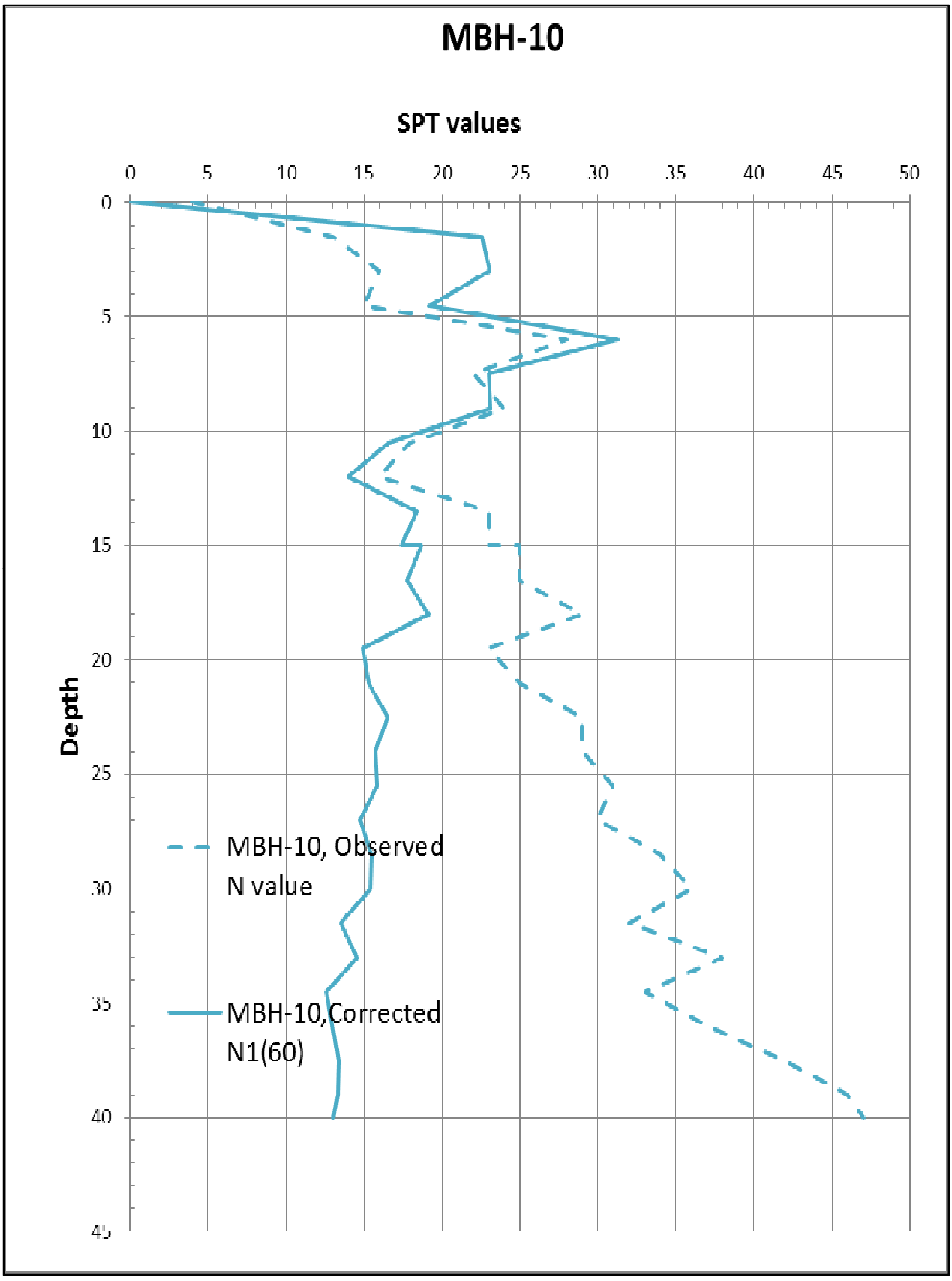

**Annexure 15.3**
**N Value profile**

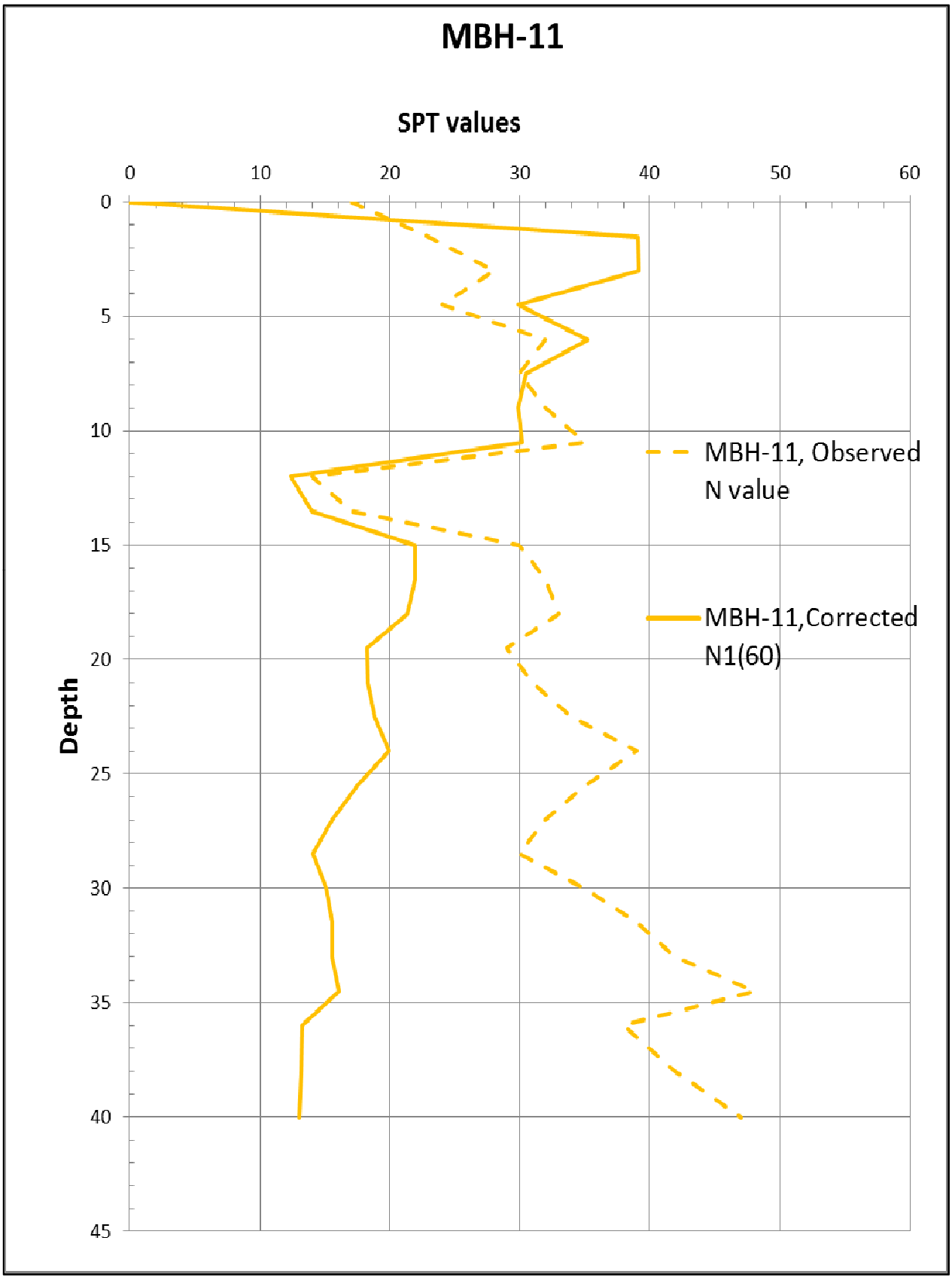

LBH-06 A
SPT values
0
10
20
30
40
50
60
0
5
10
15
20
25
30
35
Depth
LBH-06 A, Observed N value
LBH-06 A, Corrected N1(60)

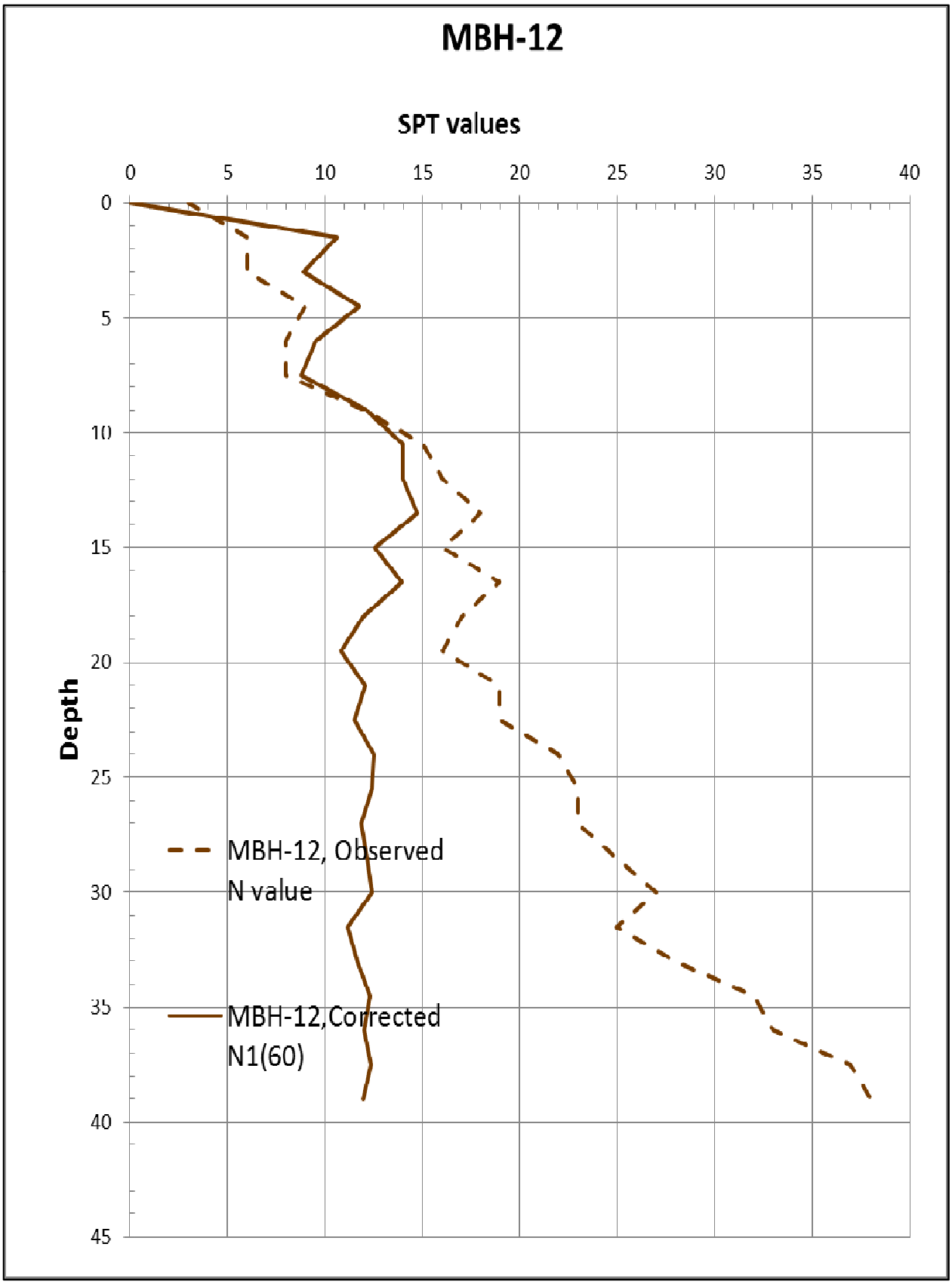

LBH-07
SPT values
0
5
10
15
20
25
30
Depth
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
37
LBH-07, Observed N value
LBH-07,Corrected N1(60)

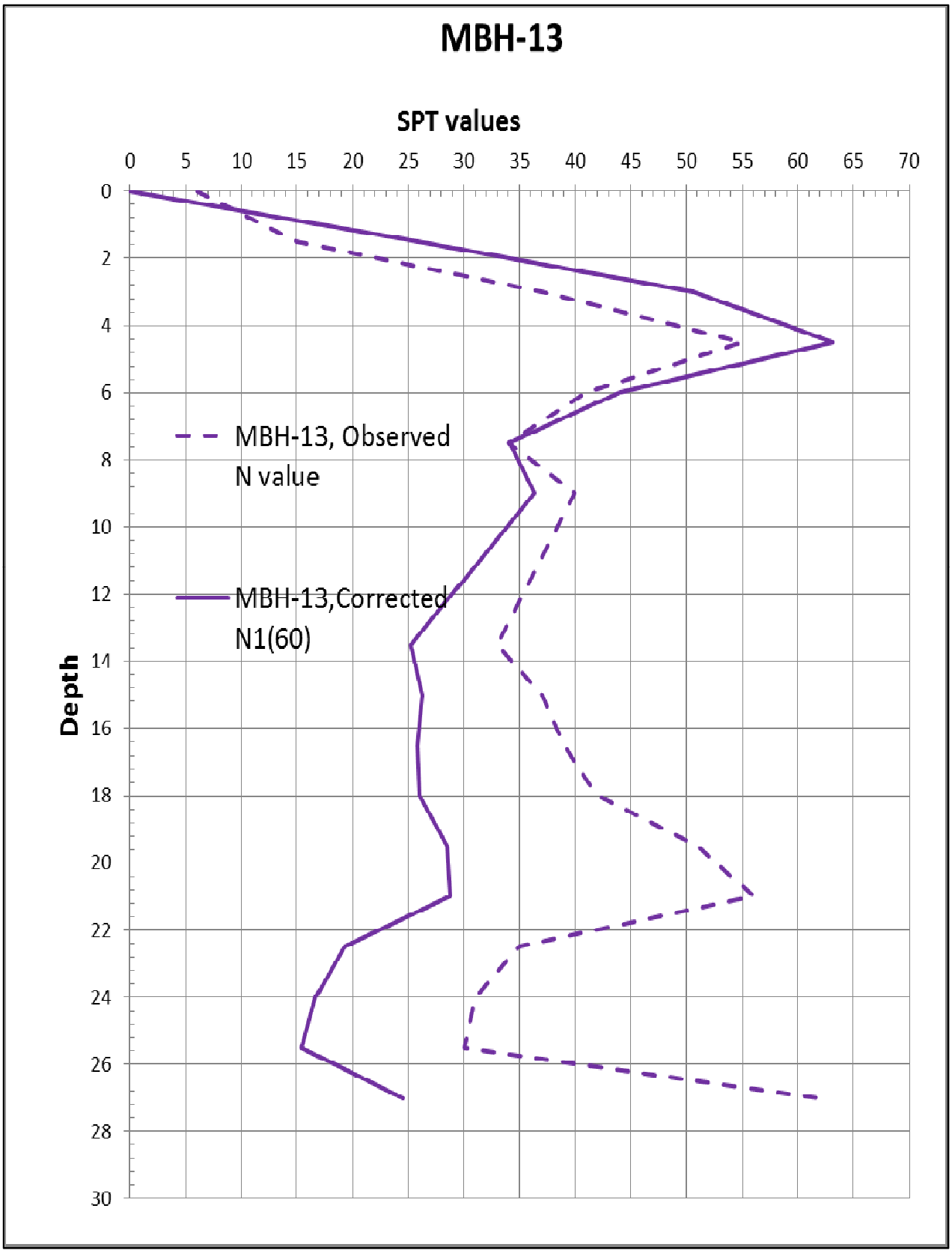

LBH-08
SPT values
0
5
10
15
20
25
30
35
40
Depth
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
LBH-08, Observed N value
LBH-08,Corrected N1(60)

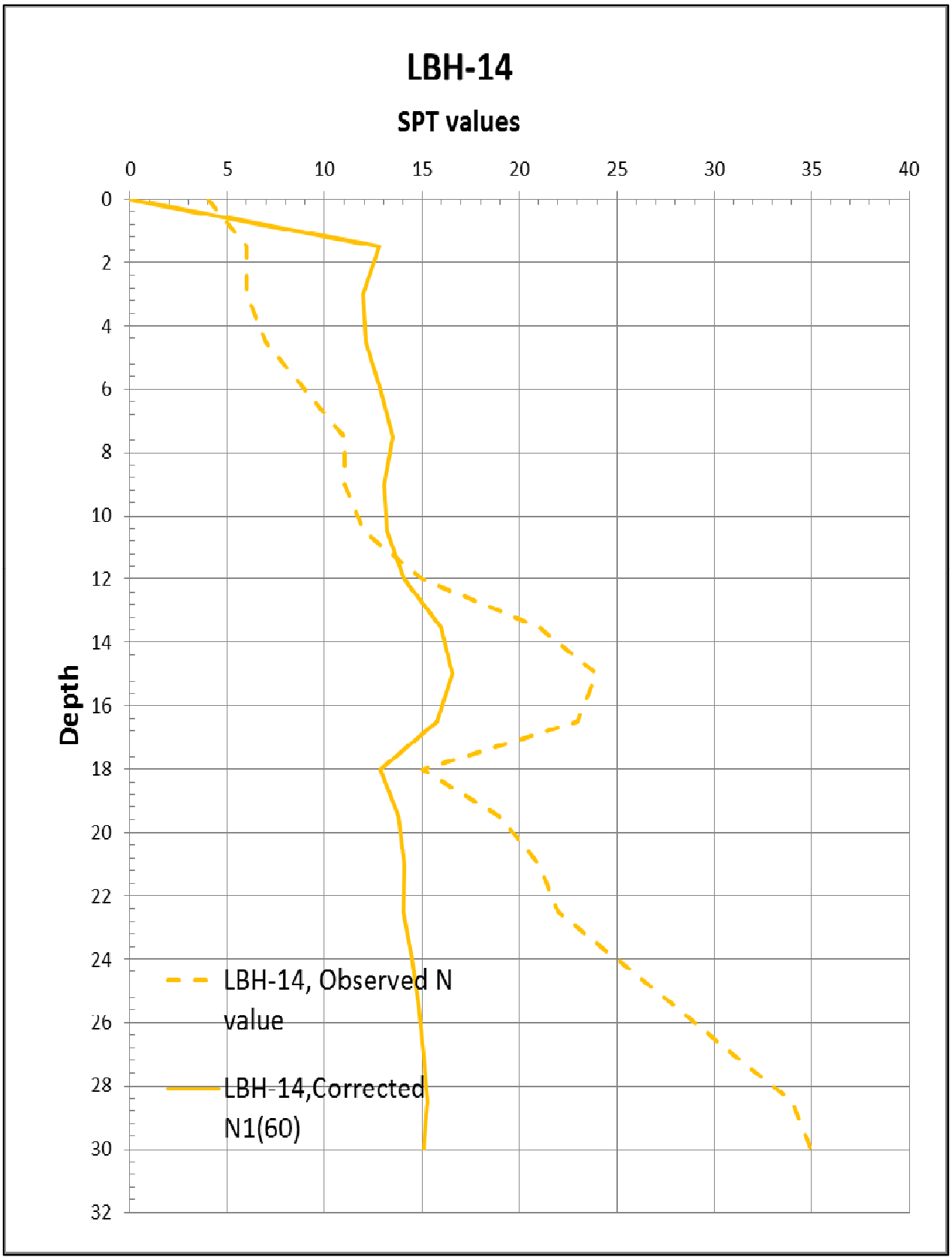

MBH-09
SPT values
0
5
10
15
20
25
30
35
40
45
50
Depth
MBH-09, Observed N value
MBH-09,Corrected N1(60)

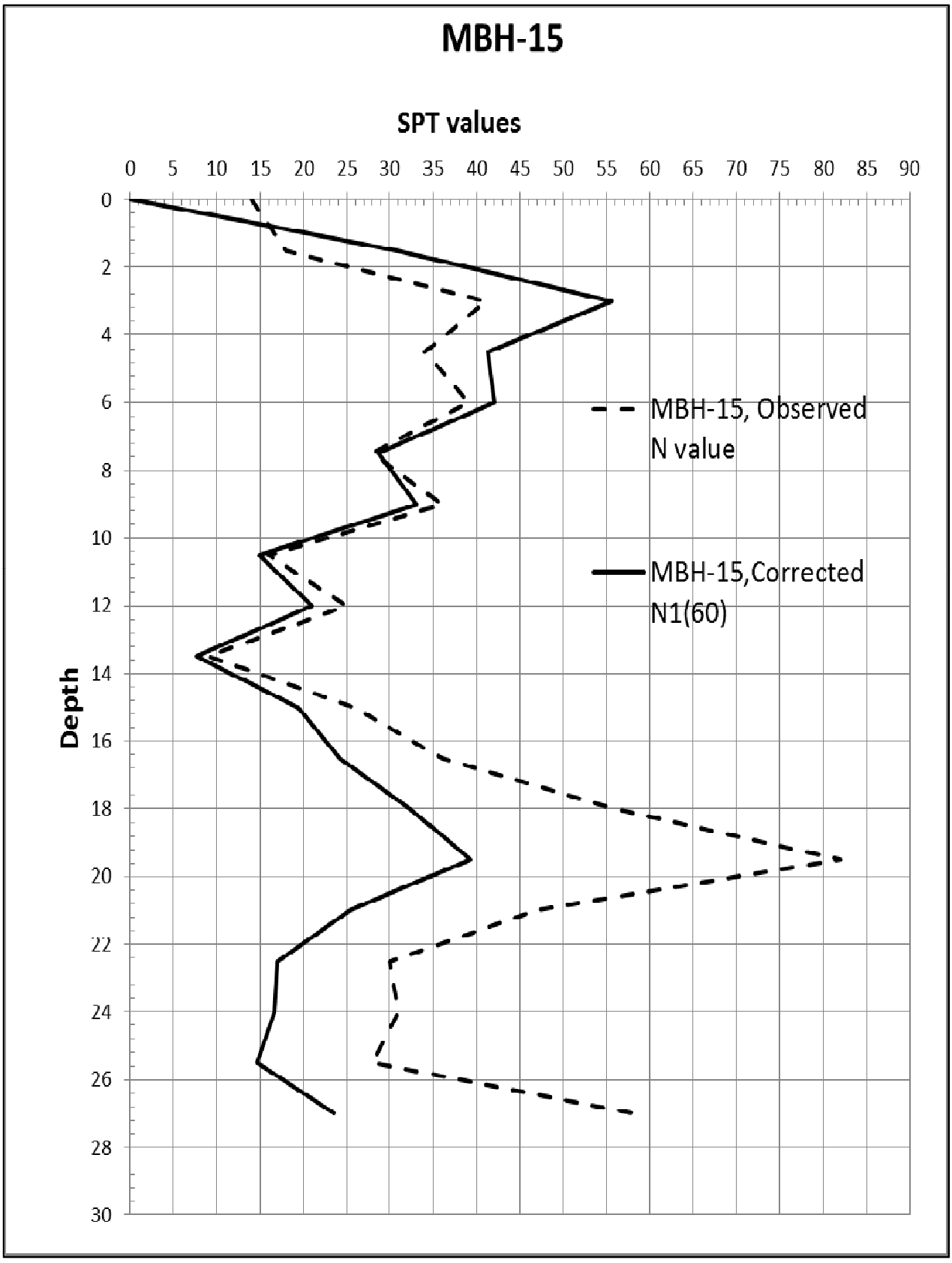

MBH-10
SPT values
0
5
10
15
20
25
30
35
40
45
50
Depth
MBH-10, Observed N value
MBH-10,Corrected N1(60)

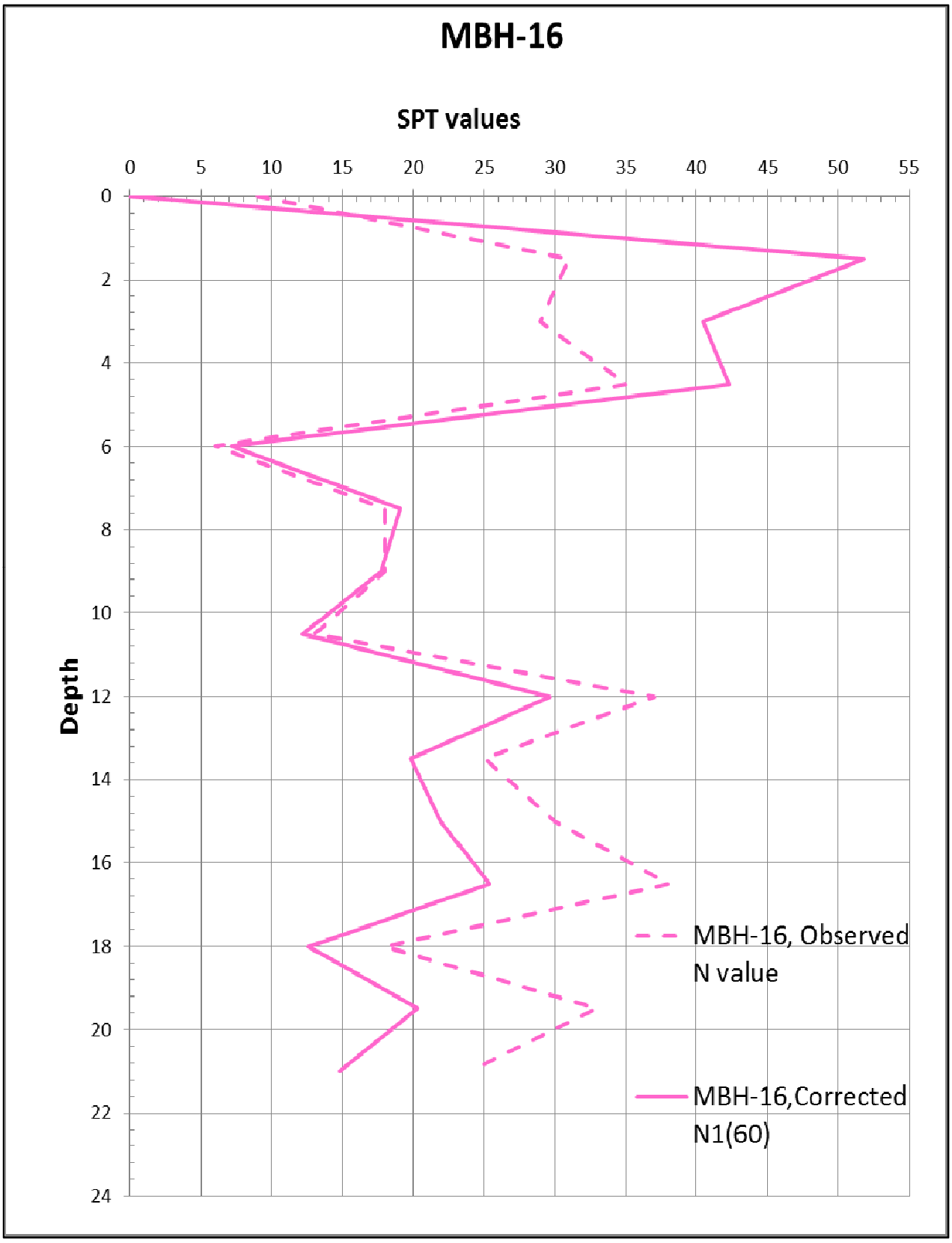

MBH-11
SPT values
0
10
20
30
40
50
60
Depth
0
5
10
15
20
25
30
35
40
45
MBH-11, Observed N value
MBH-11,Corrected N1(60)

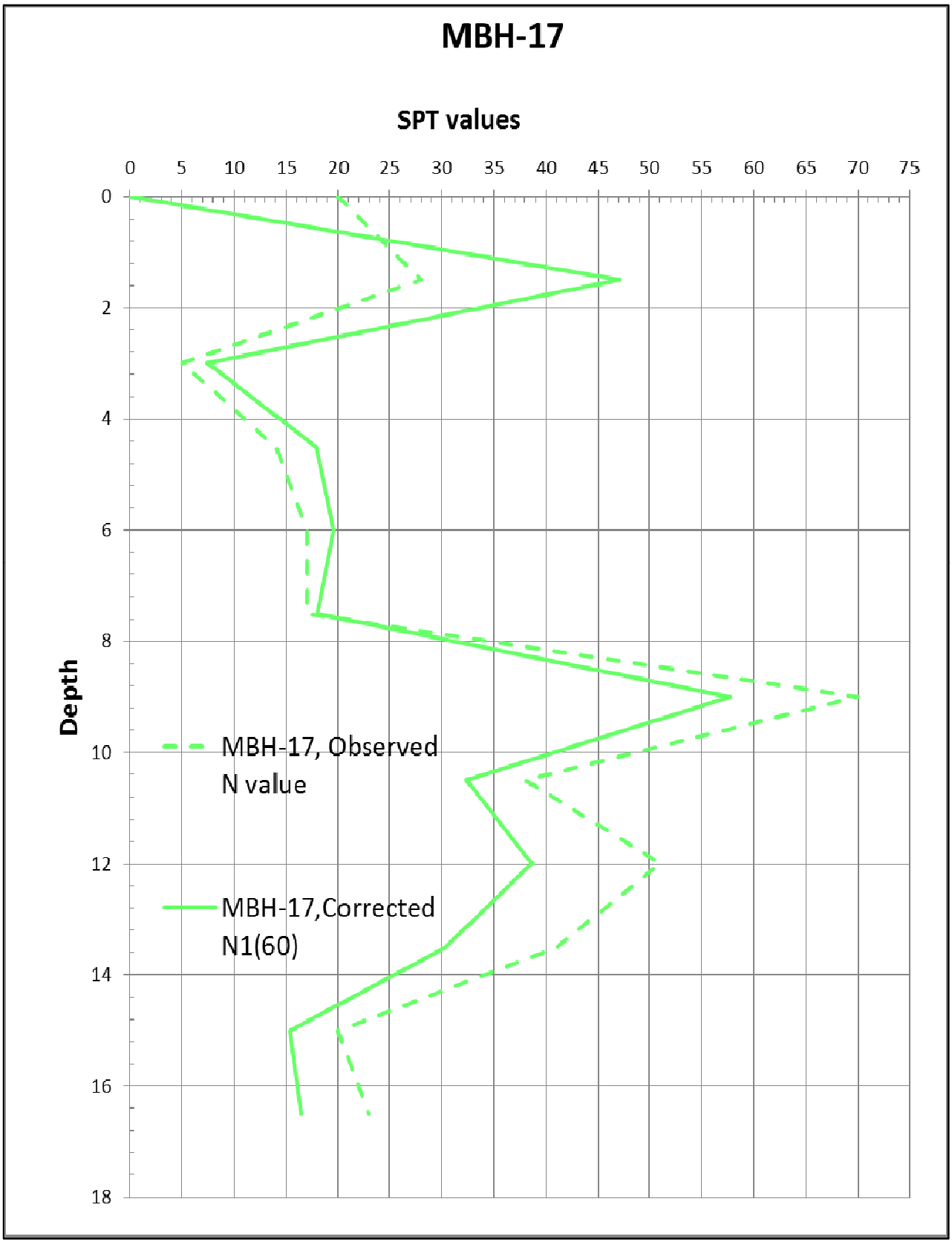

MBH-12
SPT values
0
5
10
15
20
25
30
35
40
Depth
0
5
10
15
20
25
30
35
40
45
MBH-12, Observed N value
MBH-12,Corrected N1(60)

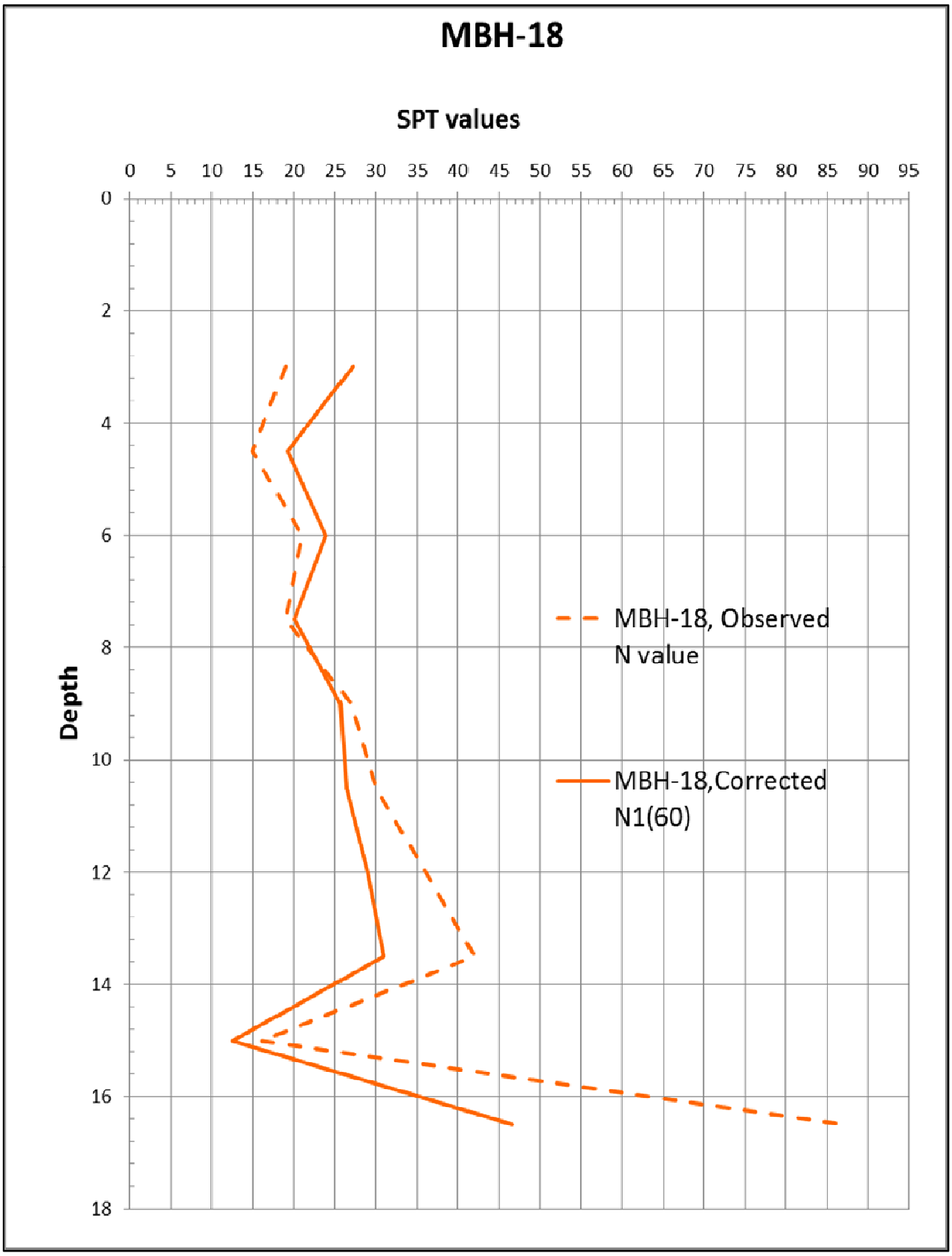

MBH-13
SPT values
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
Depth
MBH-13, Observed N value
MBH-13,Corrected N1(60)

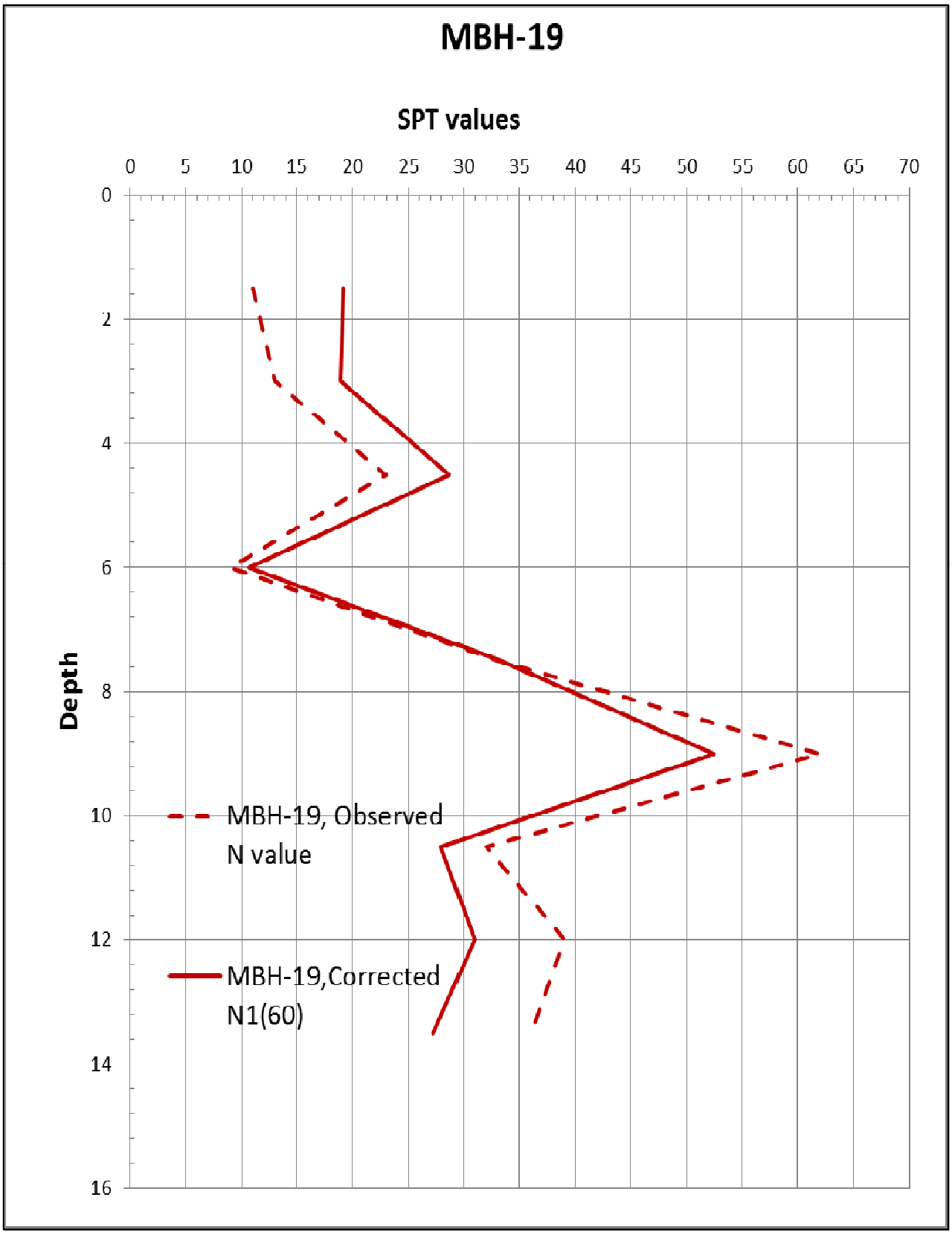

LBH-14
SPT values
0
5
10
15
20
25
30
35
40
Depth
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
LBH-14, Observed N value
LBH-14,Corrected N1(60)


MBH-15
SPT values
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
Depth
MBH-15, Observed N value
MBH-15,Corrected N1(60)


MBH-16
SPT values
0
5
10
15
20
25
30
35
40
45
50
55
Depth
0
2
4
6
8
10
12
14
16
18
20
22
24
MBH-16, Observed N value
MBH-16,Corrected N1(60)

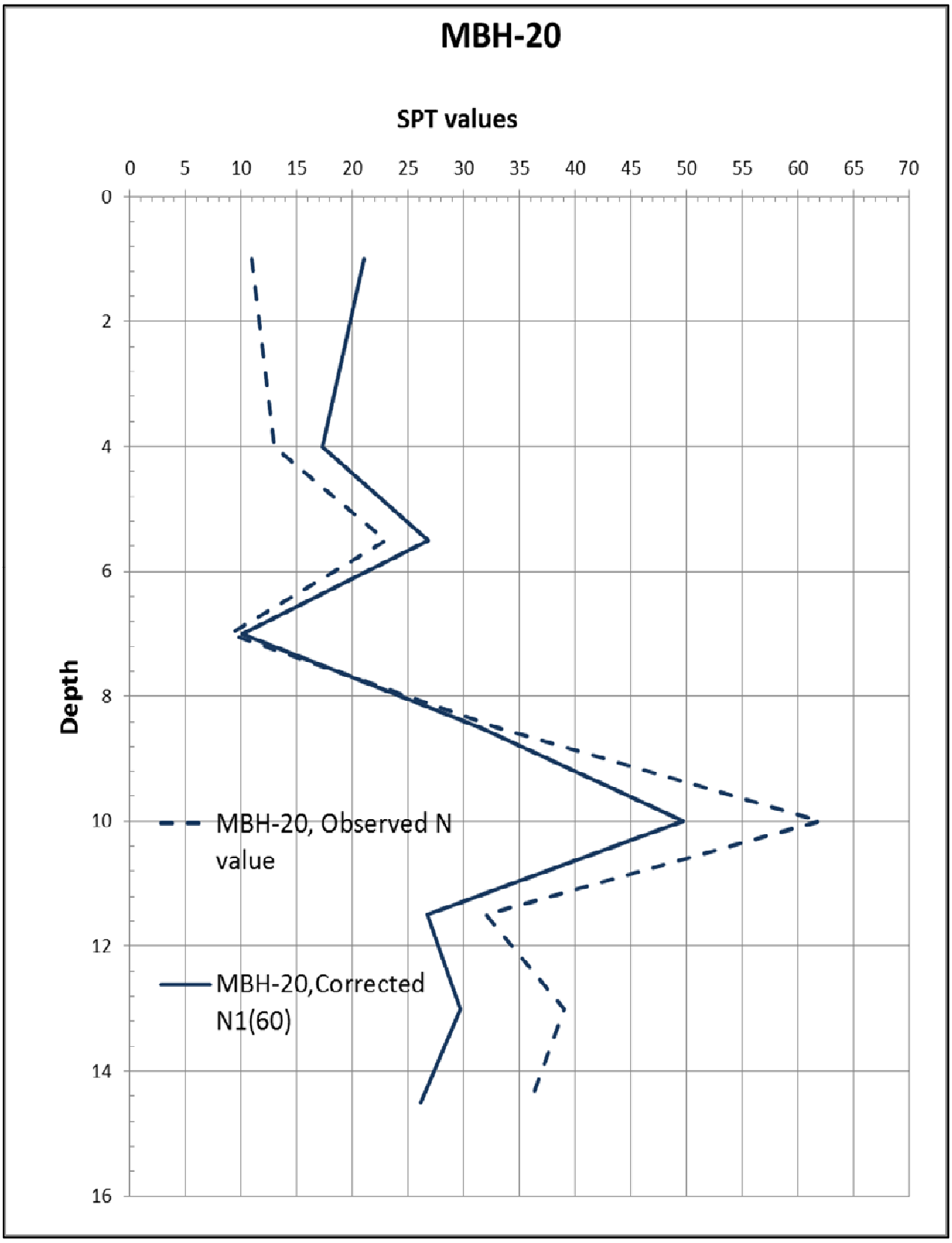

MBH-17
SPT values
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
0 2 4 6 8 10 12 14 16 18
Depth
MBH-17, Observed N value
MBH-17,Corrected N1(60)

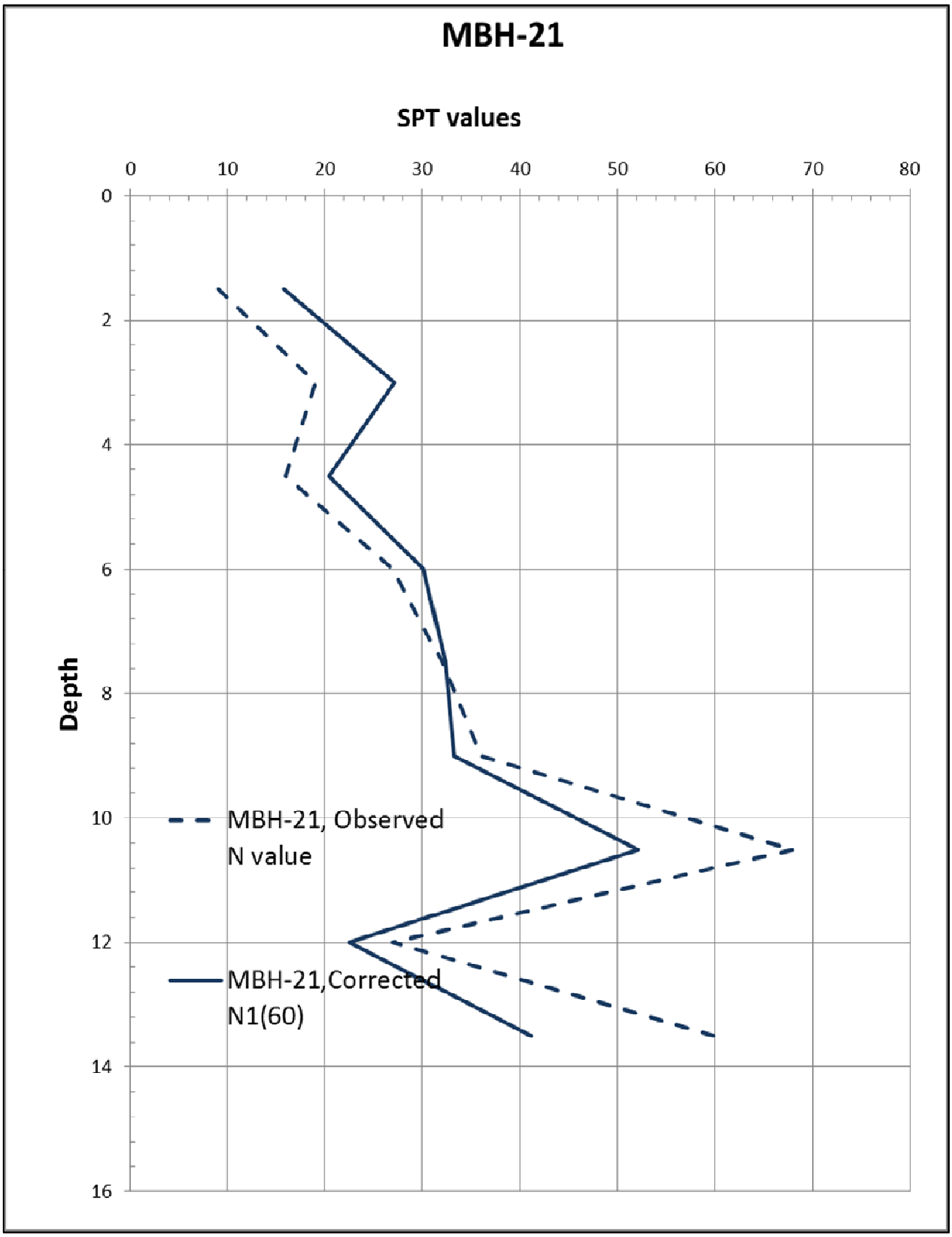

MBH-18
SPT values
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
0 2 4 6 8 10 12 14 16 18
Depth
MBH-18, Observed N value
MBH-18,Corrected N1(60)

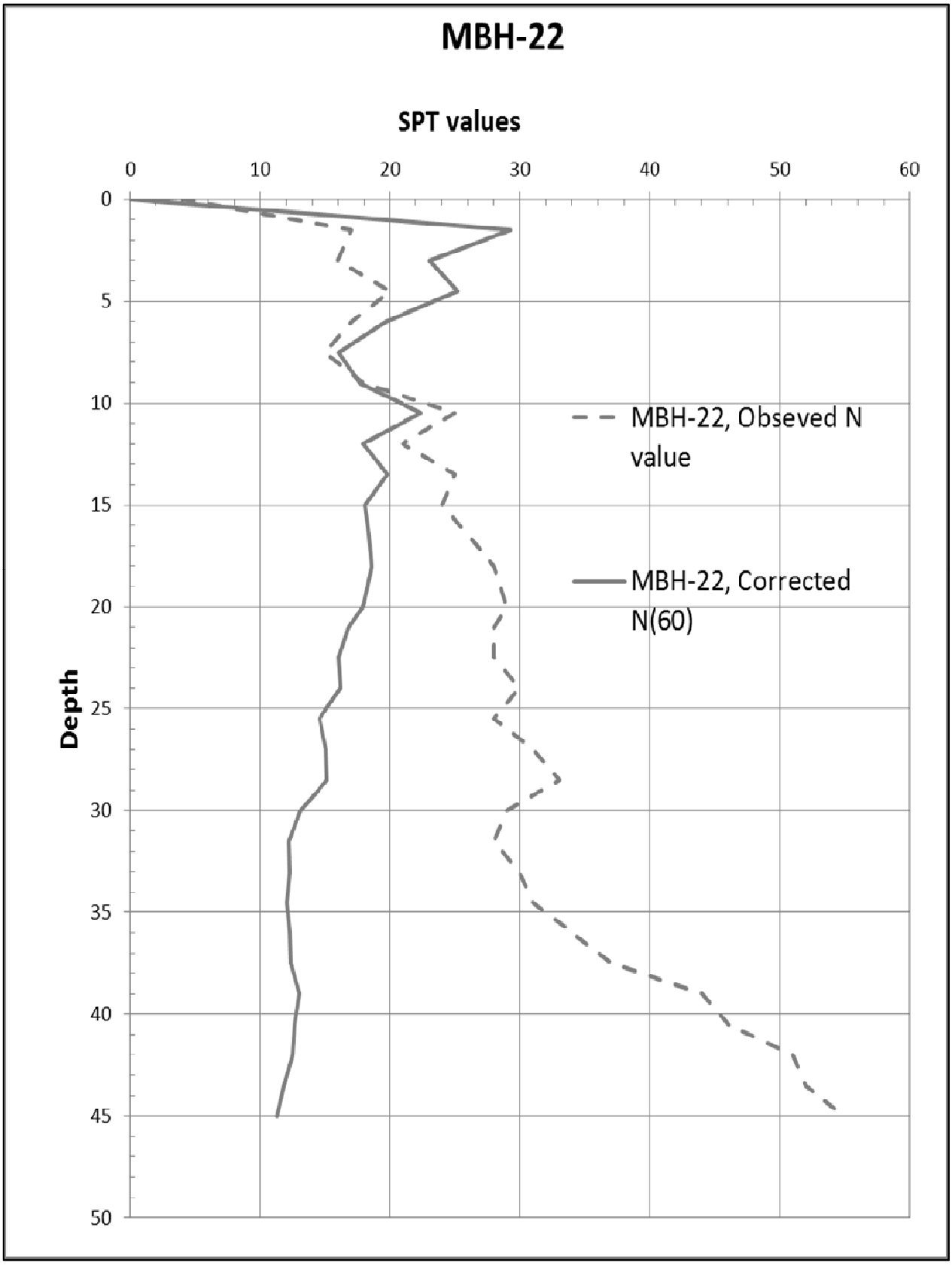


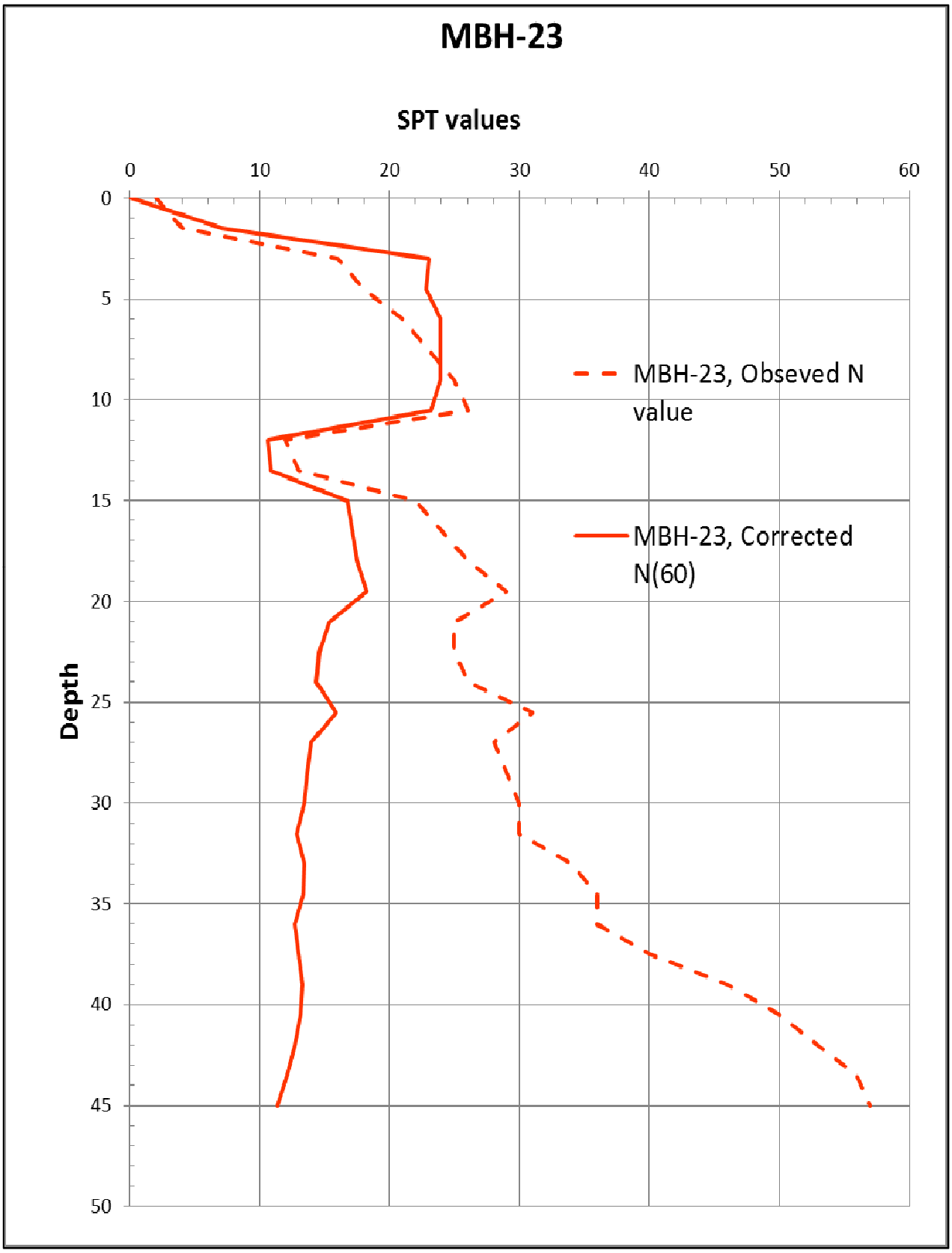


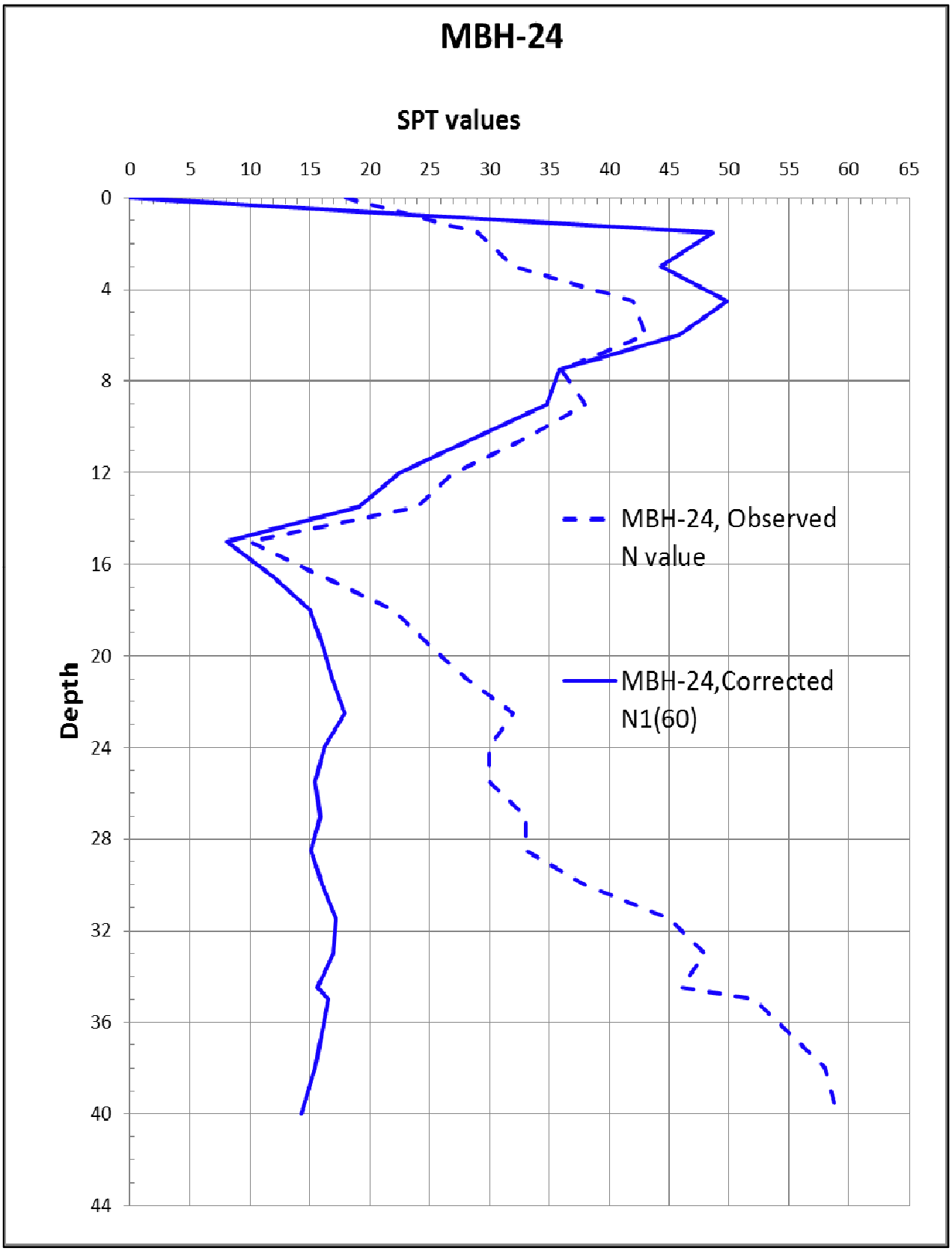

**Annexure 15.3**
**N Value profile**

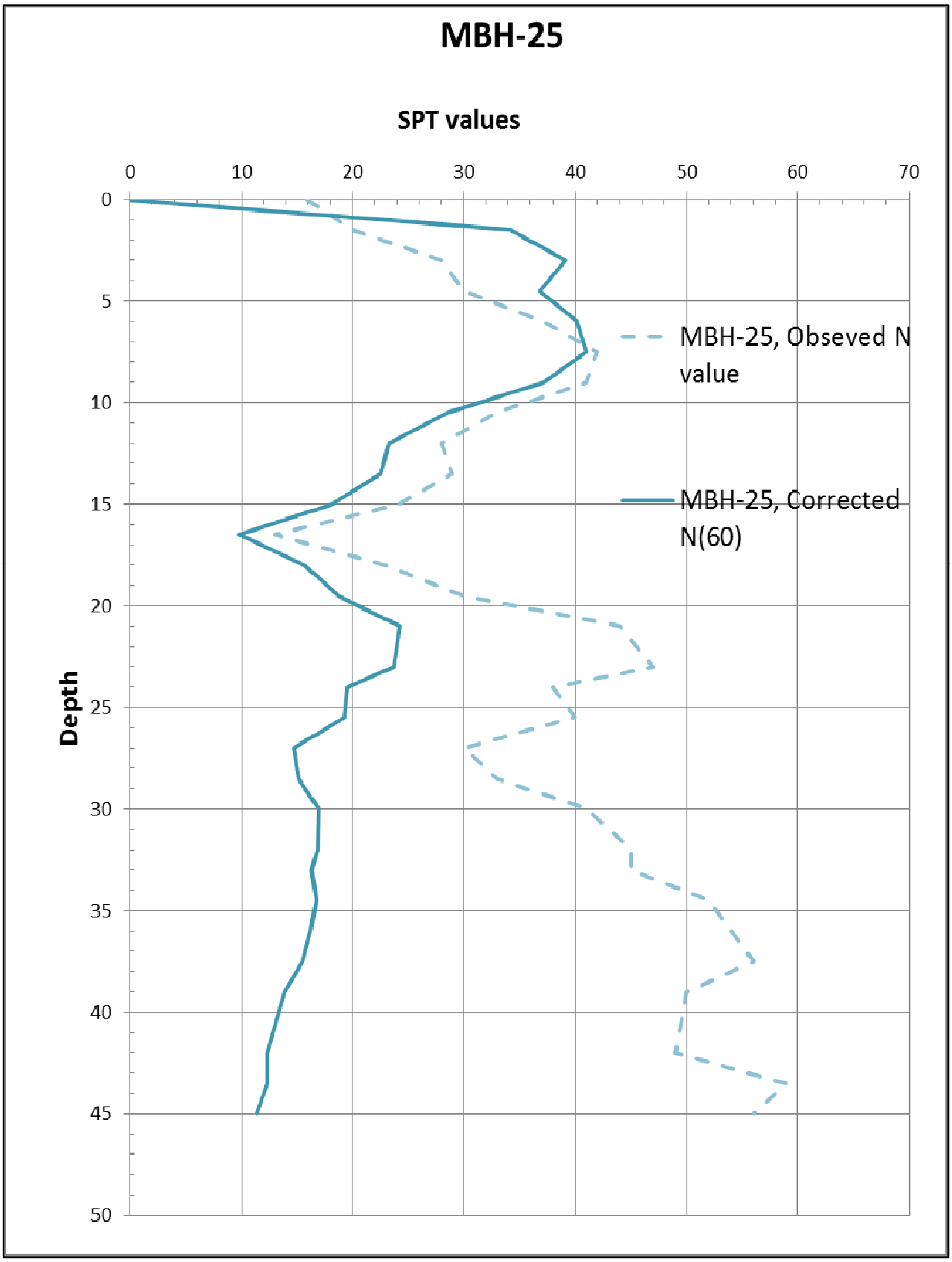

MBH-20
SPT values
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
0 2 4 6 8 10 12 14 16
Depth
MBH-20, Observed N value
MBH-20,Corrected N1(60)


MBH-21
SPT values
0
10
20
30
40
50
60
70
80
Depth
0
2
4
6
8
10
12
14
16
MBH-21, Observed N value
MBH-21,Corrected N1(60)


MBH-22
SPT values
0
10
20
30
40
50
60
Depth
0
5
10
15
20
25
30
35
40
45
50
MBH-22, Obseved N value
MBH-22, Corrected N(60)


MBH-23
SPT values
0
10
20
30
40
50
60
Depth
0
5
10
15
20
25
30
35
40
45
50
MBH-23, Obseved N value
MBH-23, Corrected N(60)


MBH-24
SPT values
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Depth
0
4
8
12
16
20
24
28
32
36
40
44
MBH-24, Observed N value
MBH-24,Corrected N1(60)






**Annexure 15.3**
**N Value profile**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-1 | 1.50-1.95 | SP-SM | | | | 18.2 | 18.85 | 8.79 | 15.95 | 2.61 | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | | | | |
| SPT-2 | 3.00-3.45 | | | | | 17.0 | 17.86 | 7.80 | 15.27 | 2.63 | | | | | | DST | | | 0.91 | 26.1 | | | | | | | | | | | | |
| SPT-3 | 4.50-4.95 | | | | | 21.0 | 18.90 | 8.84 | 15.63 | 2.59 | | | | | | DST | | | 1.28 | 25.1 | | | | | | | | | | | | |
| SPT-4 | 6.00-6.45 | SP | | | | 19.2 | 17.67 | 7.61 | 14.82 | 2.64 | 0 | 98 | <--> | <--> | 2 | | | | | | | | | | | | | | | | | | |
| SPT-5 | 7.50-7.95 | SP | | | | 17.9 | 18.42 | 8.36 | 15.62 | 2.63 | 0 | 98 | <--> | <--> | 2 | | | | | | | | | | | | | | | | | | |
| SPT-6 | 9.00-9.45 | SP | | | | 25.9 | 16.27 | 6.21 | 12.93 | 2.64 | 0 | 96 | <--> | <--> | 4 | | | | | | | | | | | | | | | | | | |
| SPT-7 | 10.50-10.95 | | | | | 23.8 | 18.45 | 8.39 | 14.90 | 2.66 | | | | | | DST | | | 1.66 | 24.7 | | | | | | | | | | | | |
| SPT-8 | 12.00-12.45 | | | | | 18.8 | 16.70 | 6.64 | 14.05 | 2.65 | | | | | | DST | | | 1.16 | 24.3 | | | | | | | | | | | | |
| SPT-9 | 13.50-13.95 | SP-SM | | | | 20.8 | 16.19 | 6.13 | 13.40 | 2.64 | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | 7.61 | 0.60 | 1.00 | 2200 | 12390 |
| SPT-10 | 15.00-15.45 | SC-SM | | | | 15.6 | 20.09 | 10.03 | 17.38 | 2.64 | 0 | 76 | 16 | 8 | 24 | | | | | | | | | | | | | | | | | | |
| SPT-11 | 16.50-16.95 | | | | | 13.8 | 19.01 | 8.95 | 16.70 | 2.58 | | | | | | DST | | | 2.74 | 23.2 | | | | | | | | | | | | |
| SPT-12 | 18.00-18.45 | | | | | 18.7 | 21.10 | 11.04 | 17.78 | 2.59 | | | | | | DST | | | 3.17 | 23.0 | | | | | | | | | | | | |
| SPT-13 | 19.50-19.95 | SP-SM | | | | 19.3 | 18.91 | 8.85 | 15.85 | 2.61 | 0 | 92 | <--> | <--> | 8 | | | | | | | | | | | | | | | | | | |
| SPT-14 | 21.00-21.45 | SP-SM | | | | 17.5 | 17.64 | 7.58 | 15.02 | 2.61 | 0 | 92 | <--> | <--> | 8 | | | | | | | | | | | | | | | | | | |
| SPT-15 | 22.50-22.95 | | | | | 17.9 | 17.86 | 7.80 | 15.15 | 2.62 | | | | | | DST | | | 1.04 | 25.0 | | | | | | | | | | | | |
| SPT-16 | 24.00-24.45 | SP-SM | | | | 13.3 | 17.60 | 7.54 | 15.53 | 2.60 | 0 | 94 | <--> | <--> | 6 | | | | | | | | | | | | | | | | | | |
| SPT-17 | 25.50-25.95 | | | | | 12.8 | 17.74 | 7.68 | 15.73 | 2.61 | | | | | | DST | | | 0.99 | 25.6 | | | | | | | | | | | | |
| SPT-18 | 27.00-27.45 | | | | | 13.7 | 16.84 | 6.78 | 14.81 | 2.63 | | | | | | DST | | | 0.66 | 25.2 | | | | | | | | | | | | |
| SPT-19 | 28.50-28.95 | SP-SM | | | | 12.5 | 16.35 | 6.29 | 14.54 | 2.64 | 0 | 94 | <--> | <--> | 6 | | | | | | | | | | | | | | | | | | |
| SPT-20 | 30.00-30.45 | | | | | 9.7 | 15.36 | 5.30 | 14.00 | 2.63 | | | | | | DST | | | 0.75 | 25.4 | | | | | | | | | | | | |
| **END OF BOREHOLE** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS : Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

\# : Decayed Wood

**Failure Type**

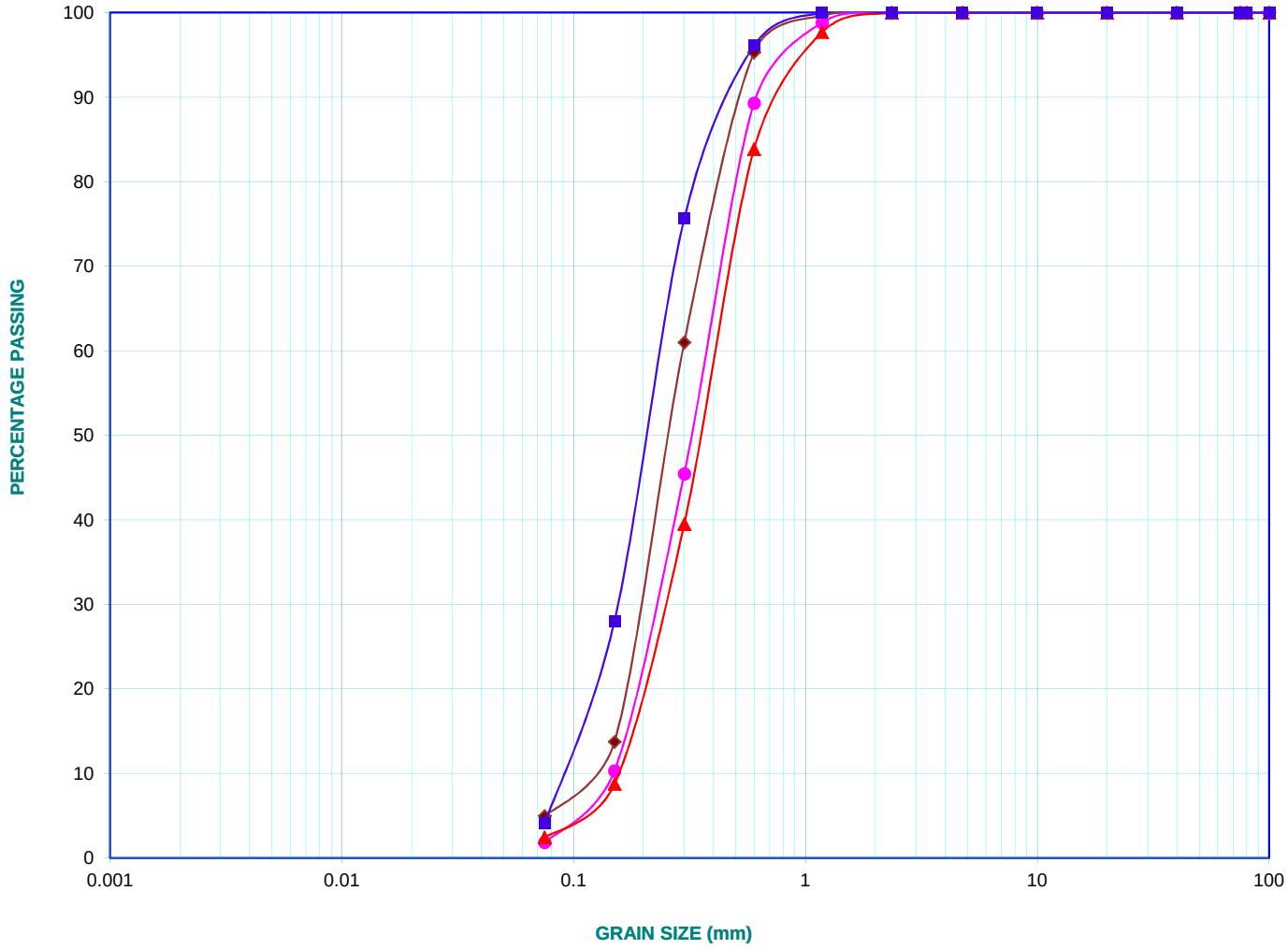
A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha**
Project Code : **CM 19 01 03**
Borehole No. : **LBH-01**

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: LBH-01** |
| **Date :** | **30-May-19** |

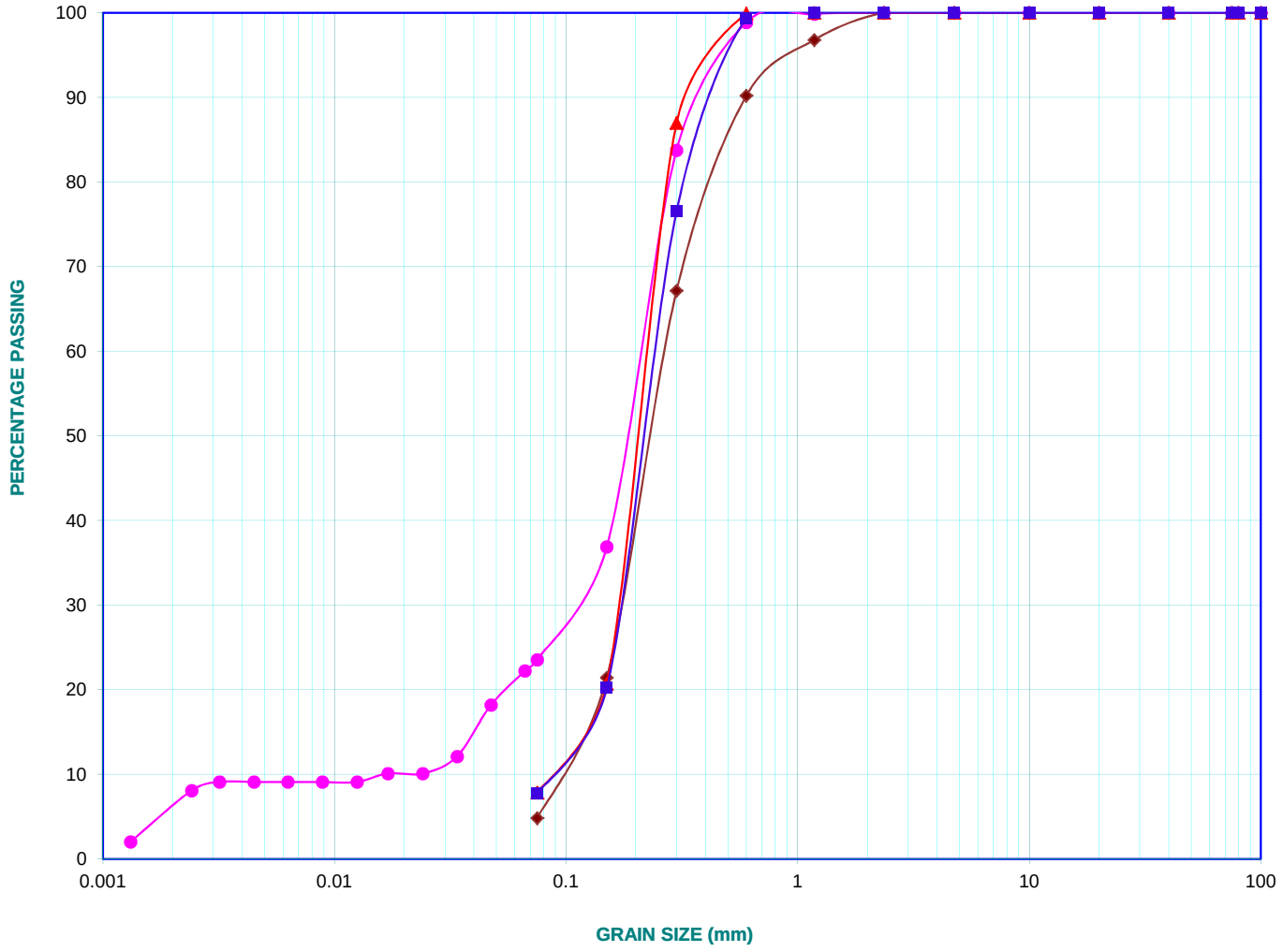
| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | LBH-01 | LBH-01 | LBH-01 | LBH-01 | | | | | | | | |
| **Depth (m)** | 1.50-1.95 | 6.00-6.45 | 7.50-7.95 | 9.00-9.45 | | | | | | | | |
| **Sample Type** | SPT-1 | SPT-4 | SPT-5 | SPT-6 | | | | | | | | |
| **Classification** | SP-SM | SP | SP | SP | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 95 | 98 | 98 | 96 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 5 | 2 | 2 | 4 | | | | | | | | |
| **D60 mm** | 0.300 | 0.380 | 0.410 | 0.240 | | | | | | | | |
| **D30 mm** | 0.200 | 0.250 | 0.270 | 0.160 | | | | | | | | |
| **D10 mm** | 0.130 | 0.150 | 0.160 | 0.090 | | | | | | | | |
| **Cu** | 2.31 | 2.53 | 2.56 | 2.67 | | | | | | | | |
| **Cc** | 1.03 | 1.10 | 1.11 | 1.19 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

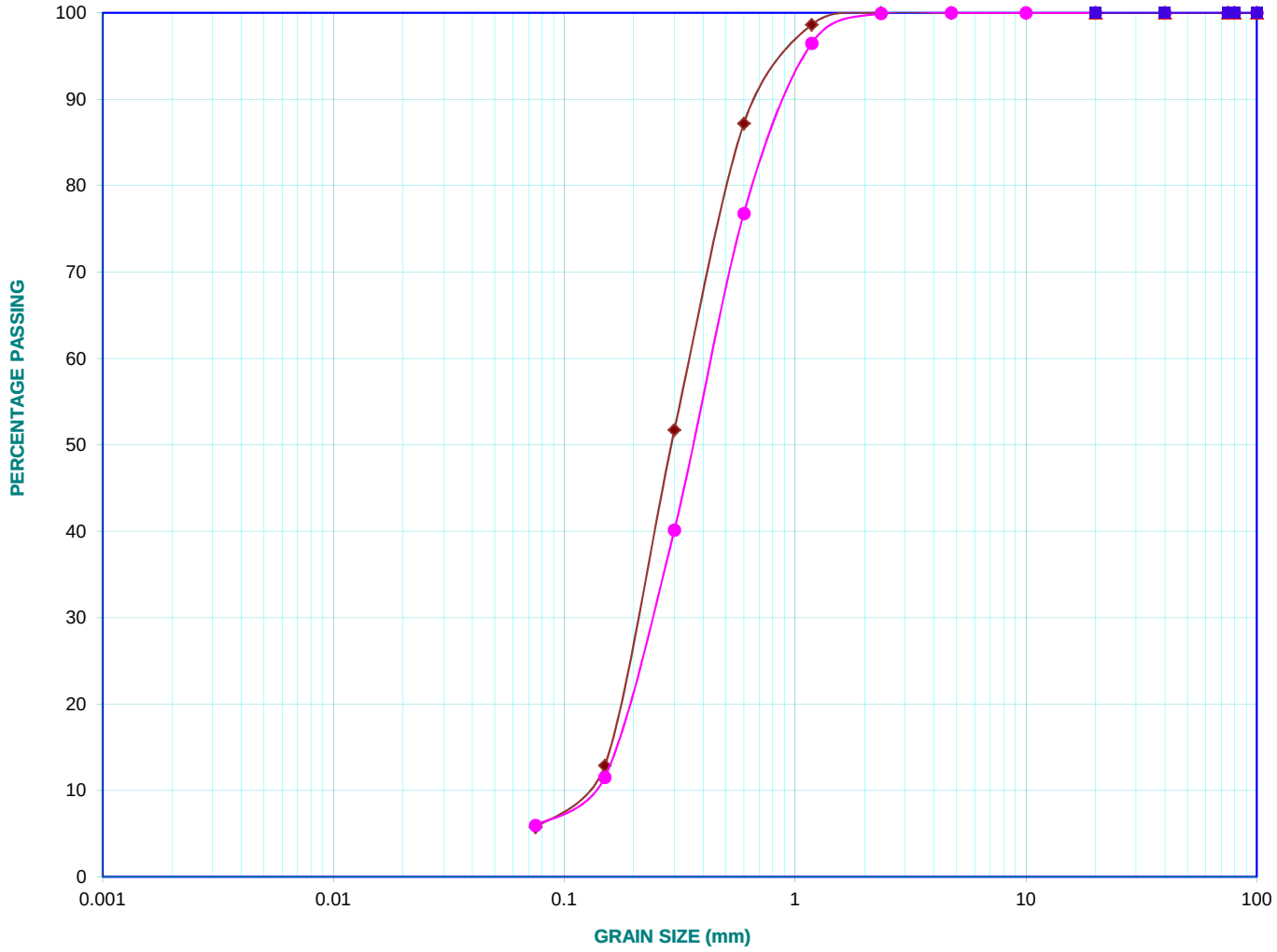
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | **Borehole No.** | **: LBH-01** | | | | | **Date :** | **30-May-19** | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | LBH-01 | LBH-01 | LBH-01 | LBH-01 | | | | | | | | |
| **Depth (m)** | 13.50-13.95 | 15.00-15.45 | 19.50-19.95 | 21.50-21.95 | | | | | | | | |
| **Sample Type** | SPT-9 | SPT-10 | SPT-13 | SPT-14 | | | | | | | | |
| **Classification** | SP-SM | SC-SM | SP-SM | SP-SM | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 95 | 76 | 92 | 92 | | | | | | | | |
| **Silt %** | <----> | 16 | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | 8 | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 5 | 24 | 8 | 8 | | | | | | | | |
| **D60 mm** | 0.280 | 0.210 | 0.220 | 0.250 | | | | | | | | |
| **D30 mm** | 0.180 | 0.120 | 0.180 | 0.180 | | | | | | | | |
| **D10 mm** | 0.100 | 0.024 | 0.090 | 0.090 | | | | | | | | |
| **Cu** | 2.80 | 8.75 | 2.44 | 2.78 | | | | | | | | |
| **Cc** | 1.16 | 2.86 | 1.64 | 1.44 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

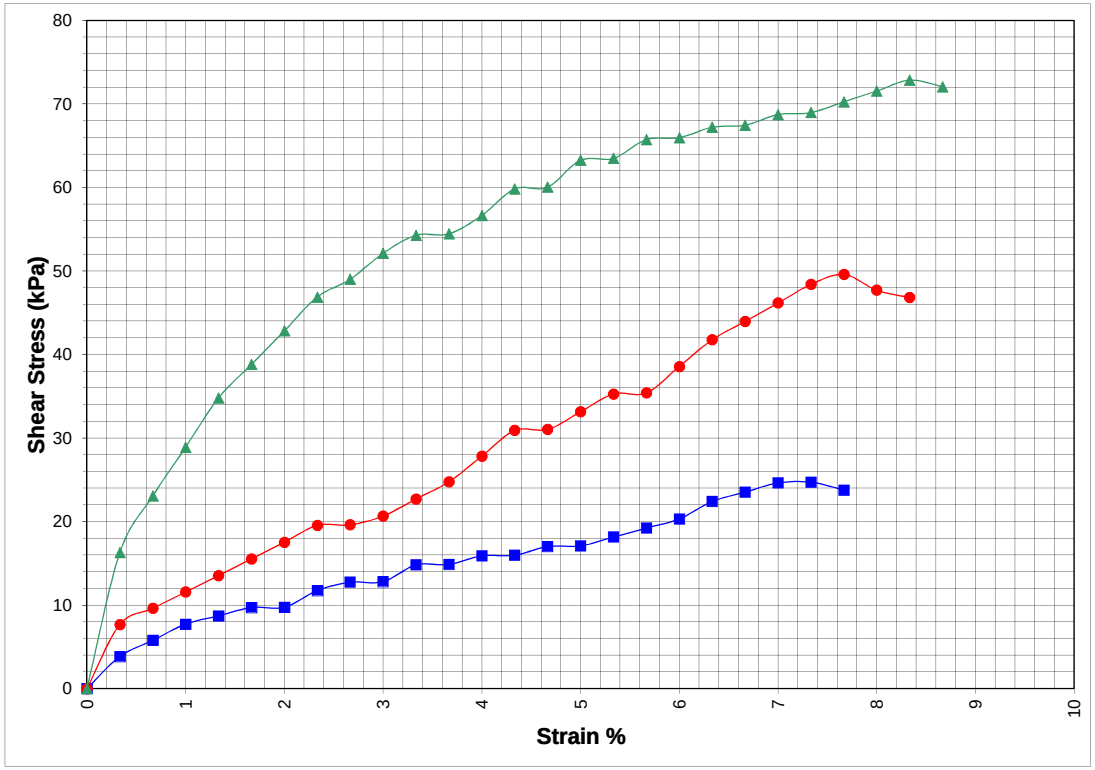
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | **Borehole No.** | | **: LBH-01** | | | | **Date :** | | **30-May-19** | |
| **Symbol** | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | LBH-01 | LBH-01 | | | | | | | | | | |
| **Depth (m)** | 24.00-24.45 | 28.50-28.95 | | | | | | | | | | |
| **Sample Type** | SPT-16 | SPT-19 | | | | | | | | | | |
| **Classification** | SP-SM | SP-SM | | | | | | | | | | |
| **Gravel %** | 0 | 0 | | | | | | | | | | |
| **Sand %** | 94 | 94 | | | | | | | | | | |
| **Silt %** | <----> | <----> | | | | | | | | | | |
| **Clay %** | <----> | <----> | | | | | | | | | | |
| **Fines % (Silt+Clay)** | 6 | 6 | | | | | | | | | | |
| **D60 mm** | 0.350 | 0.420 | | | | | | | | | | |
| **D30 mm** | 0.210 | 0.250 | | | | | | | | | | |
| **D10 mm** | 0.130 | 0.140 | | | | | | | | | | |
| **Cu** | 2.69 | 3.00 | | | | | | | | | | |
| **Cc** | 0.97 | 1.06 | | | | | | | | | | |
| **Liquid Limit %** | --- | --- | | | | | | | | | | |
| **Plastic Limit %** | --- | --- | | | | | | | | | | |
| **Plasticity Index** | --- | --- | | | | | | | | | | |

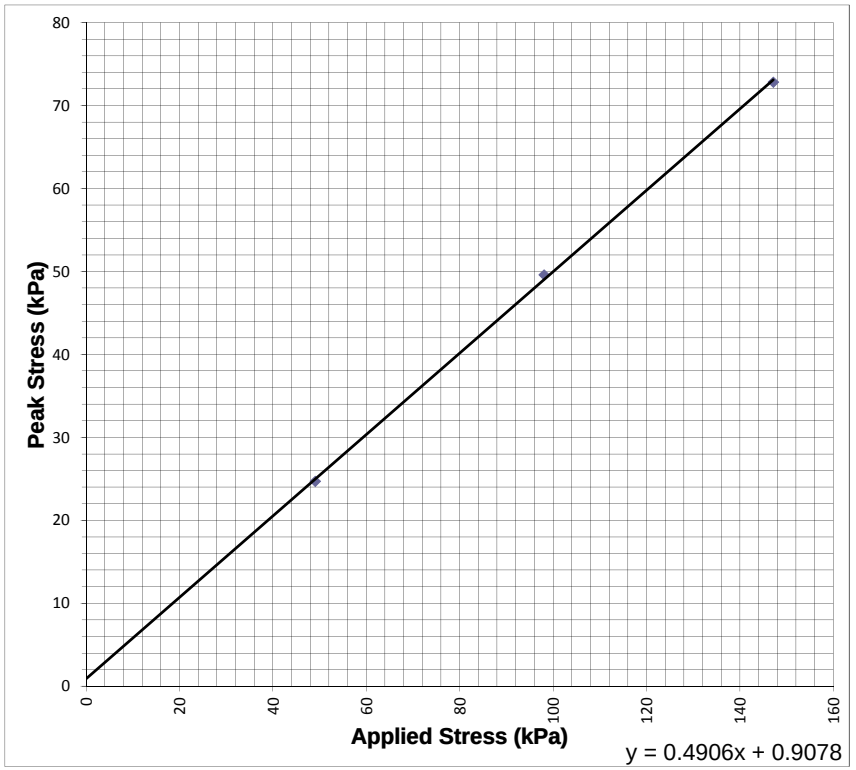



Checked By :

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 25 |
| | Stage 2 | 98 | 50 |
| | Stage 3 | 147 | 73 |

| | | |
|---|---|---|
| Angle of Friction | **26.1** | ° |
| Apparent Cohesion | **0.91** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

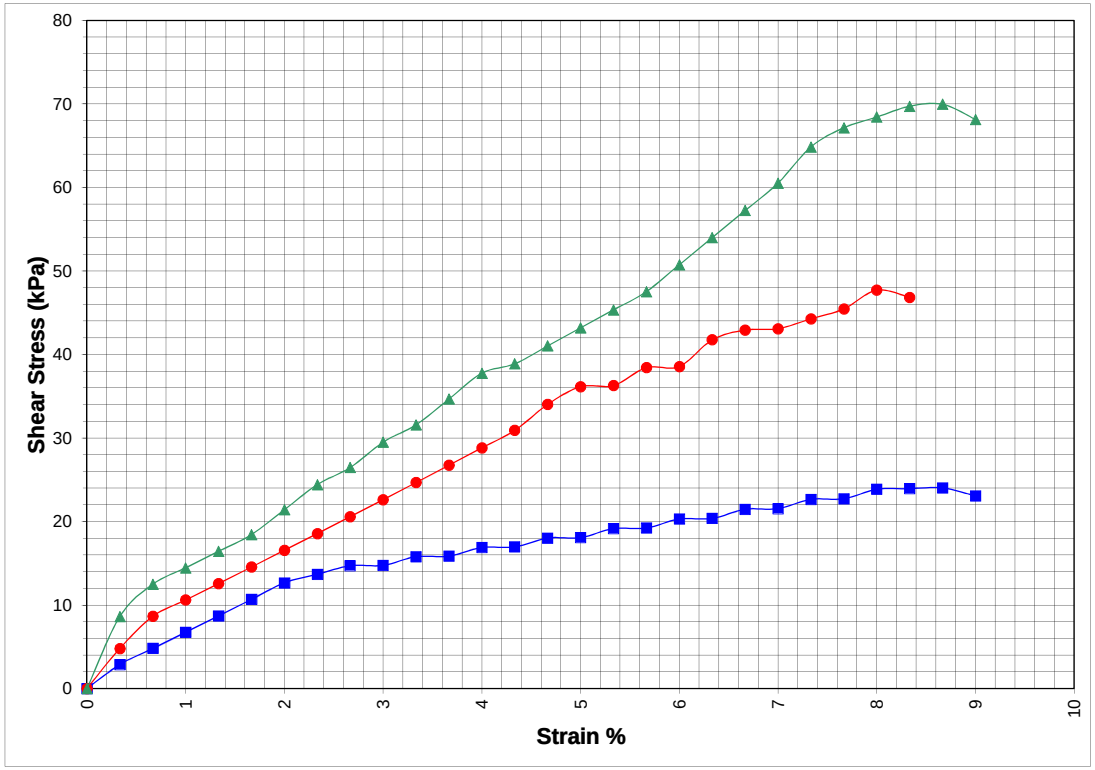
**Borehole: LBH-01**

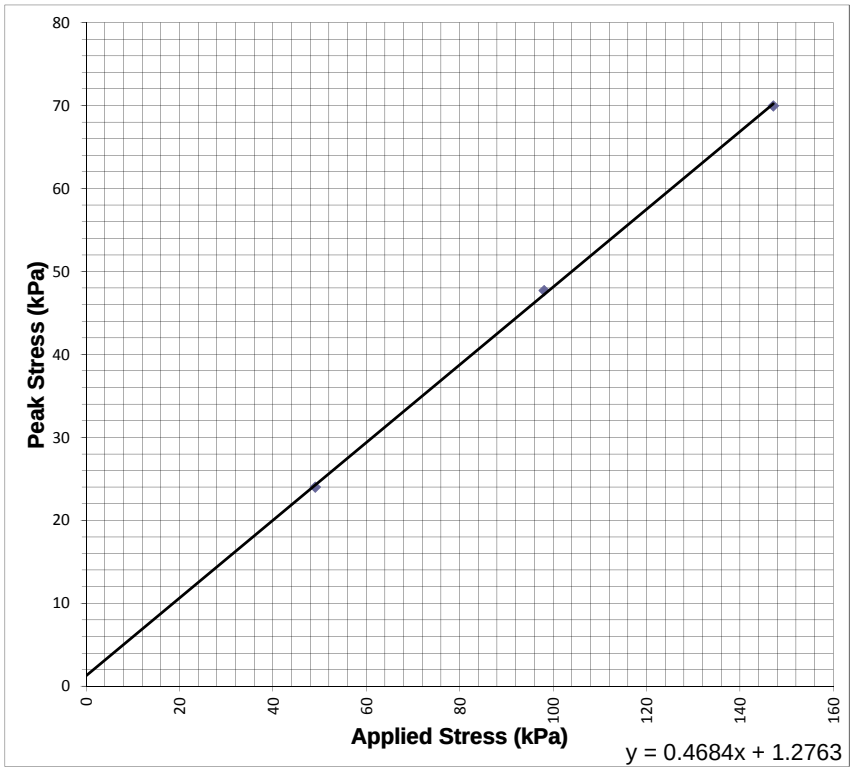
**Sample Type: SPT-02**

**Depth: 3.00-3.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 24 |
| | Stage 2 | 98 | 48 |
| | Stage 3 | 147 | 70 |

| | | |
|---|---|---|
| Angle of Friction | **25.1** | ° |
| Apparent Cohesion | **1.28** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

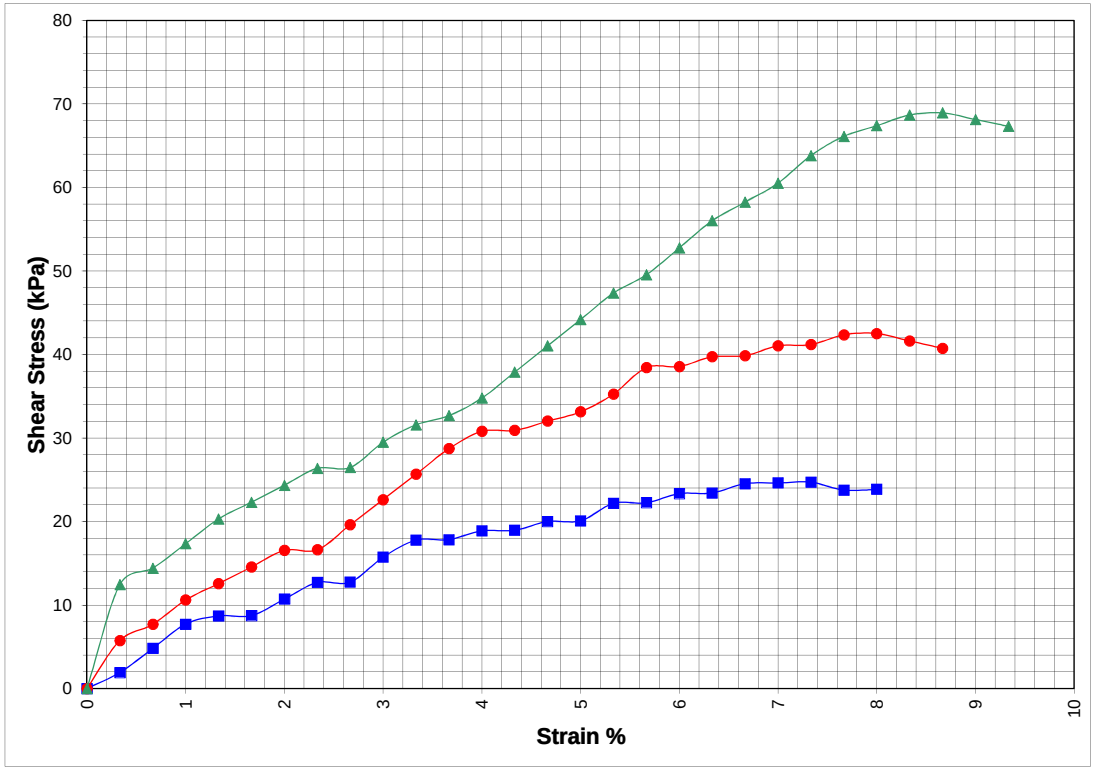
**Borehole: LBH-01**

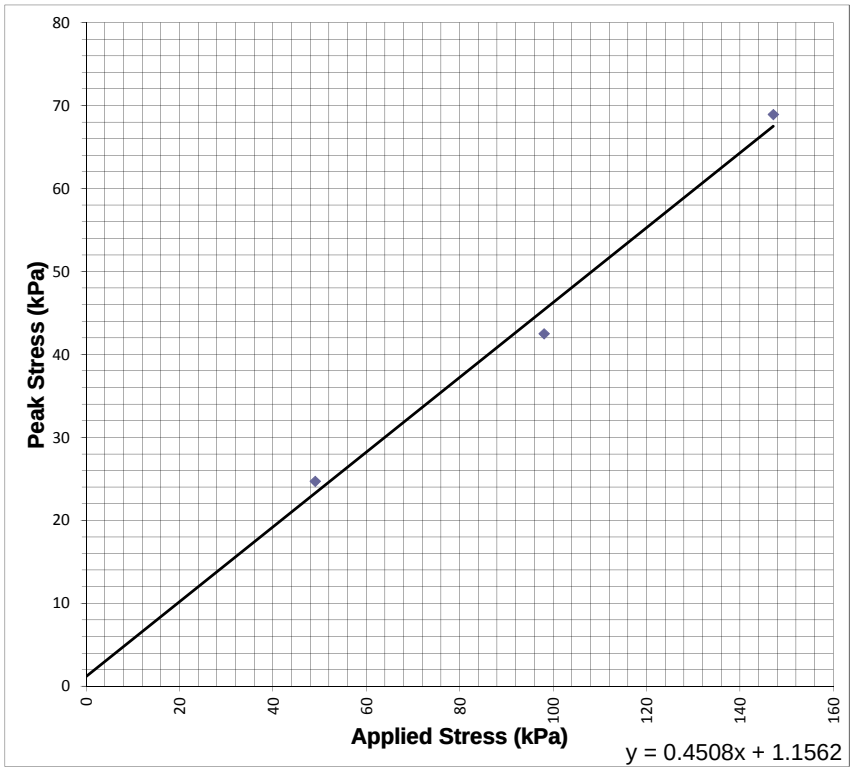
**Sample Type: SPT-03**

**Depth: 4.50-4.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 25 |
| | Stage 2 | 98 | 43 |
| | Stage 3 | 147 | 69 |

| | | |
|---|---|---|
| Angle of Friction | **24.3** | ° |
| Apparent Cohesion | **1.16** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

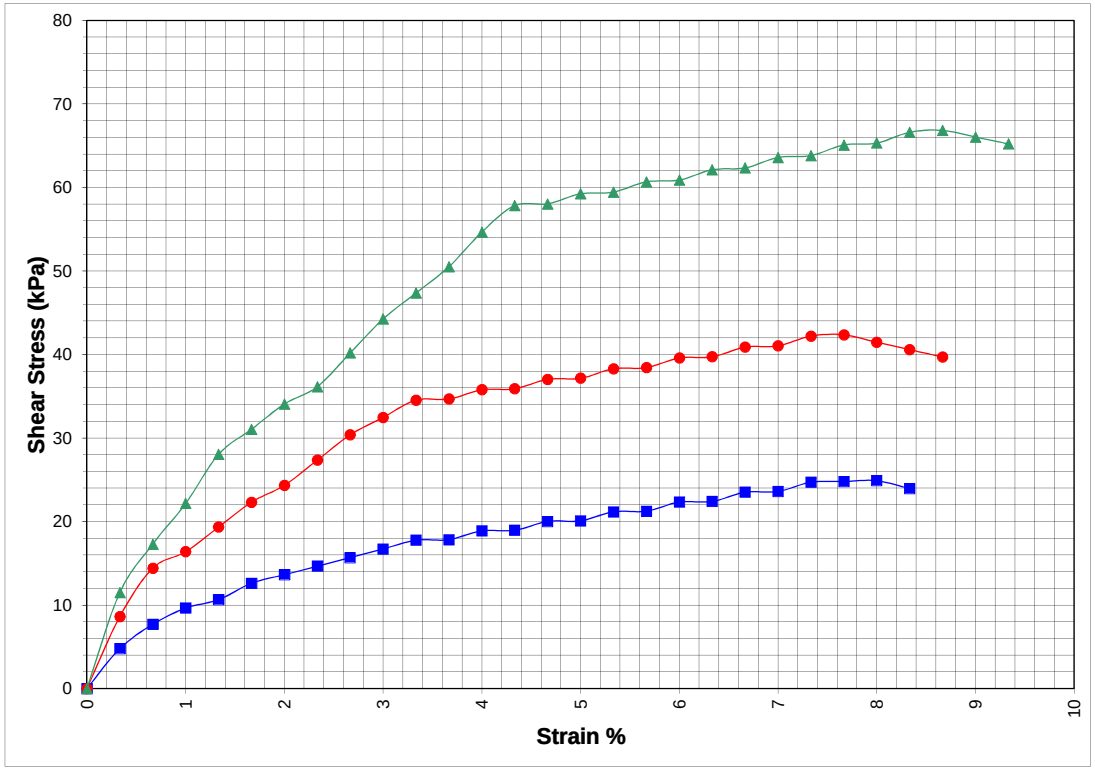
**Borehole: LBH-01**

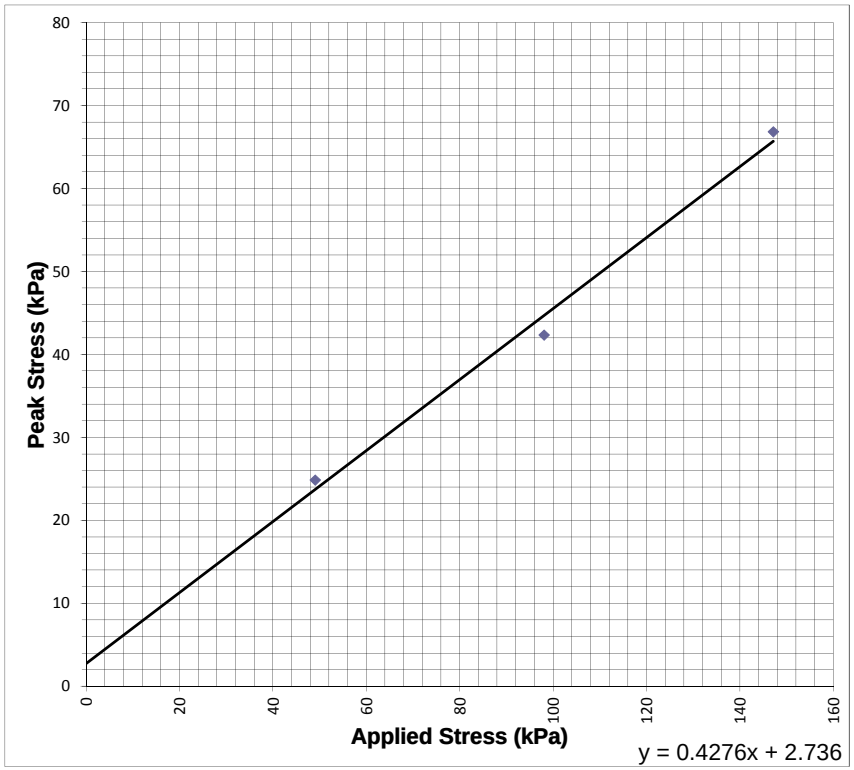
**Sample Type: SPT-08**

**Depth: 12.00-12.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 25 |
| | Stage 2 | 98 | 42 |
| | Stage 3 | 147 | 67 |

| | | |
|---|---|---|
| Angle of Friction | **23.2** | ° |
| Apparent Cohesion | **2.74** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

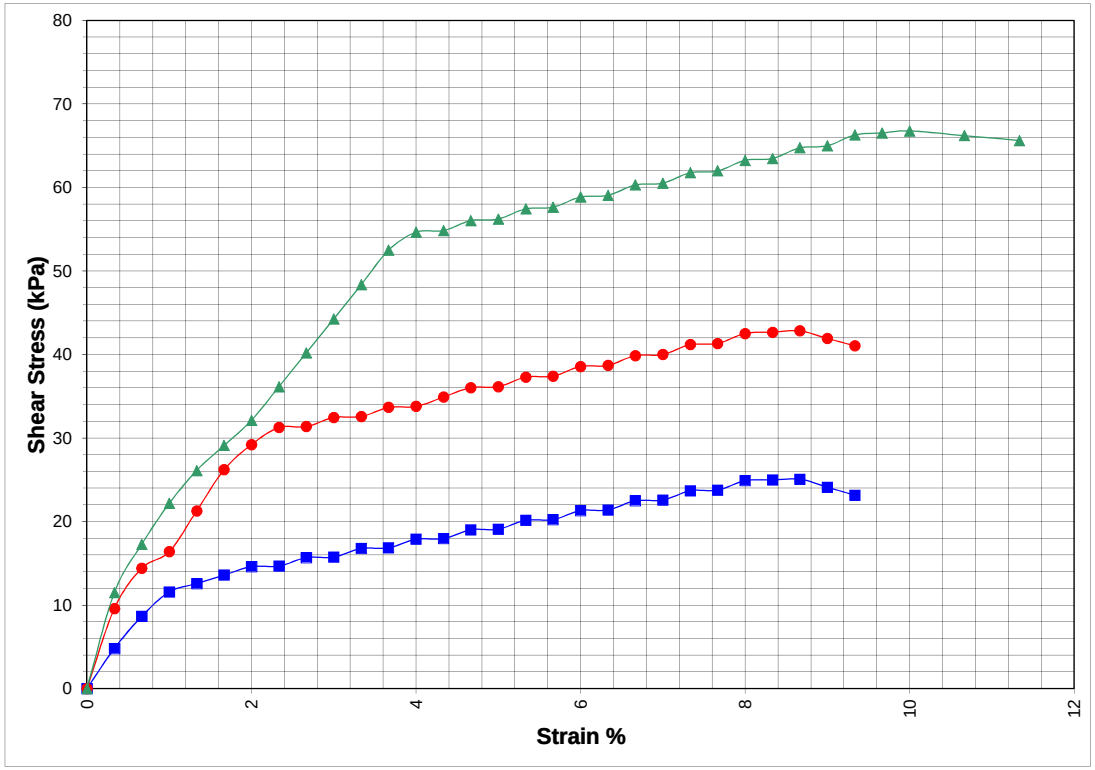
**Borehole: LBH-01**

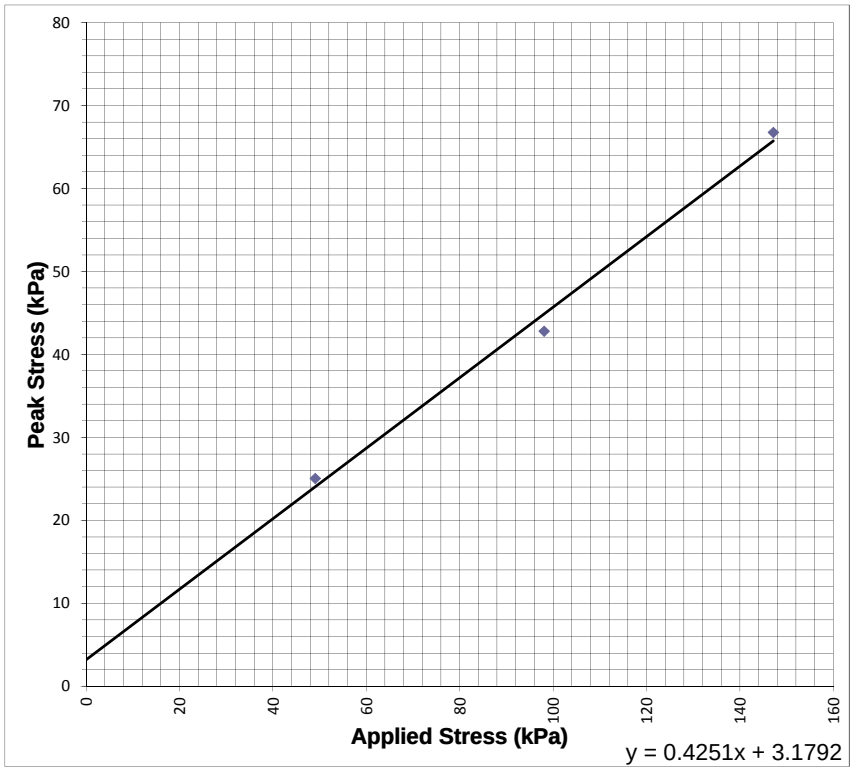
**Sample Type: SPT-11**

**Depth: 16.50-16.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 25 |
| | Stage 2 | 98 | 43 |
| | Stage 3 | 147 | 67 |

| | | |
|---|---|---|
| Angle of Friction | **23.0** | ° |
| Apparent Cohesion | **3.17** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

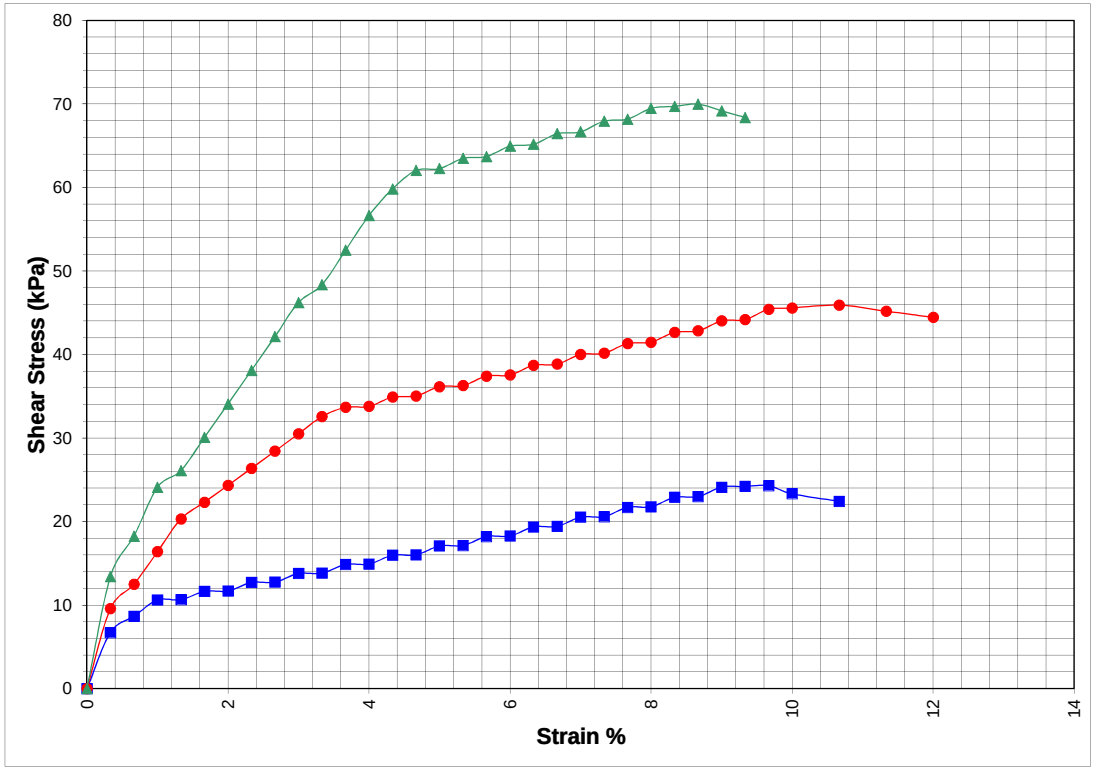
**Borehole: LBH-01**

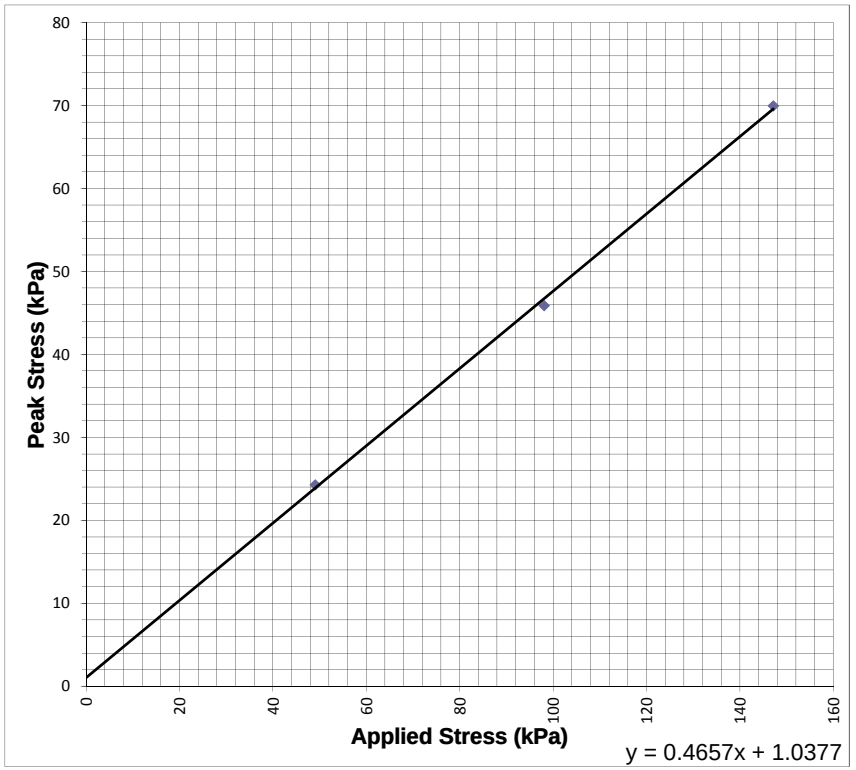
**Sample Type: SPT-12**

**Depth: 18.00-18.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 24 |
| | Stage 2 | 98 | 46 |
| | Stage 3 | 147 | 70 |

| | | |
|---|---|---|
| Angle of Friction | **25.0** | ° |
| Apparent Cohesion | **1.04** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

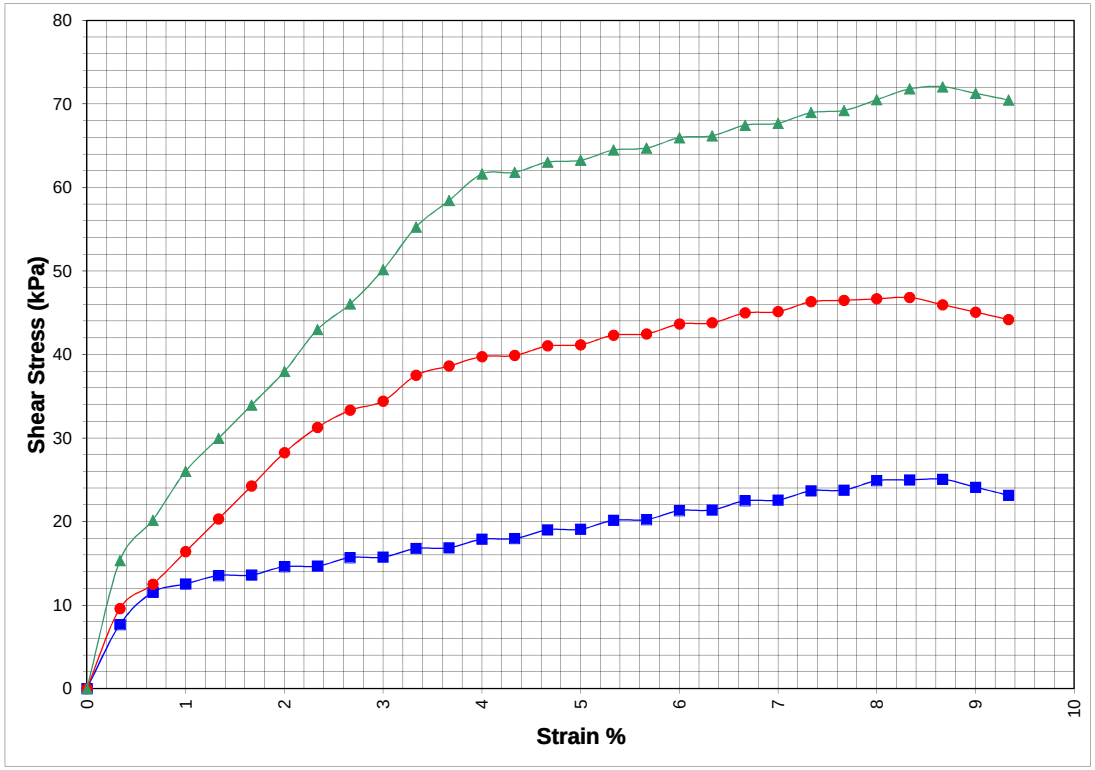
**Borehole: LBH-01**

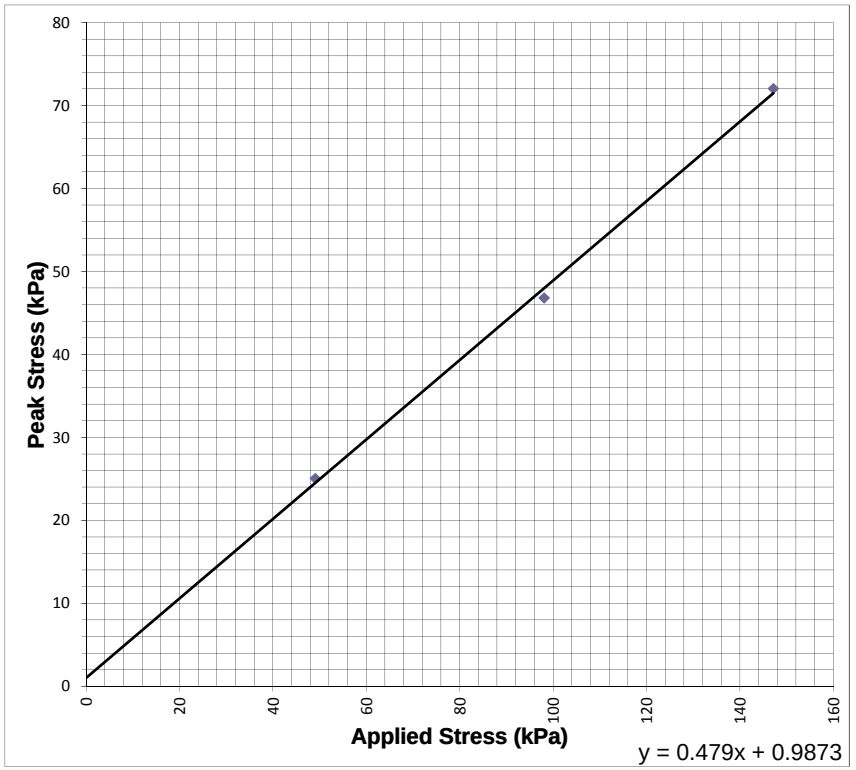
**Sample Type: SPT-15**

**Depth: 22.50-22.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 25 |
| | Stage 2 | 98 | 47 |
| | Stage 3 | 147 | 72 |

| | | |
|---|---|---|
| Angle of Friction | **25.6** | ° |
| Apparent Cohesion | **0.99** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

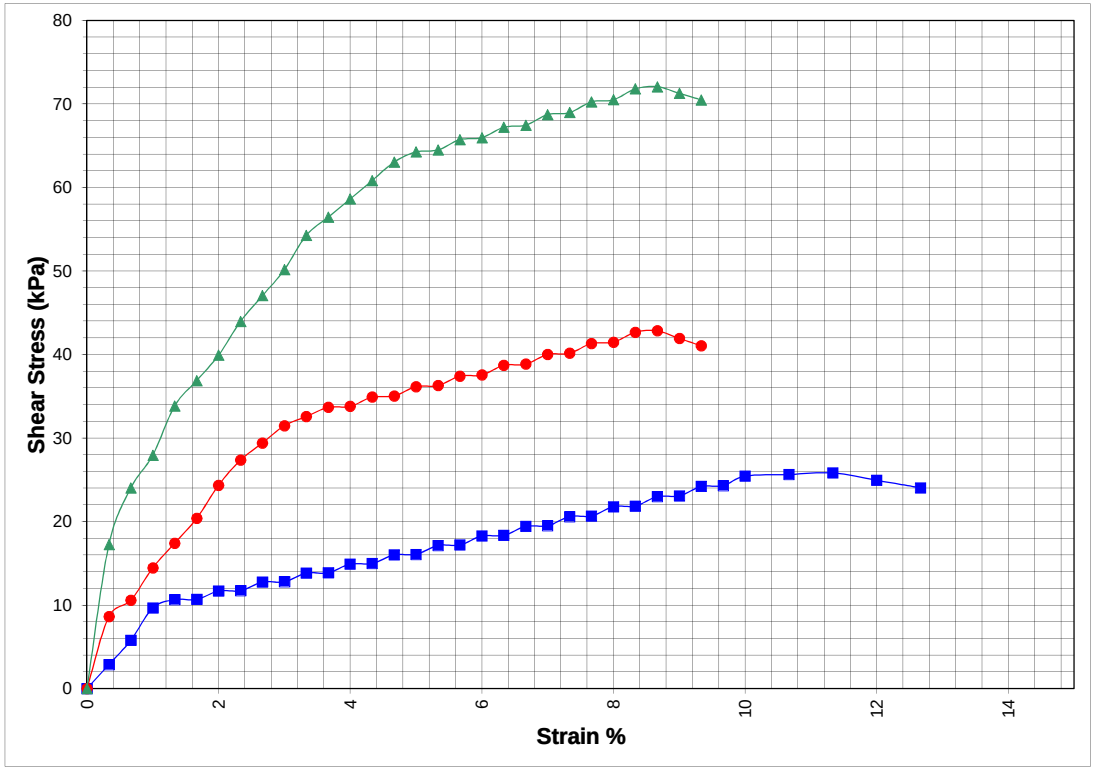
**Borehole: LBH-01**

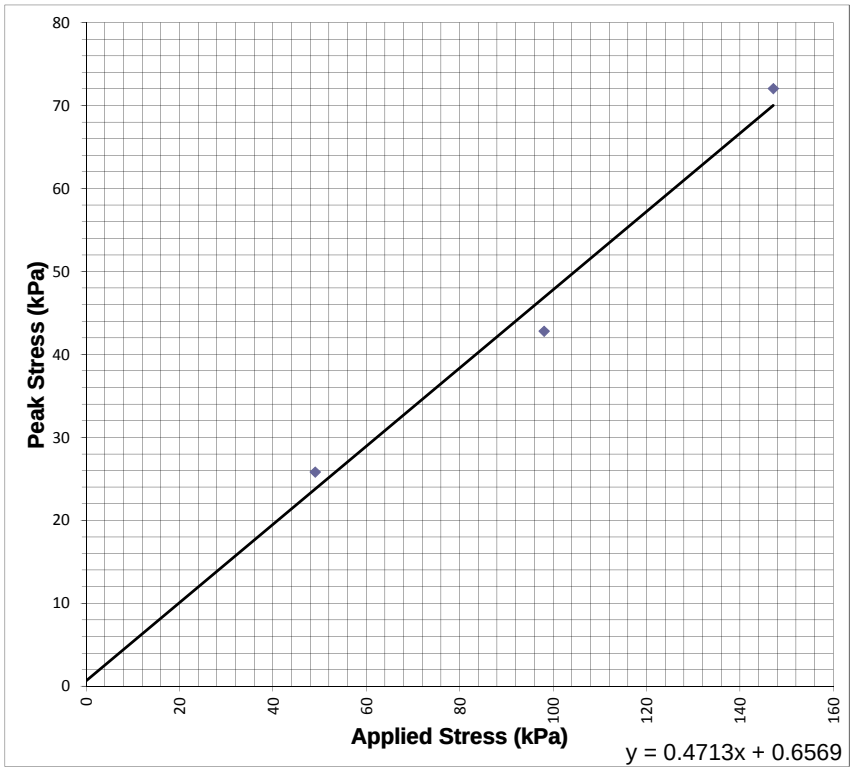
**Sample Type: SPT-16**

**Depth: 25.50-25.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 43 |
| | Stage 3 | 147 | 72 |

| | | |
|---|---|---|
| Angle of Friction | **25.2** | ° |
| Apparent Cohesion | **0.66** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

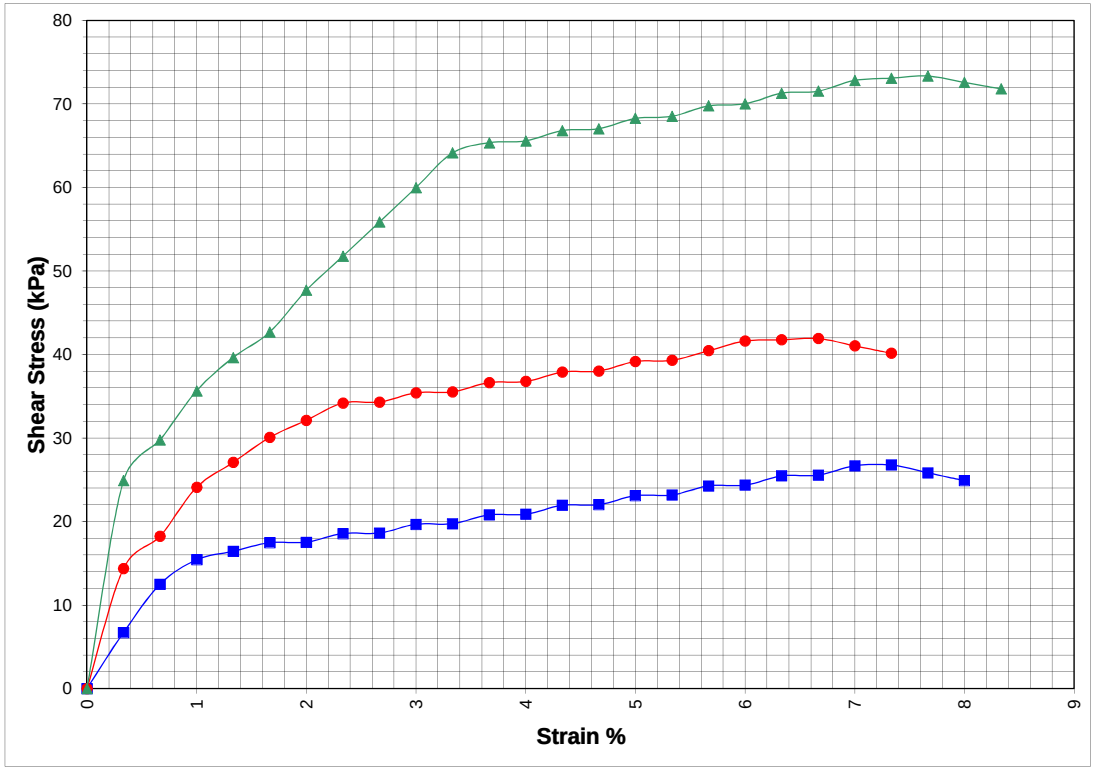
**Borehole: LBH-01**

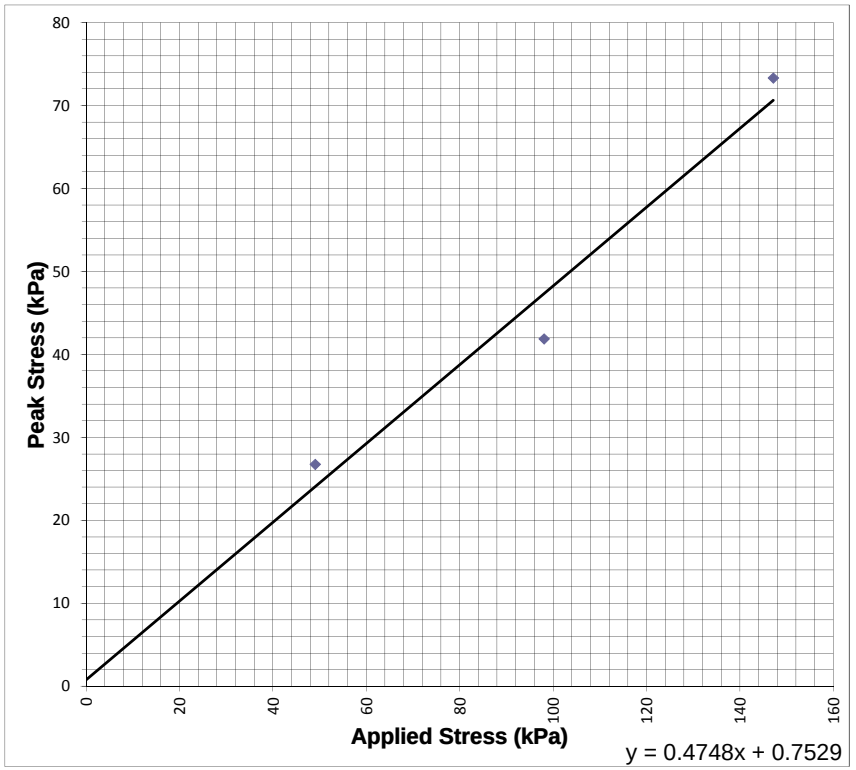
**Sample Type: SPT-18**

**Depth: 27.00-27.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 42 |
| | Stage 3 | 147 | 73 |

| | | |
|---|---|---|
| Angle of Friction | **25.4** | ° |
| Apparent Cohesion | **0.75** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: LBH-01**

**Sample Type: SPT-20**

**Depth: 30.00-30.45 m**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density ($kN/m^3$) | Submerged Unit Weight ($kN/m^3$) | Dry Density ($kN/m^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| DS | 0.00-0.50 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-1 | 1.50-1.95 | SP | | | | 6.2 | 15.28 | 5.22 | 14.39 | 2.64 | 0 | 98 | <--> | <--> | 2 | DST | | | 0.98 | 28.2 | | | | | | | | | | | | | |
| SPT-2 | 3.00-3.45 | | | | | 16.3 | 16.24 | 6.18 | 13.96 | 2.62 | | | | | | | | | | | | | | | | | | | 8.53 | 0.40 | 2.00 | 600 | 8850 |
| SPT-3 | 4.50-4.95 | SP | | | | 18.1 | 16.93 | 6.87 | 14.34 | 2.60 | 0 | 98 | <--> | <--> | 2 | | | | | | | | | | | | | | | | | | |
| SPT-4 | 6.00-6.45 | | | | | 17.4 | 17.45 | 7.39 | 14.86 | 2.62 | | | | | | DST | | | 1.50 | 27.9 | | | | | | | | | | | | | |
| SPT-5 | 7.50-7.95 | SP | | | | 19.2 | 17.29 | 7.23 | 14.51 | 2.64 | 0 | 98 | <--> | <--> | 2 | | | | | | | | | | | | | | | | | | |
| SPT-6 | 9.00-9.45 | SP-SM | | | | 18.3 | 17.75 | 7.69 | 15.00 | 2.68 | 0 | 93 | <--> | <--> | 7 | | | | | | | | | | | | | | | | | | |
| SPT-7 | 10.50-10.95 | | | | | 18.8 | 17.86 | 7.80 | 15.02 | 2.67 | | | | | | DST | | | 0.55 | 28.3 | | | | | | | | | | | | | |
| SPT-8 | 12.00-12.45 | SP-SM | | | | 16.4 | 18.09 | 8.03 | 15.55 | 2.65 | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | | | | |
| SPT-9 | 13.50-13.95 | | | | | 12.4 | 18.06 | 8.00 | 16.06 | 2.67 | | | | | | DST | | | 0.81 | 28.0 | | | | | | | | | | | | | |
| SPT-10 | 15.00-15.45 | SP | | | | 7.5 | 15.80 | 5.74 | 14.69 | 2.66 | 0 | 99 | <--> | <--> | 1 | | | | | | | | | | | | | | | | | | |
| SPT-11 | 16.50-16.95 | | | | | 3.2 | 15.22 | 5.16 | 14.75 | 2.67 | | | | | | DST | | | 1.03 | 28.7 | | | | | | | | | | | | | |
| SPT-12 | 18.00-18.45 | SP | | | | 2.1 | 15.65 | 5.59 | 15.33 | 2.67 | 0 | 99.7 | <--> | <--> | 0.3 | | | | | | | | | | | | | | | | | | |
| SPT-13 | 19.50-19.95 | SP | | | | 20.5 | 17.44 | 7.38 | 14.47 | 2.63 | 0 | 97 | <--> | <--> | 3 | | | | | | | | | | | | | | | | | | |
| SPT-14 | 21.00-21.45 | | | | | 20.1 | 17.57 | 7.51 | 14.63 | 2.61 | | | | | | DST | | | 1.12 | 26.1 | | | | | | | | | | | | | |
| SPT-15 | 22.50-22.95 | SP-SM | | | | 16.9 | 17.54 | 7.48 | 15.01 | 2.60 | 0 | 92 | <--> | <--> | 8 | | | | | | | | | | | | | | | | | | |
| SPT-16 | 24.00-24.45 | | | | | 16.1 | 17.61 | 7.55 | 15.17 | 2.64 | | | | | | DST | | | 1.51 | 27.3 | | | | | | | | | | | | | |
| SPT-17 | 25.50-25.95 | SP | | | | 17.1 | 16.76 | 6.70 | 14.31 | 2.62 | 0 | 97 | <--> | <--> | 3 | | | | | | | | | | | | | | | | | | |
| SPT-18 | 27.00-27.45 | SP | | | | 16.1 | 17.09 | 7.03 | 14.73 | 2.63 | 0 | 97 | <--> | <--> | 3 | | | | | | | | | | | | | | | | | | |
| SPT-19 | 28.50-28.95 | | | | | 14.8 | 16.25 | 6.19 | 14.15 | 2.63 | | | | | | DST | | | 1.91 | 27.0 | | | | | | | | | | | | | |
| SPT-20 | 30.00-30.45 | SP | | | | 21.1 | 15.69 | 5.63 | 12.96 | 2.62 | 0 | 96 | <--> | <--> | 4 | | | | | | | | | | | | | | | | | | |
| **END OF BOREHOLE** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

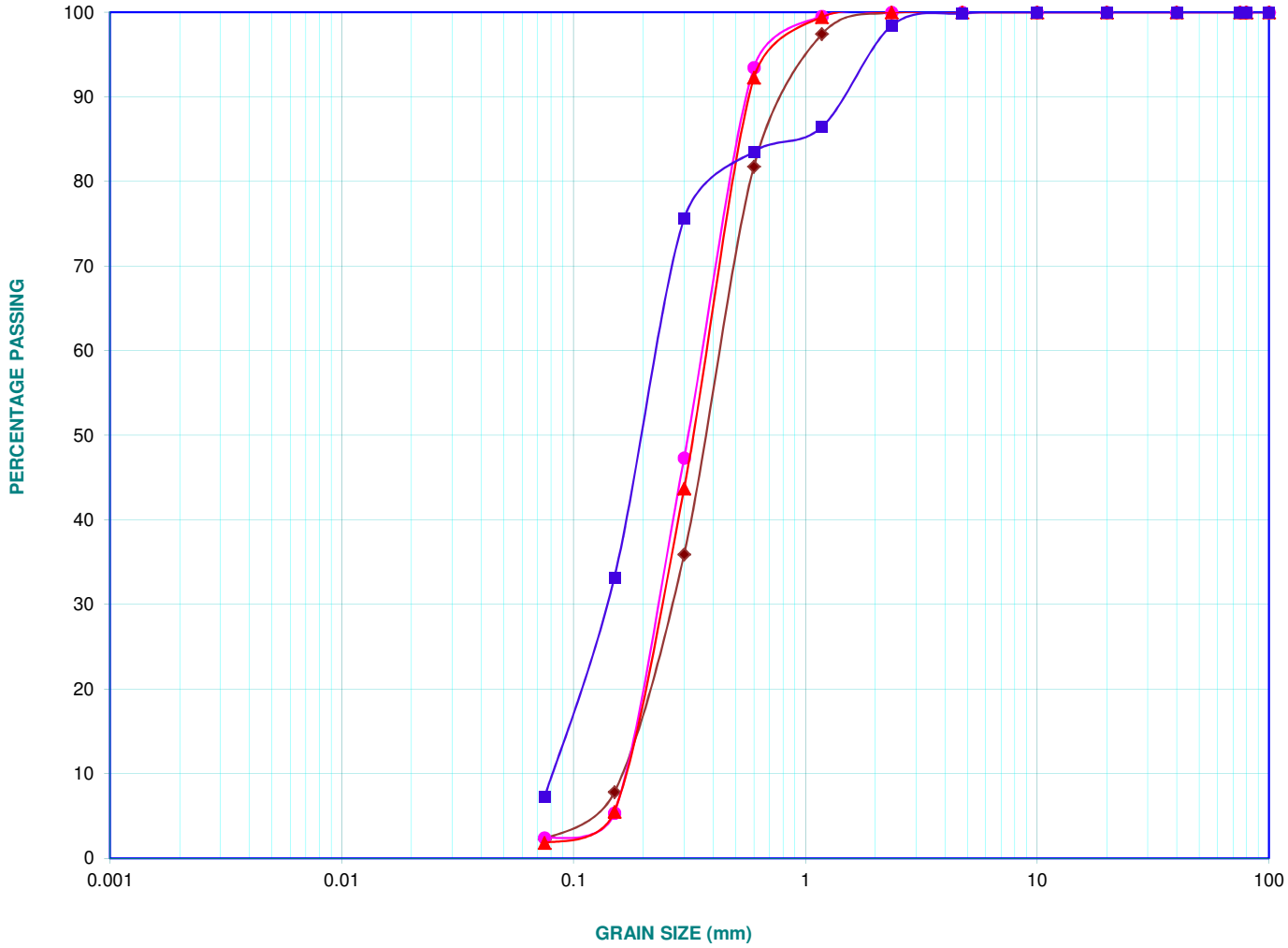
\# : Decayed Wood

**Failure Type**
A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha**
Project Code : **CM 19 01 03**
Borehole No. : **LBH-02**

# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | **Borehole No.** | **: LBH-02** | | | **Date :** | **30-May-19** | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND F | SAND M | SAND C | GRAVEL F | GRAVEL C |
| **Bore Hole .** | LBH-02 | LBH-02 | LBH-02 | LBH-02 | | | | | | | | |
| **Depth (m)** | 1.50-1.95 | 4.50-4.95 | 7.50-7.95 | 9.00-9.45 | | | | | | | | |
| **Sample Type** | SPT-1 | SPT-3 | SPT-5 | SPT-6 | | | | | | | | |
| **Classification** | SP | SP | SP | SP-SM | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 98 | 98 | 98 | 93 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 2 | 2 | 2 | 7 | | | | | | | | |
| **D60 mm** | 0.410 | 0.360 | 0.370 | 0.220 | | | | | | | | |
| **D30 mm** | 0.280 | 0.230 | 0.240 | 0.140 | | | | | | | | |
| **D10 mm** | 0.170 | 0.180 | 0.180 | 0.081 | | | | | | | | |
| **Cu** | 2.41 | 2.00 | 2.06 | 2.72 | | | | | | | | |
| **Cc** | 1.12 | 0.82 | 0.86 | 1.10 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |

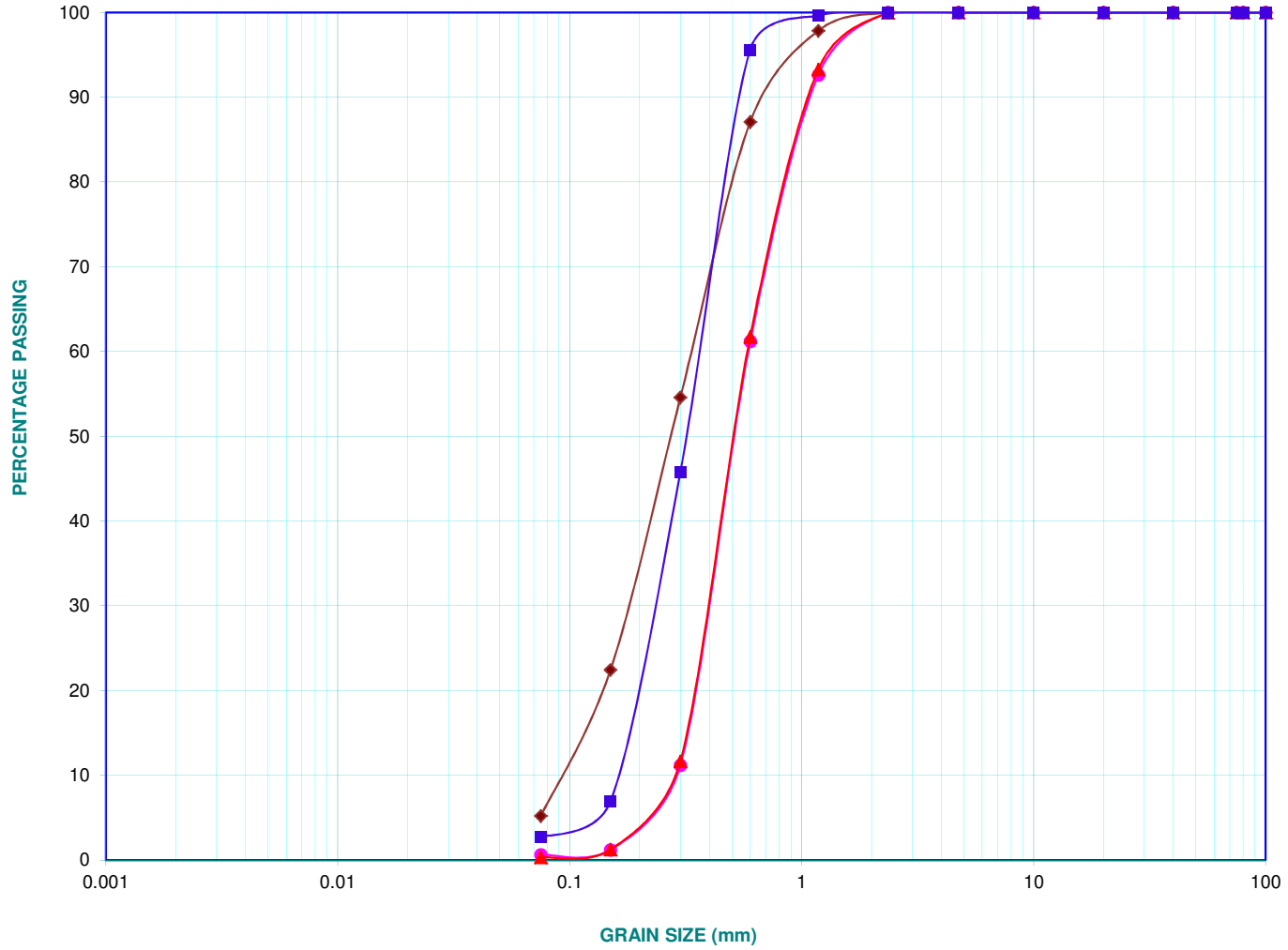



Checked By :

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: LBH-02** |
| **Date :** | **30-May-19** |

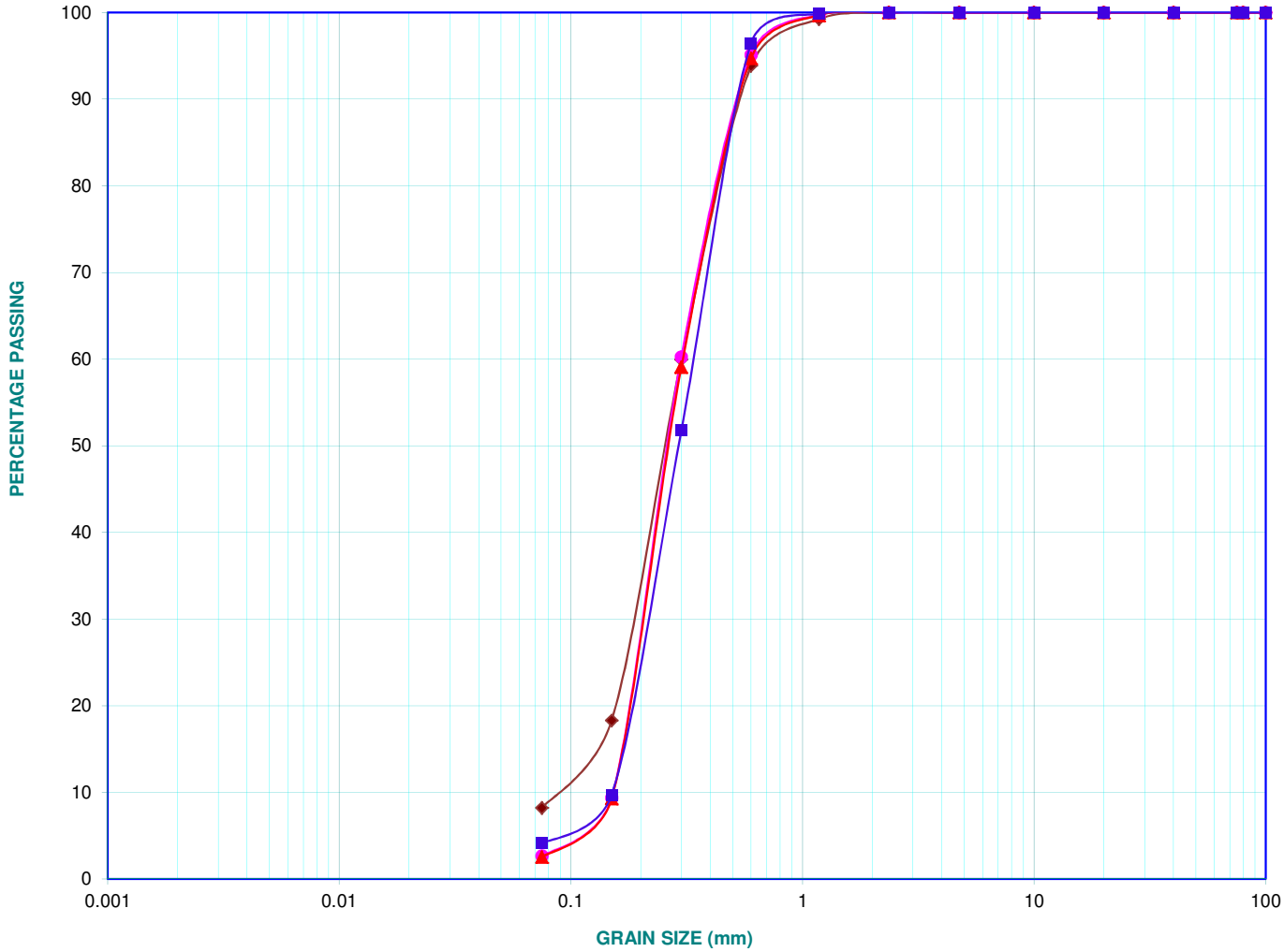
| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | LBH-02 | LBH-02 | LBH-02 | LBH-02 | | | | | | | | |
| **Depth (m)** | 12.00-12.45 | 15.00-15.45 | 18.00-18.45 | 19.50-19.95 | | | | | | | | |
| **Sample Type** | SPT-8 | SPT-10 | SPT-12 | SPT-13 | | | | | | | | |
| **Classification** | SP-SM | SP | SP | SP | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 95 | 99 | 99.67 | 97 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 5 | 1 | 0.33 | 3 | | | | | | | | |
| **D60 mm** | 0.320 | 0.590 | 0.590 | 0.380 | | | | | | | | |
| **D30 mm** | 0.180 | 0.400 | 0.400 | 0.230 | | | | | | | | |
| **D10 mm** | 0.095 | 0.290 | 0.290 | 0.170 | | | | | | | | |
| **Cu** | 3.37 | 2.03 | 2.03 | 2.24 | | | | | | | | |
| **Cc** | 1.07 | 0.94 | 0.94 | 0.82 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

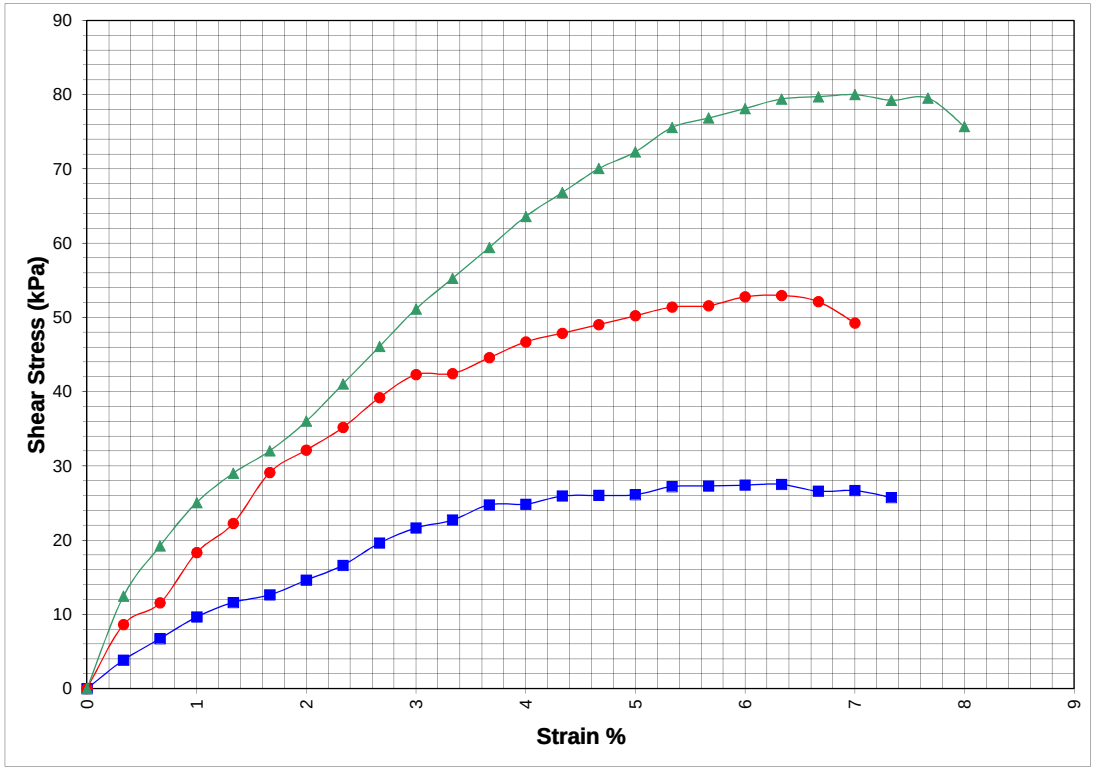
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | : Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha | | | | | | | | | | | |
| **Job No.** | : CM 19 01 03 | | | | **Borehole No.** | : LBH-02 | | | **Date :** | 30-May-19 | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | LBH-02 | LBH-02 | LBH-02 | LBH-02 | | | | | | | | |
| **Depth (m)** | 22.50-22.95 | 25.50-25.95 | 27.00-27.45 | 30.00-30.45 | | | | | | | | |
| **Sample Type** | SPT-15 | SPT-17 | SPT-18 | SPT-20 | | | | | | | | |
| **Classification** | SP-SM | SP | SP | SP | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 92 | 97 | 97 | 96 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 8 | 3 | 3 | 4 | | | | | | | | |
| **D60 mm** | 0.300 | 0.300 | 0.300 | 0.340 | | | | | | | | |
| **D30 mm** | 0.190 | 0.200 | 0.200 | 0.220 | | | | | | | | |
| **D10 mm** | 0.090 | 0.150 | 0.150 | 0.150 | | | | | | | | |
| **Cu** | 3.33 | 2.00 | 2.00 | 2.27 | | | | | | | | |
| **Cc** | 1.34 | 0.89 | 0.89 | 0.95 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |

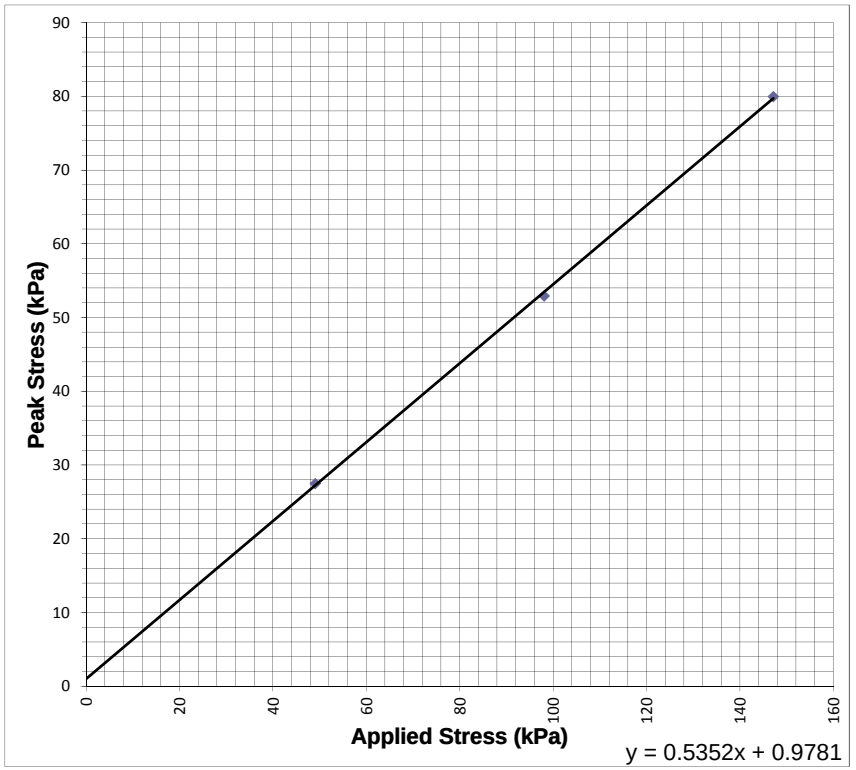



Checked By :

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 53 |
| | Stage 3 | 147 | 80 |

| | | |
|---|---|---|
| Angle of Friction | **28.16** | ° |
| Apparent Cohesion | **0.98** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

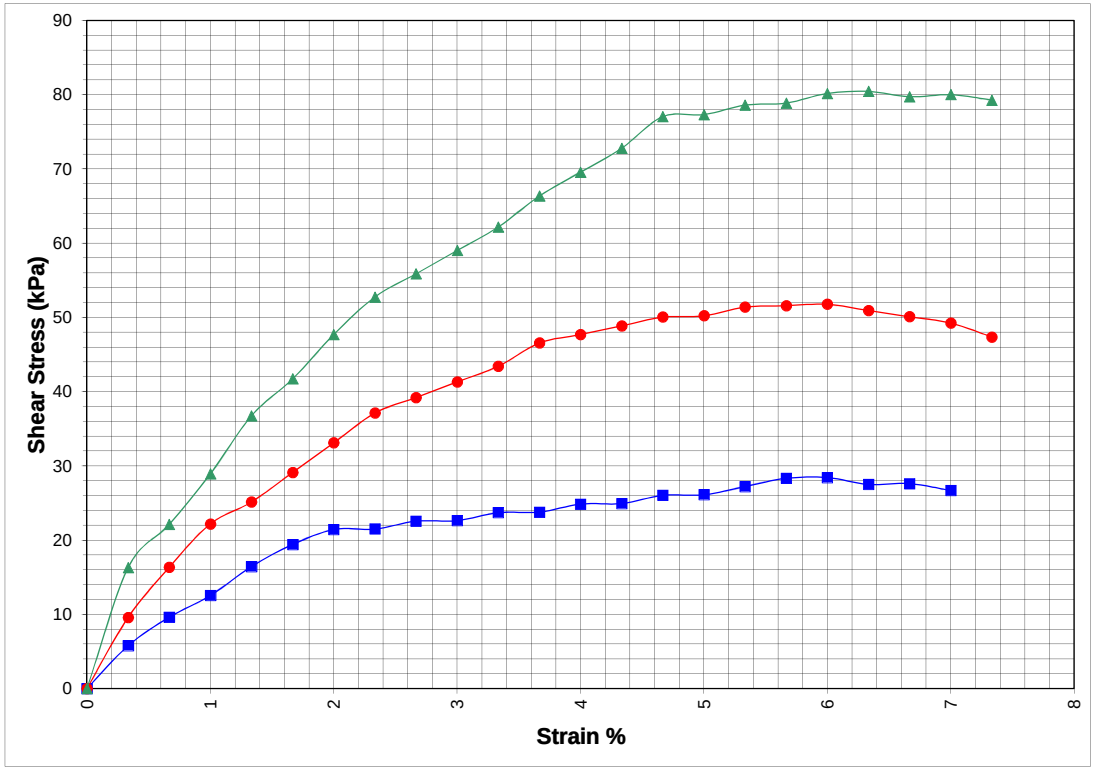
**Borehole: LBH-02**

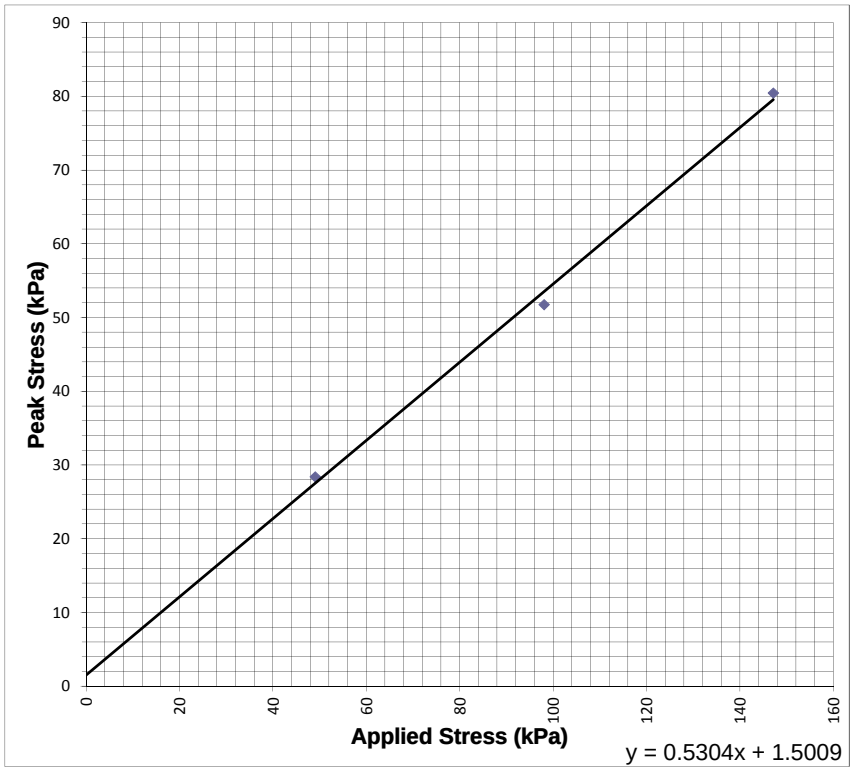
**Sample Type: SPT-02**

**Depth: 3.00-3.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 52 |
| | Stage 3 | 147 | 80 |

| | | |
|---|---|---|
| Angle of Friction | **27.9** | ° |
| Apparent Cohesion | **1.50** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

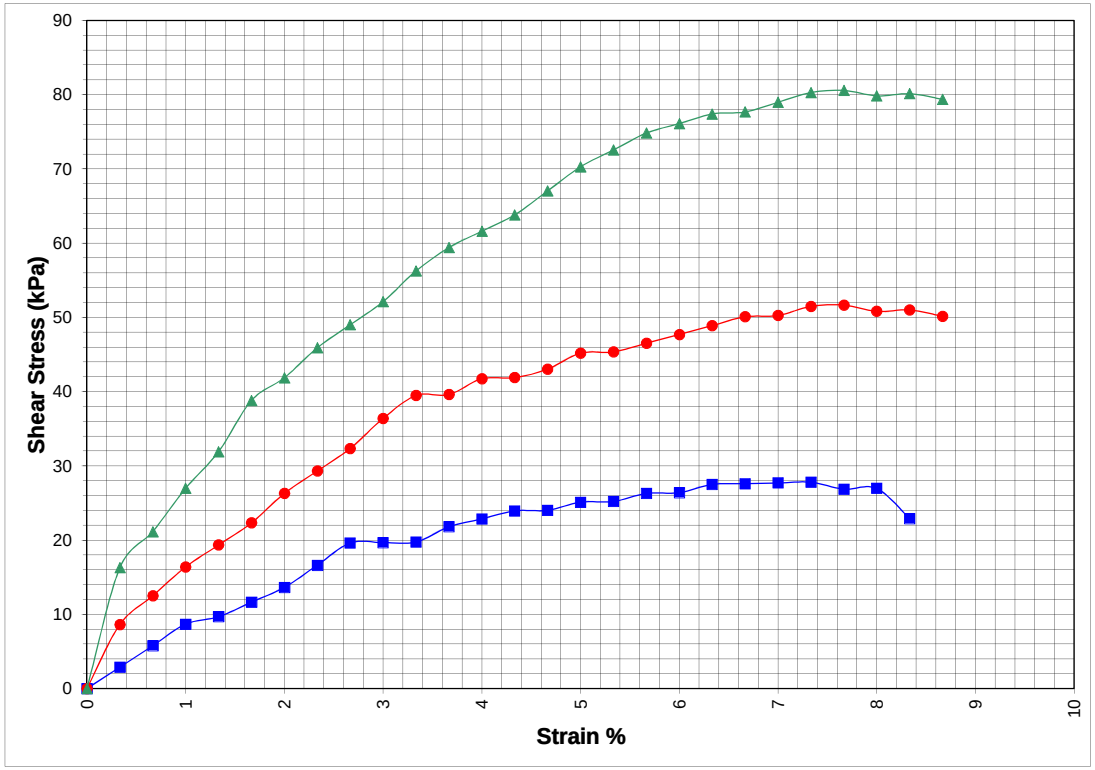
**Borehole: LBH-02**

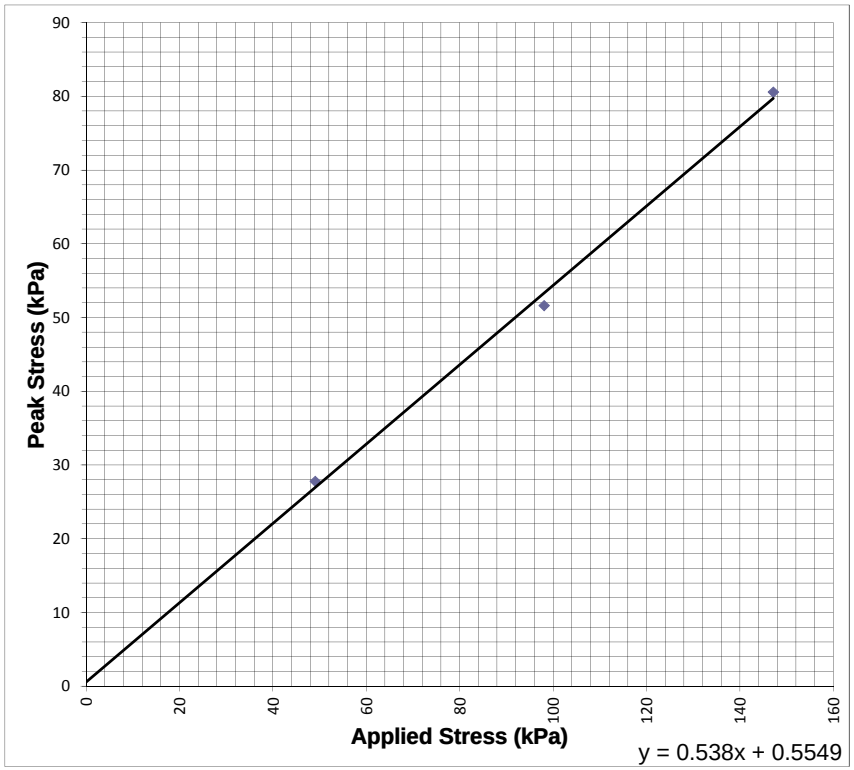
**Sample Type: SPT-04**

**Depth: 6.00-6.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 52 |
| | Stage 3 | 147 | 81 |

| | | |
|---|---|---|
| Angle of Friction | **28.28** | ° |
| Apparent Cohesion | **0.55** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

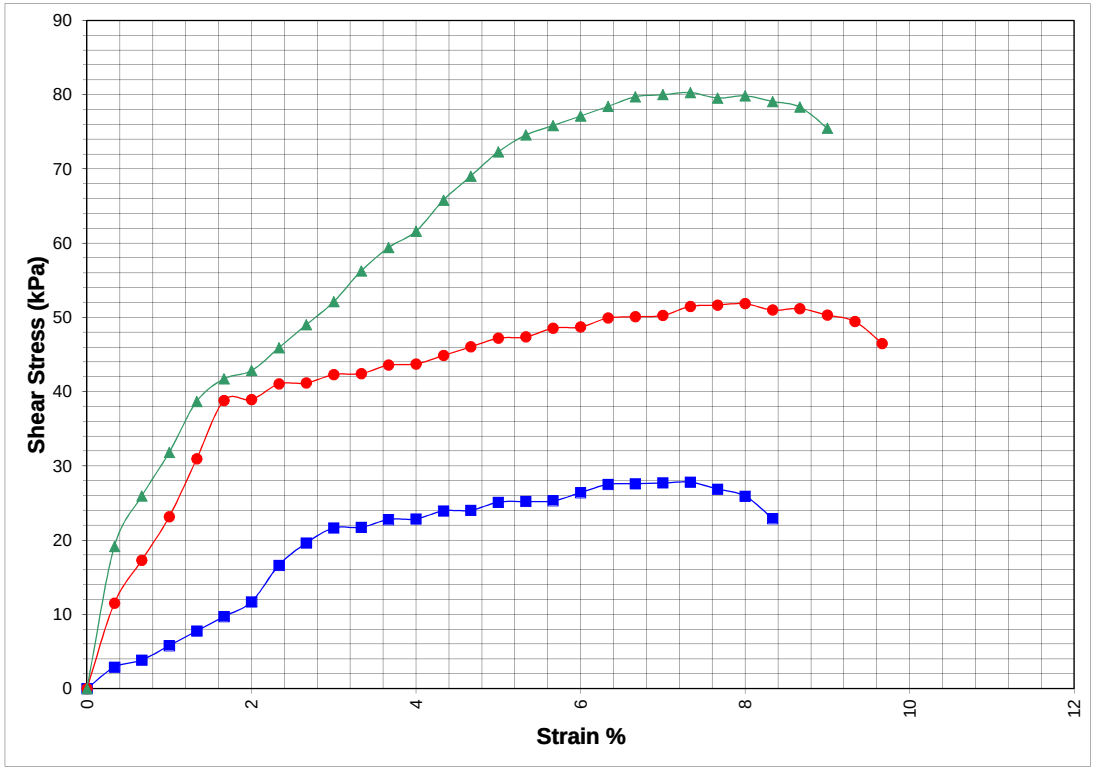
**Borehole: LBH-02**

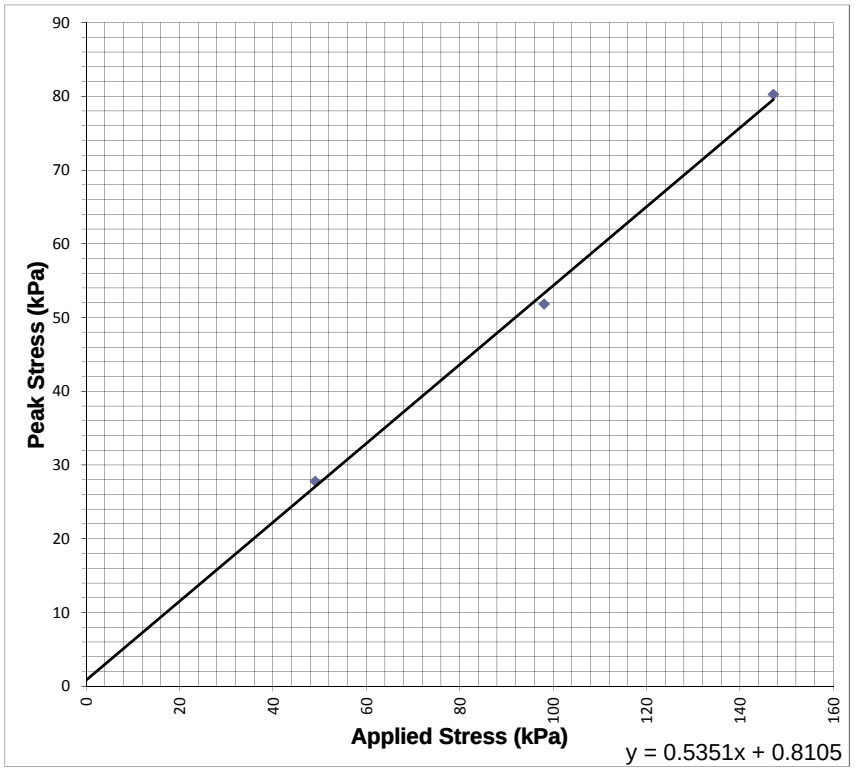
**Sample Type: SPT-07**

**Depth: 10.50-10.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 52 |
| | Stage 3 | 147 | 80 |

| | | |
|---|---|---|
| Angle of Friction | **28.02** | ° |
| Apparent Cohesion | **0.81** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

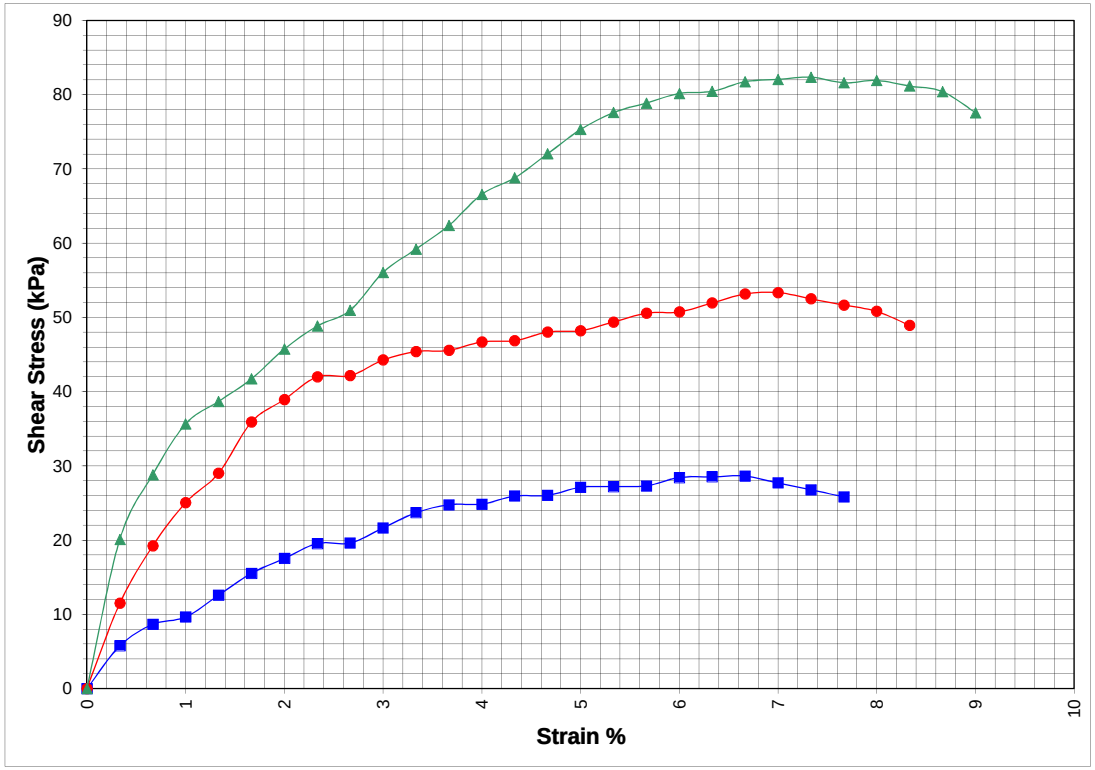
**Borehole: LBH-02**

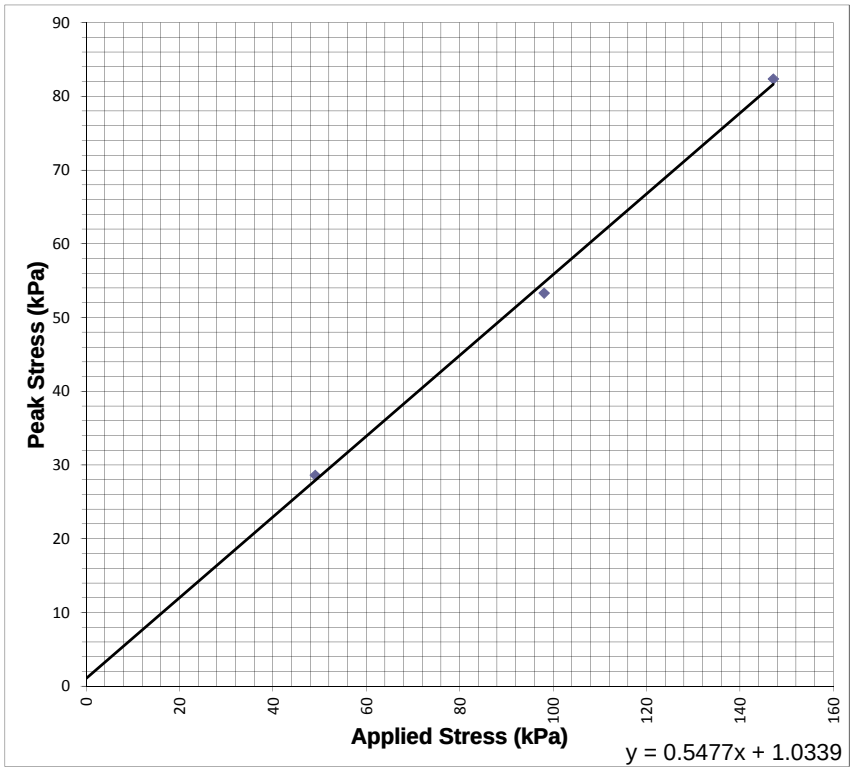
**Sample Type: SPT-09**

**Depth: 13.50-13.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 29 |
| | Stage 2 | 98 | 53 |
| | Stage 3 | 147 | 82 |

| | | |
|---|---|---|
| Angle of Friction | **28.71** | ° |
| Apparent Cohesion | **1.03** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

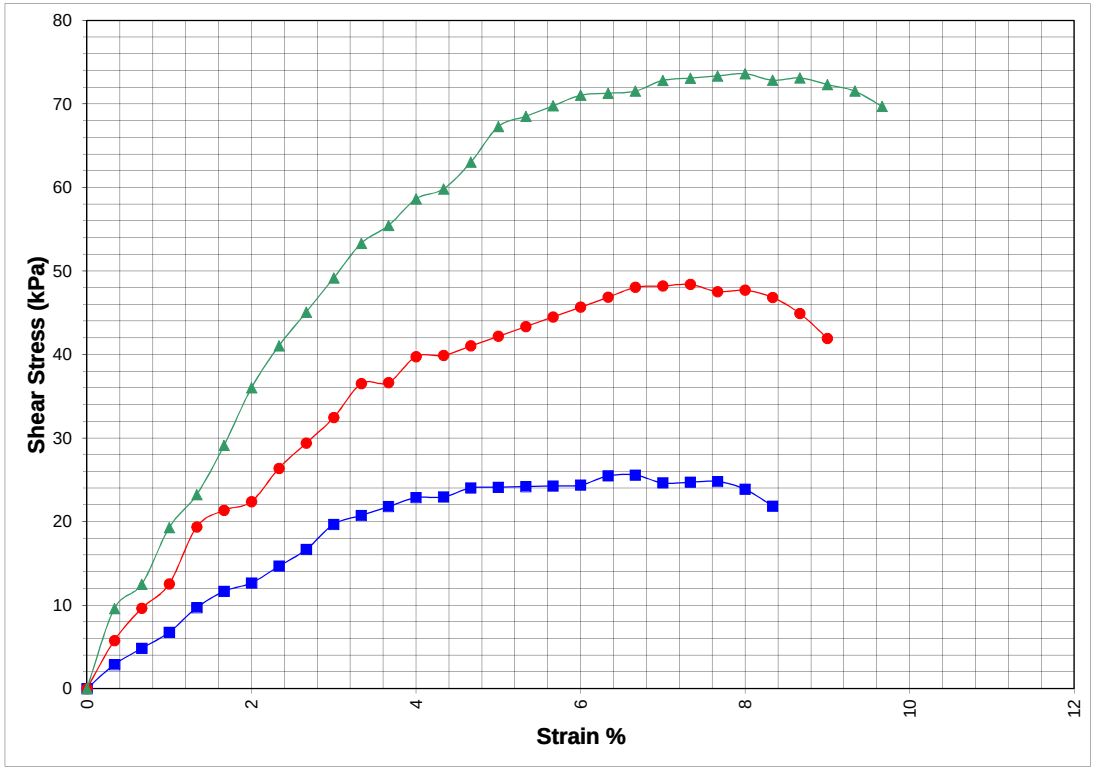
**Borehole: LBH-02**

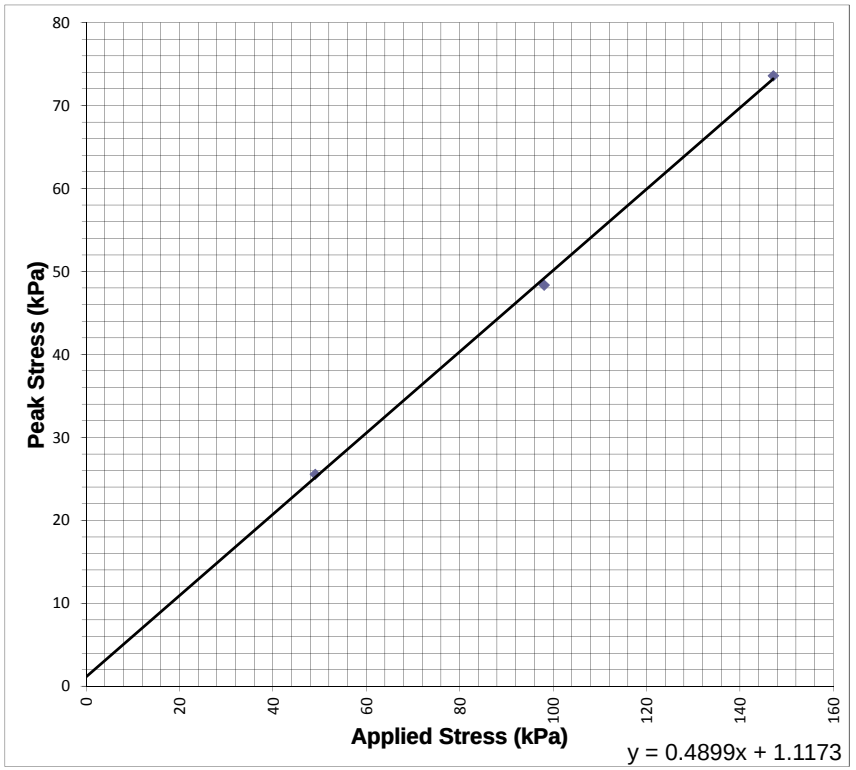
**Sample Type: SPT-11**

**Depth: 16.50-16.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 48 |
| | Stage 3 | 147 | 74 |

| | | |
|---|---|---|
| Angle of Friction | **26.10** | ° |
| Apparent Cohesion | **1.12** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

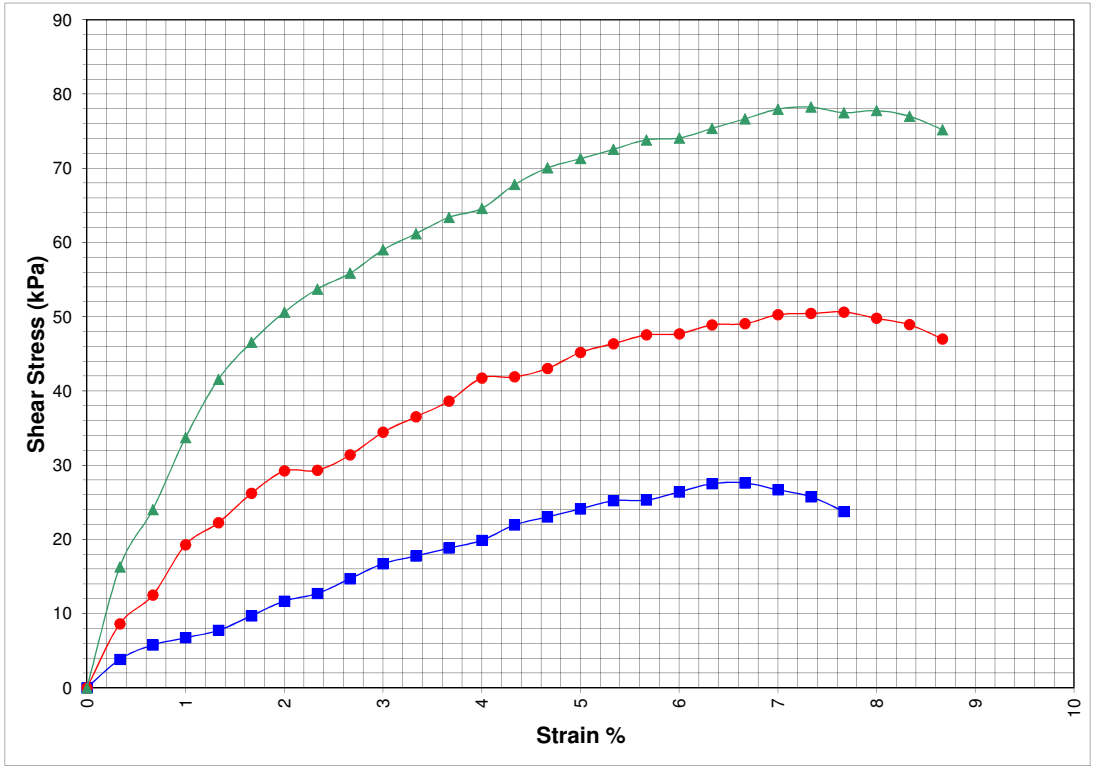
**Borehole: LBH-02**

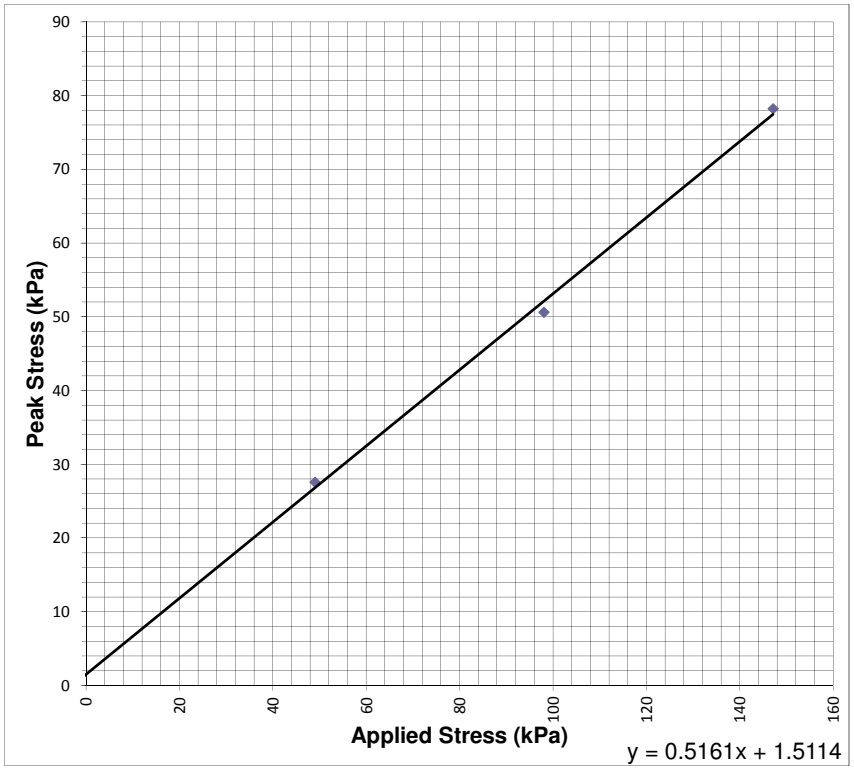
**Sample Type: SPT-14**

**Depth: 21.00-21.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 51 |
| | Stage 3 | 147 | 78 |

| | | |
|---|---|---|
| Angle of Friction | **27.30** | ° |
| Apparent Cohesion | **1.51** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

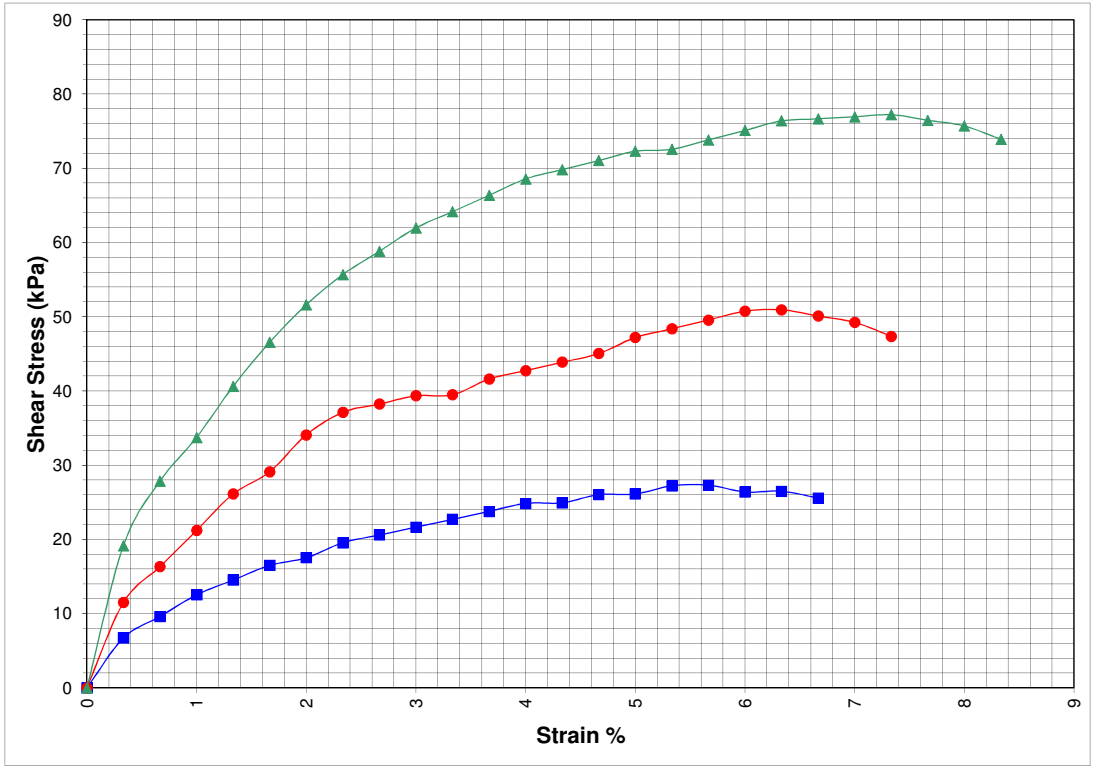
**Borehole: LBH-02**

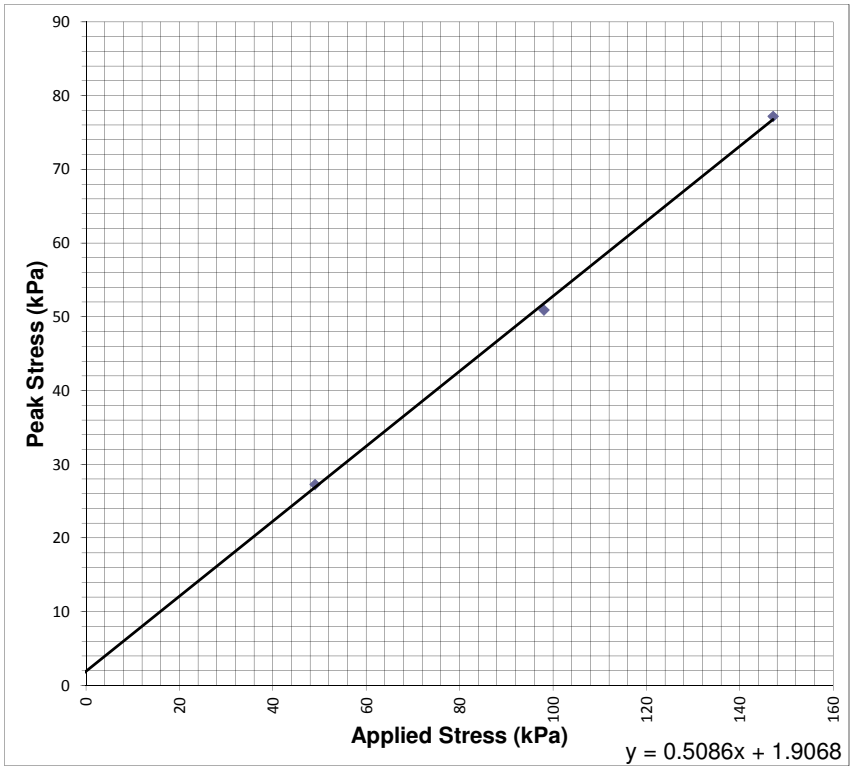
**Sample Type: SPT-16**

**Depth: 24.00-24.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 51 |
| | Stage 3 | 147 | 77 |

| | | |
|---|---|---|
| Angle of Friction | **27.0** | ° |
| Apparent Cohesion | **1.91** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: LBH-02**

**Sample Type: SPT-19**

**Depth: 28.50-28.95 m**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| DS | 0.00-0.50 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-1 | 1.50-1.95 | | | | | 19.6 | 15.78 | 5.72 | 13.19 | 2.62 | | | | | | DST | | | 1.22 | 26.3 | | | | | | | | | | | | | |
| SPT-2 | 3.00-3.45 | SP | | | | 19.9 | 16.33 | 6.27 | 13.63 | 2.61 | 0 | 98 | <--> | <--> | 2 | | | | | | | | | | | | | | | | | | |
| SPT-3 | 4.50-4.95 | | | | | 15.9 | 15.79 | 5.73 | 13.62 | 2.63 | | | | | | DST | | | 1.08 | 26.0 | | | | | | | | | 7.87 | 0.40 | 2.00 | 1300 | 7080 |
| SPT-4 | 6.00-6.45 | | | | | 16.7 | 16.12 | 6.06 | 13.82 | 2.64 | | | | | | DST | | | 1.13 | 26.8 | | | | | | | | | | | | | |
| SPT-5 | 7.50-7.95 | SP | | | | 16.5 | 15.98 | 5.92 | 13.72 | 2.63 | 0 | 99 | <--> | <--> | 1 | | | | | | | | | | | | | | | | | | |
| SPT-6 | 9.00-9.45 | | | | | 16.9 | 16.41 | 6.35 | 14.03 | 2.64 | | | | | | DST | | | 0.21 | 26.8 | | | | | | | | | | | | | |
| SPT-7 | 10.50-10.95 | SP | | | | 13.6 | 16.12 | 6.06 | 14.19 | 2.68 | 0 | 99 | <--> | <--> | 1 | | | | | | | | | | | | | | | | | | |
| SPT-8 | 12.00-12.45 | SP-SM | | | | 18.0 | 17.06 | 7.00 | 14.45 | 2.63 | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | | | | |
| SPT-9 | 13.50-13.95 | SP-SM | | | | 19.2 | 16.43 | 6.37 | 13.78 | 2.60 | 0 | 91 | <--> | <--> | 9 | | | | | | | | | | | | | | | | | | |
| SPT-10 | 15.00-15.45 | SC | 33.8 | 16.3 | 17.5 | 16.4 | 20.40 | 10.34 | 17.52 | 2.59 | 0 | 63 | 18 | 19 | 37 | | | | | | | | | | | | | | | | | | |
| UDS-1 | 16.50-17.00 | SC | 31.8 | 15.6 | 16.2 | 15.2 | 20.90 | 10.84 | 18.13 | 2.57 | 0 | 60 | 17 | 23 | 40 | | | | | | | | | 40.0 | 0.39 | 100 | 156.9 | 0.002 | | | | | |
| SPT-11 | 18.00-18.45 | | | | | 14.2 | 16.43 | 6.37 | 14.39 | 2.67 | | | | | | DST | | | 1.31 | 26.3 | | | | | | | | | | | | | |
| SPT-12 | 19.50-19.95 | SP-SM | | | | 19.4 | 17.50 | 7.44 | 14.66 | 2.61 | 0 | 89 | <--> | <--> | 11 | | | | | | | | | | | | | | | | | | |
| SPT-13 | 21.00-21.45 | SP-SM | | | | 18.6 | 17.37 | 7.31 | 14.65 | 2.60 | 0 | 91 | <--> | <--> | 9 | | | | | | | | | | | | | | | | | | |
| SPT-14 | 22.50-22.95 | SP-SM | | | | 19.8 | 17.38 | 7.32 | 14.50 | 2.61 | 0 | 92 | <--> | <--> | 8 | | | | | | | | | | | | | | | | | | |
| SPT-15 | 24.00-24.45 | | | | | 17.3 | 15.78 | 5.72 | 13.45 | 2.68 | | | | | | DST | | | 1.73 | 26.0 | | | | | | | | | | | | | |
| SPT-16 | 25.50-25.95 | SP | | | | 16.6 | 16.59 | 6.53 | 14.23 | 2.64 | 1 | 96 | <--> | <--> | 3 | | | | | | | | | | | | | | | | | | |
| SPT-17 | 27.00-27.45 | | | | | 16.5 | 16.47 | 6.41 | 14.14 | 2.68 | | | | | | DST | | | 1.73 | 26.1 | | | | | | | | | | | | | |
| SPT-18 | 28.50-28.95 | SP | | | | 17.1 | 16.27 | 6.21 | 13.89 | 2.65 | 1 | 97 | <--> | <--> | 2 | | | | | | | | | | | | | | | | | | |
| SPT-19 | 30.00-30.45 | | | | | 16.5 | 16.39 | 6.33 | 14.06 | 2.67 | | | | | | DST | | | 1.84 | 25.9 | | | | | | | | | | | | | |
| **END OF BOREHOLE** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

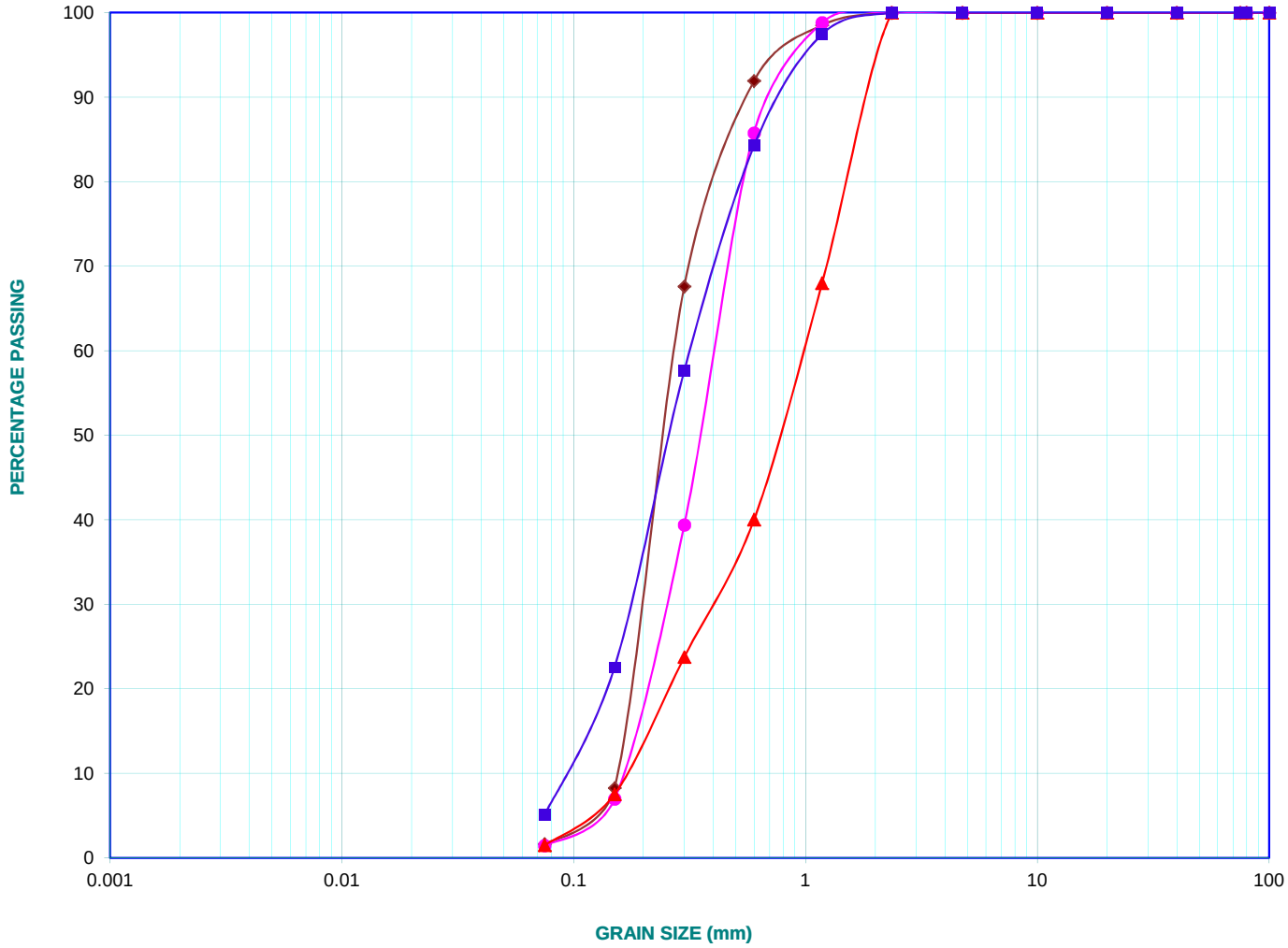
\# : Decayed Wood

**Failure Type**
A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha**
Project Code : **CM 19 01 03**
Borehole No. : **LBH-03**

# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | **Borehole No.** | **: LBH-03** | | | | | **Date :** | **31-May-19** | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | LBH-03 | LBH-03 | LBH-03 | LBH-03 | | | | | | | | |
| **Depth (m)** | 3.00-3.45 | 7.50-7.95 | 10.50-10.95 | 12.00-12.45 | | | | | | | | |
| **Sample Type** | SPT-2 | SPT-5 | SPT-7 | SPT-8 | | | | | | | | |
| **Classification** | SP | SP | SP | SP-SM | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 98 | 99 | 99 | 95 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 2 | 1 | 1 | 5 | | | | | | | | |
| **D60 mm** | 0.280 | 0.400 | 0.990 | 0.310 | | | | | | | | |
| **D30 mm** | 0.200 | 0.260 | 0.400 | 0.180 | | | | | | | | |
| **D10 mm** | 0.160 | 0.170 | 0.180 | 0.095 | | | | | | | | |
| **Cu** | 1.75 | 2.35 | 5.50 | 3.26 | | | | | | | | |
| **Cc** | 0.89 | 0.99 | 0.90 | 1.10 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |

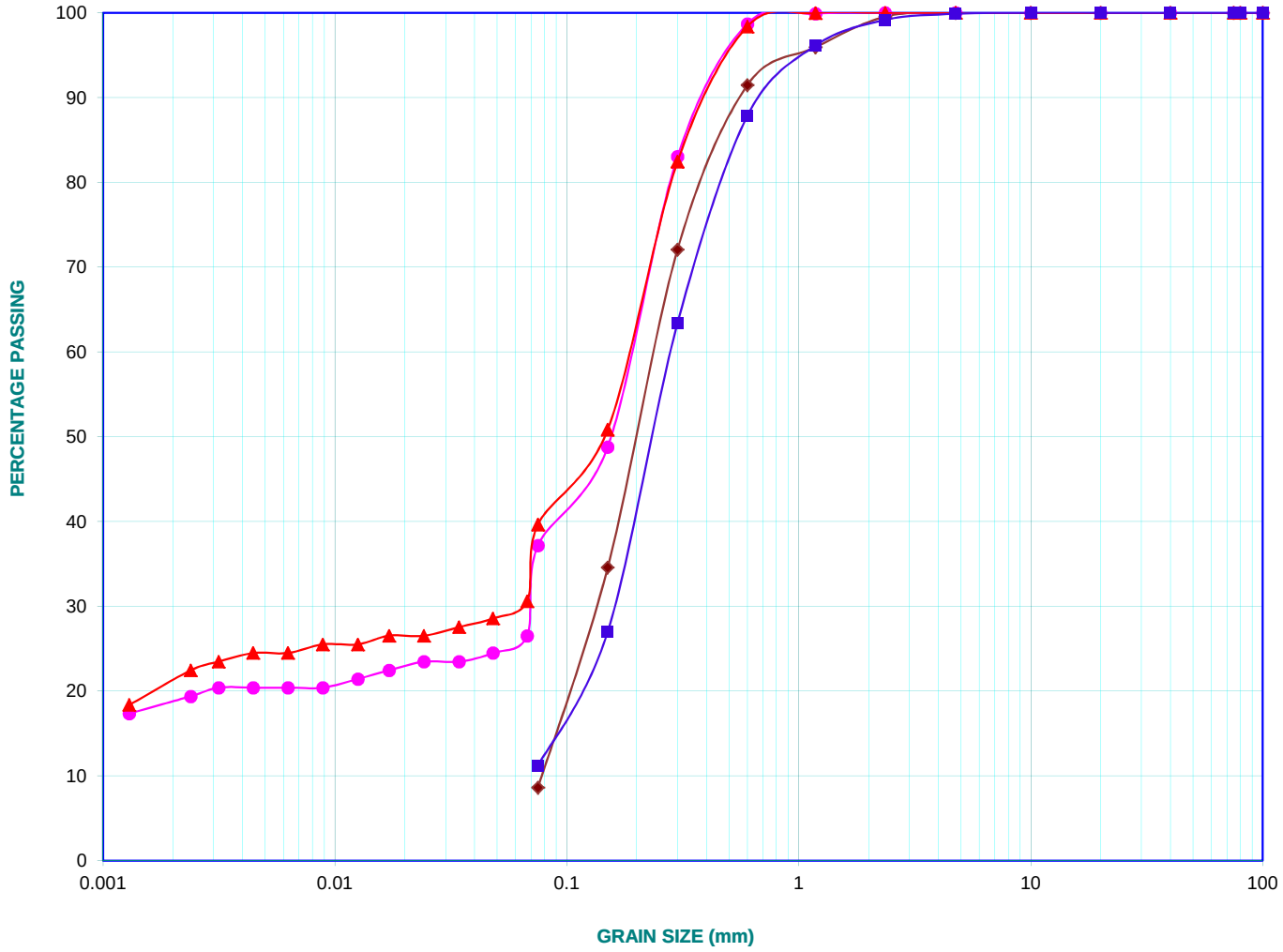



Checked By :

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: LBH-03** |
| **Date :** | **31-May-19** |

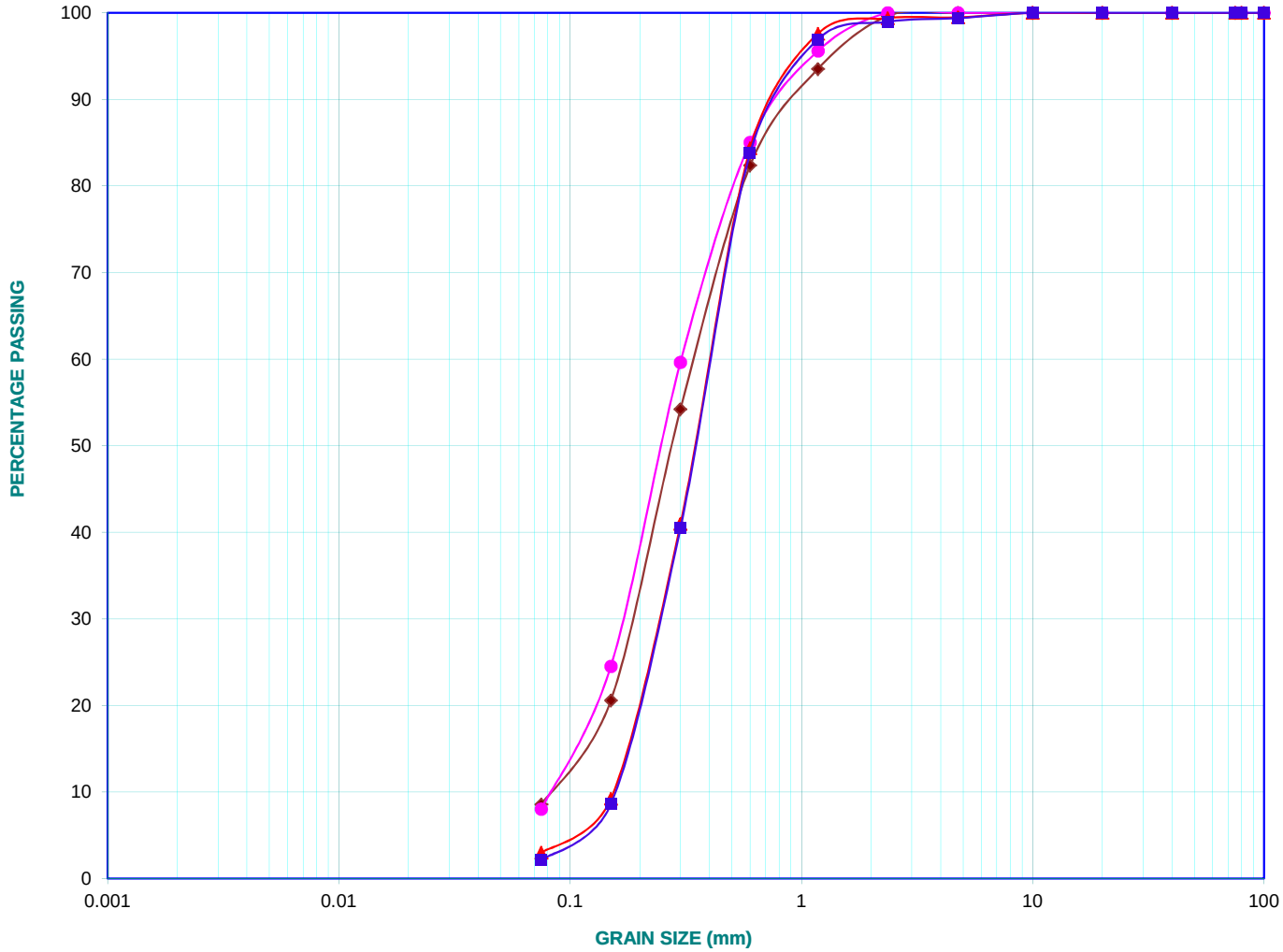
| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | LBH-03 | LBH-03 | LBH-03 | LBH-03 | | | | | | | | |
| **Depth (m)** | 13.50-13.95 | 15.00-15.45 | 16.50-17.00 | 19.50-19.95 | | | | | | | | |
| **Sample Type** | SPT-9 | SPT-10 | UDS-1 | SPT-12 | | | | | | | | |
| **Classification** | SP-SM | SC | SC | SP-SM | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 91 | 63 | 60 | 89 | | | | | | | | |
| **Silt %** | <----> | 18 | 17 | <----> | | | | | | | | |
| **Clay %** | <----> | 19 | 23 | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 9 | 37 | 40 | 11 | | | | | | | | |
| **D60 mm** | 0.230 | | | | | | | | | | | |
| **D30 mm** | 0.140 | | | | | | | | | | | |
| **D10 mm** | 0.080 | | | | | | | | | | | |
| **Cu** | 2.88 | | | | | | | | | | | |
| **Cc** | 1.07 | | | | | | | | | | | |
| **Liquid Limit %** | --- | 33.8 | 31.8 | --- | | | | | | | | |
| **Plastic Limit %** | --- | 16.3 | 15.6 | --- | | | | | | | | |
| **Plasticity Index** | --- | 17.5 | 16.2 | --- | | | | | | | | |




Checked By :

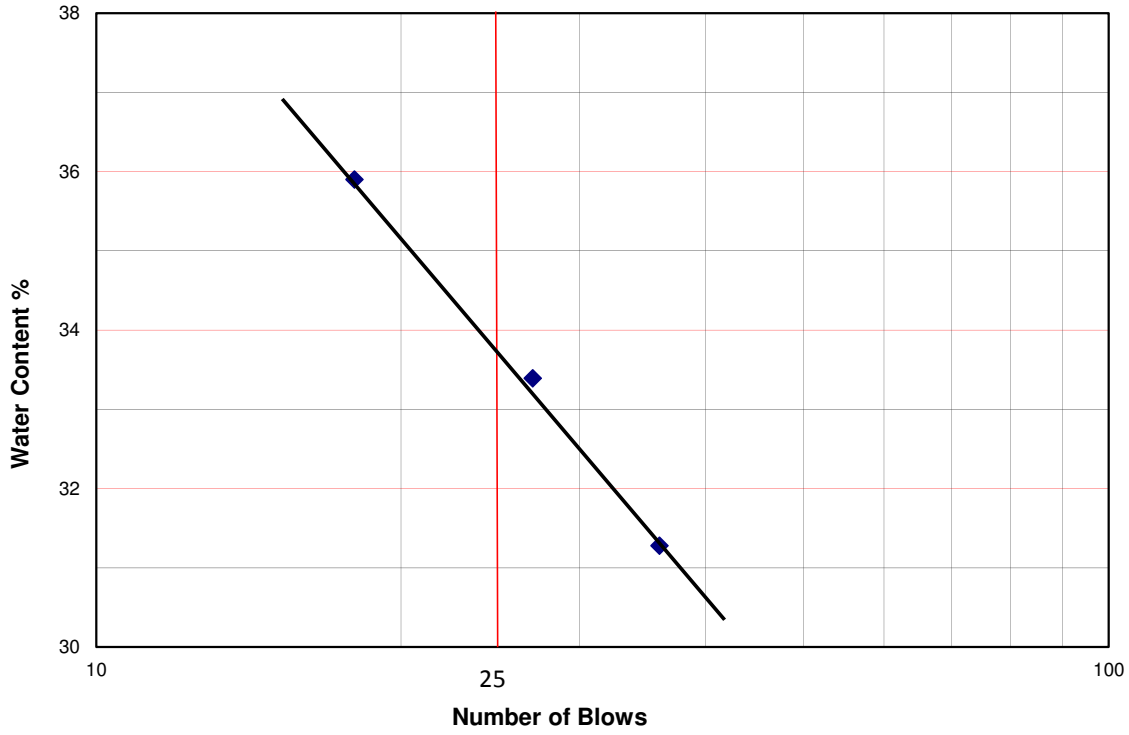
# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | **Borehole No.** | **: LBH-03** | | | | | **Date :** | **31-May-19** | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | LBH-03 | LBH-03 | LBH-03 | LBH-03 | | | | | | | | |
| **Depth (m)** | 21.00-21.45 | 22.50-22.95 | 25.50-25.95 | 28.50-28.95 | | | | | | | | |
| **Sample Type** | SPT-13 | SPT-14 | SPT-16 | SPT-18 | | | | | | | | |
| **Classification** | SP-SM | SP-SM | SP | SP | | | | | | | | |
| **Gravel %** | 0 | 0 | 1 | 1 | | | | | | | | |
| **Sand %** | 91 | 92 | 96 | 97 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 9 | 8 | 3 | 2 | | | | | | | | |
| **D60 mm** | 0.330 | 0.300 | 0.400 | 0.400 | | | | | | | | |
| **D30 mm** | 0.190 | 0.170 | 0.250 | 0.250 | | | | | | | | |
| **D10 mm** | 0.080 | 0.080 | 0.160 | 0.170 | | | | | | | | |
| **Cu** | 4.13 | 3.75 | 2.50 | 2.35 | | | | | | | | |
| **Cc** | 1.37 | 1.20 | 0.98 | 0.92 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |




Checked By :

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 32.37 | 35.52 | 37.34 | | |
| Dry Weight + Can (g) | 26.94 | 29.63 | 29.92 | | |
| Can Weight (g) | 9.58 | 11.99 | 9.25 | | |
| Water Content, % | 31.3 | 33.4 | 35.9 | | |
| Number of Blows | 36 | 27 | 18 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 17.25 | 19.33 | 18.99 |
| Dry Weight + Can (g) | 16.18 | 18.63 | 18.01 |
| Can Weight (g) | 9.52 | 14.37 | 12.01 |
| Water Content, % | 16.1 | 16.4 | 16.3 |

| | |
|---|---|
| Liquid Limit % | 33.8 |
| Plastic Limit % | 16.3 |
| Plasticity Index % | 17.5 |

Preparation of Sample :
Dry State

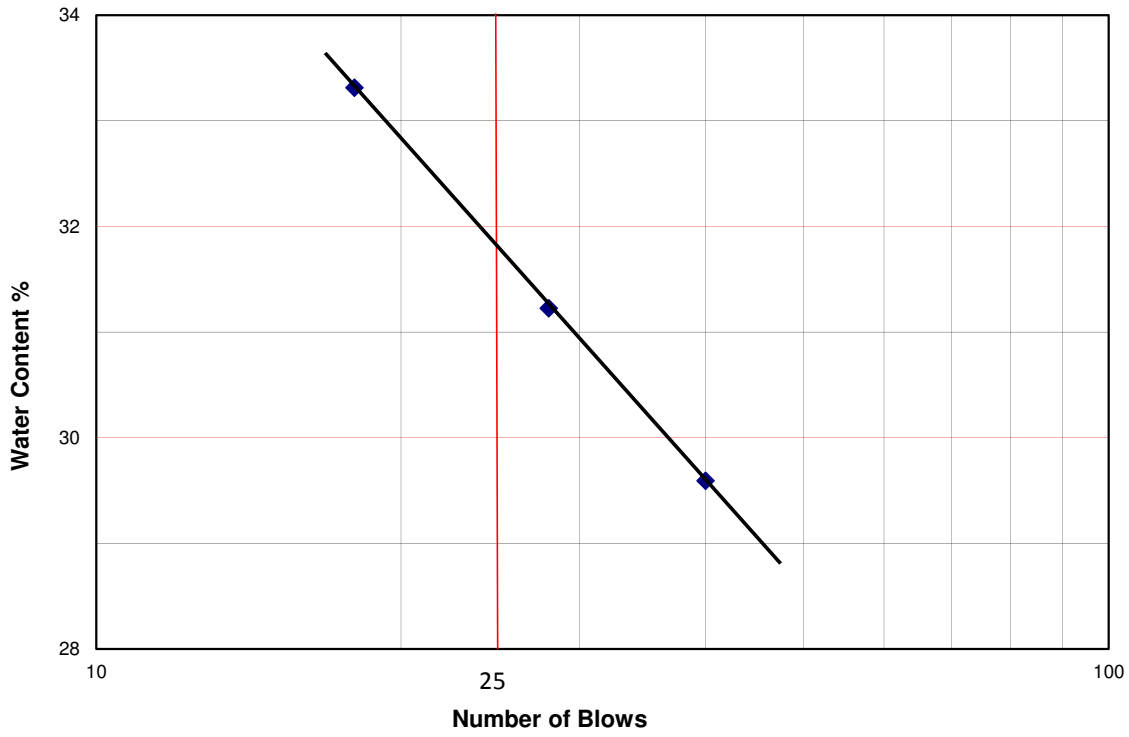
Sample Type: SPT-10

Borehole no.: LBH-03

Depth :15.00-15.45

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 37.41 | 35.33 | 29.58 | | |
| Dry Weight + Can (g) | 31.74 | 30.00 | 24.58 | | |
| Can Weight (g) | 12.58 | 12.93 | 9.57 | | |
| Water Content, % | 29.6 | 31.2 | 33.3 | | |
| Number of Blows | 40 | 28 | 18 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 23.29 | 19.59 | 16.71 |
| Dry Weight + Can (g) | 21.93 | 18.22 | 15.65 |
| Can Weight (g) | 13.16 | 9.51 | 8.84 |
| Water Content, % | 15.5 | 15.7 | 15.6 |

Liquid Limit % 31.8

Plastic Limit % 15.6

Plasticity Index % 16.2

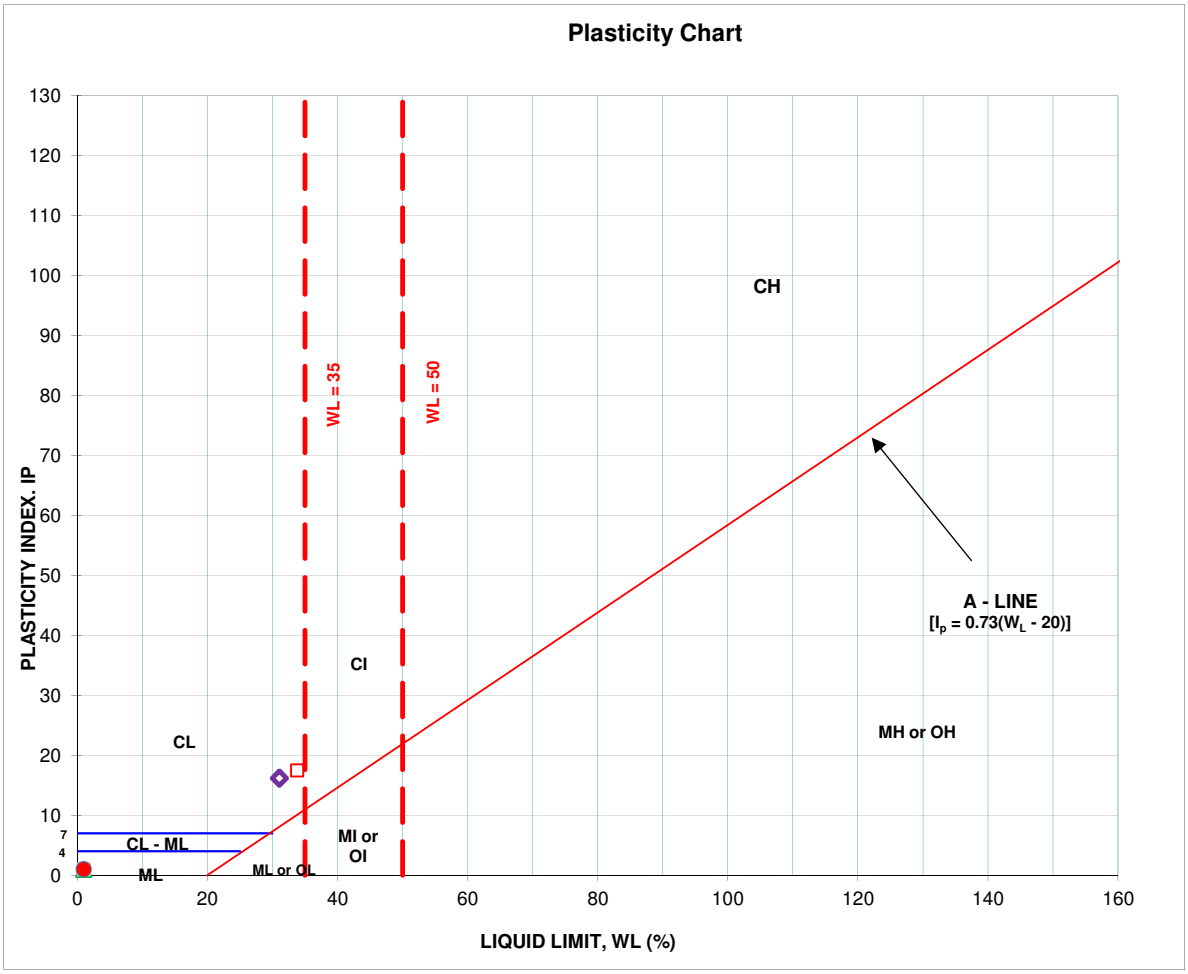
Preparation of Sample :
Dry State

Sample Type: UDS-01

Borehole no.: LBH-03

Depth :16.50-17.00

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.




| | Sample Type | Depth (m) | $W_L$ | $W_P$ | $I_P$ | Remarks |
|---|---|---|---|---|---|---|
| □ | SPT-10 | 15.00-15.45 | 33.8 | 16.3 | 17.5 | CL: Inorganic clays of low to medium plasticity. |
| ◇ | UDS-01 | 16.50-17.00 | 31.1 | 15.2 | 16.2 | CL: Inorganic clays of low to medium plasticity. |
| | | | | | | |

| | | | |
|---|---|---|---|
| ML | Inorganic silts, very fine sands, rock flour, silty or clayey fine sands | MH | Inorganic silts, or diatomaceous fine sands or silts, elastic silts |
| CL | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays | CH | Inorganic clays of high plasticity, fat clays |
| OL | Organic silts and organic silty clays of low plasticity | OH | Organic silts and organic clays of medium t high plasticity |
| CI | Clays with Intermediate plasticity | MI | Silt with intermediate plasticity |

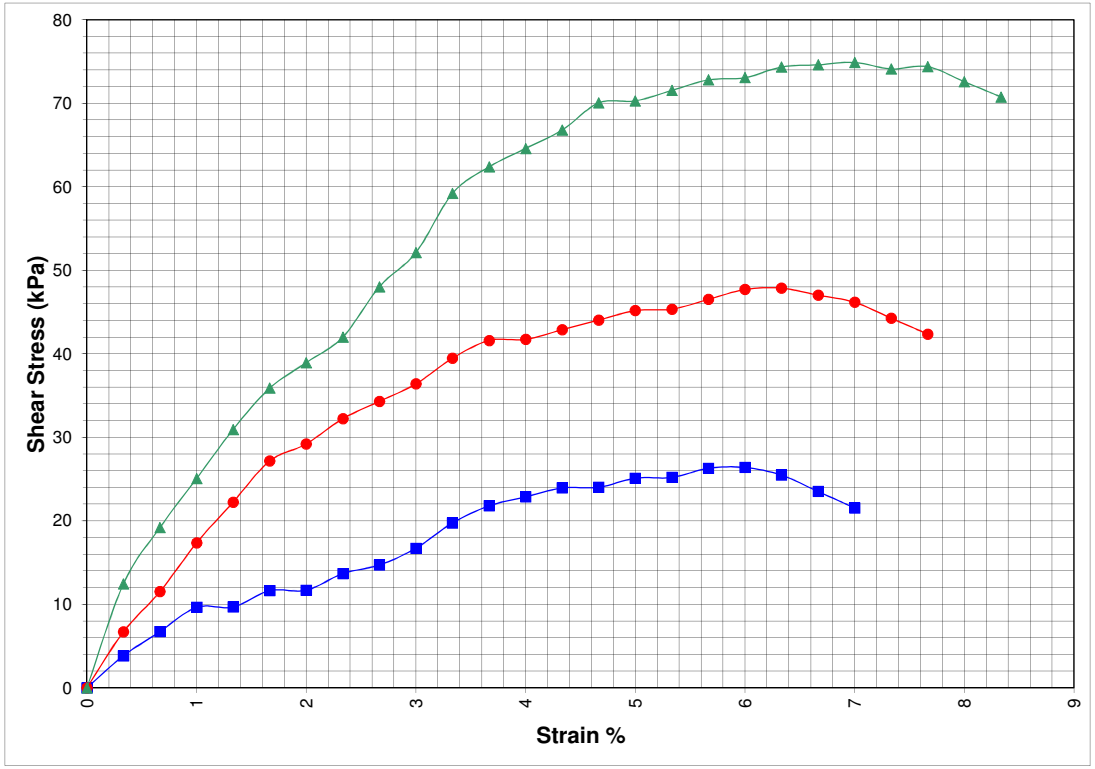
## PLASTICITY CHART (IS : 1498 - 1987)

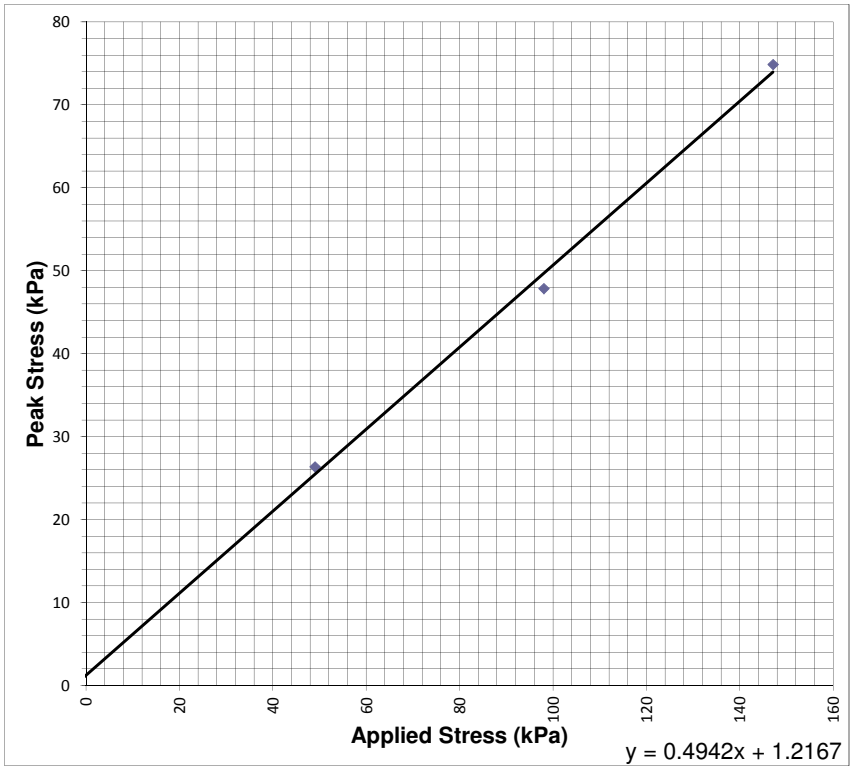
BOREHOLE NAME : LBH-03

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 48 |
| | Stage 3 | 147 | 75 |

| | | |
|---|---|---|
| Angle of Friction | **26.30** | ° |
| Apparent Cohesion | **1.22** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

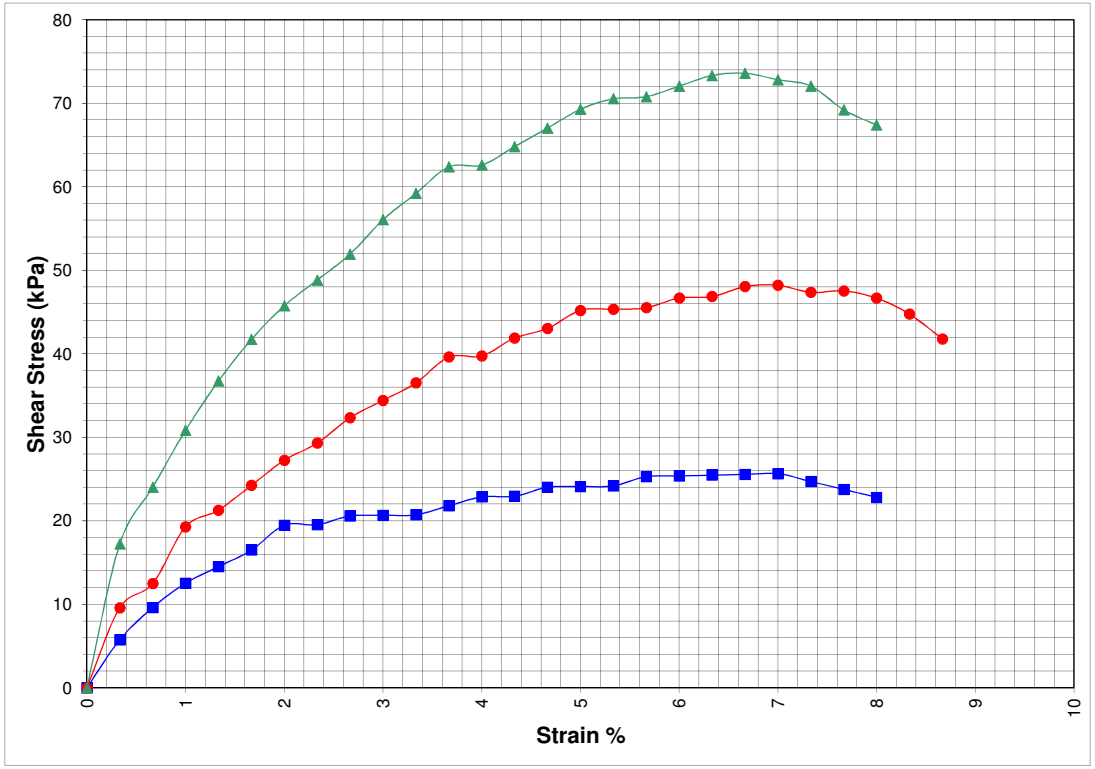
**Borehole: LBH-03**

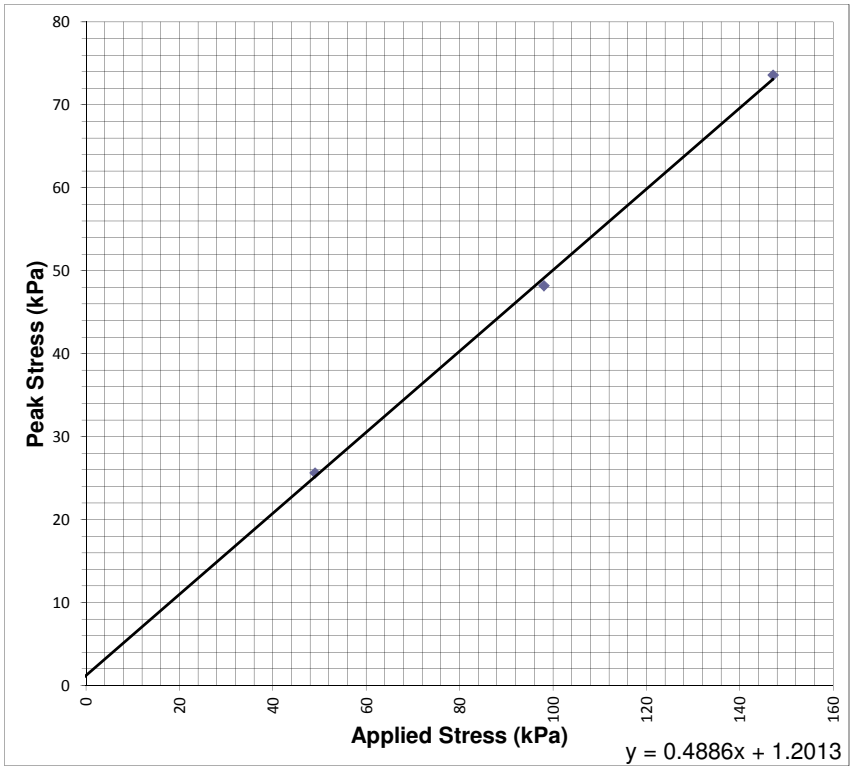
**Sample Type: SPT-01**

**Depth: 1.50-1.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 48 |
| | Stage 3 | 147 | 74 |

| | | |
|---|---|---|
| Angle of Friction | **26.04** | ° |
| Apparent Cohesion | **1.08** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

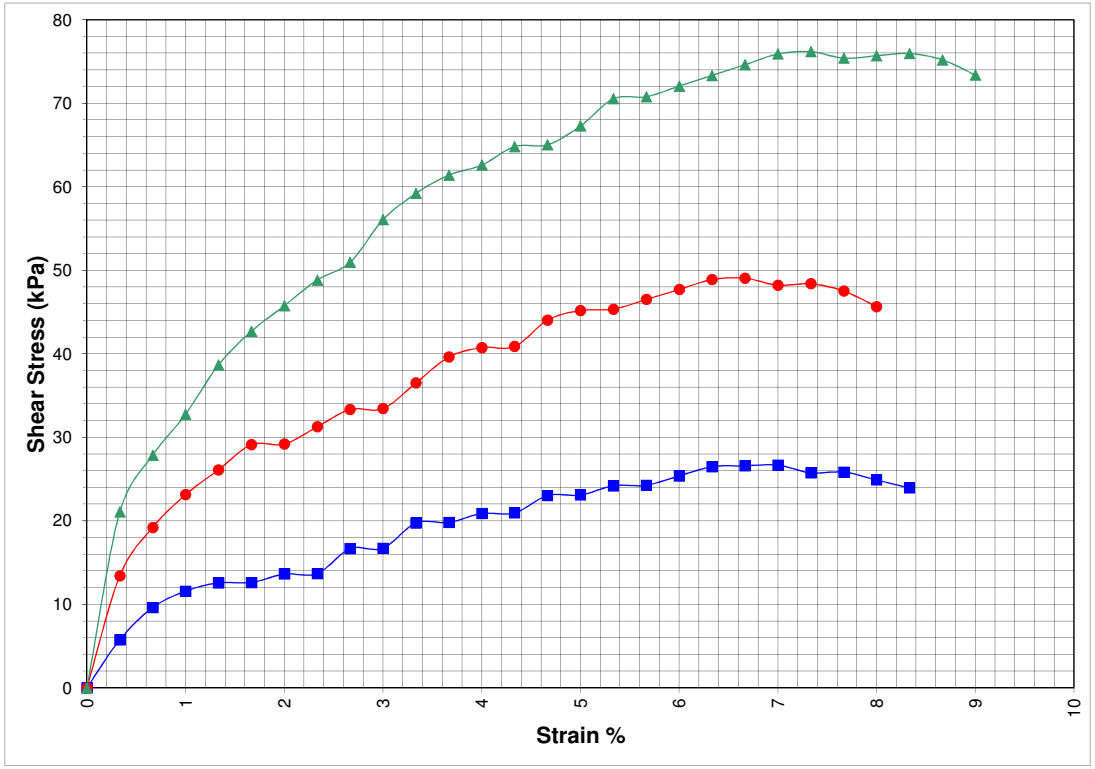
**Borehole: LBH-03**

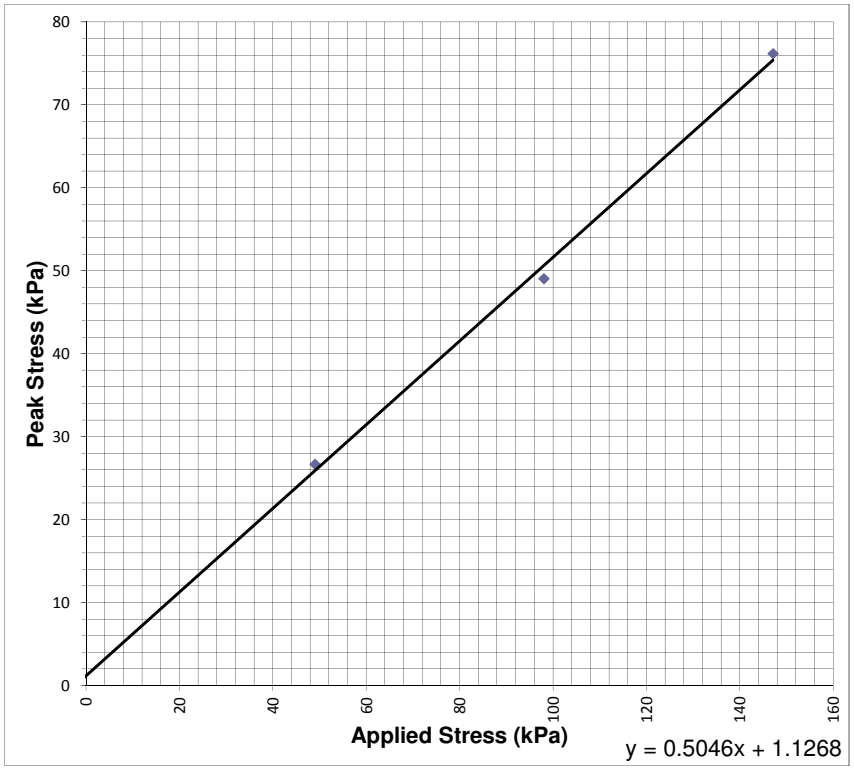
**Sample Type: SPT-03**

**Depth: 4.50-4.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 49 |
| | Stage 3 | 147 | 76 |

| | | |
|---|---|---|
| Angle of Friction | **26.78** | ° |
| Apparent Cohesion | **1.13** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

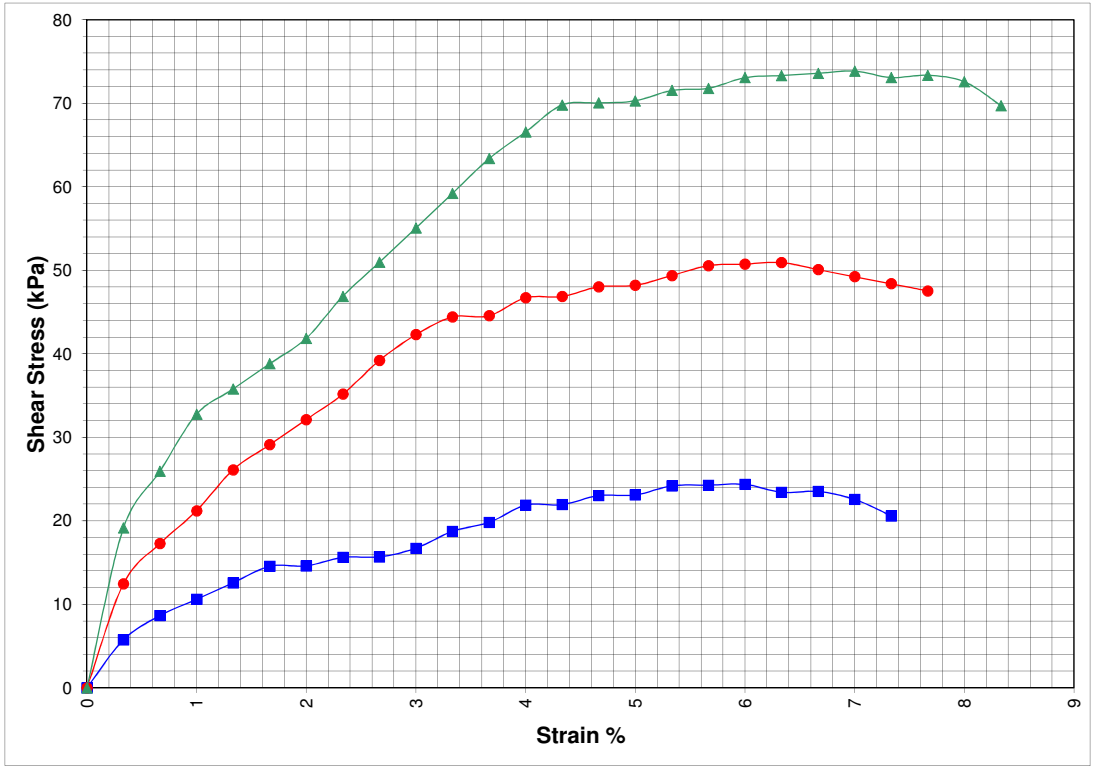
**Borehole: LBH-03**

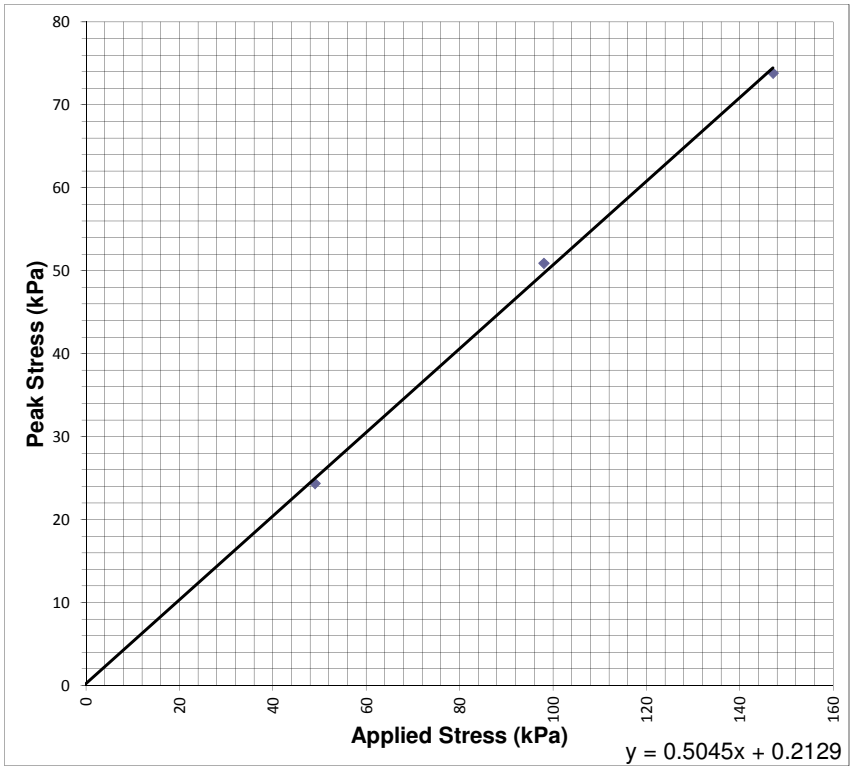
**Sample Type: SPT-04**

**Depth: 6.00-6.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 24 |
| | Stage 2 | 98 | 51 |
| | Stage 3 | 147 | 74 |

| | | |
|---|---|---|
| Angle of Friction | **26.77** | ° |
| Apparent Cohesion | **0.21** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

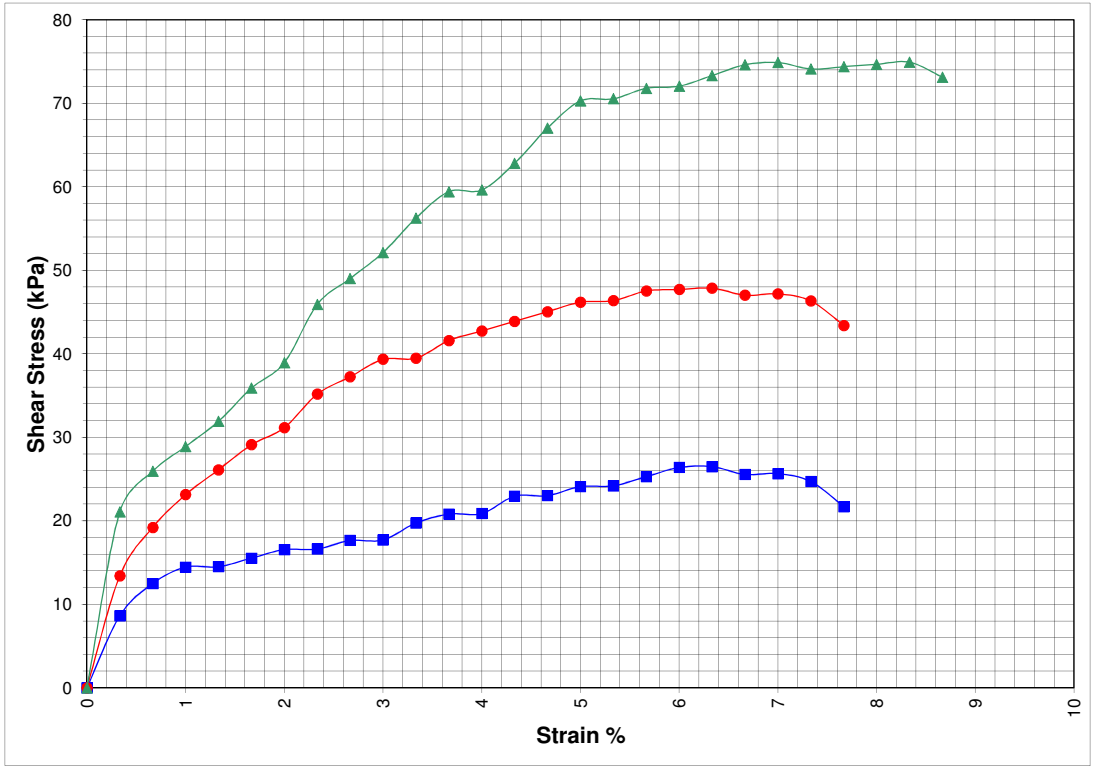
**Borehole: LBH-03**

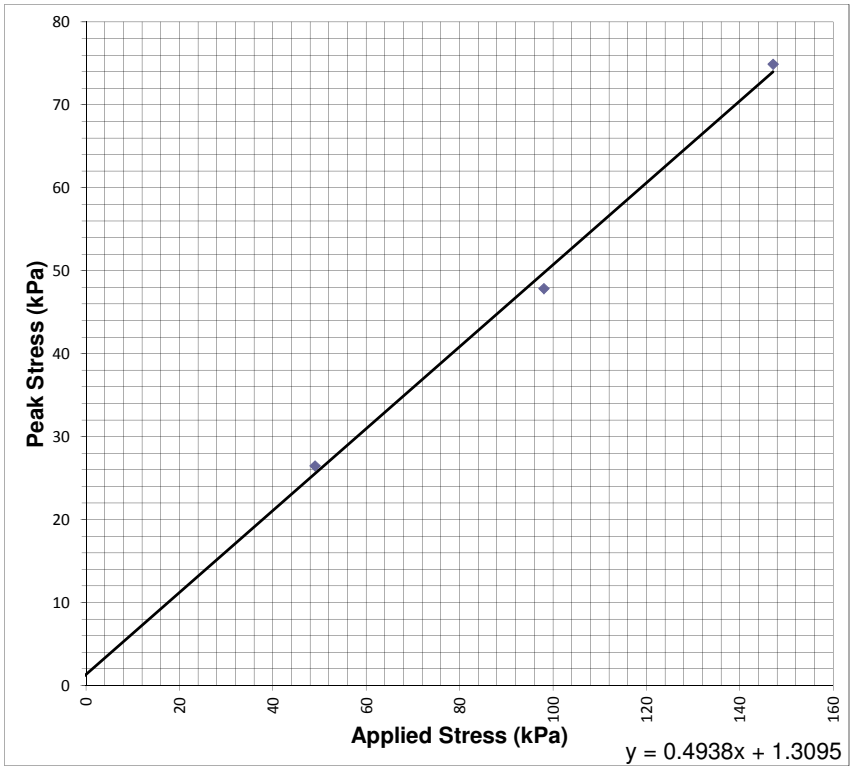
**Sample Type: SPT-06**

**Depth: 9.00-9.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 48 |
| | Stage 3 | 147 | 75 |

| | | |
|---|---|---|
| Angle of Friction | **26.28** | ° |
| Apparent Cohesion | **1.31** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

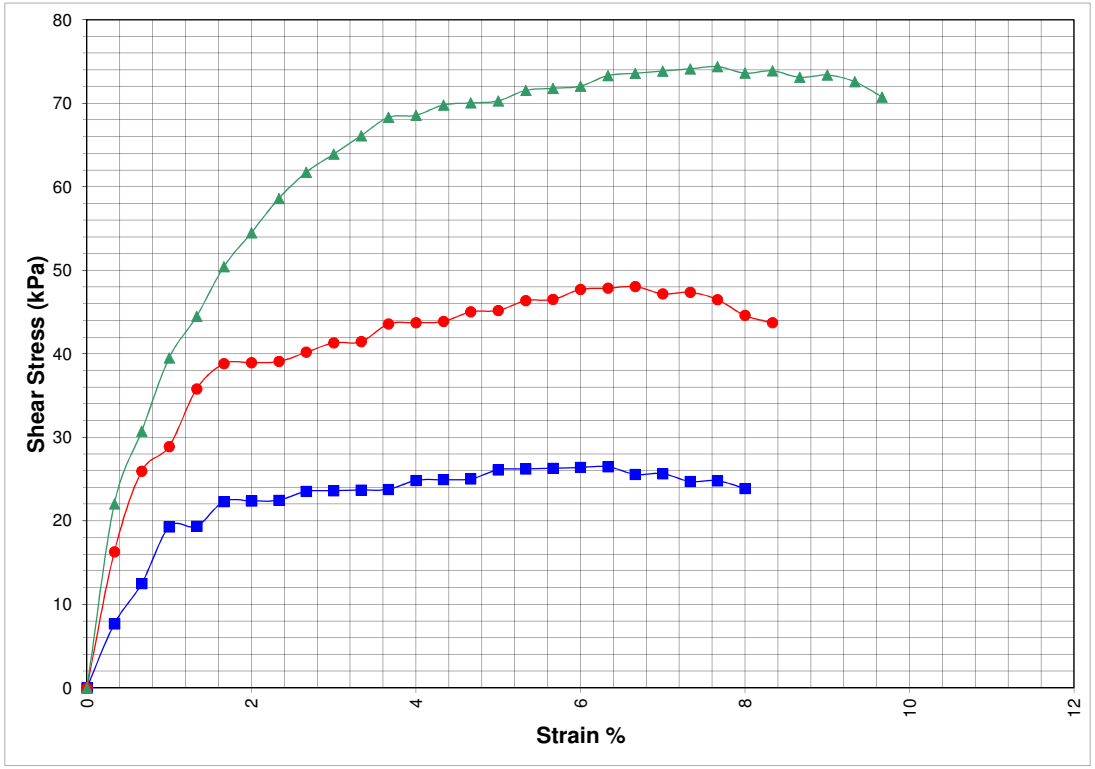
**Borehole: LBH-03**

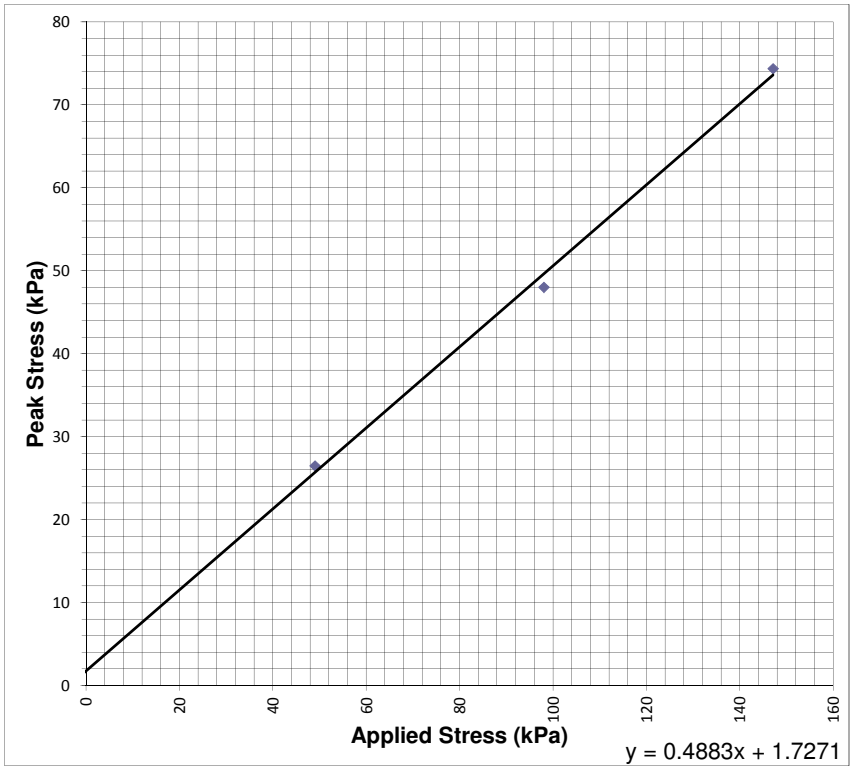
**Sample Type: SPT-11**

**Depth: 18.00-18.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 48 |
| | Stage 3 | 147 | 74 |

| | | |
|---|---|---|
| Angle of Friction | **26.03** | ° |
| Apparent Cohesion | **1.73** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

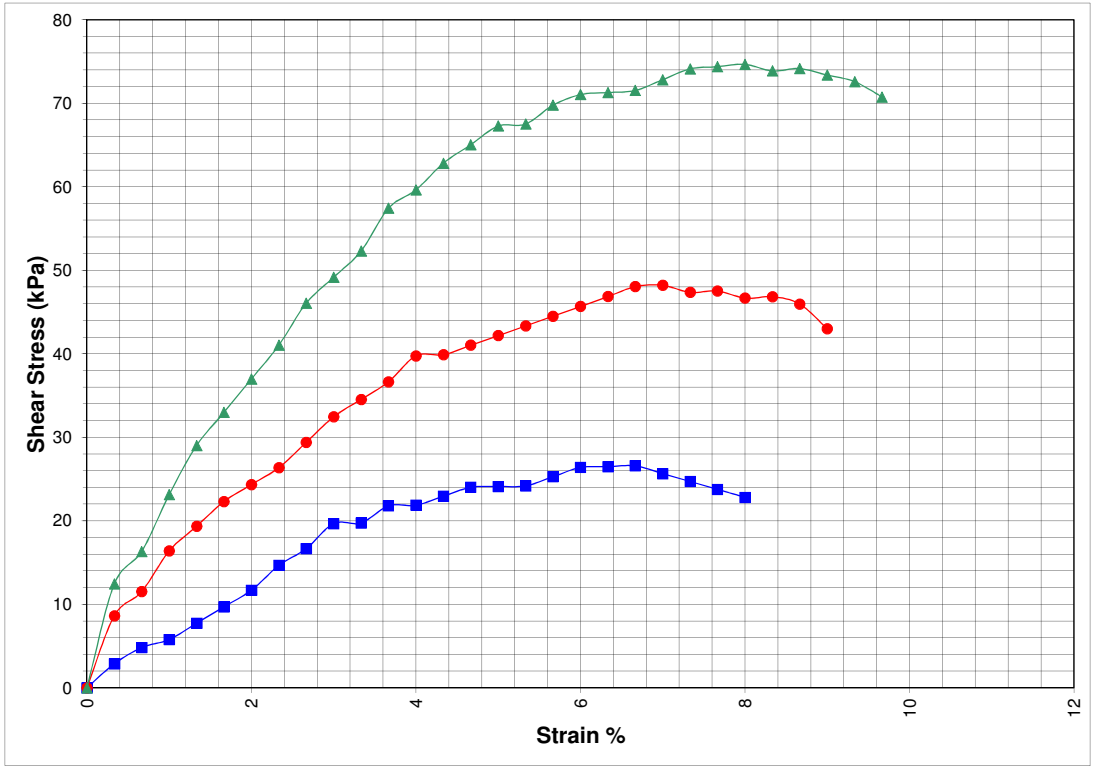
**Borehole: LBH-03**

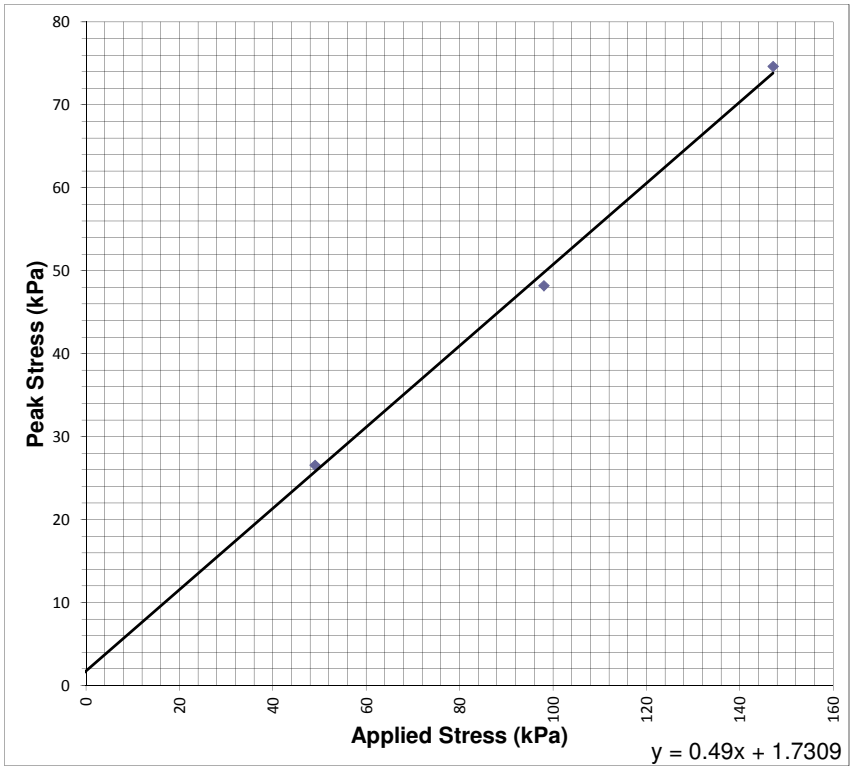
**Sample Type: SPT-15**

**Depth: 24.00-24.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 48 |
| | Stage 3 | 147 | 75 |

| | | |
|---|---|---|
| Angle of Friction | **26.10** | ° |
| Apparent Cohesion | **1.73** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

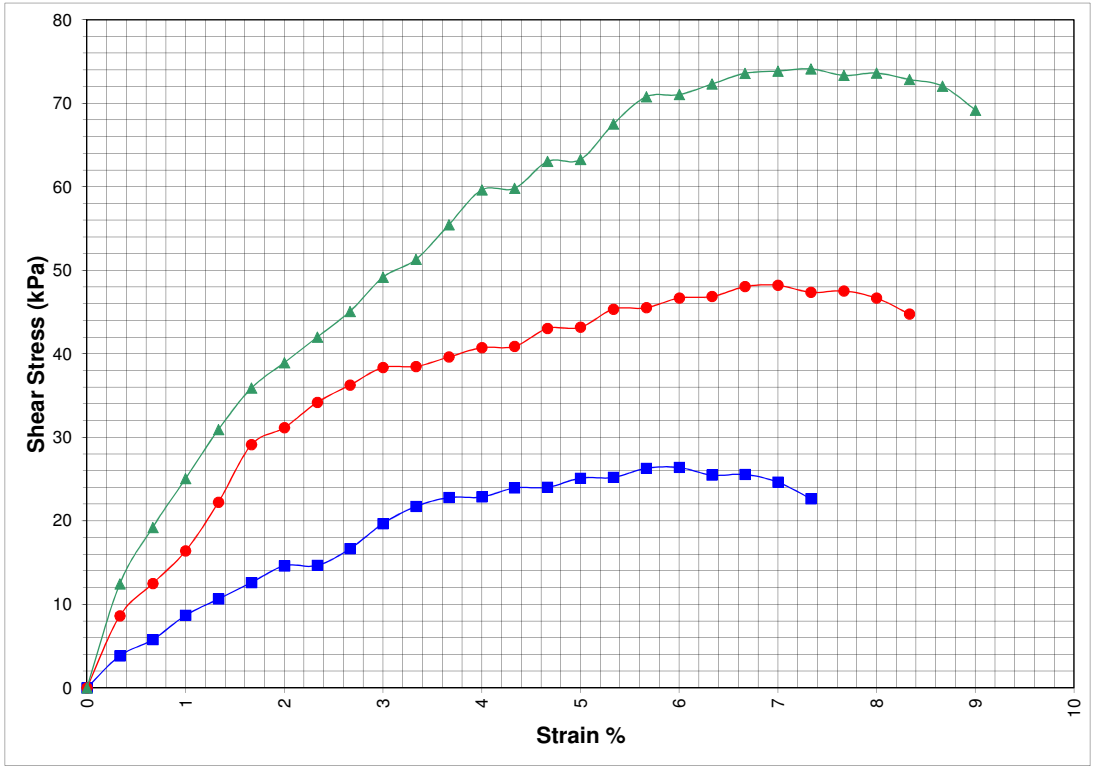
**Borehole: LBH-03**

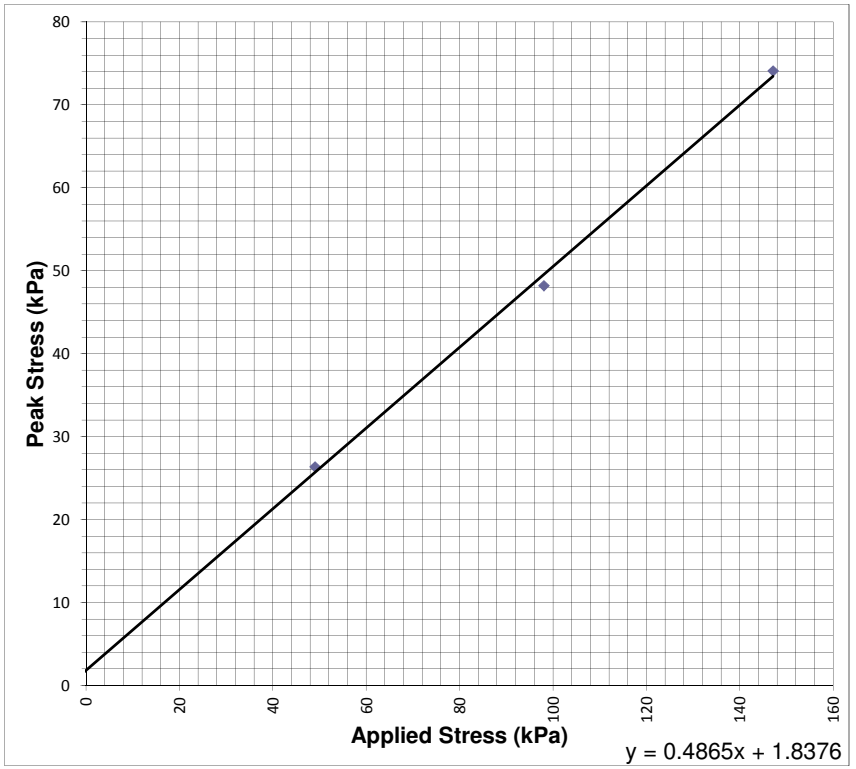
**Sample Type: SPT-17**

**Depth: 27.00-27.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 48 |
| | Stage 3 | 147 | 74 |

| | | |
|---|---|---|
| Angle of Friction | **25.94** | ° |
| Apparent Cohesion | **1.84** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: LBH-03**

**Sample Type: SPT-19**

**Depth: 30.00-30.45 m**

# CONSOLIDATION TEST

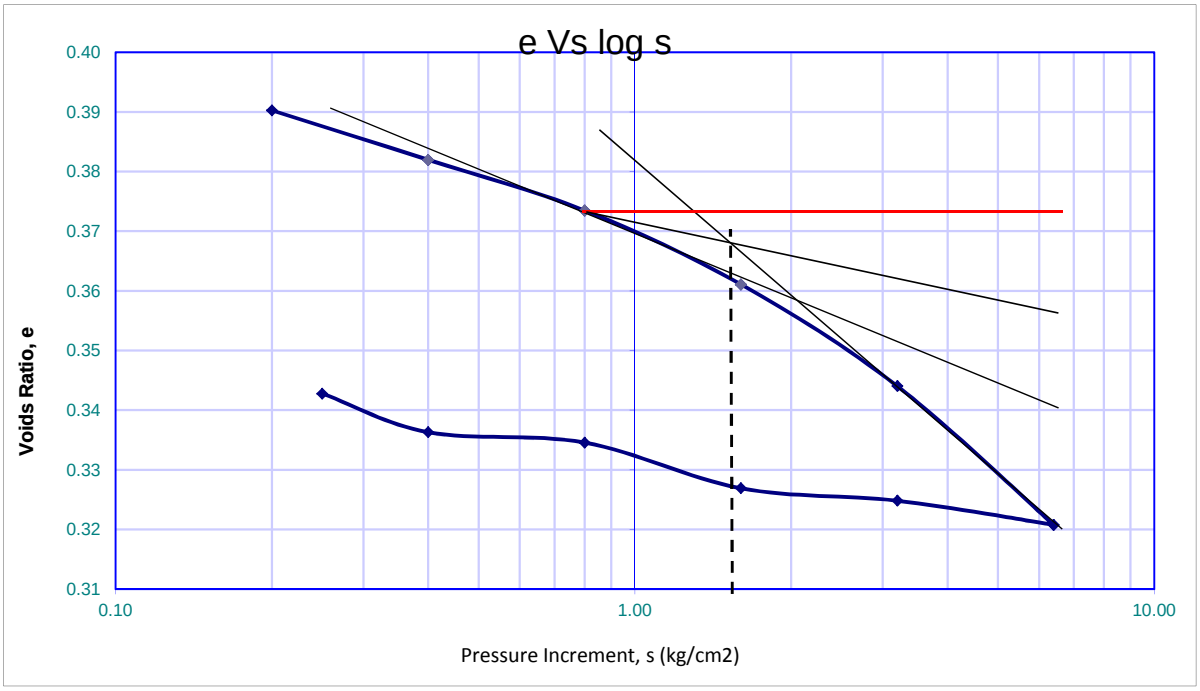
PROJECT: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha

| | | | |
|---|---|---|---|
| Bore Hole No.: | LBH-03 | Date: | 31-May-2019 |
| Depth (m): | 16.50-17.00 | Job No.: | CM 19 01 03 |
| Location: | Odisha | Sample Type: | UDS-1 |

| | *Before Test* | *After Test* | | |
|---|---|---|---|---|
| Bulk Density (gm/cc): | 2.13 | 2.17 | Height of specimen (cm): | 2.0 |
| NMC (%): | 15.22 | 13.32 | Diameter of specimen (cm): | 6.0 |
| Dry Density (gm/cc): | 1.85 | 1.92 | Cross-sectional area ($cm^2$): | 28.29 |
| Specific Gravity: | 2.57 | | Degree of saturation (%): | 100 |

| Applied Pressure ($kg/cm^2$) | | Change in length (cm) | H (cm) | Voids Ratio e | $t_{90}$ (min) | Cc | Coeff. Of compressibility av ($cm^2/kg$) | Coeff. of volume change, mv ($cm^2/kg$) | Coeff. Of consolidation cv ($cm^2/min$) |
|---|---|---|---|---|---|---|---|---|---|
| From | To | | | | | | | | |
| 0.0 | 0.00 | 0 | 2.0000 | 0.3918 | | | | | |
| 0.0 | 0.2 | 0.0023 | 1.9977 | 0.3902 | 1.21 | 0.0016 | 0.0080 | 0.0057 | 0.7000 |
| 0.2 | 0.40 | 0.0119 | 1.9858 | 0.3820 | 67.24 | 0.0275 | 0.0414 | 0.0298 | 0.0125 |
| 0.4 | 0.80 | 0.0122 | 1.9736 | 0.3735 | 2.25 | 0.0282 | 0.0212 | 0.0154 | 0.3693 |
| 0.8 | 1.60 | 0.0178 | 1.9558 | 0.3611 | 16.00 | 0.0411 | 0.0155 | 0.0113 | 0.0511 |
| 1.6 | 3.20 | 0.0245 | 1.9313 | 0.3440 | 1.21 | 0.0566 | 0.0107 | 0.0078 | 0.6618 |
| 3.2 | 6.40 | 0.0334 | 1.8979 | 0.3208 | 1.00 | 0.0772 | 0.0073 | 0.0054 | 0.7771 |
| -- | -- | -- | 1.8979 | -- | -- | | | | |
| -- | 3.20 | 0.0058 | 1.9037 | 0.3248 | | | | | |
| 3.2 | 1.60 | 0.003 | 1.9067 | 0.3269 | | | | | |
| 1.6 | 0.80 | 0.011 | 1.9177 | 0.3346 | | | | | |
| 0.8 | 0.40 | 0.0025 | 1.9202 | 0.3363 | | | | | |
| 0.4 | 0.2 | 0.0093 | 1.9295 | 0.3428 | | | | | |
| 0.2 | 0.00 | -- | -- | -- | | | | | |

LBH-03
16.50-17.00




**Preconsolidation Pressure ($kg/cm^2$):** 1.60 156.91 Kpa

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-1 | 0.00-0.25 | SP-SM | | | | 20.5 | 16.94 | 6.88 | 14.06 | 2.62 | 0 | 94 | <--> | <--> | 6 | | | | | | | | | | | | | | | | | | |
| SPT-2 | 1.50-1.72 | SP-SM | | | | 13.6 | 17.48 | 7.42 | 15.39 | | 0 | 93 | <--> | <--> | 7 | DST | | | 0.84 | 33.2 | | | | | | | | | | | | | |
| SPT-3 | 3.00-3.12 | | | | | 20.3 | 19.36 | 9.30 | 16.09 | 2.63 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-4 | 4.50-4.65 | SP-SM | | | | 16.6 | 18.52 | 8.46 | 15.88 | 2.63 | 0 | 89 | <--> | <--> | 11 | | | | | | | | | | | | | | | | | | |
| SPT-5 | 6.00-6.25 | | | | | 13.8 | 17.70 | 7.64 | 15.56 | | | | | | | DST | | | 1.13 | 32.3 | | | | | | | | | | | | |
| SPT-6 | 7.50-7.80 | SP | | | | 18.0 | 15.93 | 5.87 | 13.50 | | 0 | 96 | <--> | <--> | 4 | | | | | | | | | | | | | | | | 8.58 | 0.40 | 1.00 | 200 | 14160 |
| SPT-7 | 9.00-9.20 | | | | | 11.9 | 15.26 | 5.20 | 13.63 | | | | | | | DST | | | 1.13 | 32.0 | | | | | | | | | | | | | |
| SPT-8 | 10.50-10.75 | SP | | | | 20.1 | 17.19 | 7.13 | 14.31 | 2.63 | 0 | 96 | <--> | <--> | 4 | | | | | | | | | | | | | | | | | | |
| SPT-9 | 12.00-12.20 | | | | | 19.4 | 17.14 | 7.08 | 14.35 | | | | | | | DST | | | 1.00 | 30.1 | | | | | | | | | | | | | |
| SPT-10 | 13.50-13.70 | | | | | 23.9 | 20.41 | 10.35 | 16.47 | 2.58 | 0 | 42 | 46 | 12 | 58 | | | | | | | | | | | | | | | | | | |
| SPT-11 | 15.00-15.20 | SP-SM | | | | 18.4 | 18.95 | 8.89 | 16.01 | | 0 | 90 | <--> | <--> | 10 | | | | | | | | | | | | | | | | | | |
| SPT-12 | 16.50-16.70 | | | | | 18.3 | 16.02 | 5.96 | 13.54 | | | | | | | DST | | | 1.56 | 27.9 | | | | | | | | | | | | | |
| SPT-13 | 18.00-18.30 | SP-SM | | | | 17.3 | 17.60 | 7.54 | 15.00 | 2.64 | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | | | | |
| SPT-14 | 19.50-19.65 | | | | | 18.5 | 16.73 | 6.67 | 14.12 | 2.61 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-15 | 21.00-21.30 | | | | | 18.1 | 16.51 | 6.45 | 13.98 | | | | | | | DST | | | 1.19 | 28.3 | | | | | | | | | | | | | |
| SPT-16 | 22.50-22.80 | SP-SM | | | | 19.1 | 16.09 | 6.03 | 13.51 | 2.64 | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | | | | |
| SPT-17 | 24.00-24.25 | SP | | | | 17.9 | 16.14 | 6.08 | 13.70 | | 0 | 96 | <--> | <--> | 4 | | | | | | | | | | | | | | | | | | |
| SPT-18 | 25.50-25.80 | | | | | 16.4 | 18.41 | 8.35 | 15.81 | | | | | | | DST | | | 2.14 | 27.2 | | | | | | | | | | | | | |
| SPT-19 | 27.00-27.30 | SP | | | | 13.7 | 15.43 | 5.37 | 13.57 | 2.65 | 0 | 97 | <--> | <--> | 3 | | | | | | | | | | | | | | | | | | |
| SPT-20 | 28.50-28.75 | | | | | 12.0 | 14.36 | 4.30 | 12.82 | | | | | | | DST | | | 0.99 | 27.8 | | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

\# : Decayed Wood

**Failure Type**

A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-04**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-21 | 30.00-30.30 | SP | | | | 12.8 | 14.99 | 4.93 | 13.29 | | 0 | 96 | <--> | <--> | 4 | | | | | | | | | | | | | | | | | | |
| SPT-22 | 31.50-31.75 | | | | | 17.4 | 15.66 | 5.60 | 13.34 | 2.65 | | | | | | | | | | | | | | | | | | | 7.86 | 0.40 | 1.00 | 200 | 12390 |
| SPT-23 | 33.00-33.30 | | | | | 18.7 | 18.29 | 8.23 | 15.41 | | | | | | | DST | | | 0.86 | 27.0 | | | | | | | | | | | | |
| SPT-24 | 34.50-34.70 | SP | | | | 17.8 | 17.38 | 7.32 | 14.76 | | 0 | 97 | <--> | <--> | 3 | | | | | | | | | | | | | | | | | | |
| SPT-25 | 36.00-36.30 | | | | | 17.1 | 16.59 | 6.53 | 14.17 | 2.62 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-26 | 37.50-37.75 | SP-SM | | | | 21.0 | 18.29 | 8.23 | 15.12 | | 0 | 93 | <--> | <--> | 7 | | | | | | | | | | | | | | | | | | |
| SPT-27 | 39.00-39.30 | SP-SM | | | | 19.5 | 18.41 | 8.35 | 15.41 | 2.62 | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | | | | |
| SPT-28 | 40.50-40.75 | | | | | 17.0 | 17.76 | 7.70 | 15.18 | | | | | | | DST | | | 3.24 | 27.3 | | | | | | | | | | | | |
| SPT-29 | 42.00-42.20 | SP | | | | 17.9 | 16.63 | 6.57 | 14.10 | | 0 | 97 | <--> | <--> | 3 | | | | | | | | | | | | | | | | | | |
| SPT-30 | 43.50-43.70 | SP-SM | | | | 18.2 | 15.87 | 5.81 | 13.43 | | 0 | 94 | <--> | <--> | 6 | | | | | | | | | | | | | | | | | | |
| SPT-31 | 45.00-45.15 | | | | | 18.0 | 16.87 | 6.81 | 14.29 | 2.62 | | | | | | | | | | | | | | | | | | | | | | | |
| **END OF BOREHOLE** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
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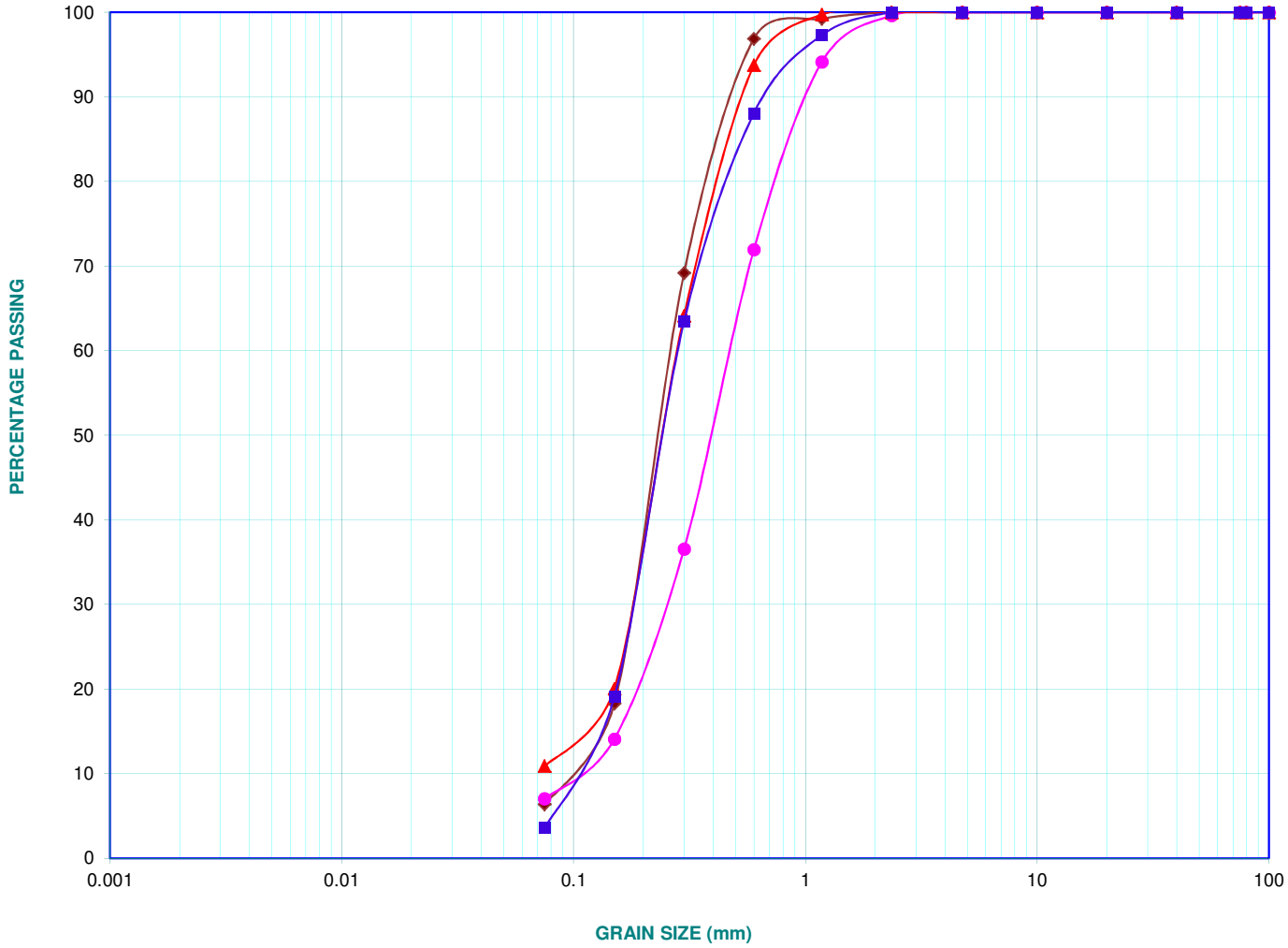
**Failure Type**

A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-04**

# GRAIN SIZE ANALYSIS

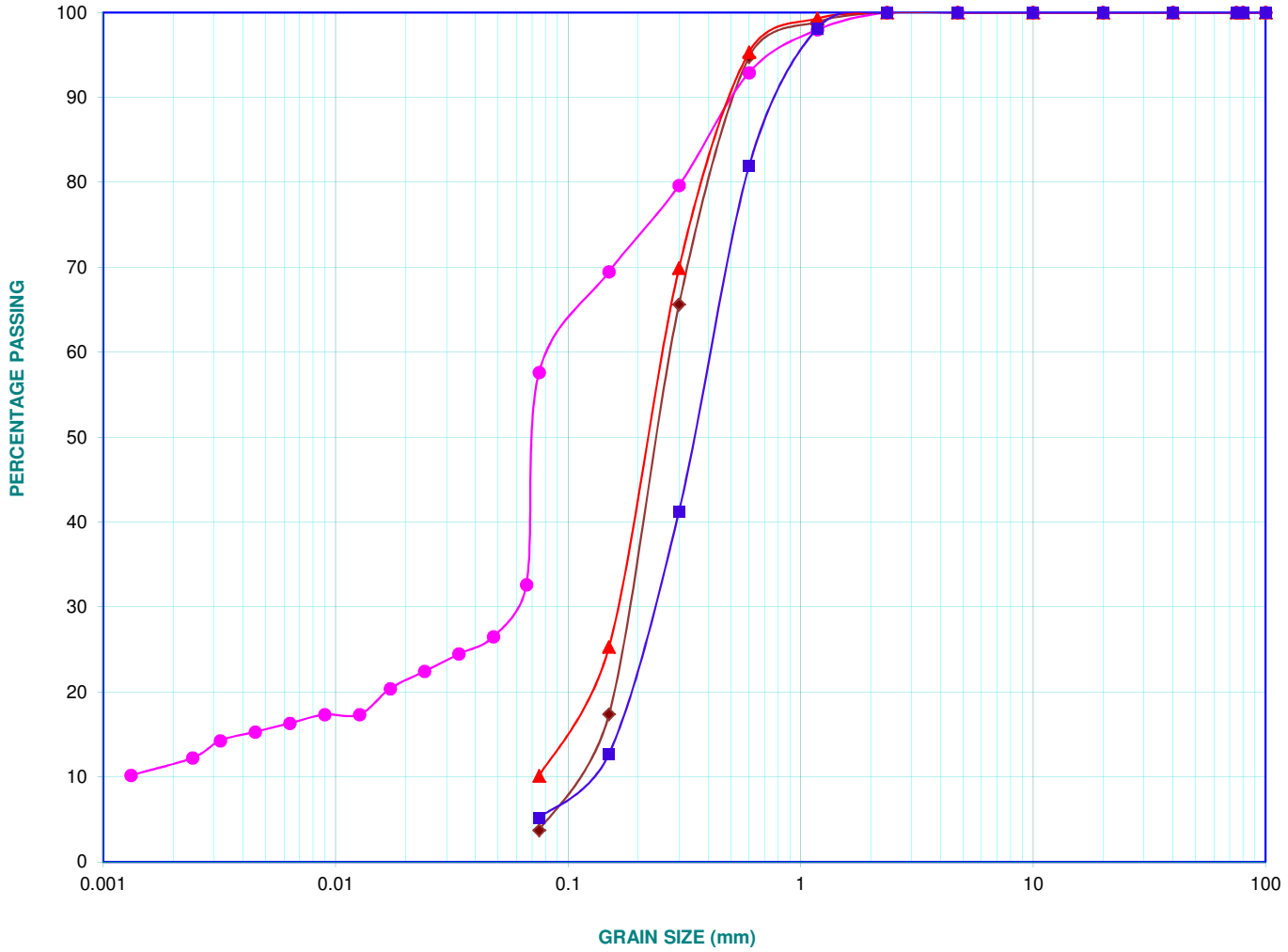
| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | **Borehole No.** | **: MBH-04** | | | **Date :** | **7-Jun-19** | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | . | SAND F | SAND M | SAND C | GRAVEL F | GRAVEL C |
| **Bore Hole .** | MBH-04 | MBH-04 | MBH-04 | MBH-04 | | | | | | | | |
| **Depth (m)** | 0.00-0.25 | 1.50-1.72 | 4.50-4.65 | 7.50-7.80 | | | | | | | | |
| **Sample Type** | SPT-1 | SPT-2 | SPT-4 | SPT-6 | | | | | | | | |
| **Classification** | SP-SM | SP-SM | SP-SM | SP | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 94 | 93 | 89 | 96 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 6 | 7 | 11 | 4 | | | | | | | | |
| **D60 mm** | 0.260 | 0.480 | 0.290 | 0.280 | | | | | | | | |
| **D30 mm** | 0.180 | 0.250 | 0.180 | 0.180 | | | | | | | | |
| **D10 mm** | 0.100 | 0.120 | 0.150 | 0.110 | | | | | | | | |
| **Cu** | 2.60 | 4.00 | 1.93 | 2.55 | | | | | | | | |
| **Cc** | 1.25 | 1.09 | 0.74 | 1.05 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | : Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha. | | | | | | | | | | |
| **Job No.** | : CM 19 01 03 | | | **Borehole No.** | : MBH-04 | | | **Date :** | 7-Jun-19 | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND F | SAND M | SAND C | GRAVEL F / GRAVEL C |
| **Bore Hole .** | MBH-04 | MBH-04 | MBH-04 | MBH-04 | | | | | | | |
| **Depth (m)** | 10.50-10.75 | 13.50-13.70 | 15.00-15.20 | 18.00-18.30 | | | | | | | |
| **Sample Type** | SPT-8 | SPT-10 | SPT-11 | SPT-13 | | | | | | | |
| **Classification** | SP | | SP-SM | SP-SM | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | |
| **Sand %** | 96 | 42 | 90 | 95 | | | | | | | |
| **Silt %** | <----> | 46 | <----> | <----> | | | | | | | |
| **Clay %** | <----> | 12 | <----> | <----> | | | | | | | |
| **Fines % (Silt+Clay)** | 4 | 58 | 10 | 5 | | | | | | | |
| **D60 mm** | 0.280 | 0.080 | 0.150 | 0.400 | | | | | | | |
| **D30 mm** | 0.180 | 0.060 | 0.170 | 0.230 | | | | | | | |
| **D10 mm** | 0.120 | 0.001 | 0.075 | 0.140 | | | | | | | |
| **Cu** | 2.33 | 61.54 | 2.00 | 2.86 | | | | | | | |
| **Cc** | 0.96 | 34.62 | 2.57 | 0.94 | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | |

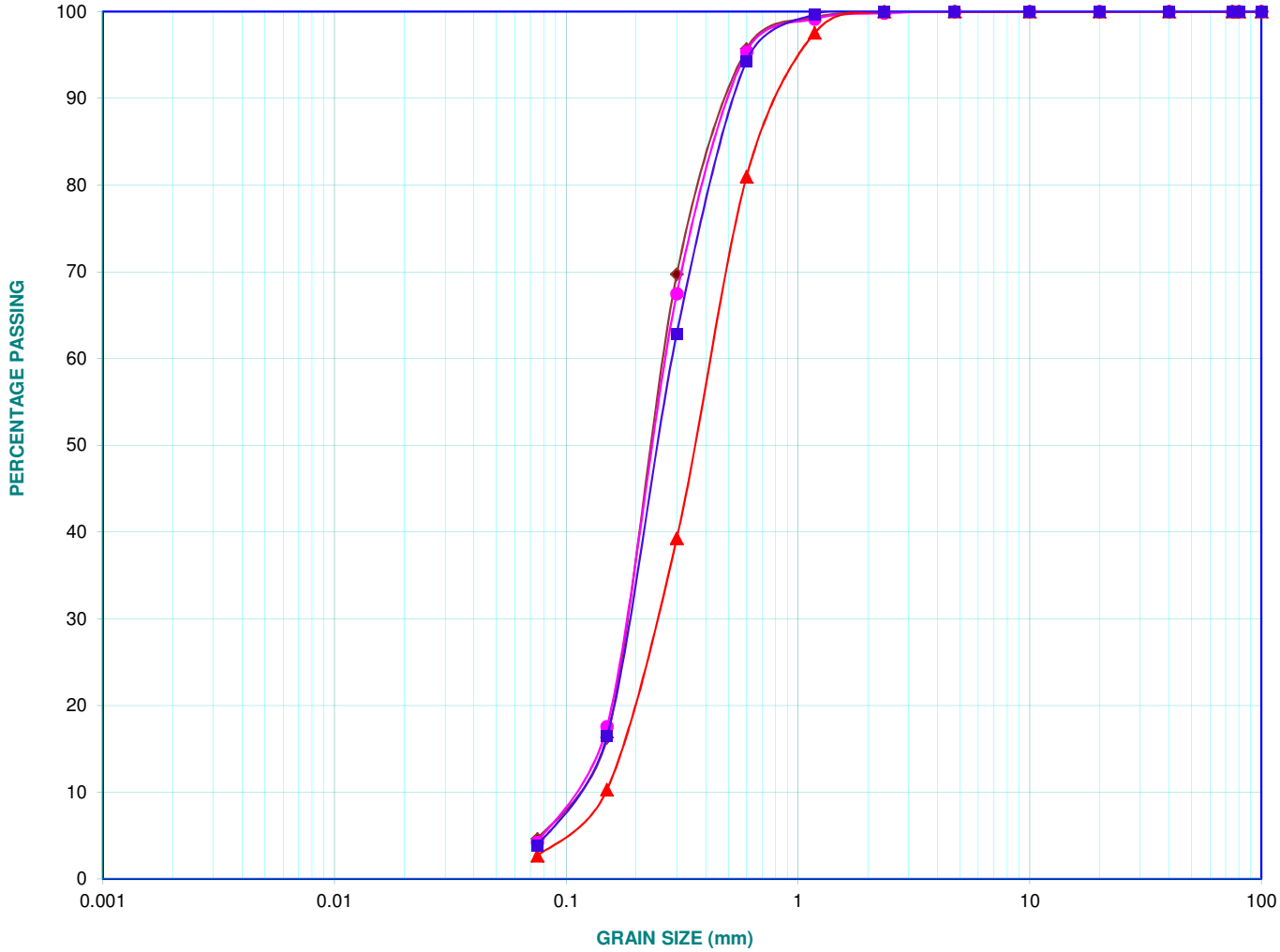



Checked By :

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-04** |
| **Date :** | **7-Jun-19** |

| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-04 | MBH-04 | MBH-04 | MBH-04 | | | | | | | | |
| **Depth (m)** | 22.50-22.80 | 24.00-24.25 | 27.00-27.30 | 30.00-30.30 | | | | | | | | |
| **Sample Type** | SPT-16 | SPT-17 | SPT-19 | SPT-21 | | | | | | | | |
| **Classification** | SP-SM | SP | SP | SP | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 95 | 96 | 97 | 96 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 5 | 4 | 3 | 4 | | | | | | | | |
| **D60 mm** | 0.270 | 0.280 | 0.410 | 0.300 | | | | | | | | |
| **D30 mm** | 0.190 | 0.180 | 0.250 | 0.190 | | | | | | | | |
| **D10 mm** | 0.120 | 0.120 | 0.160 | 0.120 | | | | | | | | |
| **Cu** | 2.25 | 2.33 | 2.56 | 2.50 | | | | | | | | |
| **Cc** | 1.11 | 0.96 | 0.95 | 1.00 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |

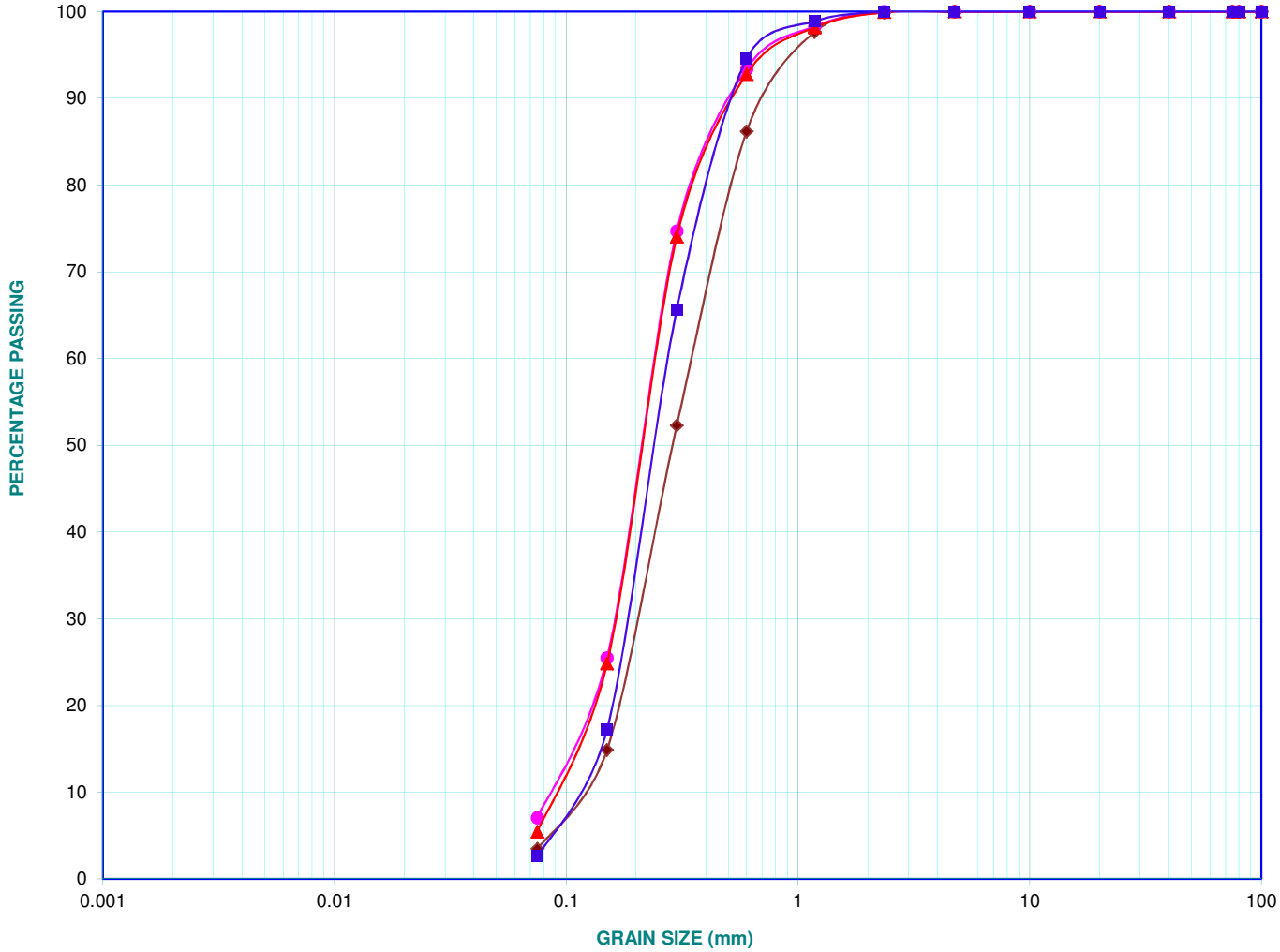



Checked By :

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-04** |
| **Date :** | **7-Jun-19** |

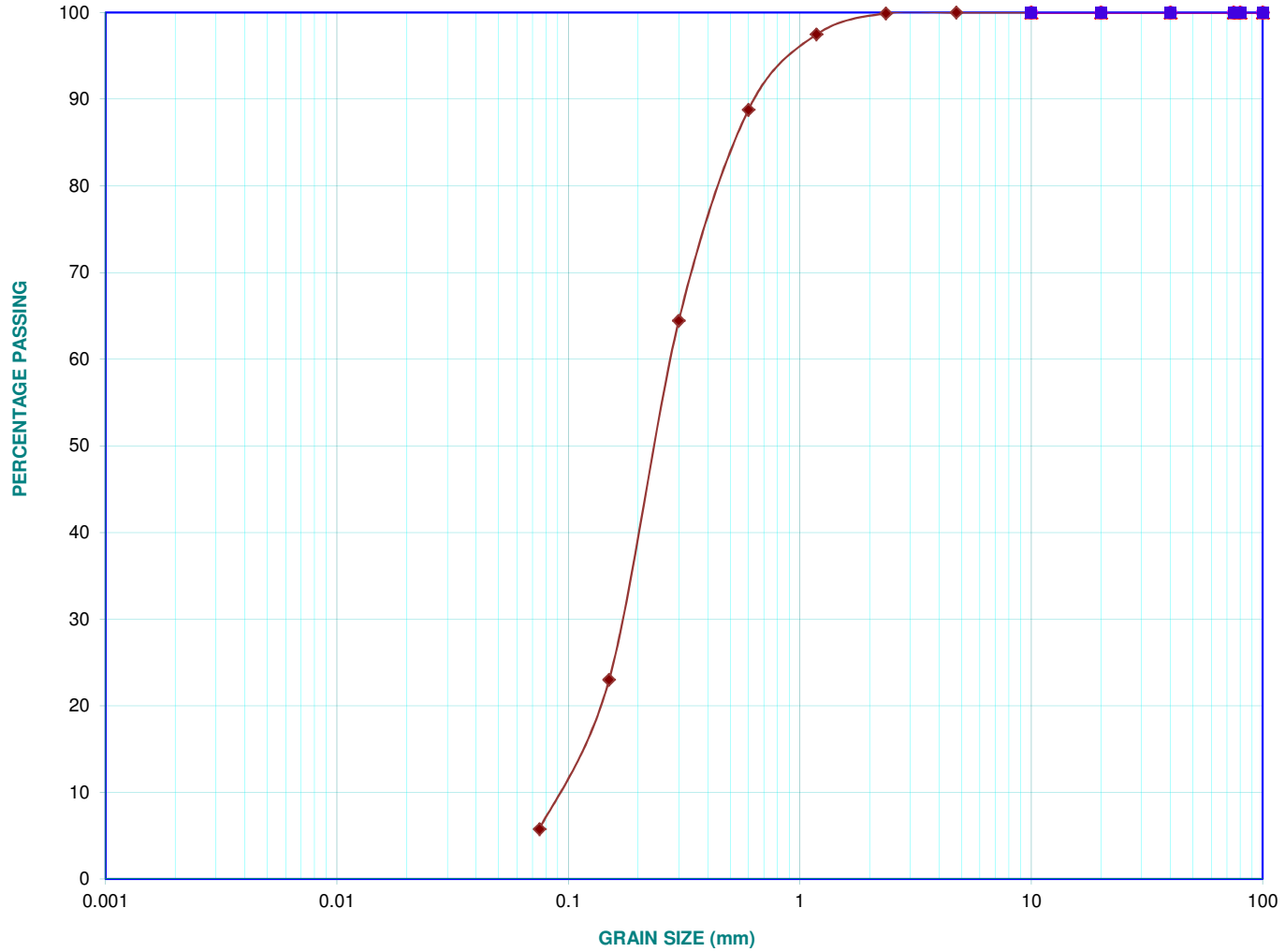
| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-04 | MBH-04 | MBH-04 | MBH-04 | | | | | | | | |
| **Depth (m)** | 34.50-34.70 | 37.50-37.75 | 39.00-39.30 | 42.00-42.20 | | | | | | | | |
| **Sample Type** | SPT-24 | SPT-26 | SPT-27 | SPT-29 | | | | | | | | |
| **Classification** | SP | SP-SM | SP-SM | SP | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 97 | 93 | 95 | 97 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 3 | 7 | 5 | 3 | | | | | | | | |
| **D60 mm** | 0.350 | 0.250 | 0.250 | 0.280 | | | | | | | | |
| **D30 mm** | 0.200 | 0.160 | 0.160 | 0.190 | | | | | | | | |
| **D10 mm** | 0.130 | 0.089 | 0.081 | 0.120 | | | | | | | | |
| **Cu** | 2.69 | 2.81 | 3.09 | 2.33 | | | | | | | | |
| **Cc** | 0.88 | 1.15 | 1.26 | 1.07 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

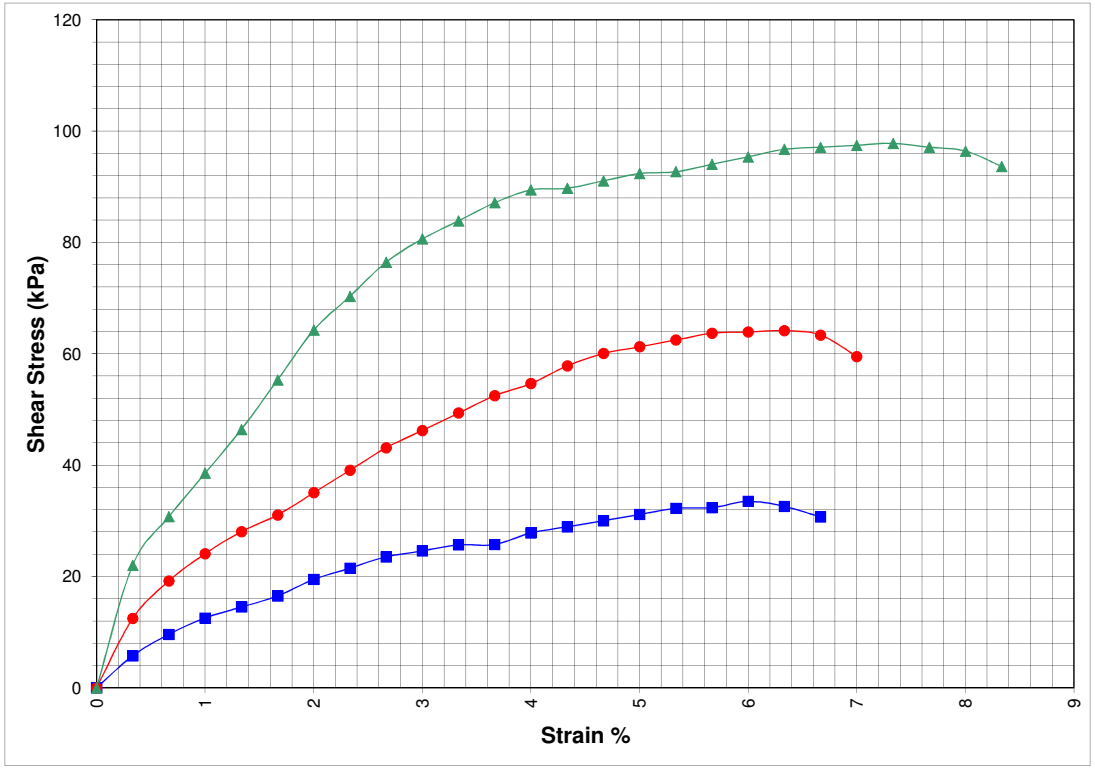
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | **Borehole No.** | **: MBH-04** | | | | | **Date :** | **7-Jun-19** | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-04 | | | | | | | | | | | |
| **Depth (m)** | 43.50-43.70 | | | | | | | | | | | |
| **Sample Type** | SPT-30 | | | | | | | | | | | |
| **Classification** | SP-SM | | | | | | | | | | | |
| **Gravel %** | 0 | | | | | | | | | | | |
| **Sand %** | 94 | | | | | | | | | | | |
| **Silt %** | <----> | | | | | | | | | | | |
| **Clay %** | <----> | | | | | | | | | | | |
| **Fines % (Silt+Clay)** | 6 | | | | | | | | | | | |
| **D60 mm** | 0.280 | | | | | | | | | | | |
| **D30 mm** | 0.180 | | | | | | | | | | | |
| **D10 mm** | 0.091 | | | | | | | | | | | |
| **Cu** | 3.08 | | | | | | | | | | | |
| **Cc** | 1.27 | | | | | | | | | | | |
| **Liquid Limit %** | --- | | | | | | | | | | | |
| **Plastic Limit %** | --- | | | | | | | | | | | |
| **Plasticity Index** | --- | | | | | | | | | | | |

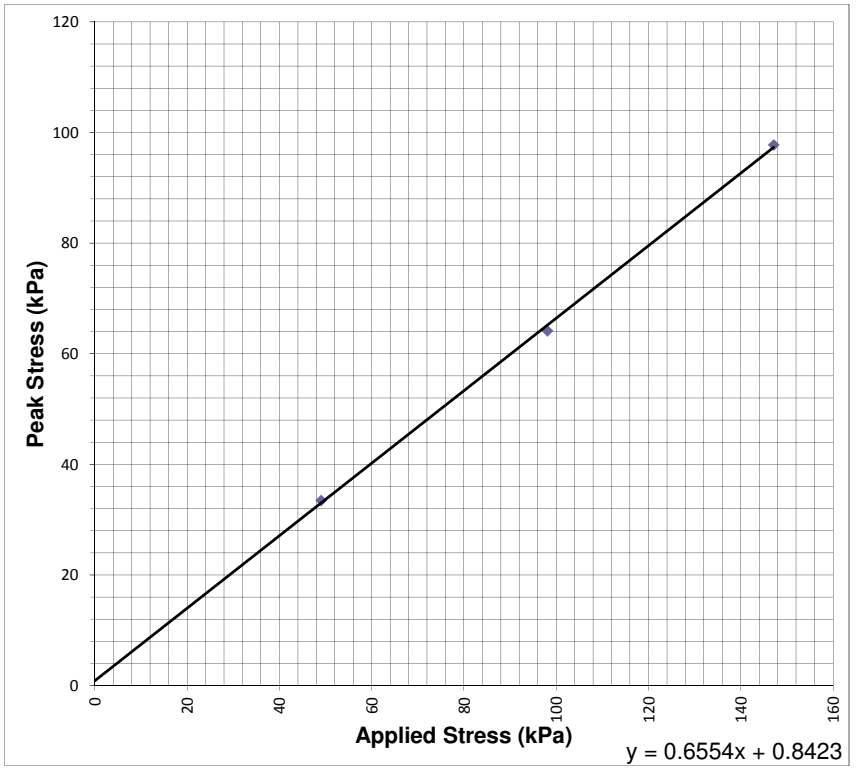



Checked By :

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 33 |
| | Stage 2 | 98 | 64 |
| | Stage 3 | 147 | 98 |

| | | |
|---|---|---|
| Angle of Friction | **33.24** | ° |
| Apparent Cohesion | **0.84** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

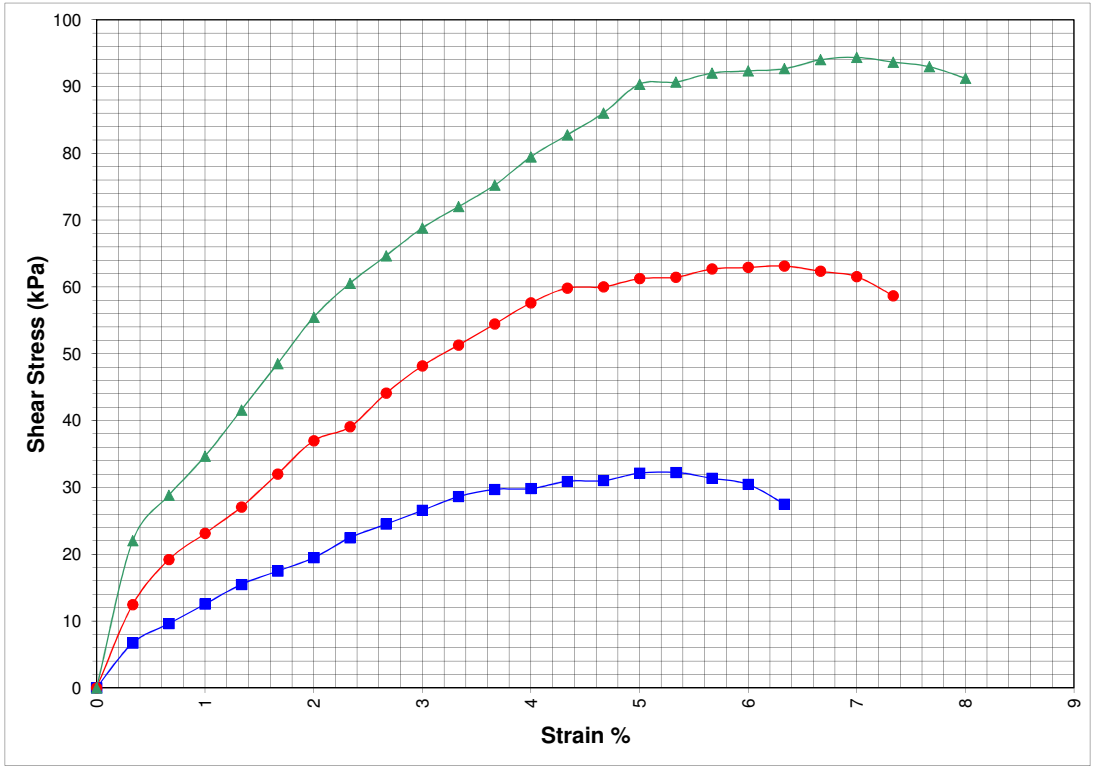
**Borehole: MBH-04**

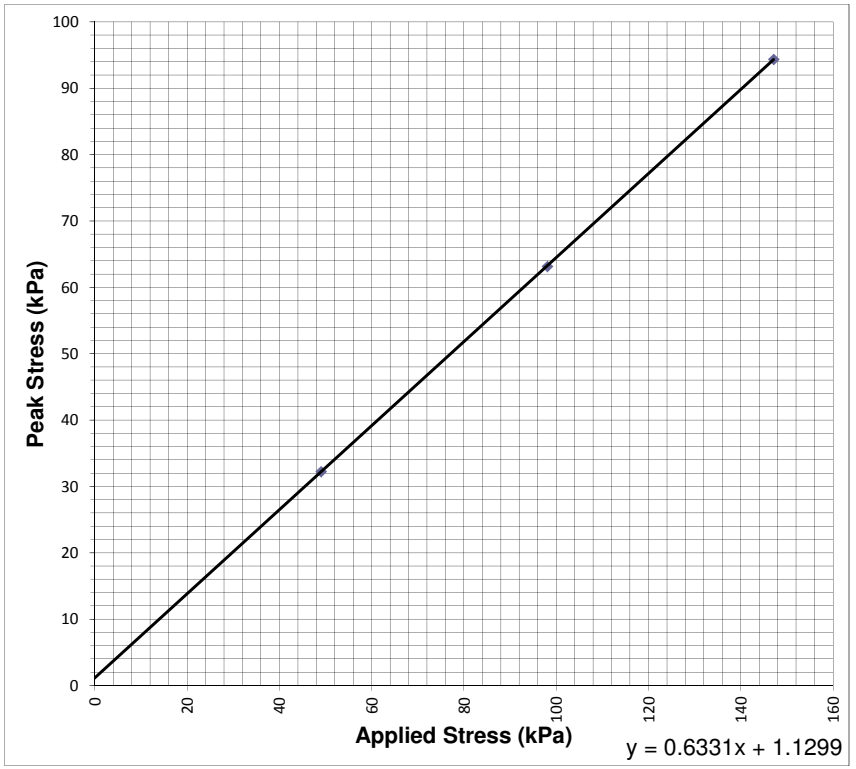
**Sample Type: SPT-02**

**Depth: 1.50-1.72 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 32 |
| | Stage 2 | 98 | 63 |
| | Stage 3 | 147 | 94 |

| | | |
|---|---|---|
| Angle of Friction | **32.3** | ° |
| Apparent Cohesion | **1.13** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

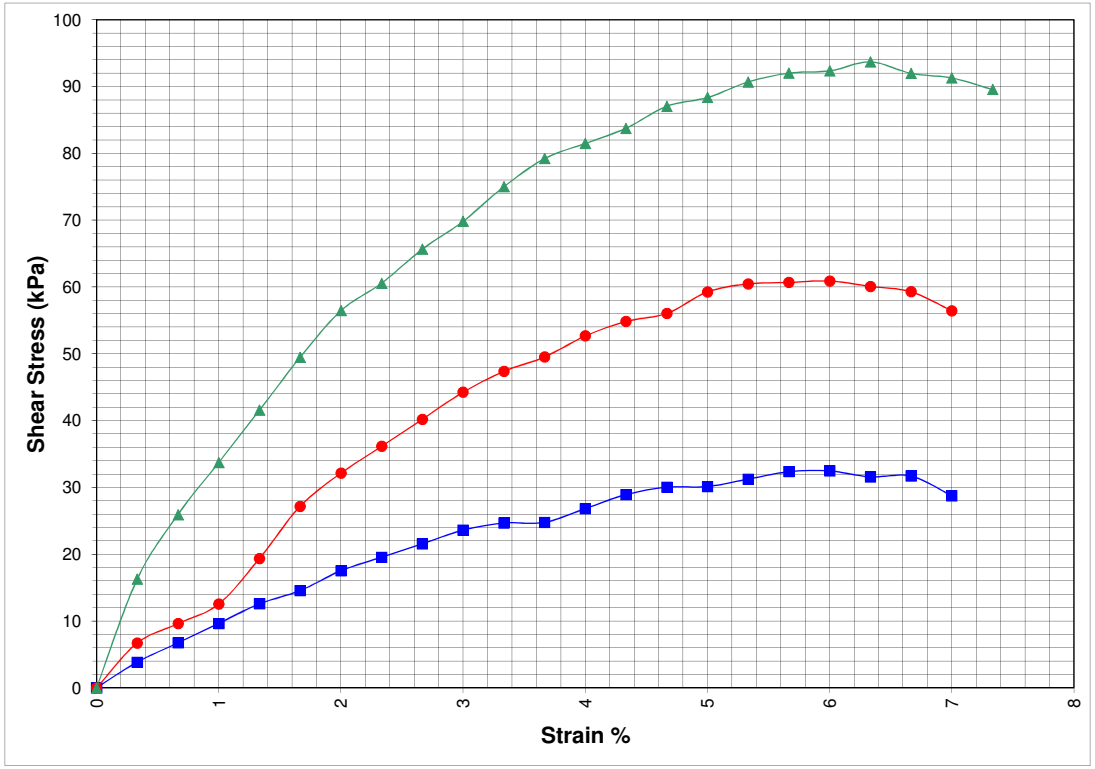
**Borehole: MBH-04**

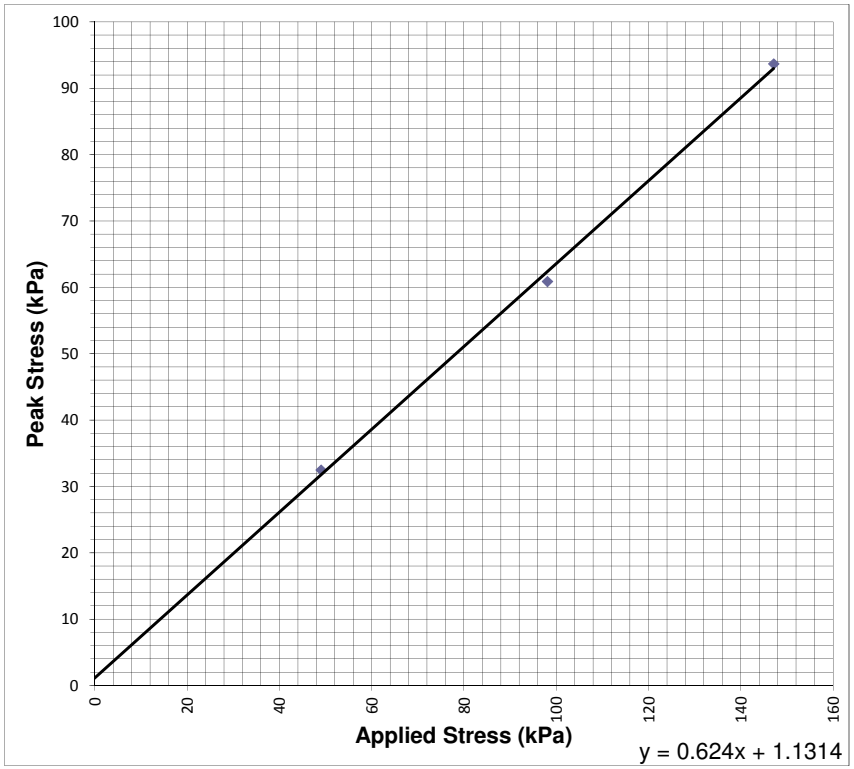
**Sample Type: SPT-05**

**Depth: 6.00-6.25 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 32 |
| | Stage 2 | 98 | 61 |
| | Stage 3 | 147 | 94 |

| | | |
|---|---|---|
| Angle of Friction | **32.0** | ° |
| Apparent Cohesion | **1.13** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

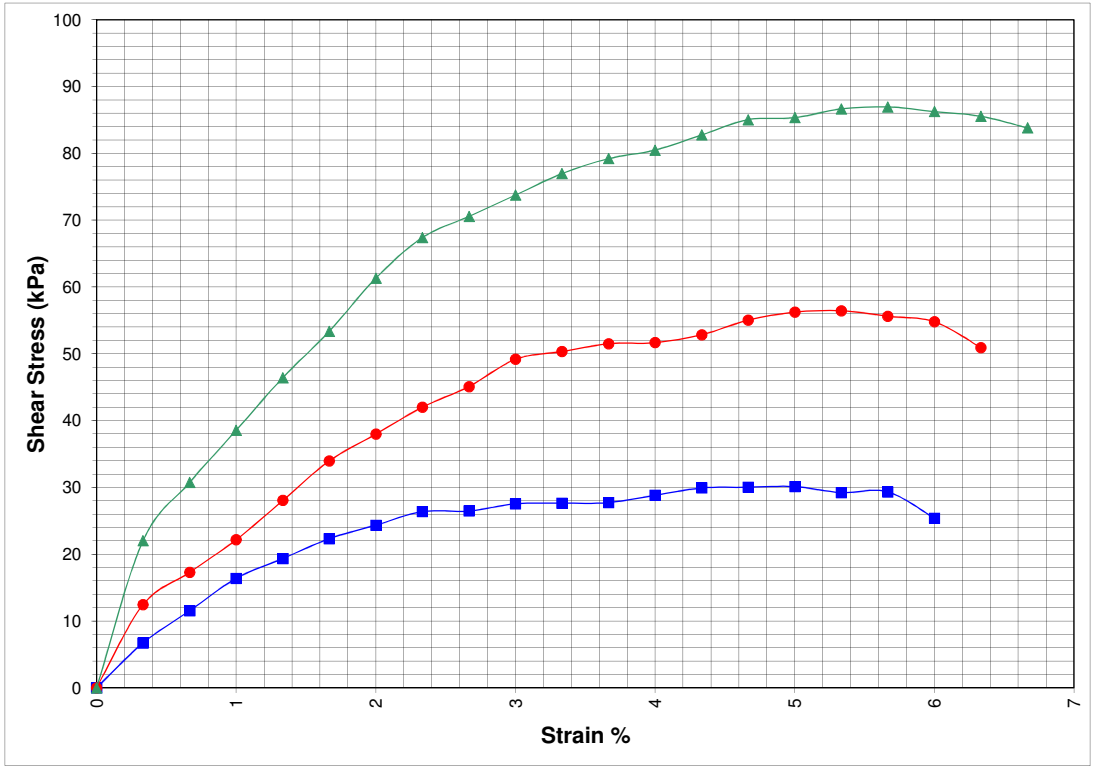
**Borehole: MBH-04**

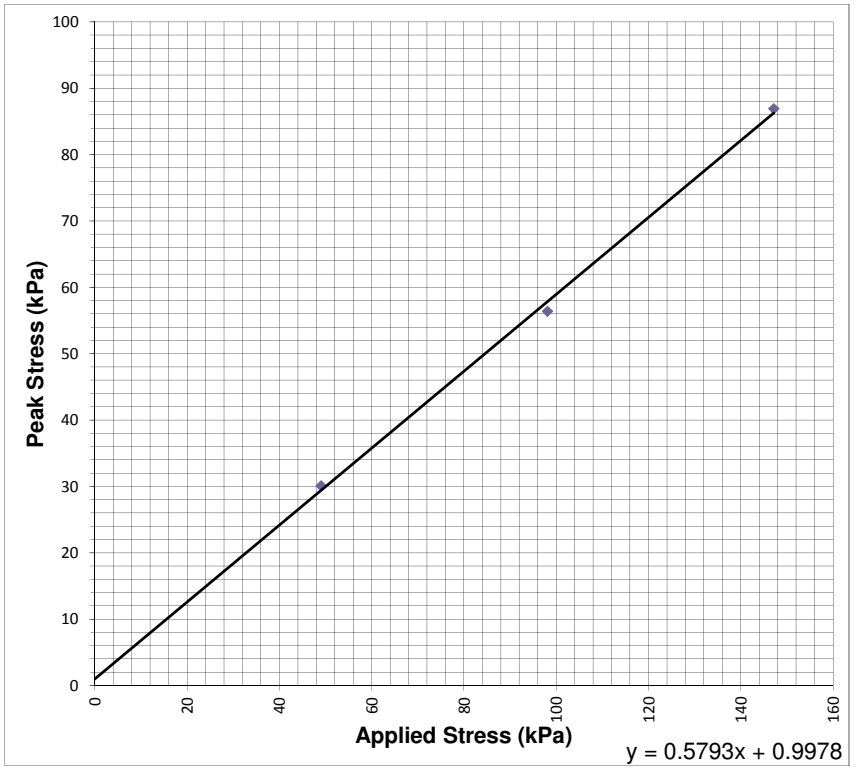
**Sample Type: SPT-07**

**Depth: 9.00-9.20 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 30 |
| | Stage 2 | 98 | 56 |
| | Stage 3 | 147 | 87 |

| | | |
|---|---|---|
| Angle of Friction | **30.1** | ° |
| Apparent Cohesion | **1.00** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

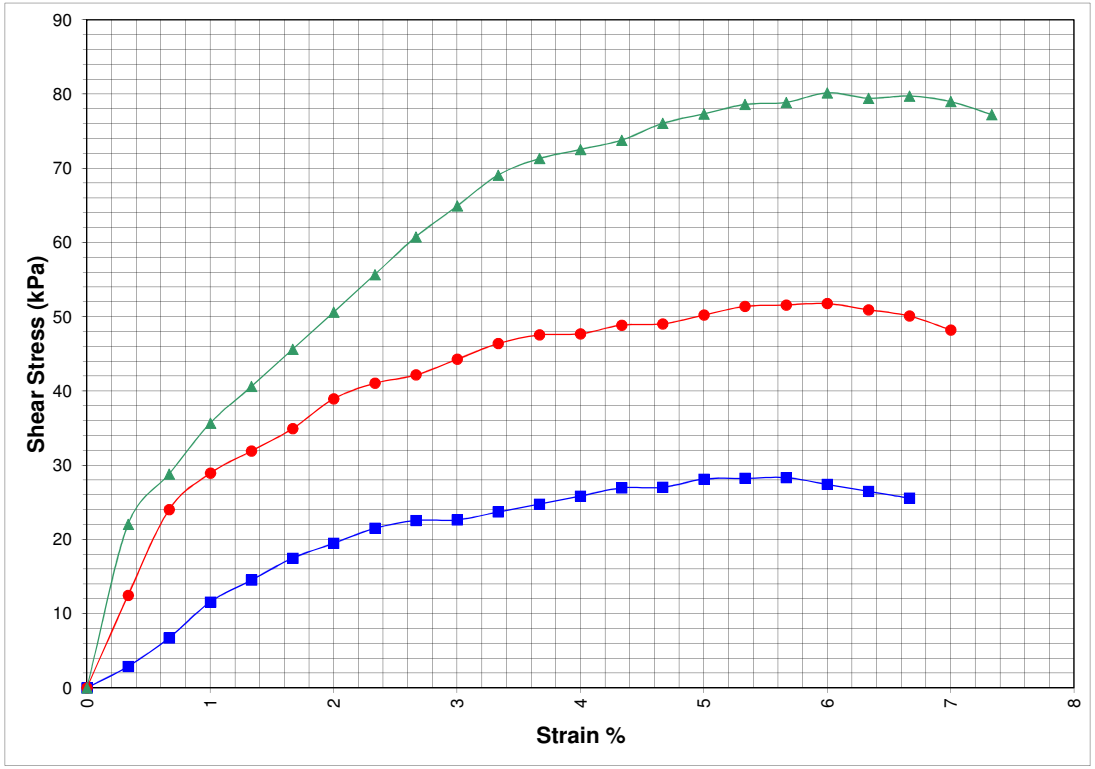
**Borehole: MBH-04**

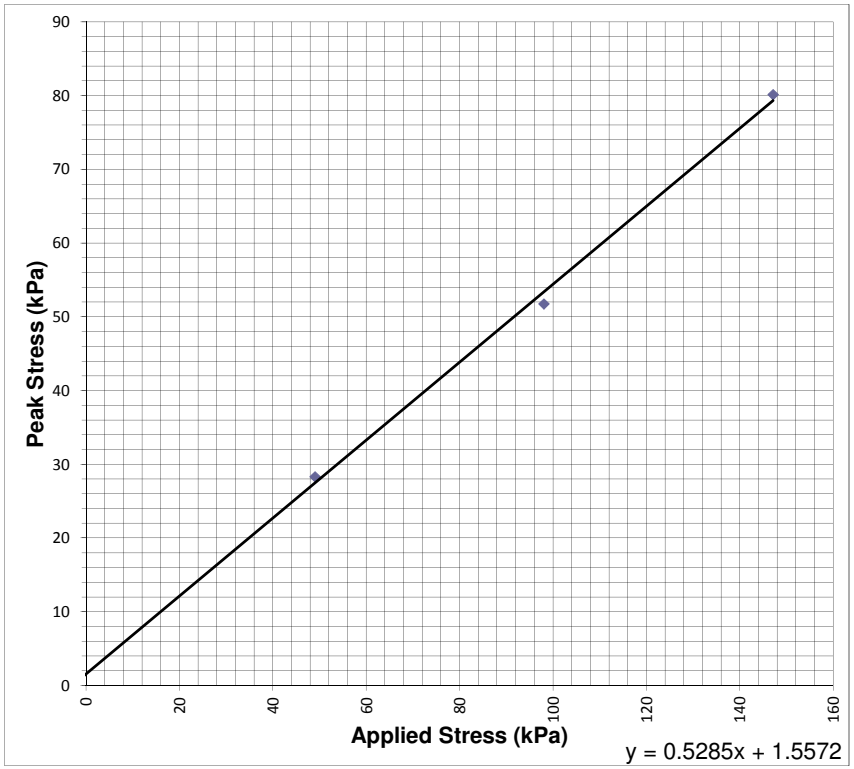
**Sample Type: SPT-09**

**Depth: 12.00-12.20 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 52 |
| | Stage 3 | 147 | 80 |

| | | |
|---|---|---|
| Angle of Friction | **27.9** | ° |
| Apparent Cohesion | **1.56** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

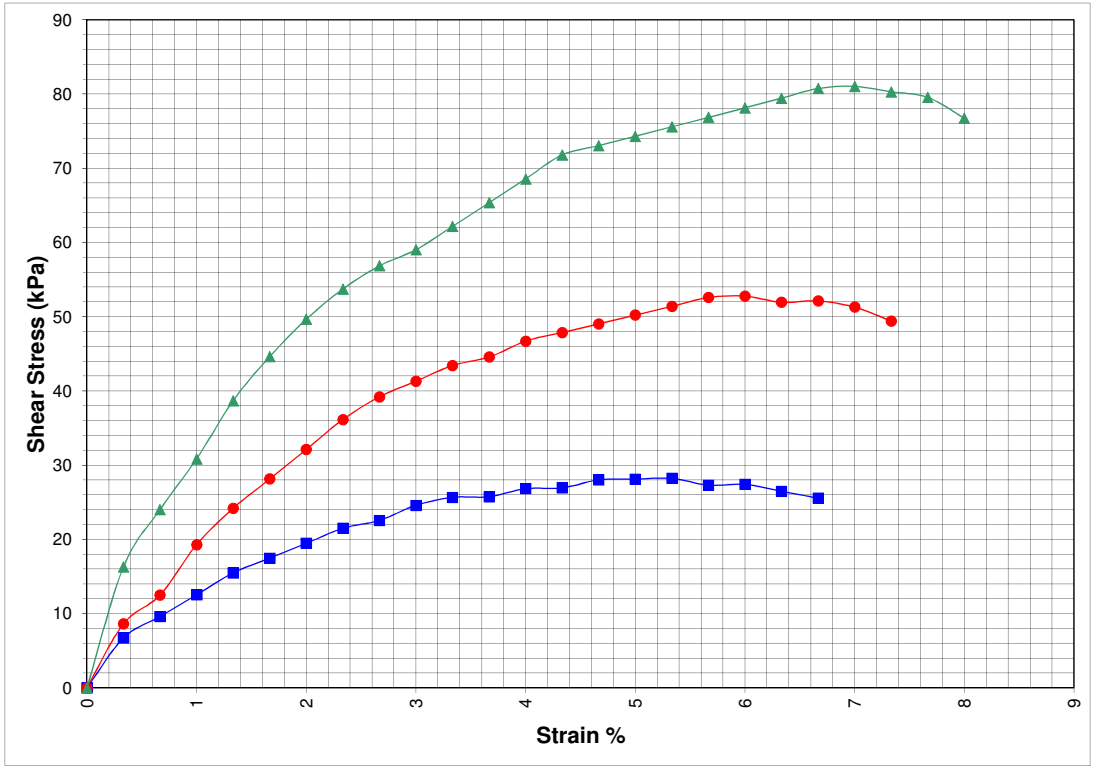
**Borehole: MBH-04**

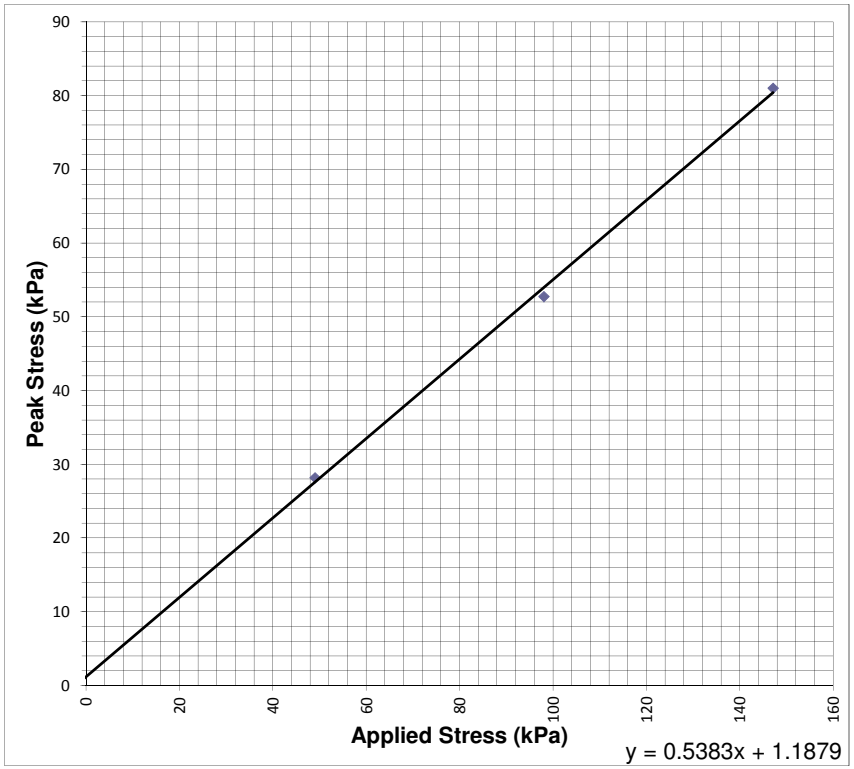
**Sample Type: SPT-12**

**Depth: 16.50-16.72 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 53 |
| | Stage 3 | 147 | 81 |

| | | |
|---|---|---|
| Angle of Friction | **28.3** | ° |
| Apparent Cohesion | **1.19** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

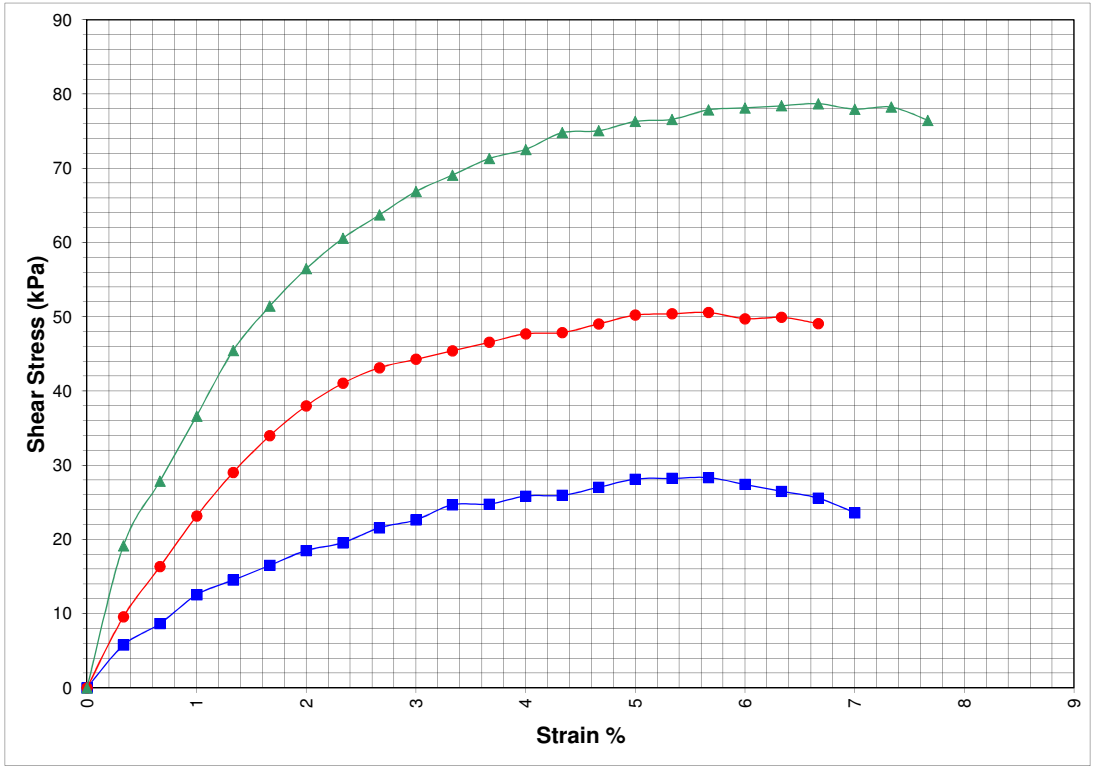
**Borehole: MBH-04**

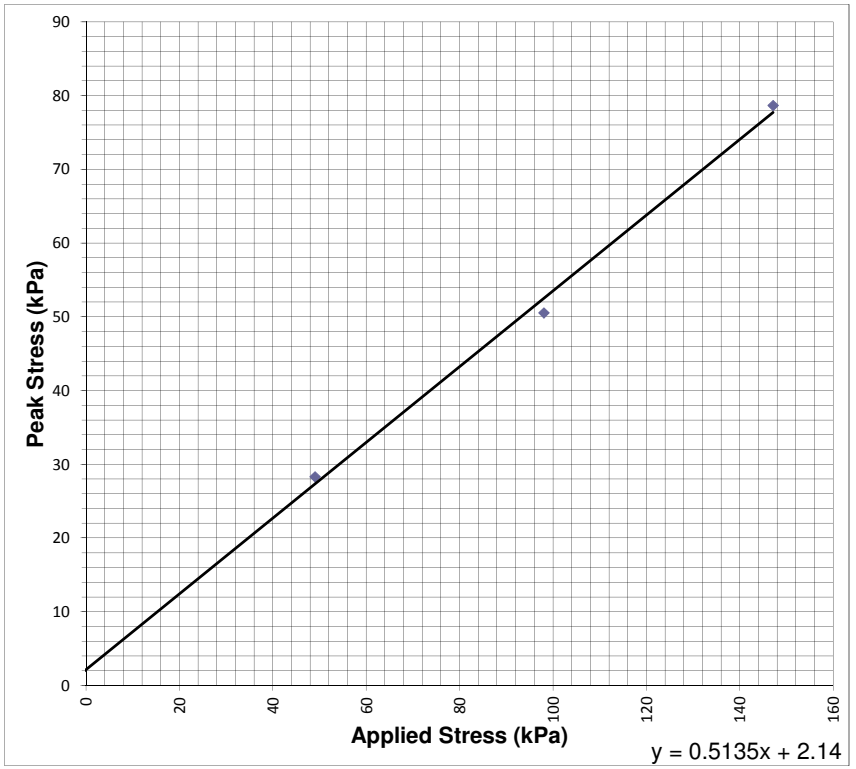
**Sample Type: SPT-15**

**Depth: 21.00-21.30 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 51 |
| | Stage 3 | 147 | 79 |

| | | |
|---|---|---|
| Angle of Friction | **27.2** | ° |
| Apparent Cohesion | **2.14** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

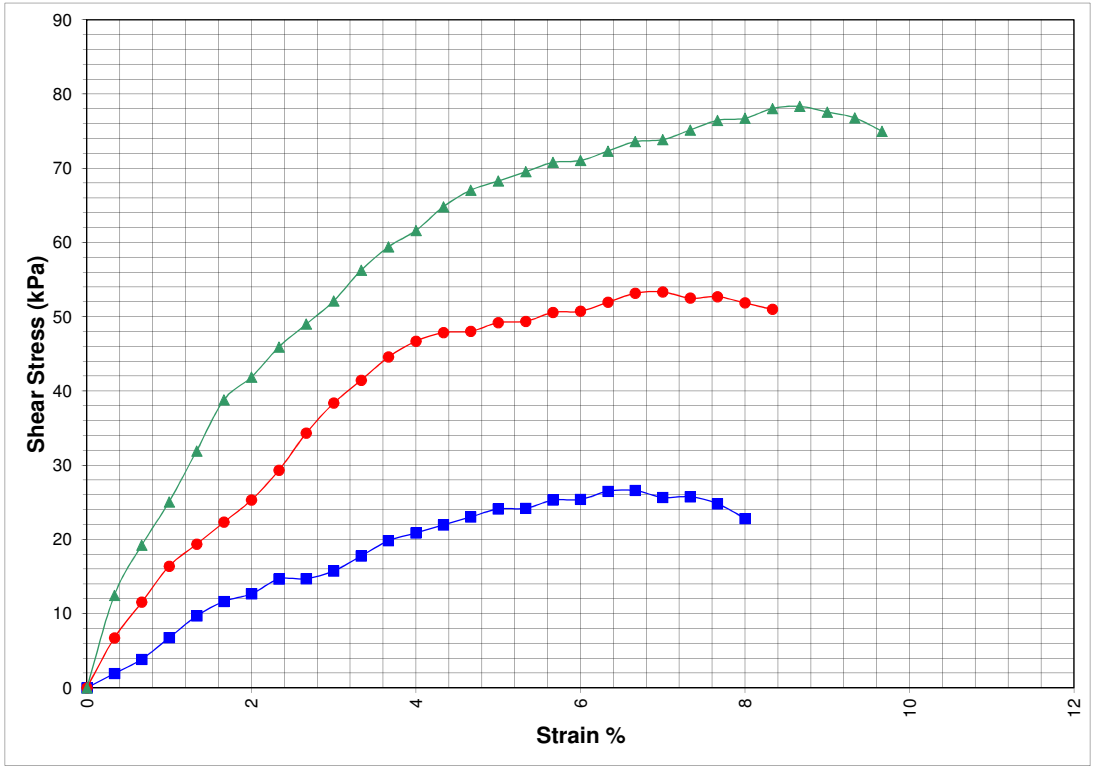
**Borehole: MBH-04**

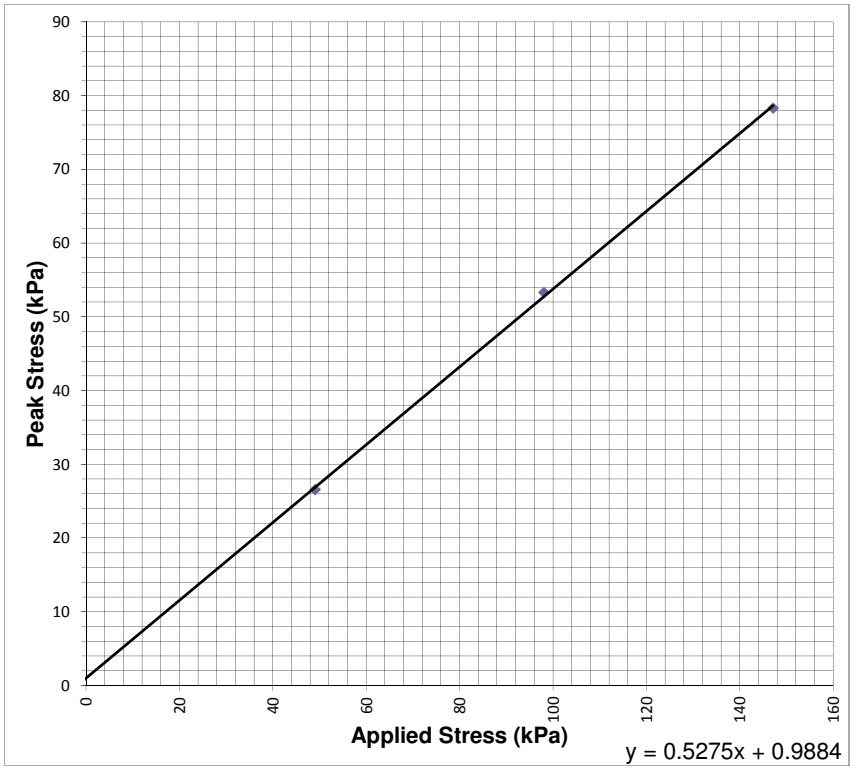
**Sample Type: SPT-18**

**Depth: 25.50-25.80 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 53 |
| | Stage 3 | 147 | 78 |

| | | |
|---|---|---|
| Angle of Friction | **27.8** | ° |
| Apparent Cohesion | **0.99** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

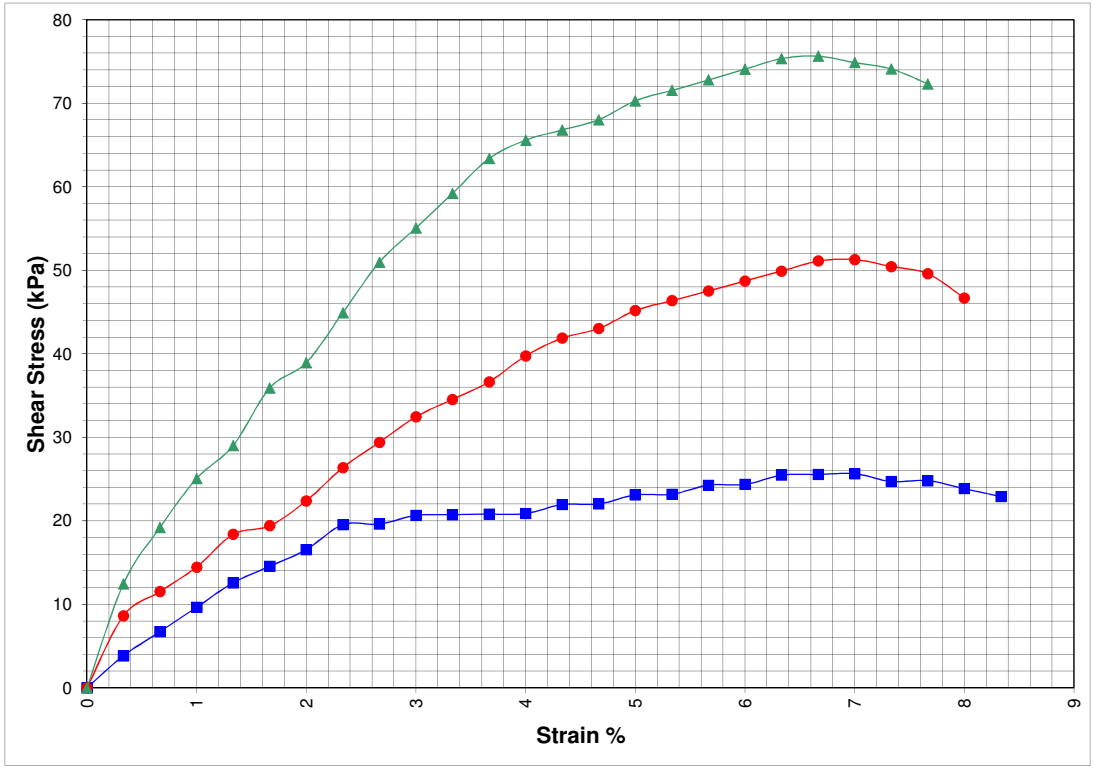
**Borehole: MBH-04**

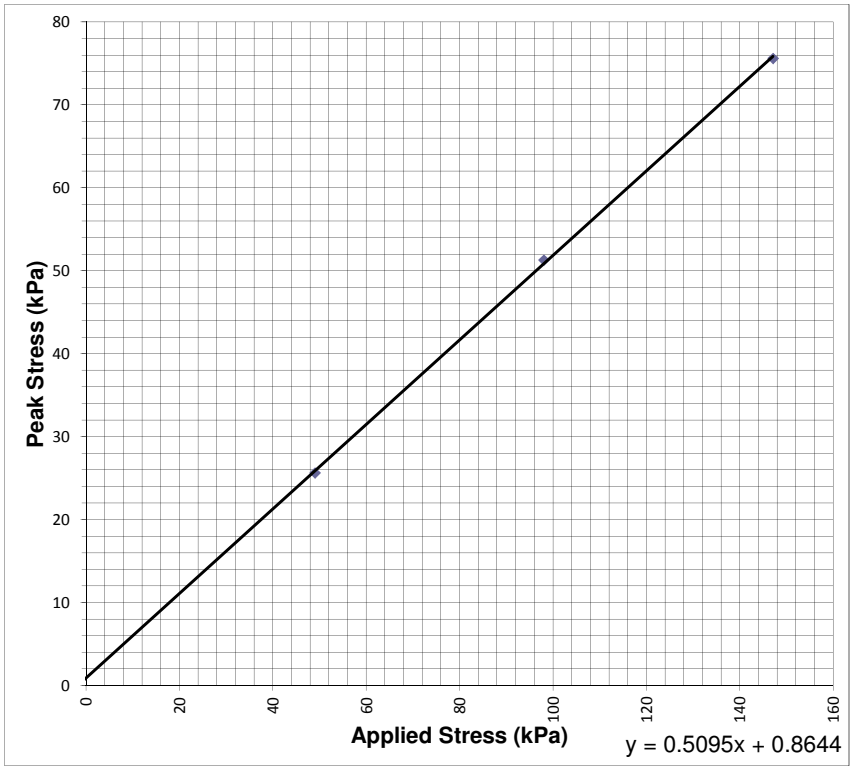
**Sample Type: SPT-20**

**Depth: 28.50-28.75 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 51 |
| | Stage 3 | 147 | 76 |

| | | |
|---|---|---|
| Angle of Friction | **27.0** | ° |
| Apparent Cohesion | **0.86** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

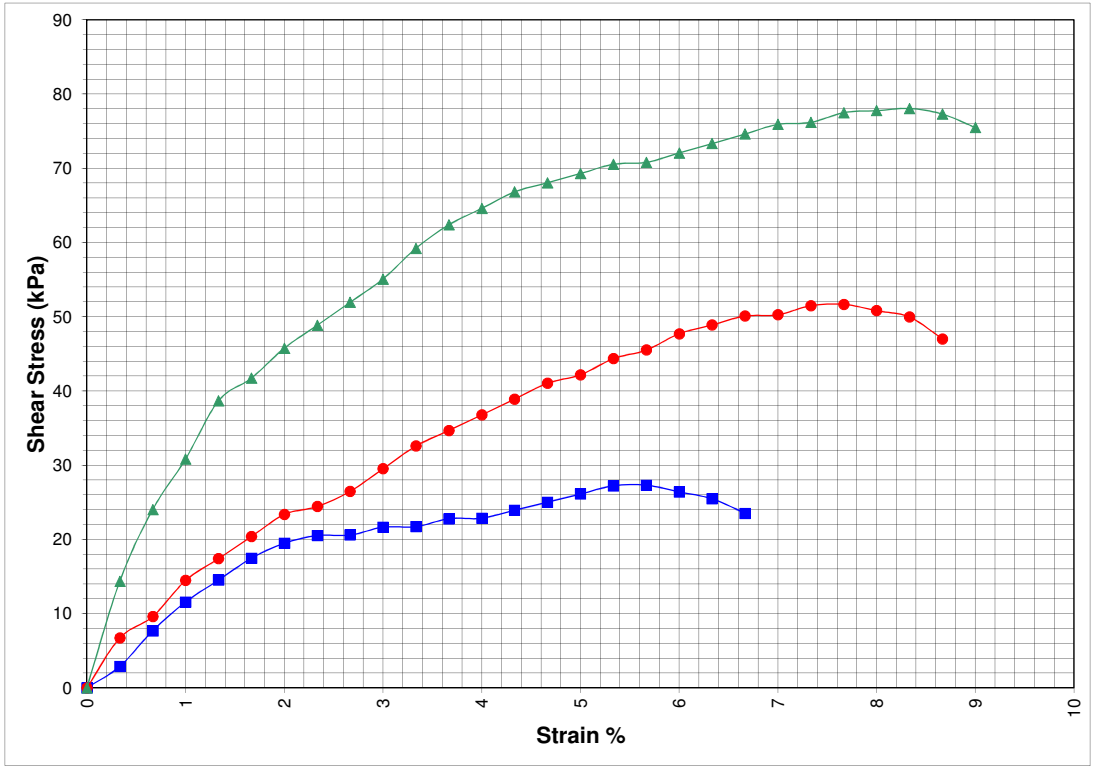
**Borehole: MBH-04**

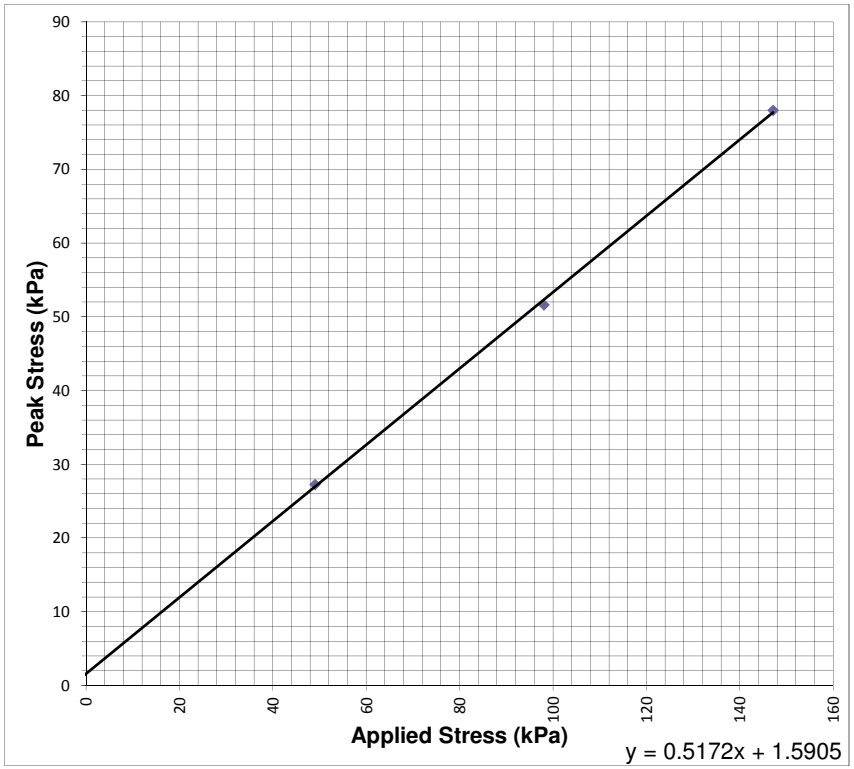
**Sample Type: SPT-23**

**Depth: 33.00-33.30 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 52 |
| | Stage 3 | 147 | 78 |

| | | |
|---|---|---|
| Angle of Friction | **27.35** | ° |
| Apparent Cohesion | **3.24** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: MBH-04**

**Sample Type: SPT-28**

**Depth: 40.50-40.75 m**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| DS | 0.00-0.50 | | | | | 17.8 | 17.35 | 7.29 | 14.72 | 2.64 | 0 | 87 | <--> | <--> | 13 | | | | | | | | | | | | | | | | | | |
| SPT-1 | 1.50-1.95 | | | | | 18.3 | 17.40 | 7.34 | 14.71 | 2.65 | | | | | | DST | | | 0.72 | 27.4 | | | | | | | | | | | | |
| SPT-2 | 3.00-3.45 | SP | | | | 17.3 | 17.38 | 7.32 | 14.82 | 2.62 | 0 | 99 | <--> | <--> | 1 | | | | | | | | | | | | | | | | | | |
| SPT-3 | 4.50-4.95 | | | | | 17.8 | 17.33 | 7.27 | 14.71 | 2.66 | | | | | | DST | | | 1.52 | 27.2 | | | | | | | | | 7.12 | 0.30 | 2.00 | 1600 | 14160 |
| SPT-4 | 6.00-6.45 | | | | | 15.2 | 17.42 | 7.36 | 15.12 | 2.68 | | | | | | DST | | | 1.29 | 25.9 | | | | | | | | | | | | | |
| SPT-5 | 7.50-7.95 | SP | | | | 17.2 | 17.51 | 7.45 | 14.93 | 2.61 | 0 | 98 | <--> | <--> | 2 | | | | | | | | | | | | | | | | | | |
| SPT-6 | 9.00-9.45 | | | | | 12.9 | 17.82 | 7.76 | 15.78 | 2.67 | | | | | | DST | | | 0.25 | 31.7 | | | | | | | | | | | | | |
| SPT-7 | 10.50-10.95 | SP | | | | 12.1 | 17.92 | 7.86 | 15.98 | 2.68 | 0 | 98 | <--> | <--> | 2 | | | | | | | | | | | | | | | | | | |
| SPT-8 | 12.00-12.45 | | | | | 16.1 | 16.78 | 6.72 | 14.46 | 2.61 | | | | | | DST | | | 1.47 | 26.6 | | | | | | | | | | | | | |
| SPT-9 | 13.50-13.95 | SP | | | | 18.3 | 16.88 | 6.82 | 14.27 | 2.60 | 0 | 96 | <--> | <--> | 4 | | | | | | | | | | | | | | | | | | |
| SPT-10 | 15.00-15.45 | | | | | 22.8 | 16.36 | 6.30 | 13.32 | 2.61 | | | | | | DST | | | 2.60 | 27.2 | | | | | | | | | | | | | |
| SPT-11 | 16.50-16.95 | | | | | 22.1 | 18.04 | 7.98 | 14.77 | 2.59 | 0 | 87 | <--> | <--> | 13 | | | | | | | | | | | | | | | | | | |
| SPT-12 | 18.00-18.45 | | | | | 19.3 | 17.77 | 7.71 | 14.90 | 2.62 | | | | | | DST | | | 2.32 | 28.3 | | | | | | | | | | | | | |
| SPT-13 | 19.50-19.95 | SP-SM | | | | 20.9 | 17.89 | 7.83 | 14.80 | 2.57 | 0 | 88 | <--> | <--> | 12 | | | | | | | | | | | | | | | | | | |
| SPT-14 | 21.00-21.45 | SP-SM | | | | 10.8 | 16.83 | 6.77 | 15.18 | 2.63 | 0 | 91 | <--> | <--> | 9 | | | | | | | | | | | | | | | | | | |
| SPT-15 | 22.50-22.95 | SP-SM | | | | 10.0 | 16.11 | 6.05 | 14.65 | 2.64 | 0 | 92 | <--> | <--> | 8 | | | | | | | | | | | | | | | | | | |
| SPT-16 | 24.00-24.45 | | | | | 15.8 | 17.09 | 7.03 | 14.76 | 2.66 | | | | | | DST | | | 2.12 | 27.2 | | | | | | | | | | | | | |
| SPT-17 | 25.50-25.95 | SP-SM | | | | 8.2 | 16.86 | 6.80 | 15.59 | 2.63 | 0 | 93 | <--> | <--> | 7 | | | | | | | | | | | | | | | | | | |
| SPT-18 | 27.00-27.45 | | | | | 17.2 | 16.92 | 6.86 | 14.44 | 2.66 | | | | | | DST | | | 1.56 | 28.0 | | | | | | | | | | | | | |
| **END OF BOREHOLE** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

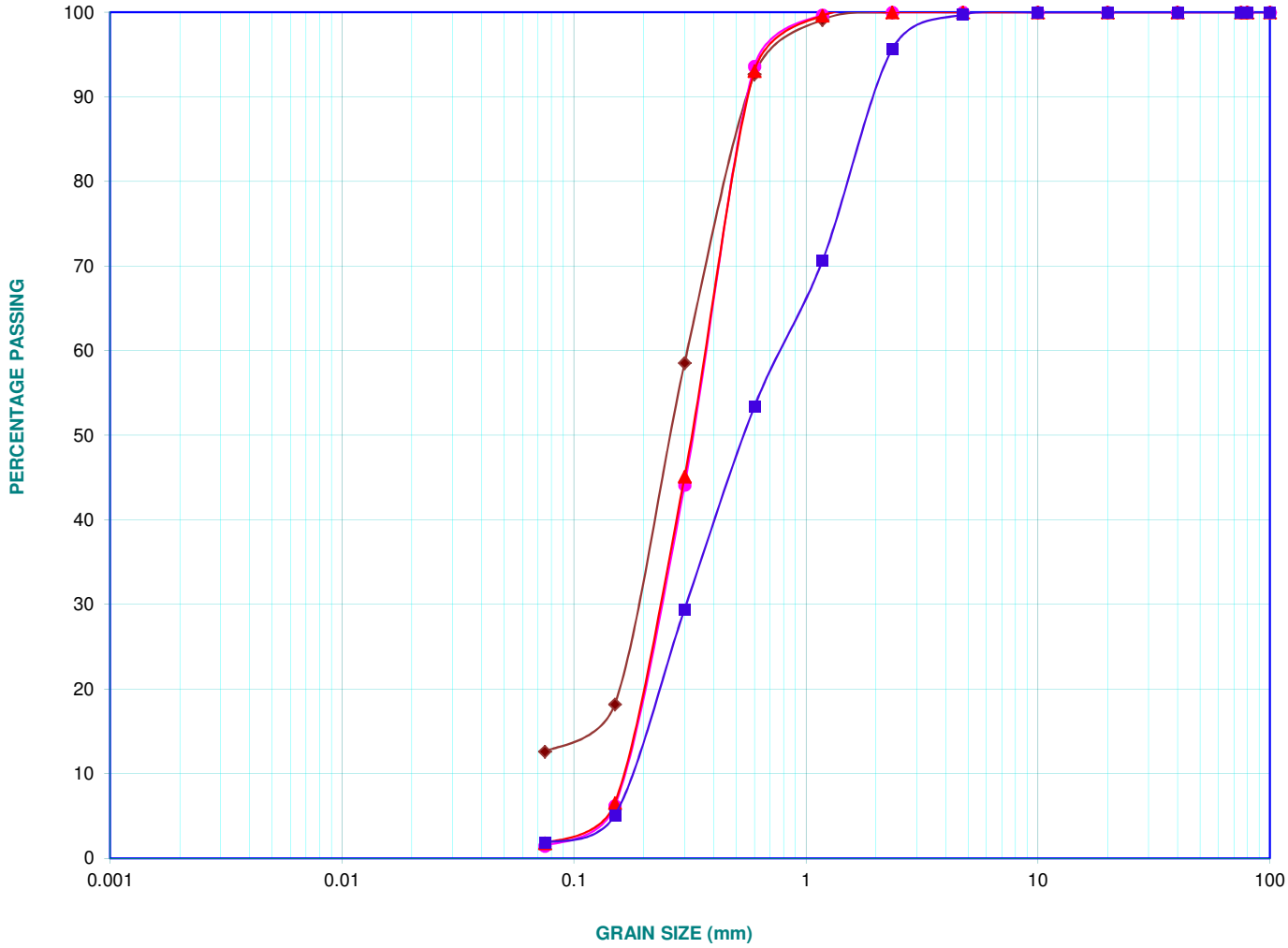
\# : Decayed Wood

**Failure Type**
A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha**
Project Code : **CM 19 01 03**
Borehole No. : **LBH-05A**

# GRAIN SIZE ANALYSIS

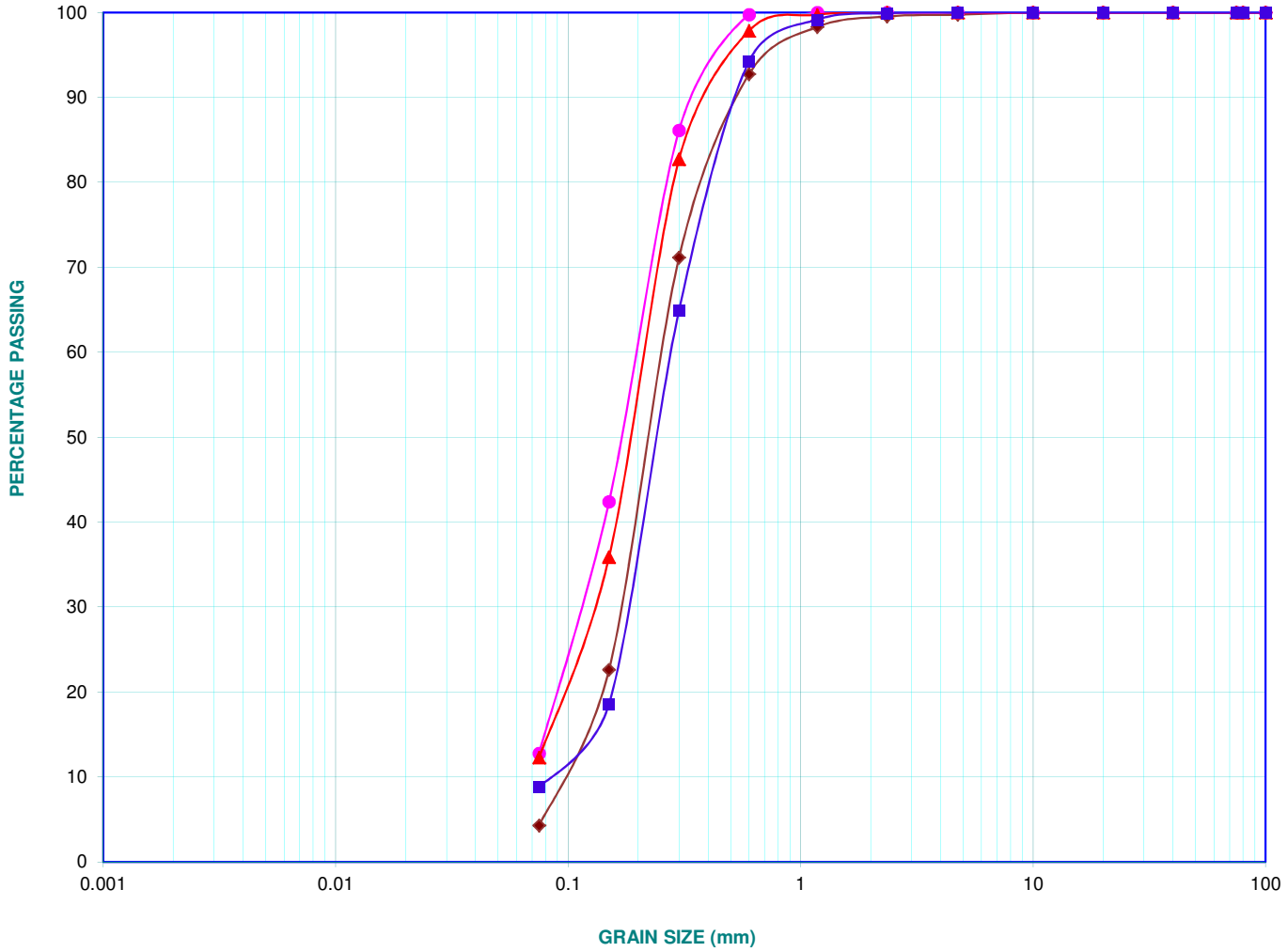
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | **Borehole No.** | **: LBH-05A** | | | | | **Date :** | **30-May-19** | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | LBH-05A | LBH-05A | LBH-05A | LBH-05A | | | | | | | | |
| **Depth (m)** | 0.00-0.50 | 3.00-3.45 | 7.50-7.95 | 10.50-10.95 | | | | | | | | |
| **Sample Type** | DS | SPT-1 | SPT-5 | SPT-7 | | | | | | | | |
| **Classification** | | SP | SP | SP | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 87 | 99 | 98 | 98 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 13 | 1 | 2 | 2 | | | | | | | | |
| **D60 mm** | | 0.380 | 0.370 | 0.790 | | | | | | | | |
| **D30 mm** | | 0.250 | 0.250 | 0.300 | | | | | | | | |
| **D10 mm** | | 0.170 | 0.170 | 0.190 | | | | | | | | |
| **Cu** | | 2.24 | 2.18 | 4.16 | | | | | | | | |
| **Cc** | | 0.97 | 0.99 | 0.60 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

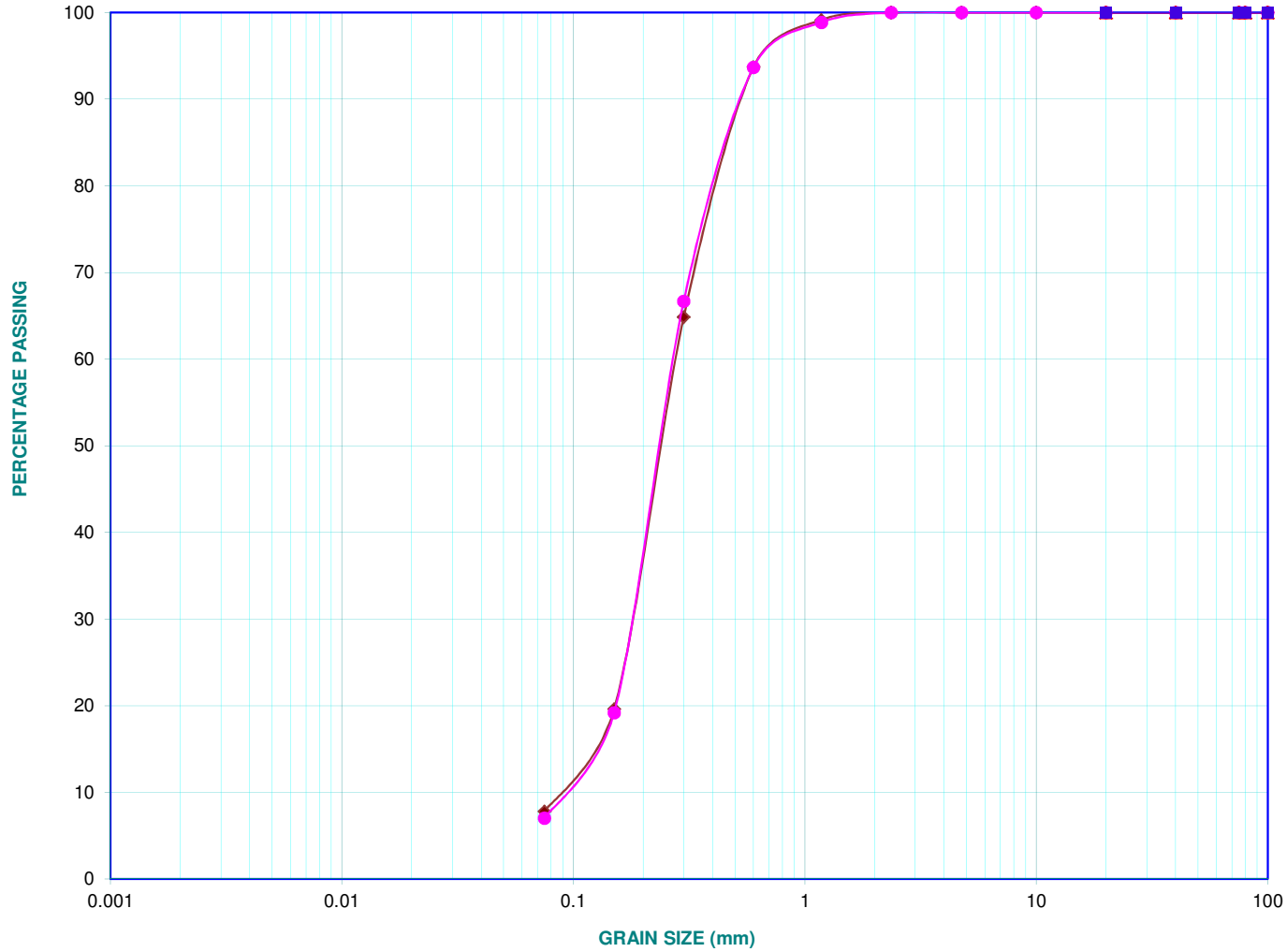
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | **Borehole No.** | **: LBH-05A** | | | | | **Date :** | **30-May-19** | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | LBH-05A | LBH-05A | LBH-05A | LBH-05A | | | | | | | | |
| **Depth (m)** | 13.50-13.95 | 16.50-16.95 | 19.50-19.95 | 21.00-21.45 | | | | | | | | |
| **Sample Type** | SPT-9 | SPT-11 | SPT-13 | SPT-14 | | | | | | | | |
| **Classification** | SP | | SP-SM | SP-SM | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 96 | 87 | 88 | 91 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 4 | 13 | 12 | 9 | | | | | | | | |
| **D60 mm** | 0.250 | | | 0.280 | | | | | | | | |
| **D30 mm** | 0.180 | | | 0.190 | | | | | | | | |
| **D10 mm** | 0.100 | | | 0.088 | | | | | | | | |
| **Cu** | 2.50 | | | 3.18 | | | | | | | | |
| **Cc** | 1.30 | | | 1.47 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

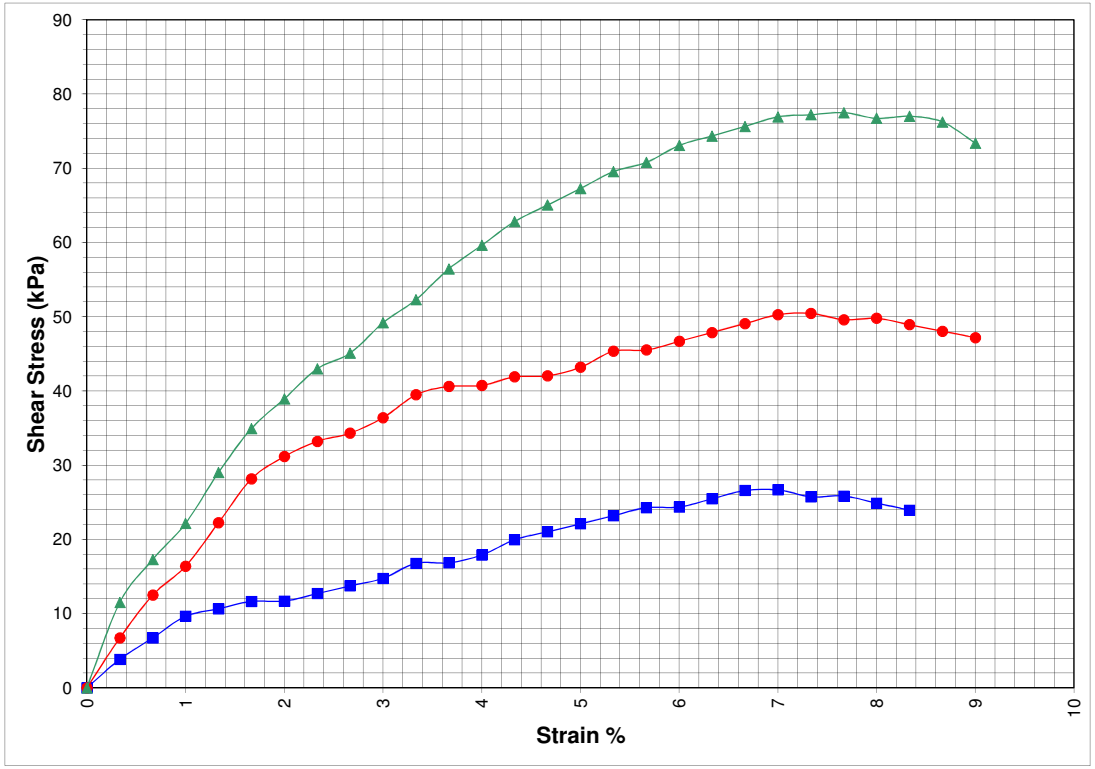
| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | **Borehole No.** | | **: LBH-05A** | | | **Date :** | | **30-May-19** | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND F | SAND M | SAND C | GRAVEL F / GRAVEL C |
| **Bore Hole .** | LBH-05A | LBH-05A | | | | | | | | | |
| **Depth (m)** | 22.50-22.95 | 25.50-25.95 | | | | | | | | | |
| **Sample Type** | SPT-15 | SPT-17 | | | | | | | | | |
| **Classification** | SP-SM | SP-SM | | | | | | | | | |
| **Gravel %** | 0 | 0 | | | | | | | | | |
| **Sand %** | 92 | 93 | | | | | | | | | |
| **Silt %** | <----> | <----> | | | | | | | | | |
| **Clay %** | <----> | <----> | | | | | | | | | |
| **Fines % (Silt+Clay)** | 8 | 7 | | | | | | | | | |
| **D60 mm** | 0.290 | 0.280 | | | | | | | | | |
| **D30 mm** | 0.190 | 0.190 | | | | | | | | | |
| **D10 mm** | 0.090 | 0.095 | | | | | | | | | |
| **Cu** | 3.22 | 2.95 | | | | | | | | | |
| **Cc** | 1.38 | 1.36 | | | | | | | | | |
| **Liquid Limit %** | --- | --- | | | | | | | | | |
| **Plastic Limit %** | --- | --- | | | | | | | | | |
| **Plasticity Index** | --- | --- | | | | | | | | | |

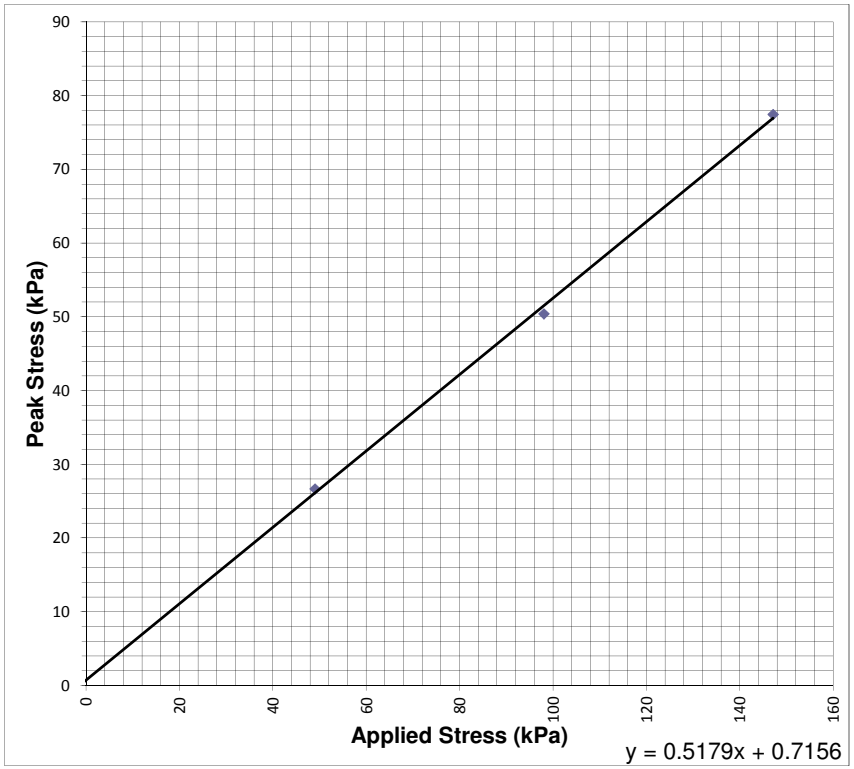



Checked By :

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 50 |
| | Stage 3 | 147 | 77 |

| | | |
|---|---|---|
| Angle of Friction | **27.38** | ° |
| Apparent Cohesion | **0.72** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

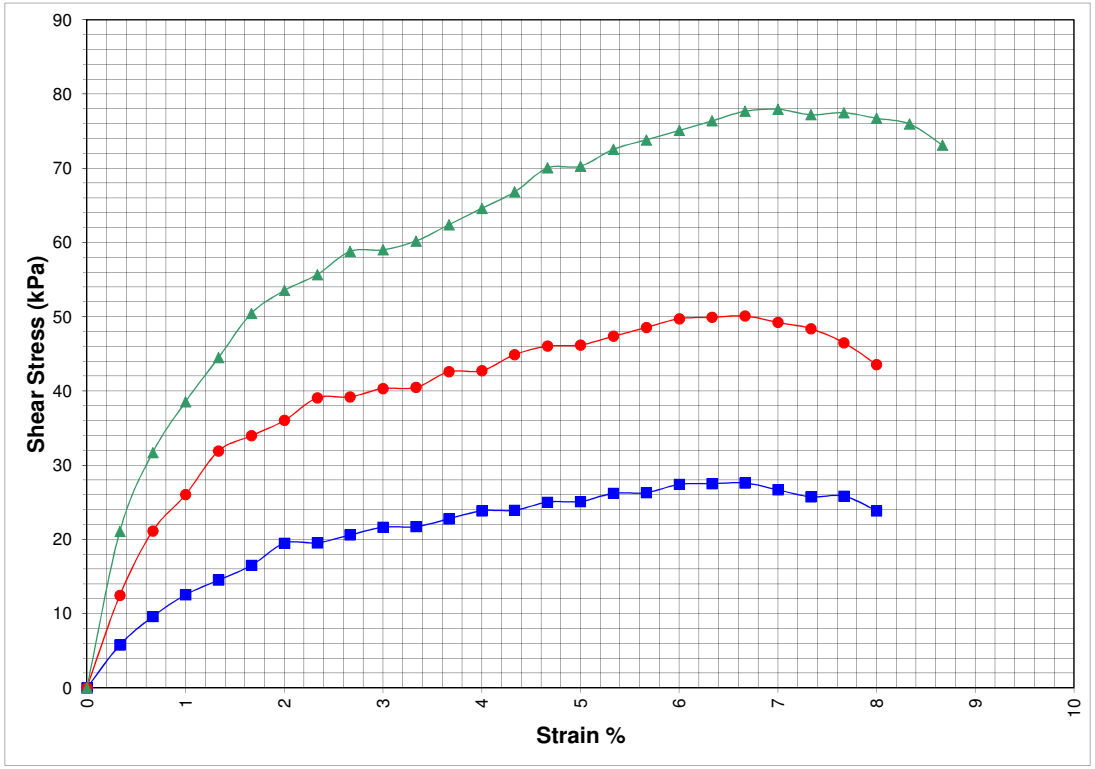
**Borehole: LBH-05A**

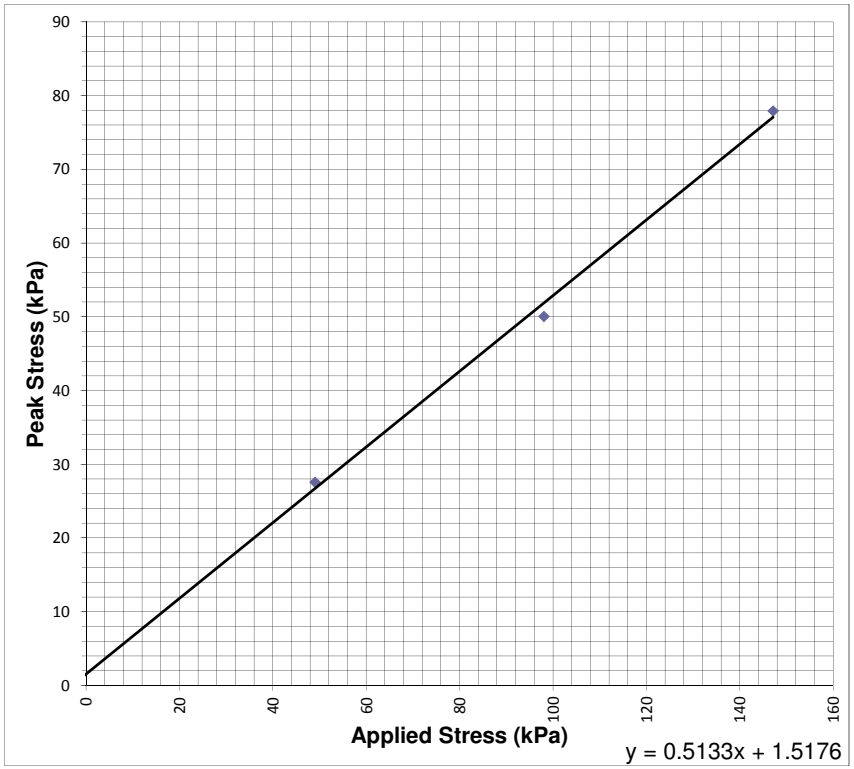
**Sample Type: SPT-01**

**Depth: 1.50-1.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 50 |
| | Stage 3 | 147 | 78 |

| | | |
|---|---|---|
| Angle of Friction | **27.17** | ° |
| Apparent Cohesion | **1.52** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

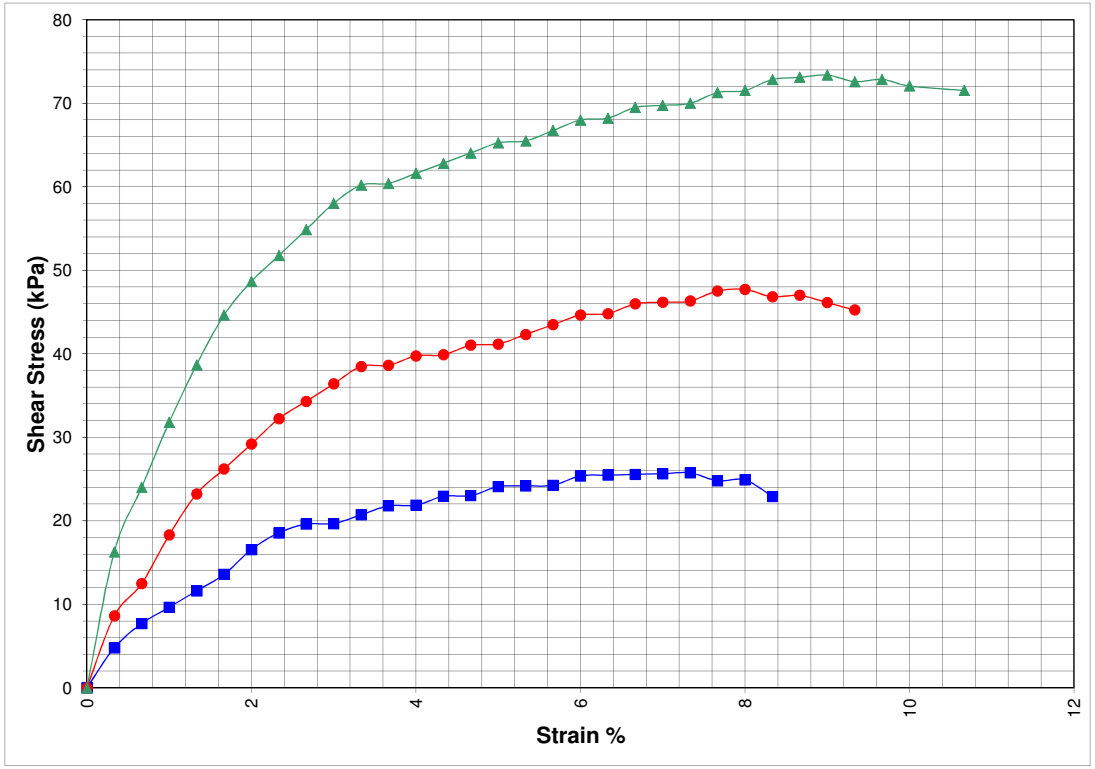
**Borehole: LBH-05A**

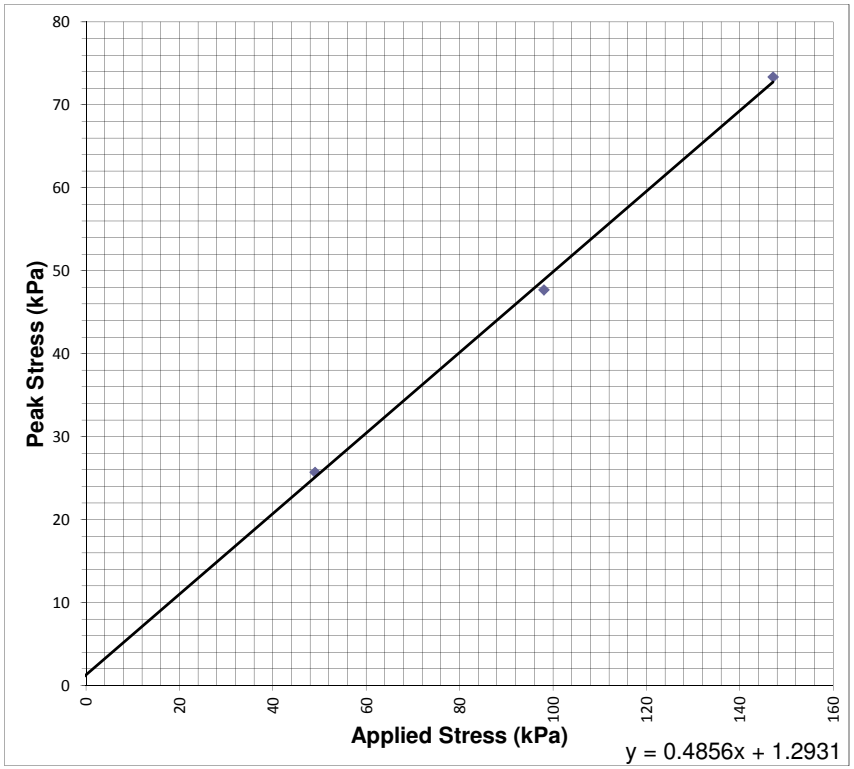
**Sample Type: SPT-013**

**Depth: 4.50-4.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 48 |
| | Stage 3 | 147 | 73 |

| | | |
|---|---|---|
| Angle of Friction | **25.90** | ° |
| Apparent Cohesion | **1.29** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

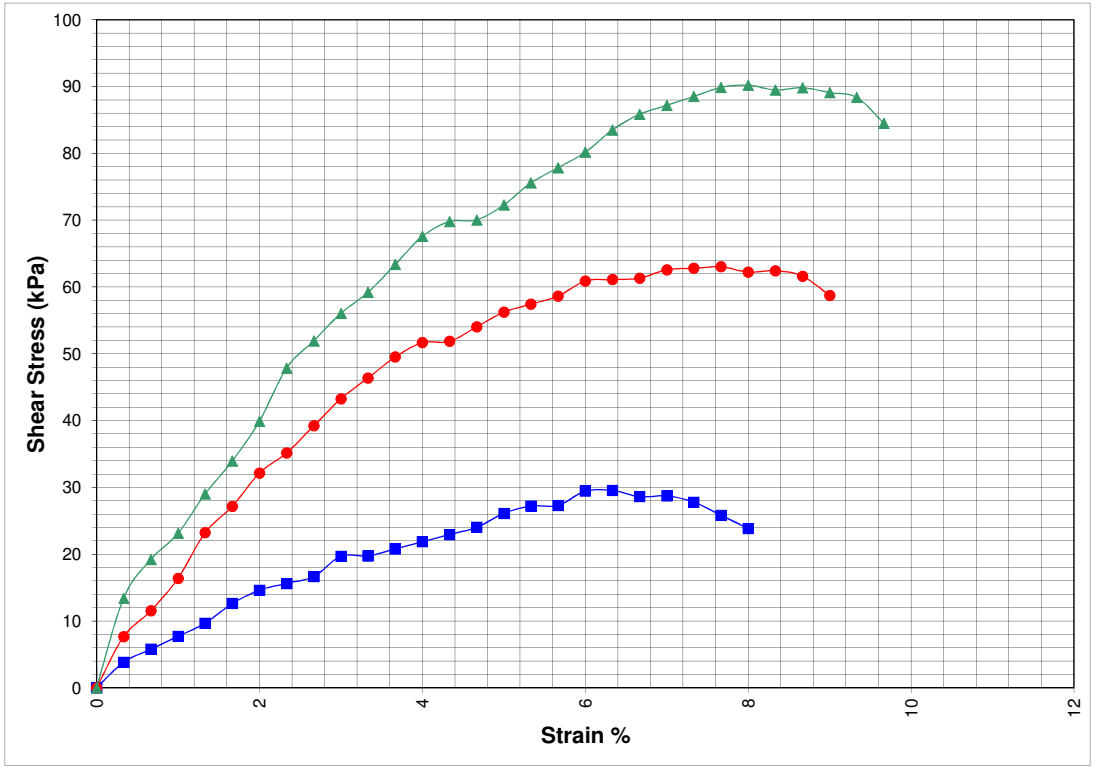
**Borehole: LBH-05A**

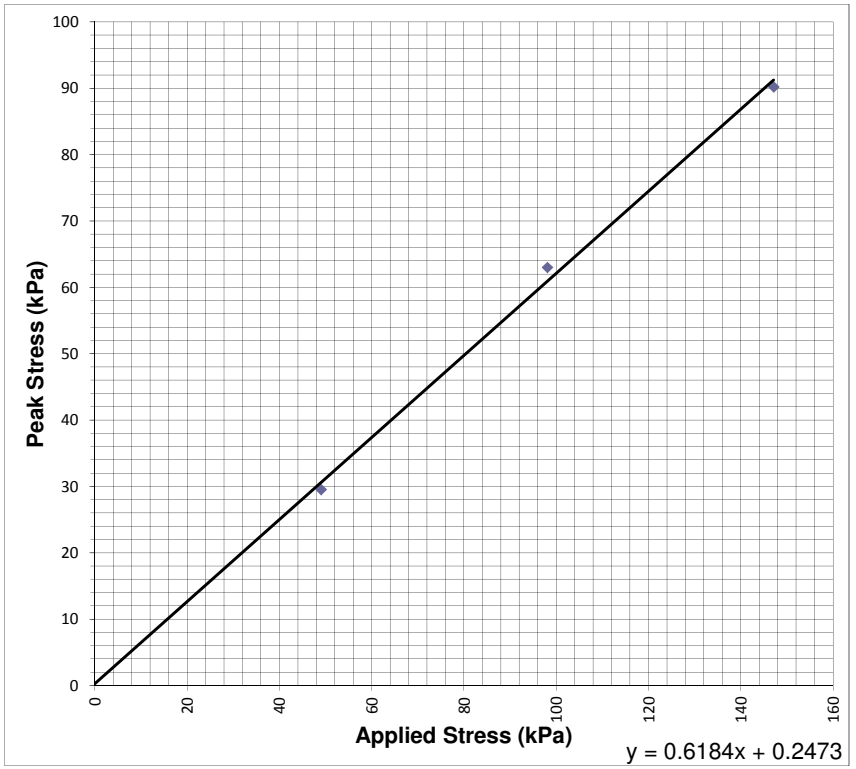
**Sample Type: SPT-04**

**Depth: 6.00-6.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 30 |
| | Stage 2 | 98 | 63 |
| | Stage 3 | 147 | 90 |

| | | |
|---|---|---|
| Angle of Friction | **31.73** | ° |
| Apparent Cohesion | **0.25** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

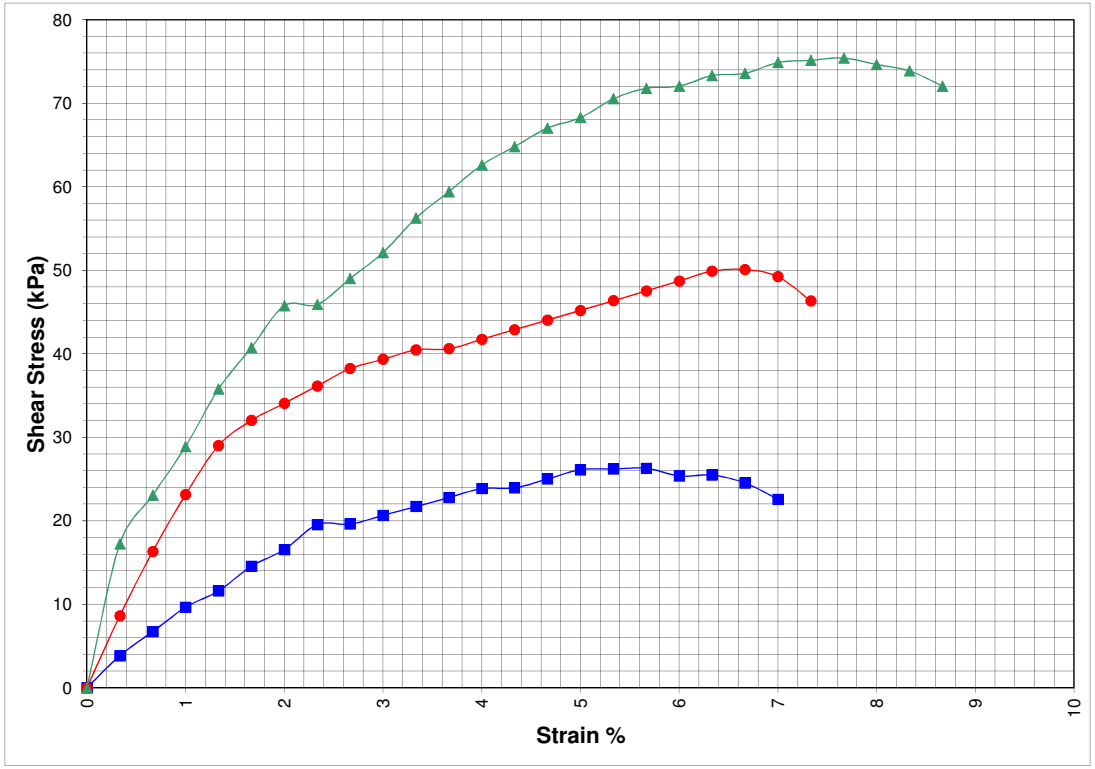
**Borehole: LBH-05A**

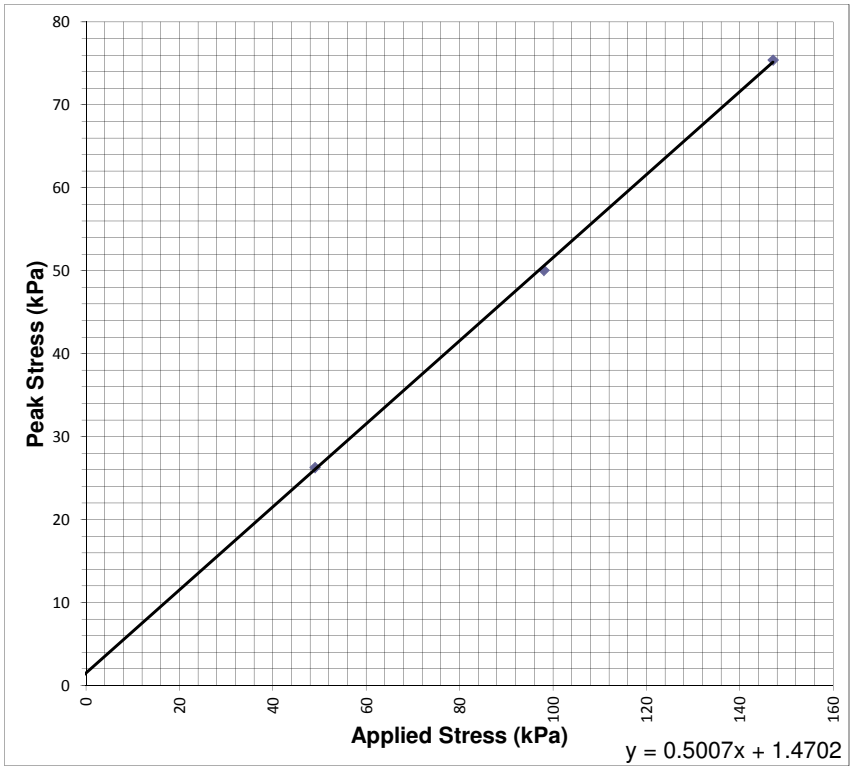
**Sample Type: SPT-06**

**Depth: 9.00-9.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 50 |
| | Stage 3 | 147 | 75 |

| | | |
|---|---|---|
| Angle of Friction | **26.60** | ° |
| Apparent Cohesion | **1.47** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

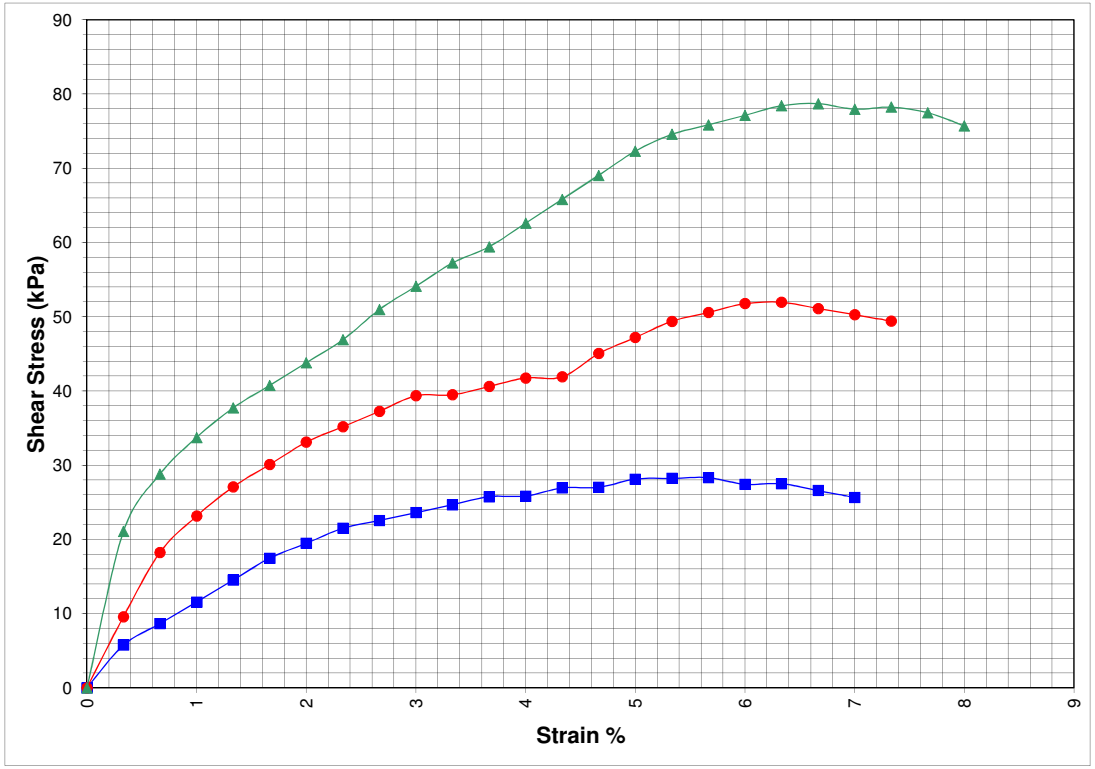
**Borehole: LBH-05A**

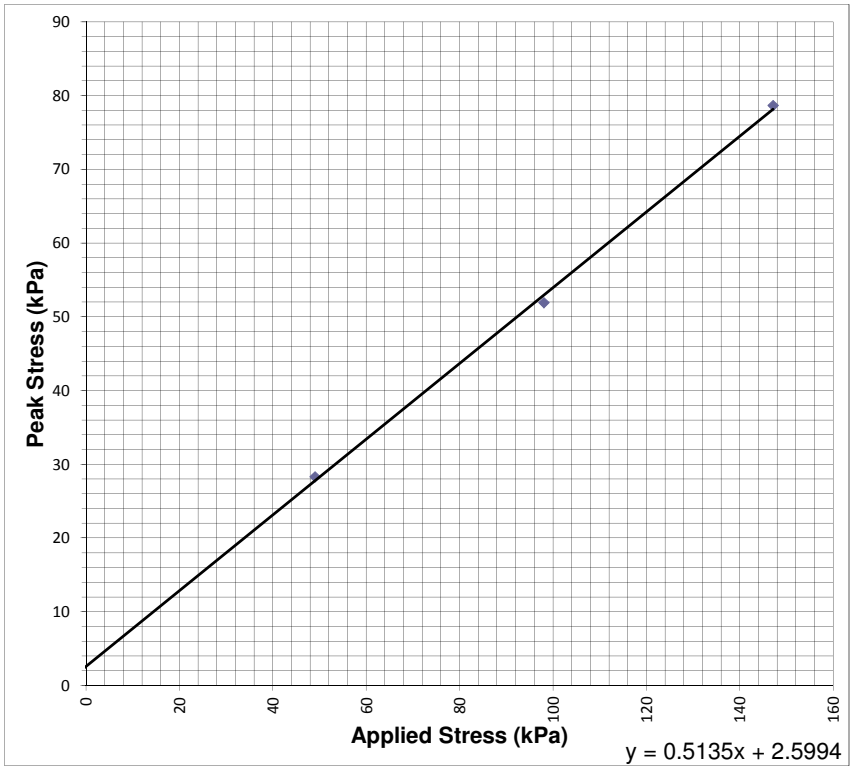
**Sample Type: SPT-08**

**Depth: 12.00-12.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 52 |
| | Stage 3 | 147 | 79 |

| | | |
|---|---|---|
| Angle of Friction | **27.18** | ° |
| Apparent Cohesion | **2.60** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

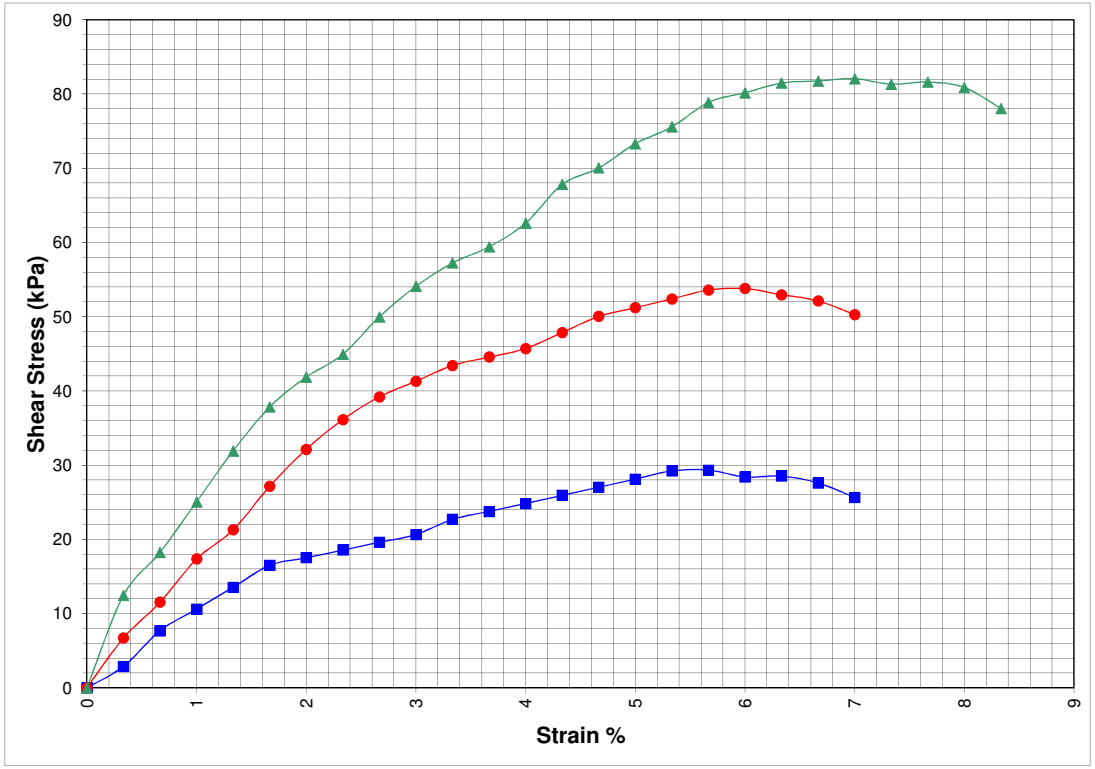
**Borehole: LBH-05A**

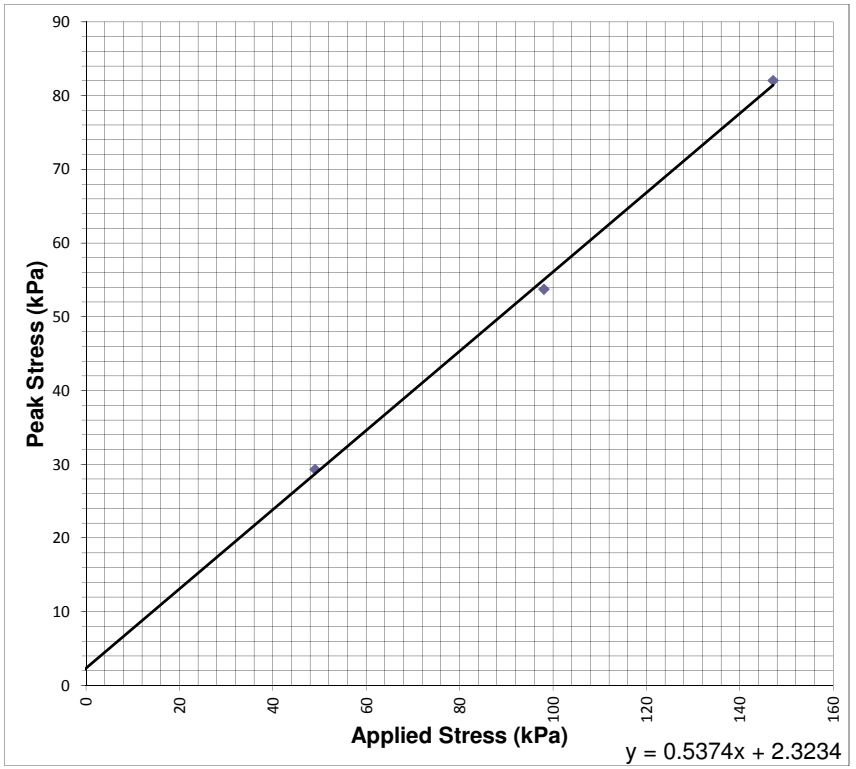
**Sample Type: SPT-10**

**Depth: 15.00-15.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 29 |
| | Stage 2 | 98 | 54 |
| | Stage 3 | 147 | 82 |

| | | |
|---|---|---|
| Angle of Friction | **28.25** | ° |
| Apparent Cohesion | **2.32** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

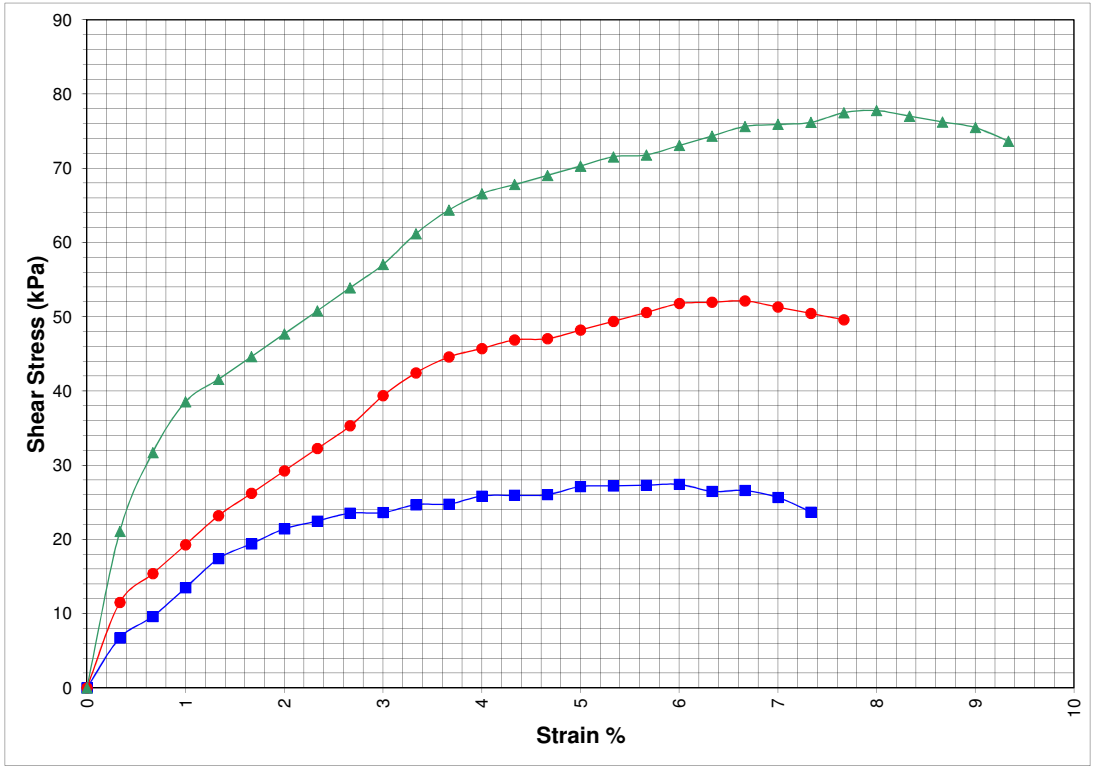
**Borehole: LBH-05A**

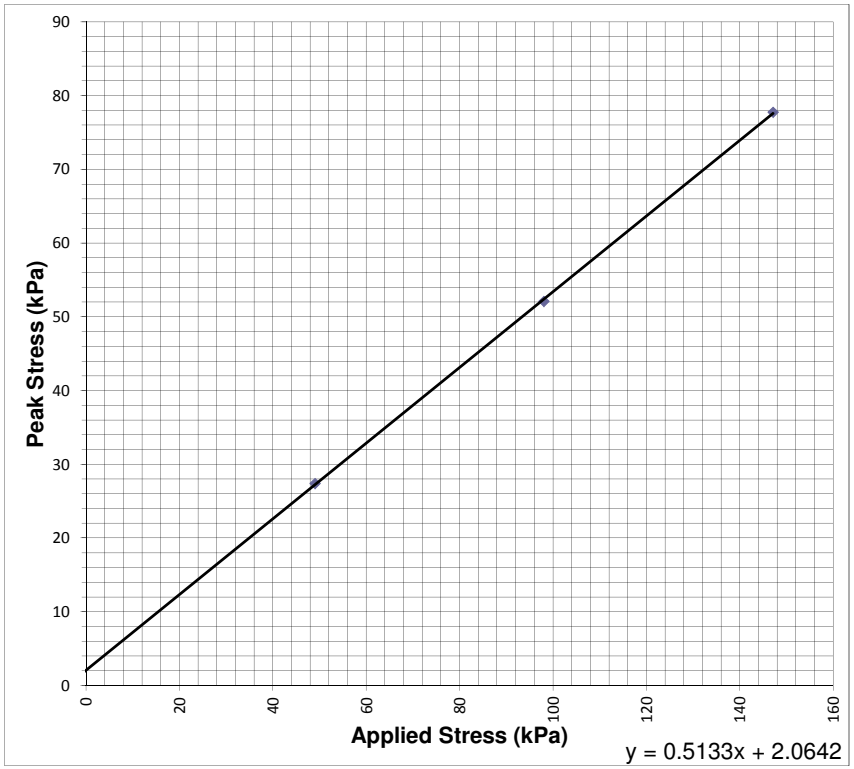
**Sample Type: SPT-12**

**Depth: 18.00-18.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 52 |
| | Stage 3 | 147 | 78 |

| | | |
|---|---|---|
| Angle of Friction | **27.17** | ° |
| Apparent Cohesion | **2.12** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

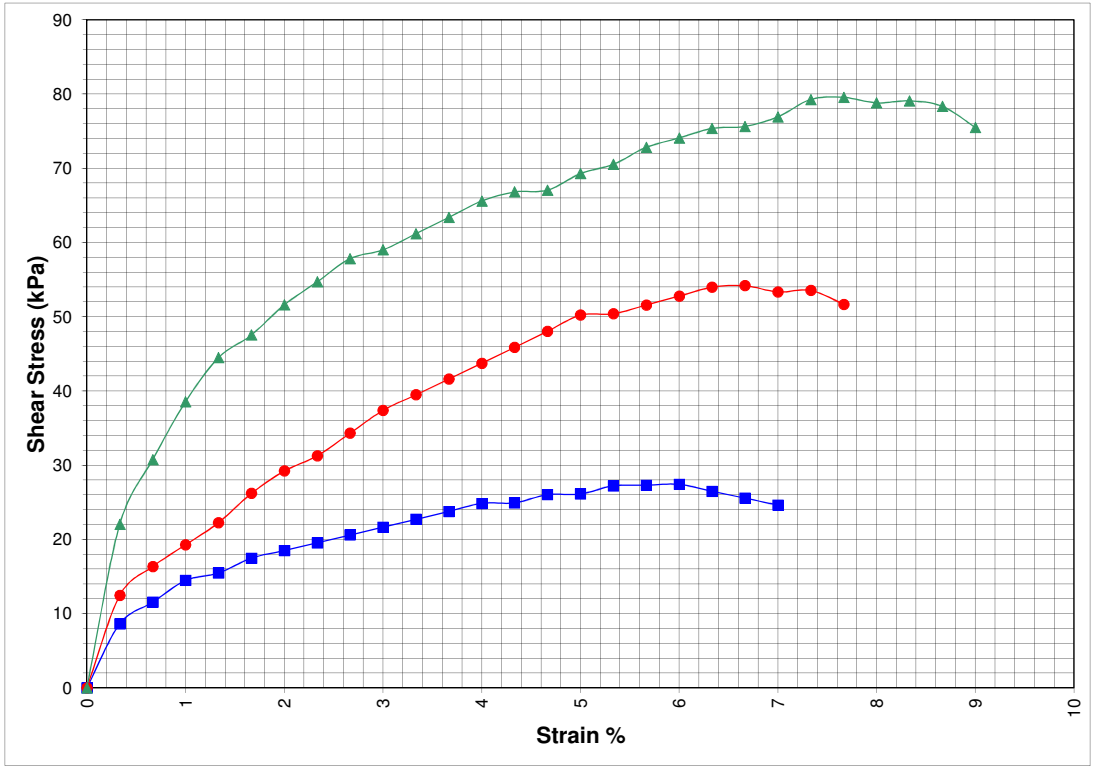
**Borehole: LBH-05A**

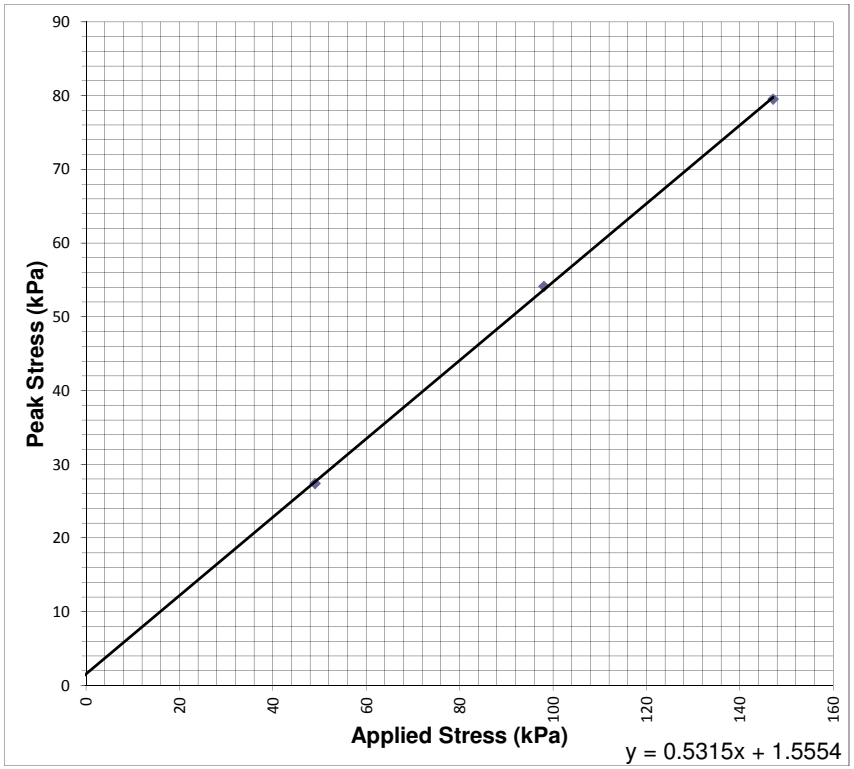
**Sample Type: SPT-16**

**Depth: 24.00-24.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 54 |
| | Stage 3 | 147 | 80 |

| | | |
|---|---|---|
| Angle of Friction | **27.99** | ° |
| Apparent Cohesion | **1.56** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: LBH-05A**

**Sample Type: SPT-18**

**Depth: 27.00-27.45 m**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-1 | 0.00-0.30 | SP | | | | 19.2 | 17.24 | 7.18 | 14.47 | 2.63 | 0 | 98 | <--> | <--> | 2 | | | | | | | | | | | | | | | | | | |
| SPT-2 | 1.50-1.80 | | | | | 17.5 | 18.06 | 8.00 | 15.37 | | | | | | | DST | | | 0.43 | 27.8 | | | | | | | | | | | | |
| SPT-3 | 3.00-3.20 | | | | | 19.8 | 18.26 | 8.20 | 15.24 | 2.61 | | | | | | | | | | | | | | | | | | | | | | |
| SPT-4 | 4.50-4.70 | SP | | | | 16.4 | 16.48 | 6.42 | 14.16 | 2.62 | 0 | 97 | <--> | <--> | 3 | | | | | | | | | | | | | | | | | | |
| SPT-5 | 6.00-6.15 | | | | | 15.9 | 15.85 | 5.79 | 13.68 | 2.59 | | | | | | | | | | | | | | | | | | | 7.99 | 0.20 | 1.00 | 1000 | 8850 |
| SPT-6 | 7.50-7.68 | | | | | 15.4 | 17.38 | 7.32 | 15.06 | | | | | | | DST | | | 0.19 | 32.6 | | | | | | | | | | | | |
| SPT-7 | 9.00-9.10 | | | | | 17.6 | 16.52 | 6.46 | 14.04 | 2.60 | | | | | | | | | | | | | | | | | | | | | | |
| SPT-8 | 10.50-10.64 | SP-SM | | | | 20.8 | 15.94 | 5.88 | 13.19 | | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | | | | |
| SPT-9 | 12.00-12.30 | | | | | 21.3 | 17.31 | 7.25 | 14.27 | | | | | | | DST | | | 0.43 | 28.9 | | | | | | | | | | | | |
| SPT-10 | 13.50-13.75 | SP-SM | | | | 18.6 | 17.20 | 7.14 | 14.50 | 2.63 | 0 | 91 | <--> | <--> | 9 | | | | | | | | | | | | | | | | | | |
| SPT-11 | 15.00-15.22 | | | | | 19.8 | 17.88 | 7.82 | 14.93 | | | | | | | DST | | | 0.59 | 27.2 | | | | | | | | | | | | |
| SPT-12 | 16.50-16.70 | SM / SC | | | | 19.8 | 18.28 | 8.22 | 15.26 | | 0 | 83 | <--> | <--> | 17 | | | | | | | | | | | | | | | | | | |
| SPT-13 | 18.00-18.15 | SP-SM | | | | 18.7 | 18.18 | 8.12 | 15.31 | | 0 | 92 | <--> | <--> | 8 | | | | | | | | | | | | | | | | | | |
| SPT-14 | 19.50-19.60 | | | | | 19.3 | 17.86 | 7.80 | 14.97 | 2.59 | | | | | | | | | | | | | | | | | | | | | | |
| SPT-15 | 21.00-21.15 | | | | | 19.1 | 17.59 | 7.53 | 14.77 | | | | | | | DST | | | 1.50 | 28.4 | | | | | | | | | | | | |
| SPT-16 | 22.50-22.75 | | | | | 18.1 | 17.51 | 7.45 | 14.82 | 2.61 | | | | | | | | | | | | | | | | | | | 8.28 | 0.50 | 1.00 | 600 | 14160 |
| SPT-17 | 24.00-24.10 | SP | | | | 16.9 | 16.19 | 6.13 | 13.85 | | 0 | 97 | <--> | <--> | 3 | | | | | | | | | | | | | | | | | | |
| SPT-18 | 25.50-25.65 | | | | | 17.1 | 16.85 | 6.79 | 14.39 | | | | | | | DST | | | 0.19 | 29.1 | | | | | | | | | | | | |
| SPT-19 | 27.00-27.15 | SP | | | | 18.4 | 16.94 | 6.88 | 14.31 | 2.59 | 0 | 98 | <--> | <--> | 2 | | | | | | | | | | | | | | | | | | |
| SPT-20 | 28.50-28.65 | | | | | 17.8 | 17.57 | 7.51 | 14.91 | | | | | | | DST | | | 0.47 | 28.3 | | | | | | | | | | | | |
| SPT-21 | 30.00-30.12 | SP | | | | 18.1 | 17.51 | 7.45 | 14.82 | 2.61 | 0 | 96 | <--> | <--> | 4 | | | | | | | | | | | | | | | | | | |

**END OF BOREHOLE**

**Notes :**

DS : Disturbed Sample
WAX/UDS : Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

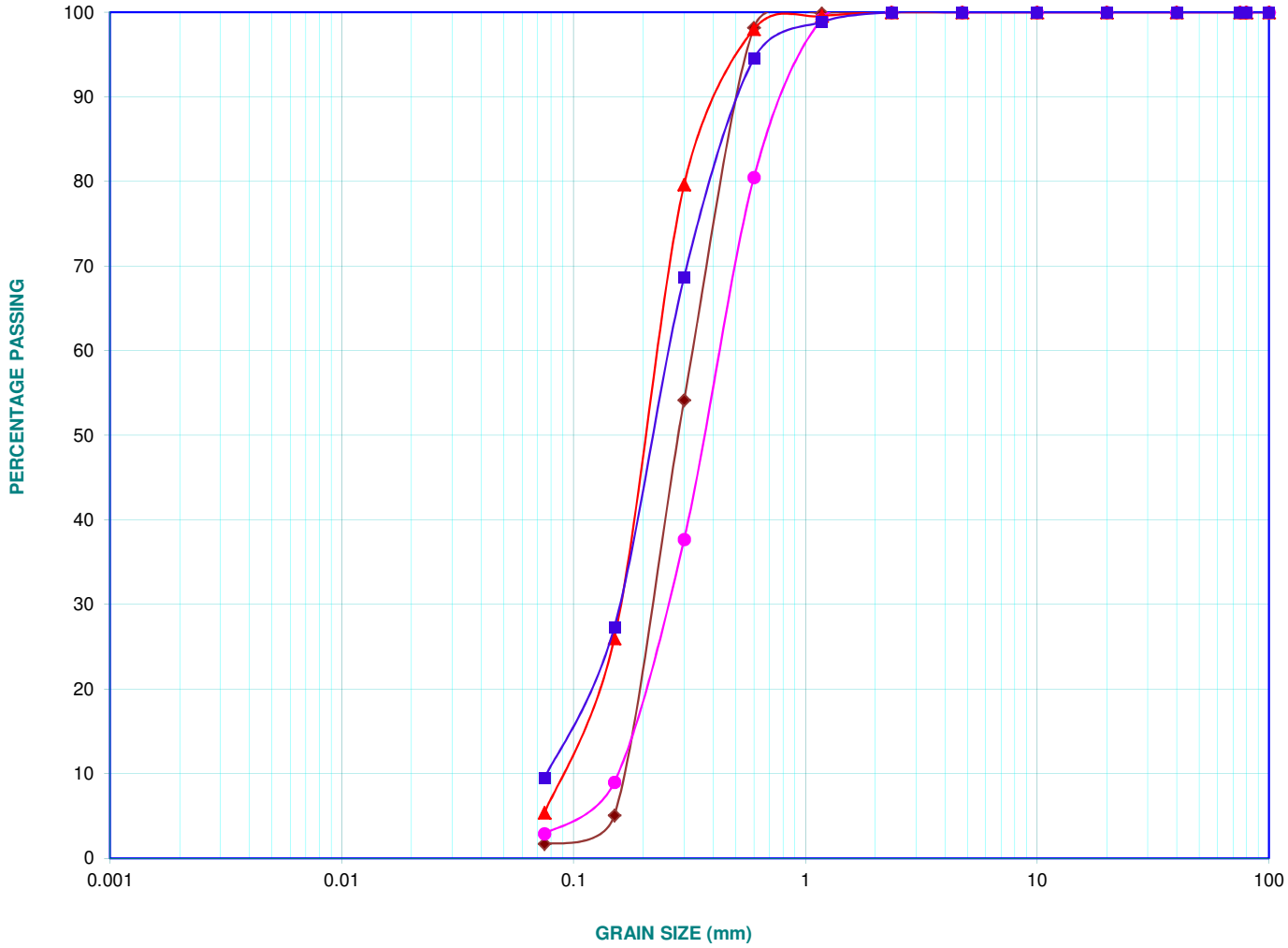
\# : Decayed Wood

**Failure Type**
A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.**
Project Code : **CM 19 01 03**
Borehole No. : **LBH-06A**

# GRAIN SIZE ANALYSIS

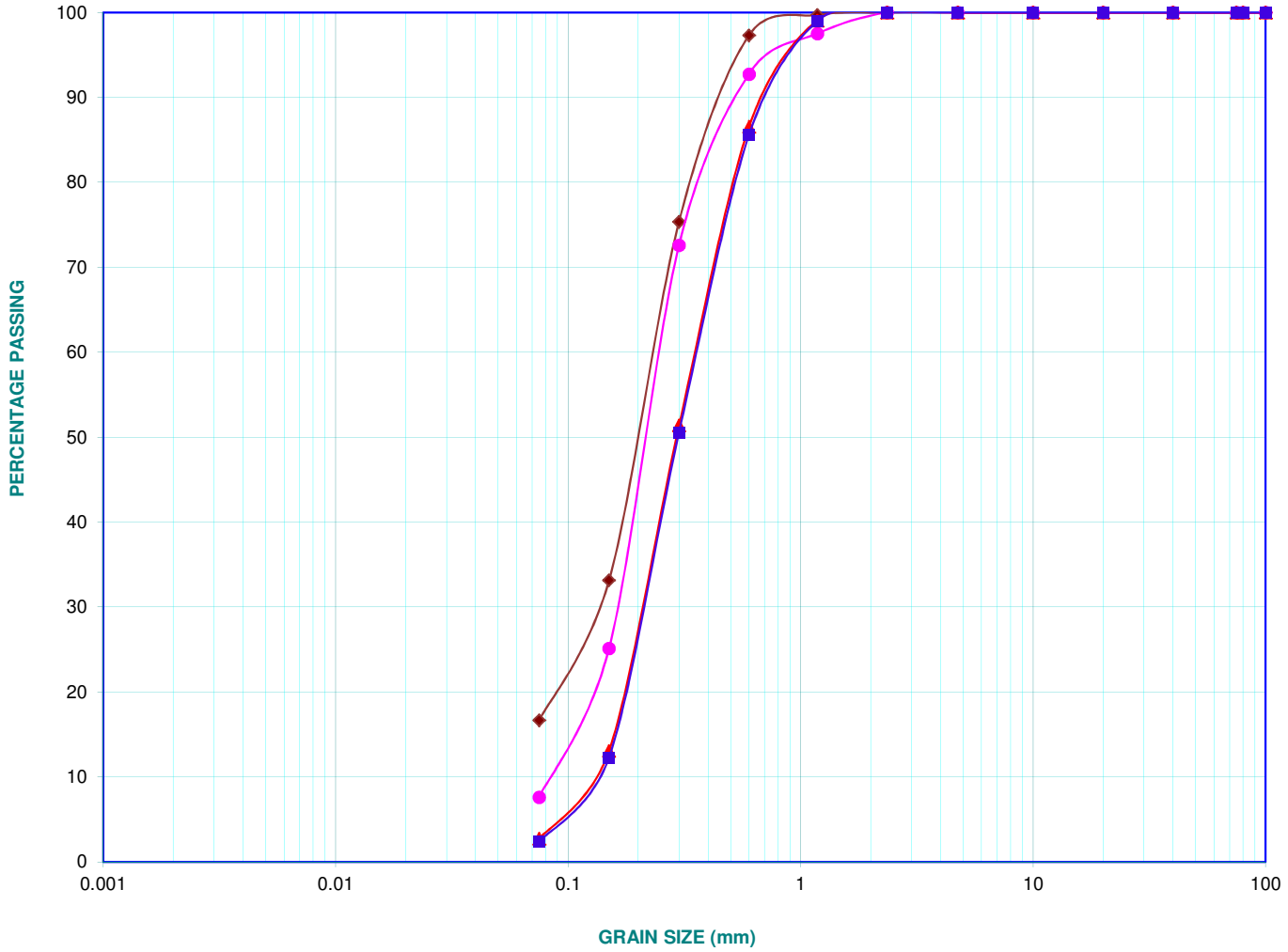
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | : Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha. | | | | | | | | | | | |
| **Job No.** | : CM 19 01 03 | | | **Borehole No.** | : LBH-06A | | | | | **Date :** | 15-Jun-19 | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | LBH-06A | LBH-06A | LBH-06A | LBH-06A | | | | | | | | |
| **Depth (m)** | 0.00-0.30 | 4.50-4.70 | 10.50-10.64 | 13.50-13.75 | | | | | | | | |
| **Sample Type** | SPT-1 | SPT-4 | SPT-8 | SPT-10 | | | | | | | | |
| **Classification** | SP | SP | SP-SM | SP-SM | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 98 | 97 | 95 | 91 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 2 | 3 | 5 | 9 | | | | | | | | |
| **D60 mm** | 0.320 | 0.410 | 0.230 | 0.250 | | | | | | | | |
| **D30 mm** | 0.210 | 0.260 | 0.170 | 0.160 | | | | | | | | |
| **D10 mm** | 0.180 | 0.160 | 0.090 | 0.075 | | | | | | | | |
| **Cu** | 1.78 | 2.56 | 2.56 | 3.33 | | | | | | | | |
| **Cc** | 0.77 | 1.03 | 1.40 | 1.37 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | : Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha. | | | | | | | | | | |
| **Job No.** | : CM 19 01 03 | | | **Borehole No.** | : LBH-06A | | | | **Date :** | 15-Jun-19 | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND F | SAND M | SAND C | GRAVEL F / GRAVEL C |
| **Bore Hole .** | LBH-06A | LBH-06A | LBH-06A | LBH-06A | | | | | | | |
| **Depth (m)** | 16.50-16.70 | 18.00-18.15 | 24.00-24.10 | 27.00-27.15 | | | | | | | |
| **Sample Type** | SPT-12 | SPT-13 | SPT-17 | SPT-19 | | | | | | | |
| **Classification** | SM/SC | SP-SM | SP | SP | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | |
| **Sand %** | 83 | 92 | 97 | 98 | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | |
| **Fines % (Silt+Clay)** | 17 | 8 | 3 | 2 | | | | | | | |
| **D60 mm** | | 0.250 | 0.360 | 0.360 | | | | | | | |
| **D30 mm** | | 0.170 | 0.210 | 0.210 | | | | | | | |
| **D10 mm** | | 0.085 | 0.150 | 0.150 | | | | | | | |
| **Cu** | | 2.94 | 2.40 | 2.40 | | | | | | | |
| **Cc** | | 1.36 | 0.82 | 0.82 | | | | | | | |
| **Liquid Limit %** | --- | | --- | --- | | | | | | | |
| **Plastic Limit %** | --- | | --- | --- | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | |

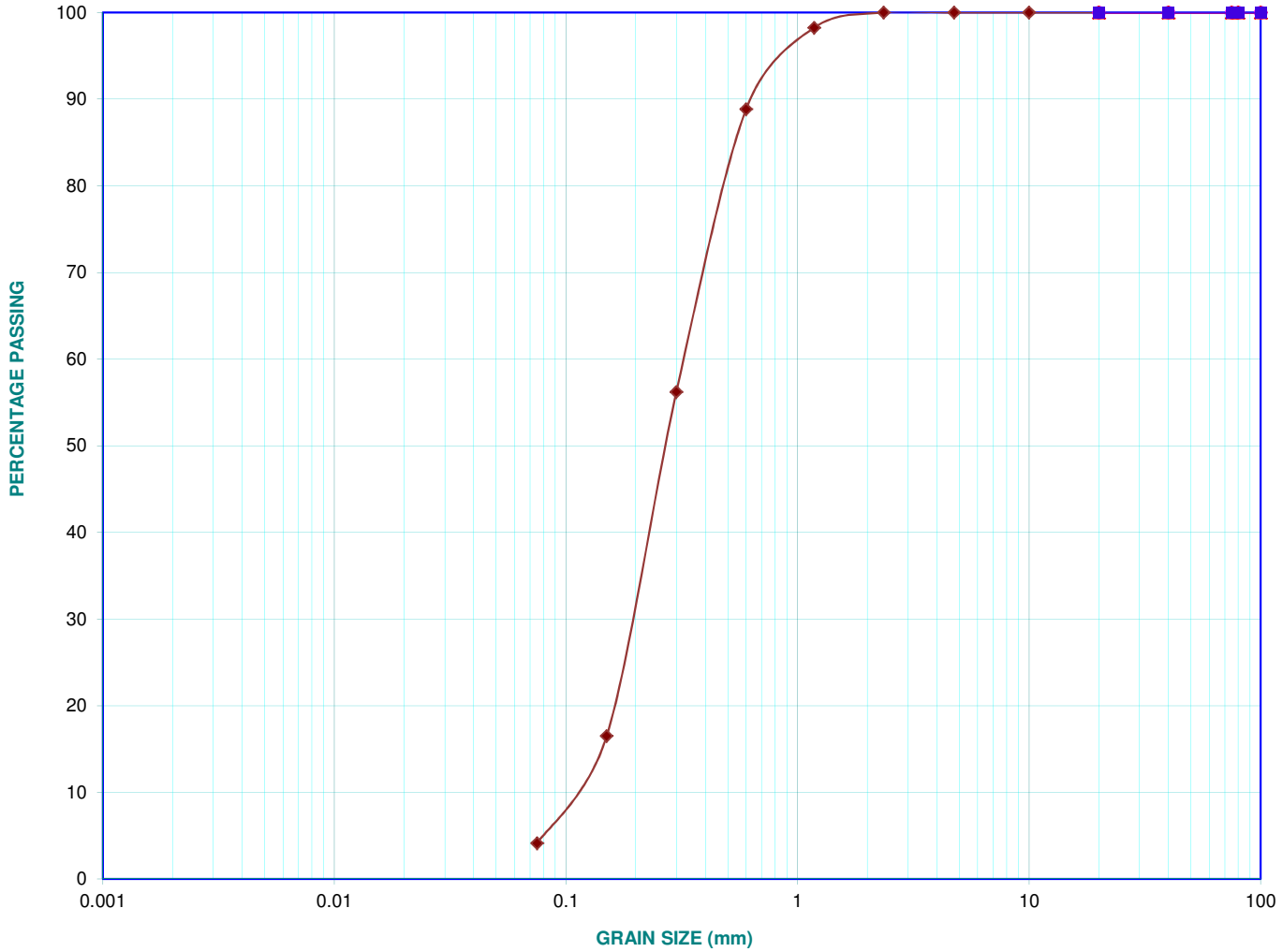



Checked By :

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: LBH-06A** |
| **Date :** | **15-Jun-19** |

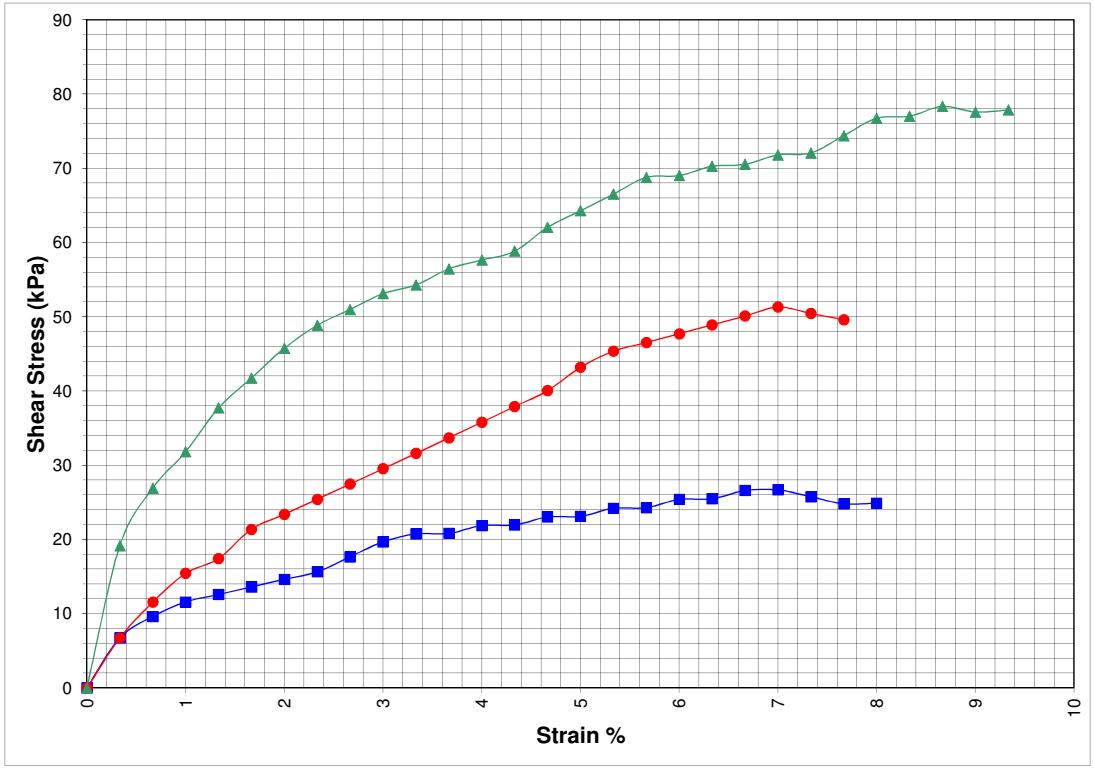
| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | LBH-06A | | | | | | | | | | | |
| **Depth (m)** | 30.00-30.12 | | | | | | | | | | | |
| **Sample Type** | SPT-21 | | | | | | | | | | | |
| **Classification** | SP | | | | | | | | | | | |
| **Gravel %** | 0 | | | | | | | | | | | |
| **Sand %** | 96 | | | | | | | | | | | |
| **Silt %** | <----> | | | | | | | | | | | |
| **Clay %** | <----> | | | | | | | | | | | |
| **Fines % (Silt+Clay)** | 4 | | | | | | | | | | | |
| **D60 mm** | 0.310 | | | | | | | | | | | |
| **D30 mm** | 0.200 | | | | | | | | | | | |
| **D10 mm** | 0.120 | | | | | | | | | | | |
| **Cu** | 2.58 | | | | | | | | | | | |
| **Cc** | 1.08 | | | | | | | | | | | |
| **Liquid Limit %** | --- | | | | | | | | | | | |
| **Plastic Limit %** | --- | | | | | | | | | | | |
| **Plasticity Index** | --- | | | | | | | | | | | |

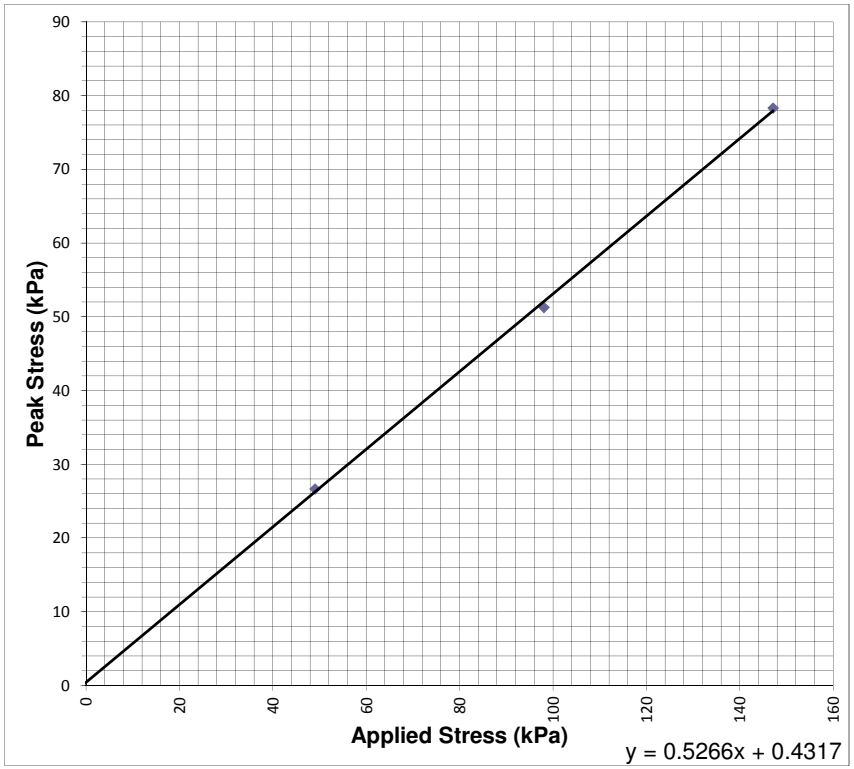



Checked By :

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 51 |
| | Stage 3 | 147 | 78 |

| | | |
|---|---|---|
| Angle of Friction | **27.77** | ° |
| Apparent Cohesion | **0.43** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

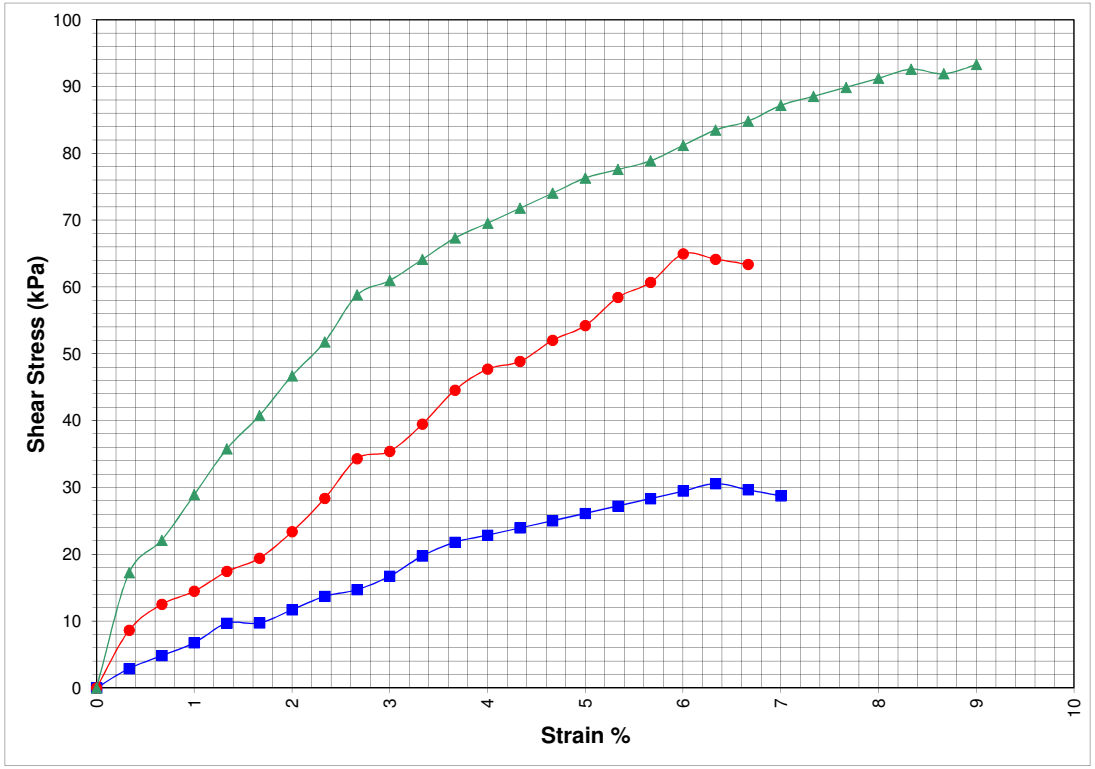
**Borehole: LBH-06A**

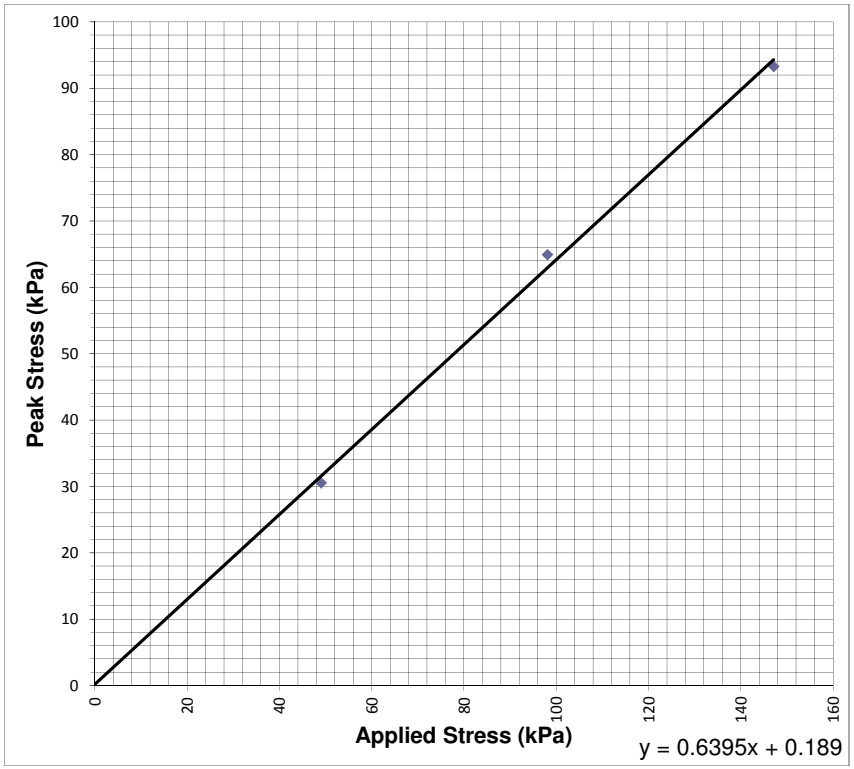
**Sample Type: SPT-02**

**Depth: 1.50-1.80 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 31 |
| | Stage 2 | 98 | 65 |
| | Stage 3 | 147 | 93 |

| | | |
|---|---|---|
| Angle of Friction | **32.60** | ° |
| Apparent Cohesion | **0.19** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

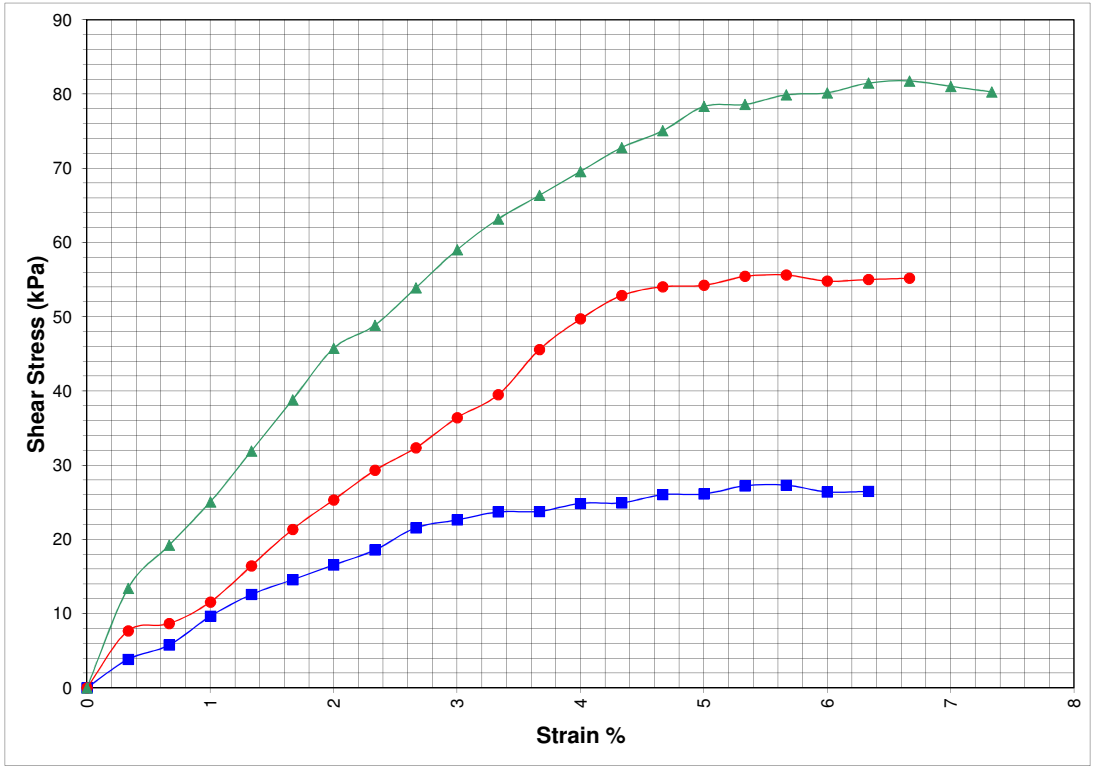
**Borehole: LBH-06A**

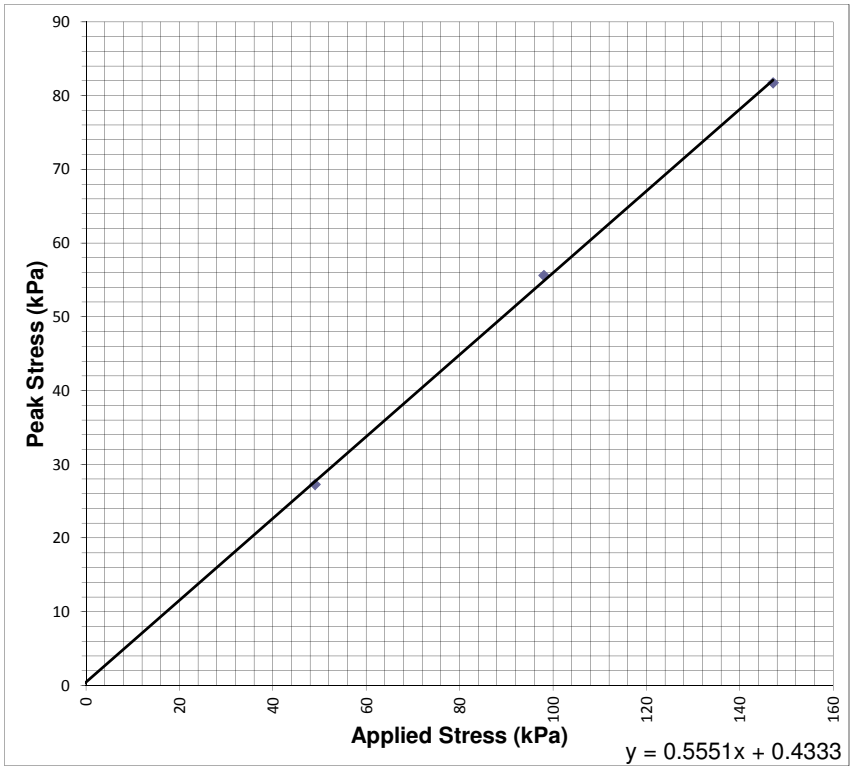
**Sample Type: SPT-06**

**Depth: 7.50-7.68 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 56 |
| | Stage 3 | 147 | 82 |

| | | |
|---|---|---|
| Angle of Friction | **28.90** | ° |
| Apparent Cohesion | **0.43** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

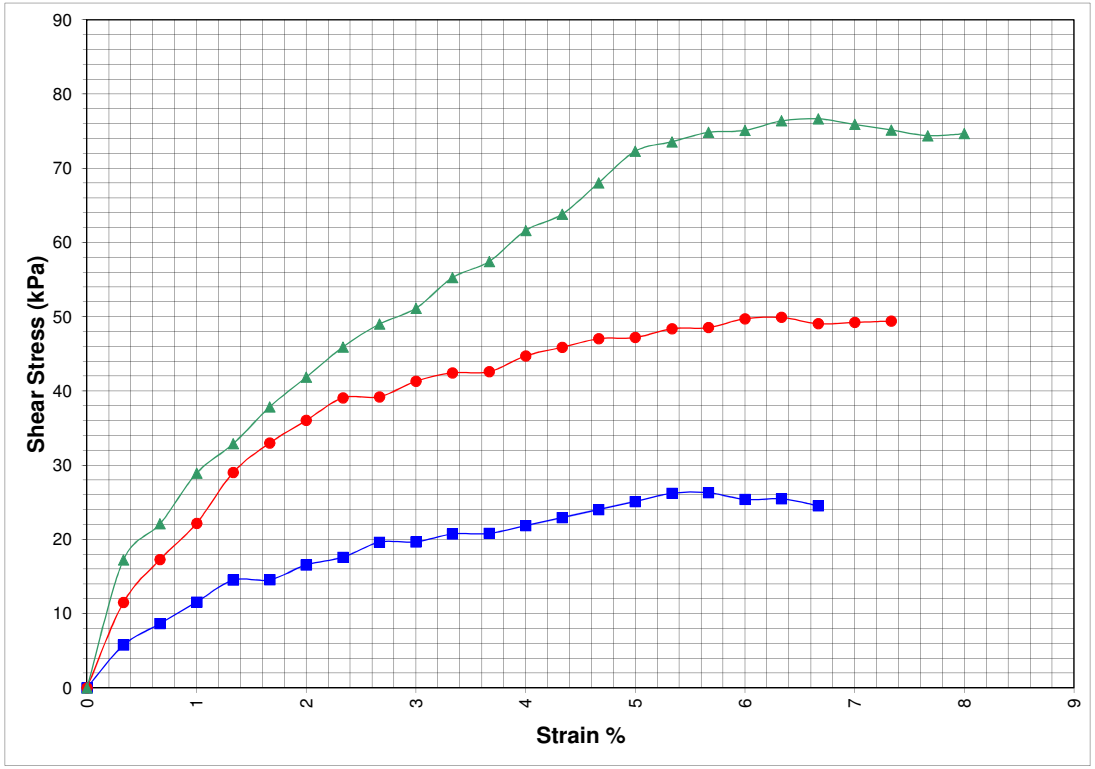
**Borehole: LBH-06A**

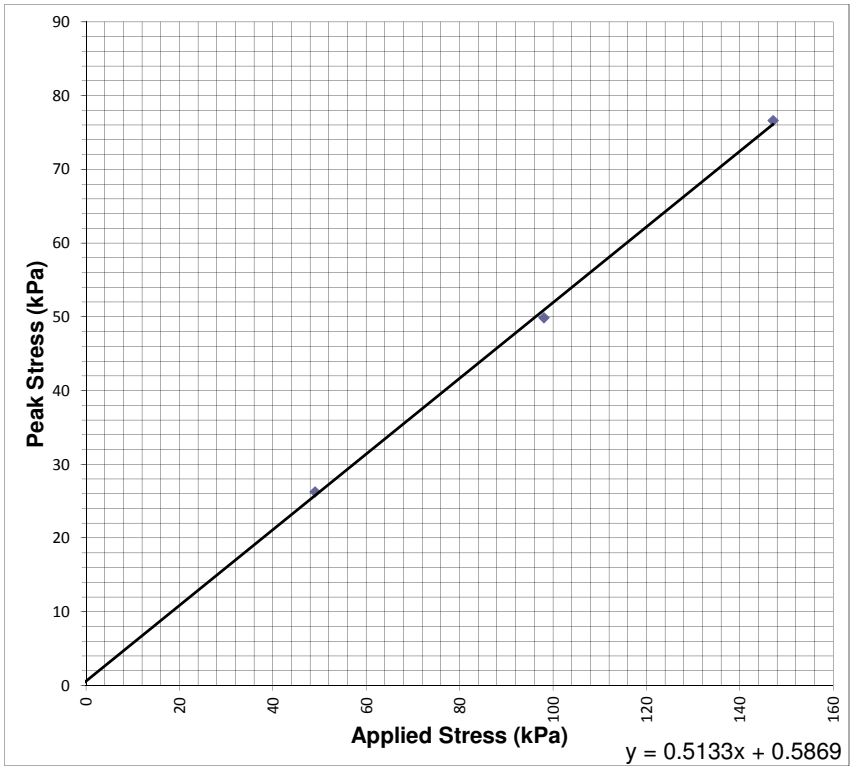
**Sample Type: SPT-09**

**Depth: 12.00-12.30 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 50 |
| | Stage 3 | 147 | 77 |

| | | |
|---|---|---|
| Angle of Friction | **27.17** | ° |
| Apparent Cohesion | **0.59** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

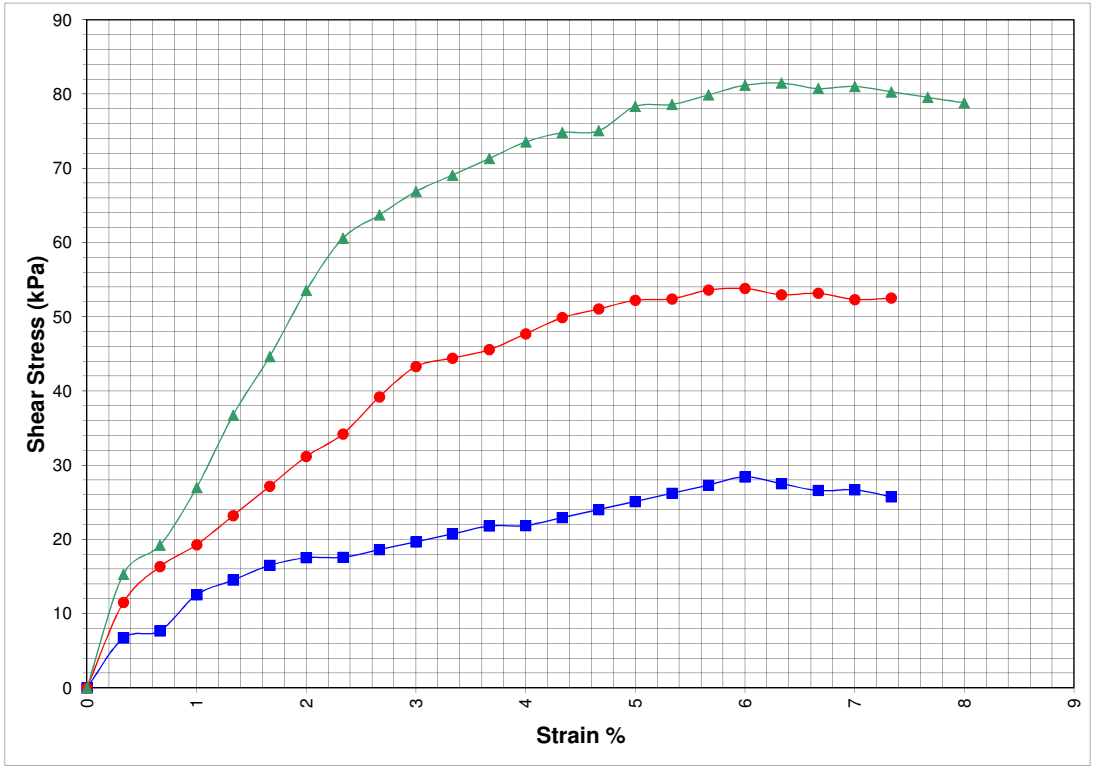
**Borehole: LBH-06A**

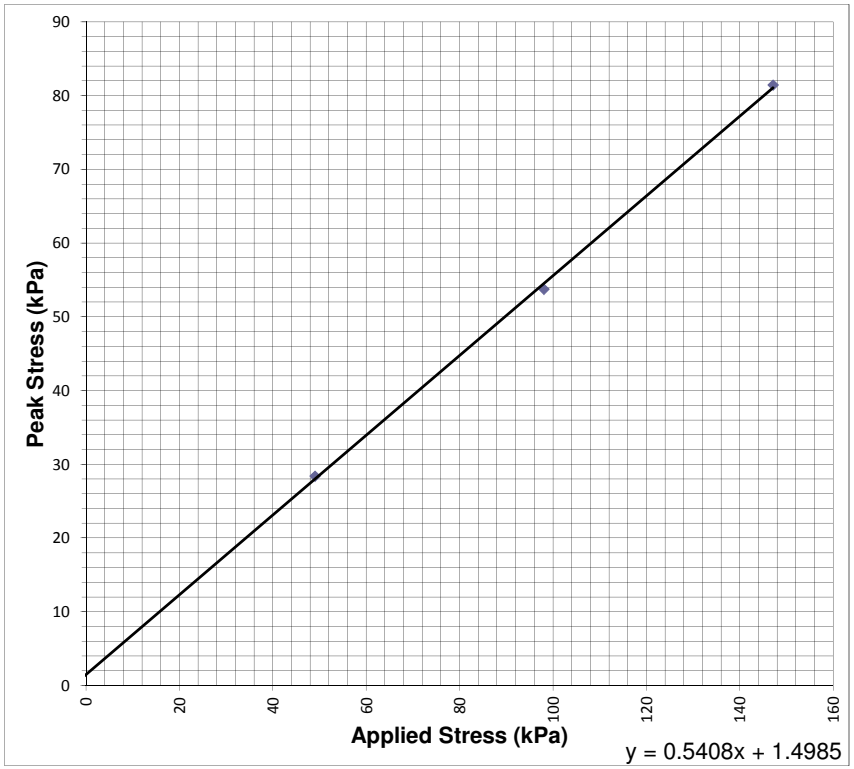
**Sample Type: SPT-11**

**Depth: 15.00-15.22 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 54 |
| | Stage 3 | 147 | 81 |

| | | |
|---|---|---|
| Angle of Friction | **28.40** | ° |
| Apparent Cohesion | **1.50** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

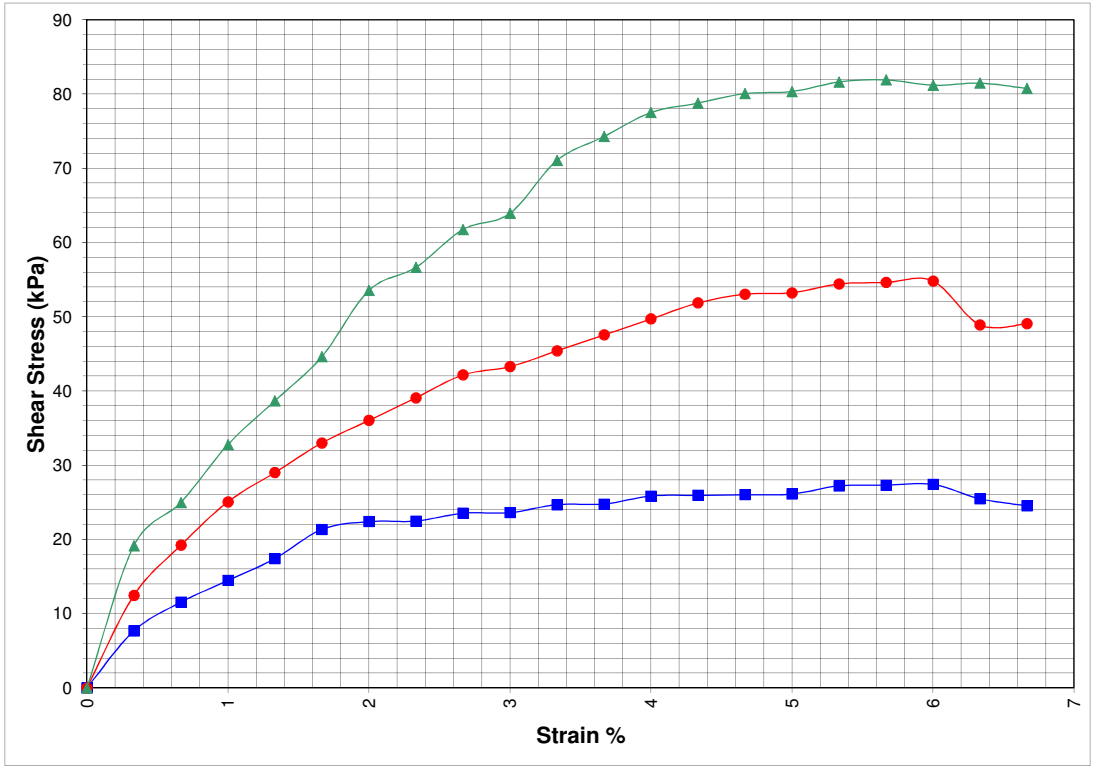
**Borehole: LBH-06A**

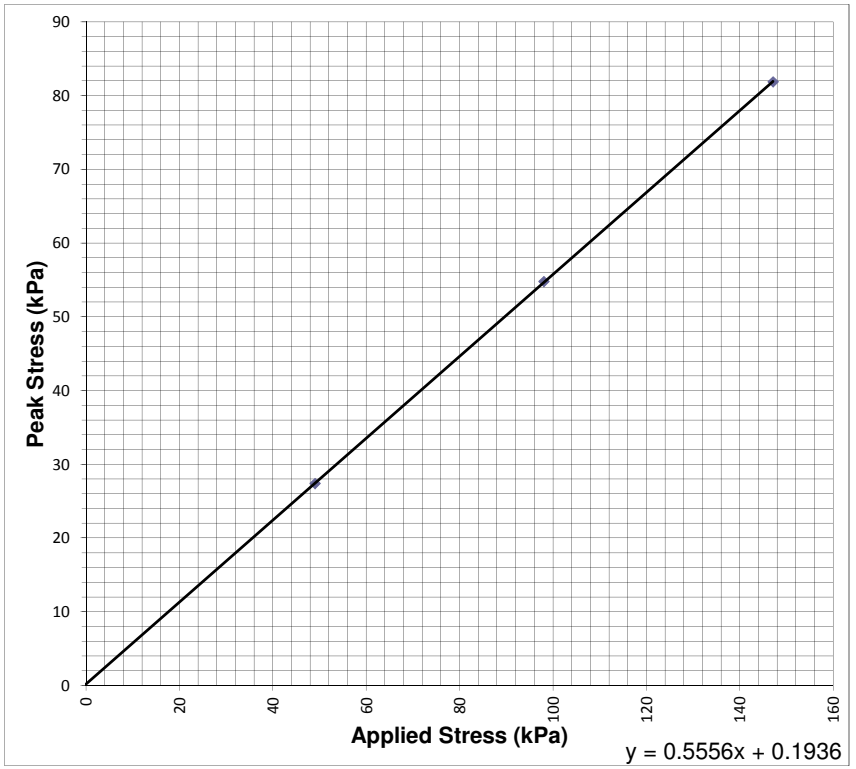
**Sample Type: SPT-15**

**Depth: 21.00-21.15 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 55 |
| | Stage 3 | 147 | 82 |

| | | |
|---|---|---|
| Angle of Friction | **29.06** | ° |
| Apparent Cohesion | **0.19** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

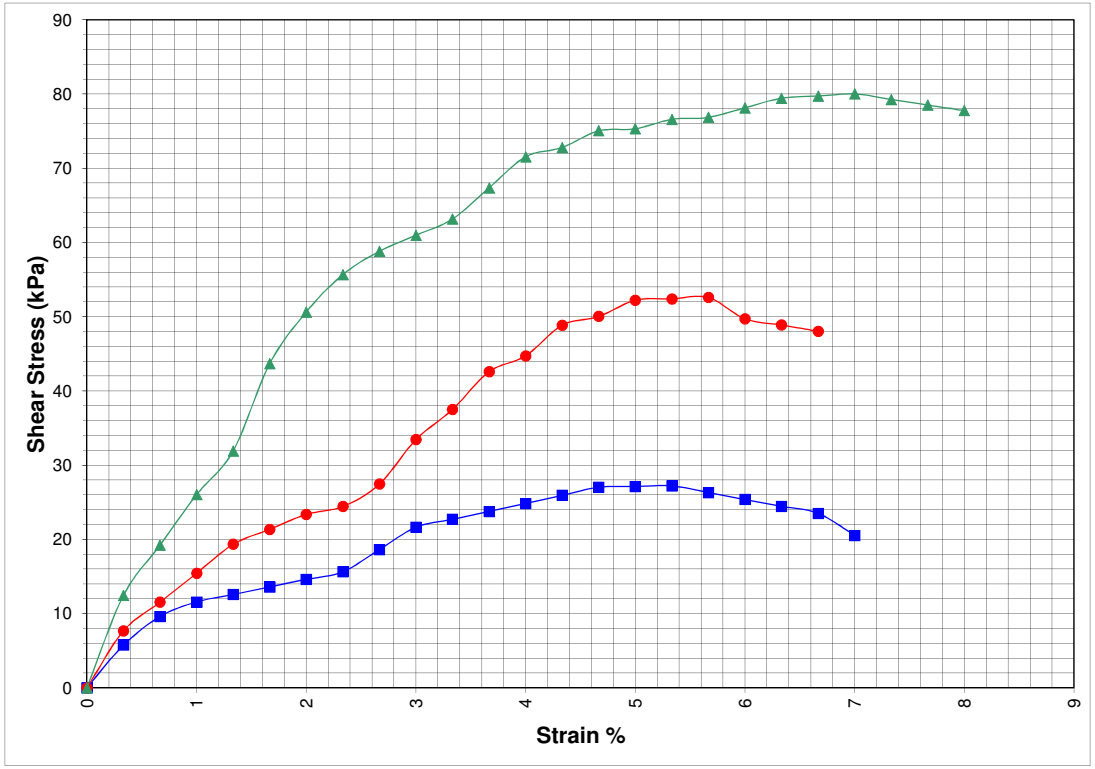
**Borehole: LBH-06A**

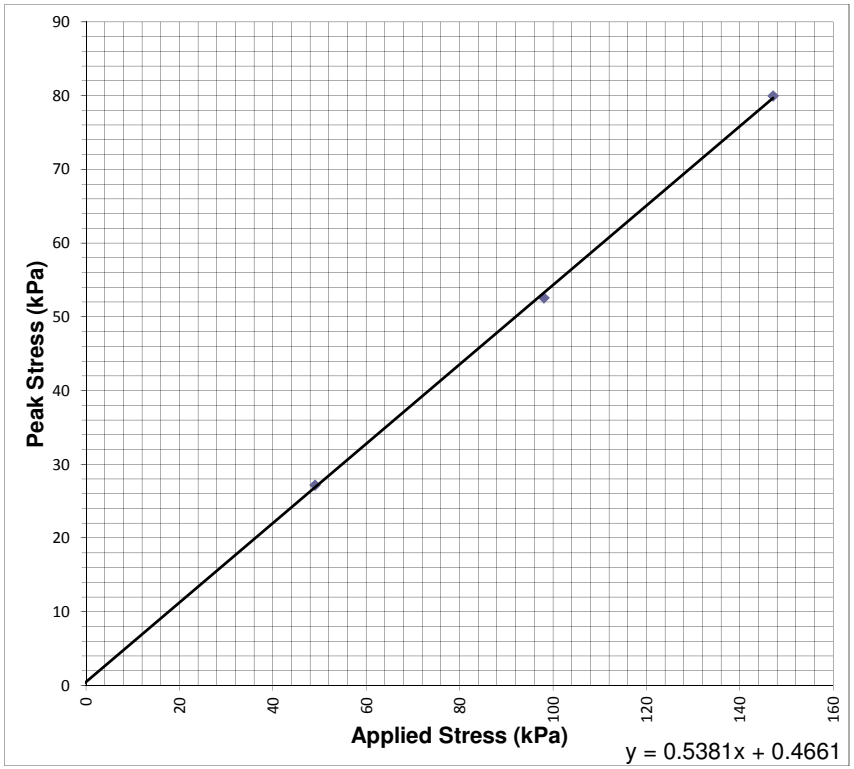
**Sample Type: SPT-18**

**Depth: 25.50-25.65 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 53 |
| | Stage 3 | 147 | 80 |

| | | |
|---|---|---|
| Angle of Friction | **28.28** | ° |
| Apparent Cohesion | **0.47** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: LBH-06A**

**Sample Type: SPT-20**

**Depth: 28.50-28.65 m**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density ($kN/m^3$) | Submerged Unit Weight ($kN/m^3$) | Dry Density ($kN/m^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| DS | 0.00-0.50 | | | | | 2.8 | 16.61 | 6.55 | 16.16 | 2.63 | | | | | | DST | | | 1.77 | 24.5 | | | | | | | | | | | | | |
| SPT-1 | 1.50-1.95 | SP | | | | 19.1 | 17.97 | 7.91 | 15.09 | 2.62 | 0 | 99 | <--> | <--> | 1 | | | | | | | | | | | | | | | | | | |
| SPT-2 | 3.00-3.45 | SP | | | | 17.8 | 17.82 | 7.76 | 15.13 | 2.61 | 0 | 99 | <--> | <--> | 1 | | | | | | | | | | | | | | | | | | |
| SPT-3 | 4.50-4.95 | | | | | 9.9 | 17.79 | 7.73 | 16.19 | 2.65 | | | | | | DST | | | 1.53 | 27.4 | | | | | | | | | | | | | |
| SPT-4 | 6.00-6.45 | | | | | 18.9 | 17.32 | 7.26 | 14.56 | 2.67 | | | | | | DST | | | 2.34 | 27.4 | | | | | | | | | | | | | |
| SPT-5 | 7.50-7.95 | SP | | | | 19.2 | 17.70 | 7.64 | 14.85 | 2.64 | 0 | 99 | <--> | <--> | 1 | | | | | | | | | | | | | | | | | | |
| SPT-6 | 9.00-9.45 | SP | | | | 14.5 | 16.89 | 6.83 | 14.75 | 2.67 | 0 | 99 | <--> | <--> | 1 | | | | | | | | | | | | | | | | | | |
| SPT-7 | 10.50-10.95 | | | | | 20.7 | 16.65 | 6.59 | 13.80 | 2.60 | | | | | | DST | | | 0.96 | 27.0 | | | | | | | | | | | | | |
| SPT-8 | 12.00-12.45 | SP-SM | | | | 21.3 | 17.39 | 7.33 | 14.34 | 2.61 | 0 | 95 | <--> | <--> | 5 | DST | | | 0.93 | 28.4 | | | | | | | | | | | | | |
| SPT-9 | 13.50-13.95 | SP-SM | | | | 22.5 | 17.33 | 7.27 | 14.14 | 2.60 | 0 | 91 | <--> | <--> | 9 | DST | | | 0.78 | 28.9 | | | | | | | | | | | | | |
| SPT-10 | 15.00-15.45 | | | | | 20.4 | 17.44 | 7.38 | 14.48 | 2.59 | 0 | 83 | <--> | <--> | 17 | | | | | | | | | | | | | | | | | | |
| SPT-11 | 16.50-17.00 | | | | | 20.7 | 16.84 | 6.78 | 13.95 | 2.64 | | | | | | DST | | | 1.82 | 27.5 | | | | | | | | | | | | | |
| SPT-12 | 18.00-18.45 | CL | 29.4 | 16.4 | 13.0 | 18.9 | 20.91 | 10.85 | 17.59 | 2.61 | | | | | | | | | | | | | | | | | | | | | | | |
| UDS-1 | 19.50-20.00 | SC | 27.5 | 15.4 | 12.1 | 13.6 | 21.22 | 11.16 | 18.69 | 2.59 | 0 | 64 | 16 | 20 | 36 | UU | 114.2 | A | | | | | | 30.0 | 0.36 | 97.0 | 186.3 | 0.003 | 6.90 | 2.30 | 1.00 | 700 | 8850 |
| SPT-13 | 21.00-21.45 | CL | 28.4 | 15.8 | 12.6 | 18.4 | 20.95 | 10.89 | 17.69 | 2.60 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-14 | 22.50-22.95 | | | | | 22.8 | 17.45 | 7.39 | 14.21 | 2.65 | | | | | | DST | | | 2.19 | 28.3 | | | | | | | | | | | | | |
| SPT-15 | 24.00-24.45 | SP-SM | | | | 23.5 | 17.52 | 7.46 | 14.18 | 2.61 | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | | | | |
| SPT-16 | 25.50-25.95 | | | | | 16.8 | 17.57 | 7.51 | 15.04 | 2.62 | | | | | | DST | | | 1.40 | 27.8 | | | | | | | | | | | | | |
| SPT-17 | 27.00-27.45 | SP | | | | 18.8 | 17.70 | 7.64 | 14.91 | 2.61 | 0 | 98 | <--> | <--> | 2 | | | | | | | | | | | | | | | | | | |
| SPT-18 | 28.50-28.95 | | | | | 16.3 | 17.63 | 7.57 | 15.16 | 2.66 | | | | | | DST | | | 2.38 | 27.7 | | | | | | | | | | | | | |
| SPT-19 | 30.00-30.45 | SP-SM | | | | 16.5 | 17.51 | 7.45 | 15.03 | 2.61 | 0 | 94 | <--> | <--> | 6 | | | | | | | | | | | | | | | | | | |
| END OF BOREHOLE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

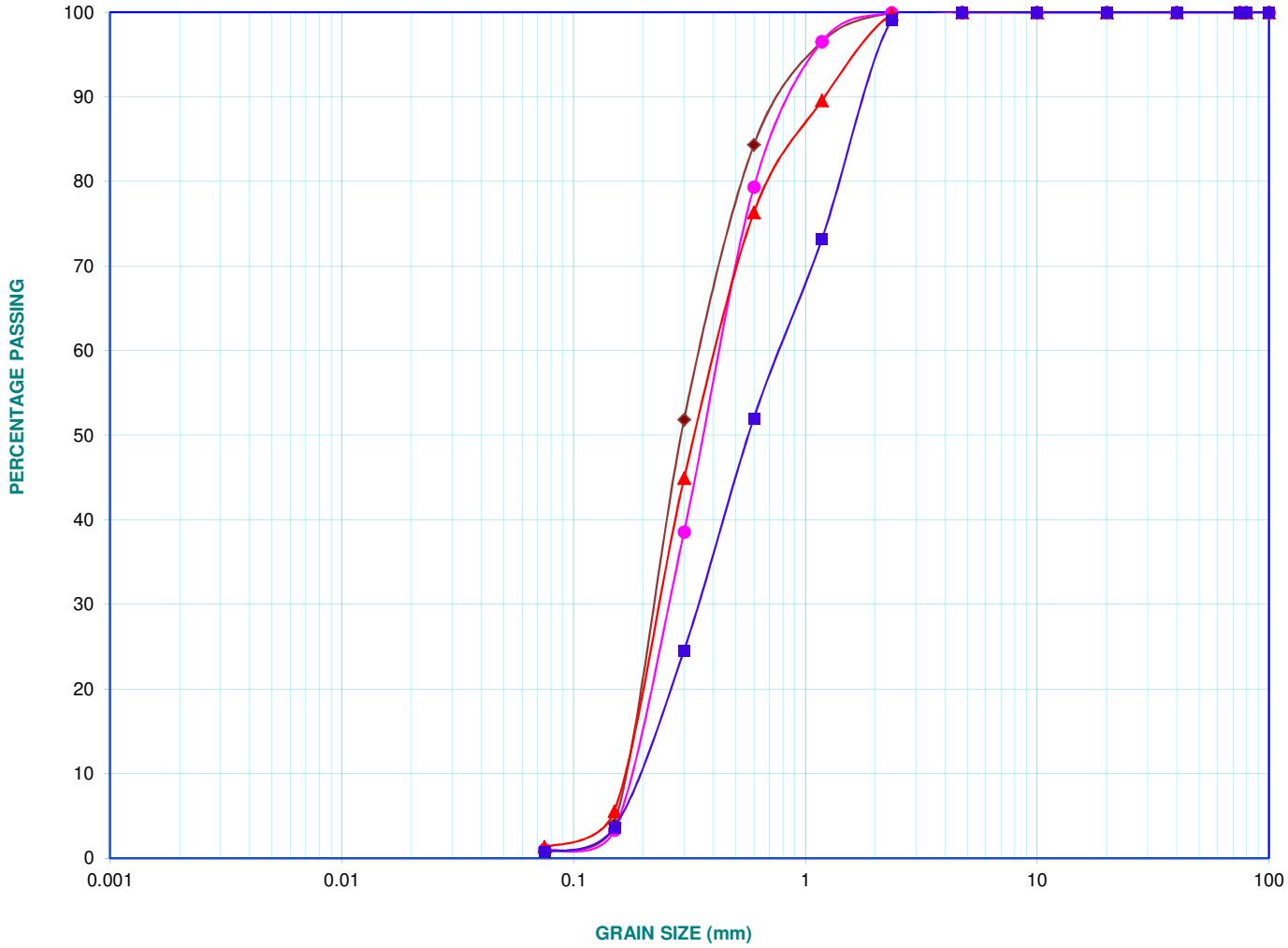
\# : Decayed Wood

**Failure Type**
A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha**
Project Code : **CM 19 01 03**
Borehole No. : **LBH-07-Opt.1**

# GRAIN SIZE ANALYSIS

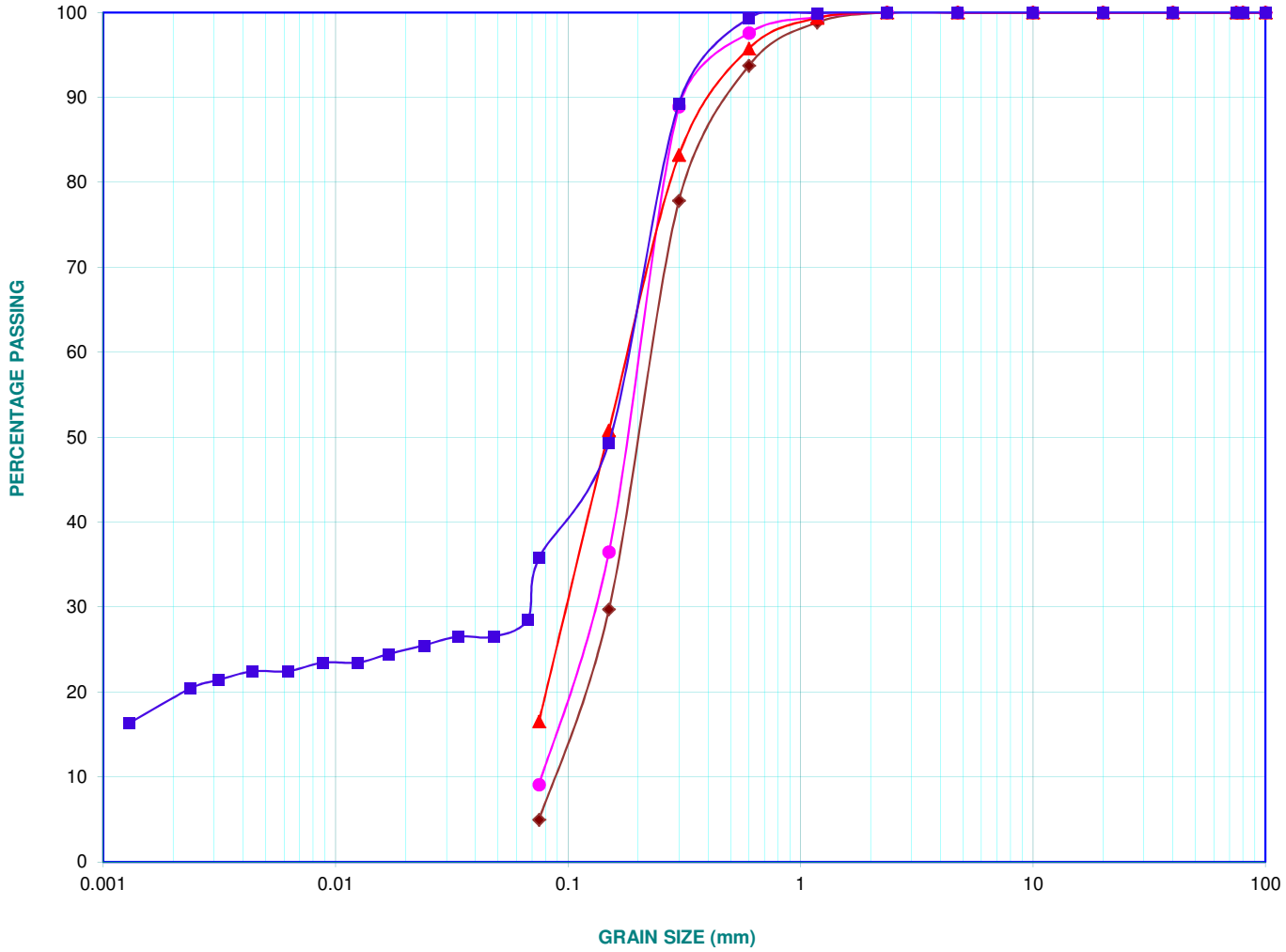
| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | | **Borehole No.** | **: LBH-07-Opt.1** | | | **Date :** | **31-May-19** | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND F | SAND M | SAND C | GRAVEL F / GRAVEL C |
| **Bore Hole .** | LBH-07-Opt.1 | LBH-07-Opt.1 | LBH-07-Opt.1 | LBH-07-Opt.1 | | | | | | | |
| **Depth (m)** | 1.50-1.95 | 3.00-3.45 | 7.50-7.95 | 9.00-9.45 | | | | | | | |
| **Sample Type** | SPT-1 | SPT-2 | SPT-5 | SPT-6 | | | | | | | |
| **Classification** | SP | SP | SP | SP | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | |
| **Sand %** | 99 | 99 | 99 | 99 | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | |
| **Fines % (Silt+Clay)** | 1 | 1 | 1 | 1 | | | | | | | |
| **D60 mm** | 0.350 | 0.410 | 0.400 | 0.780 | | | | | | | |
| **D30 mm** | 0.220 | 0.260 | 0.230 | 0.340 | | | | | | | |
| **D10 mm** | 0.180 | 0.190 | 0.180 | 0.100 | | | | | | | |
| **Cu** | 1.94 | 2.16 | 2.22 | 7.80 | | | | | | | |
| **Cc** | 0.77 | 0.87 | 0.73 | 1.48 | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

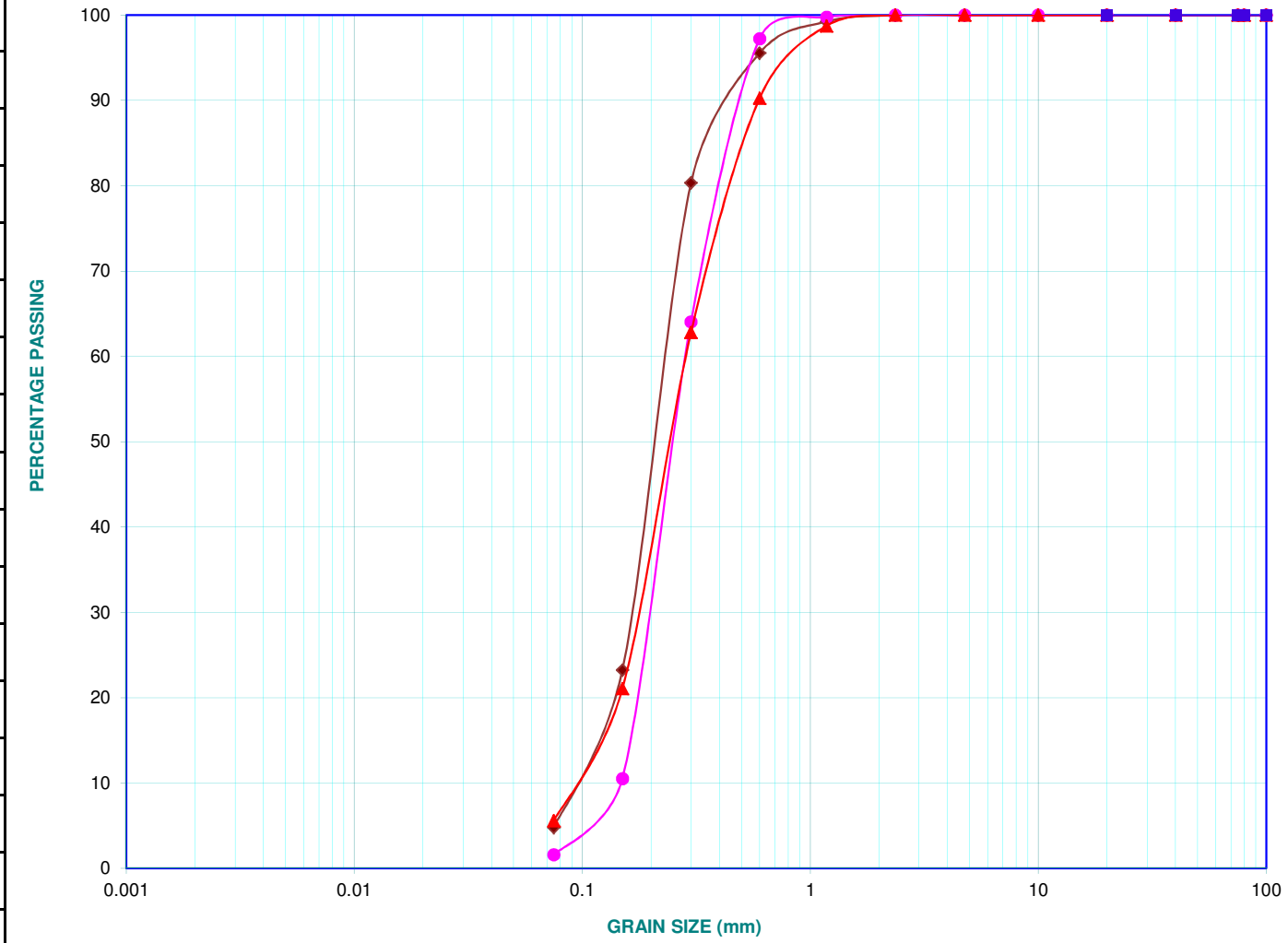
| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | : Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha | | | | | | | | | | |
| **Job No.** | : CM 19 01 03 | | | **Borehole No.** | : LBH-07-Opt.1 | | | **Date :** | 31-May-19 | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND F | SAND M | SAND C | GRAVEL F / GRAVEL C |
| **Bore Hole .** | LBH-07-Opt.1 | LBH-07-Opt.1 | LBH-07-Opt.1 | LBH-07-Opt.1 | | | | | | | |
| **Depth (m)** | 12.00-12.45 | 13.50-13.95 | 15.00-15.45 | 19.50-20.00 | | | | | | | |
| **Sample Type** | SPT-8 | SPT-9 | SPT-10 | UDS-1 | | | | | | | |
| **Classification** | SP-SM | SP-SM | | SC | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | |
| **Sand %** | 95 | 91 | 83 | 64 | | | | | | | |
| **Silt %** | <----> | <----> | <----> | 16 | | | | | | | |
| **Clay %** | <----> | <----> | <----> | 20 | | | | | | | |
| **Fines % (Silt+Clay)** | 5 | 9 | 17 | 36 | | | | | | | |
| **D60 mm** | 0.230 | 0.200 | | | | | | | | | |
| **D30 mm** | 0.150 | 0.140 | | | | | | | | | |
| **D10 mm** | 0.090 | 0.078 | | | | | | | | | |
| **Cu** | 2.56 | 2.56 | | | | | | | | | |
| **Cc** | 1.09 | 1.26 | | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | 27.5 | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | 15.4 | | | | | | | |
| **Plasticity Index** | --- | --- | --- | 12.1 | | | | | | | |




Checked By :

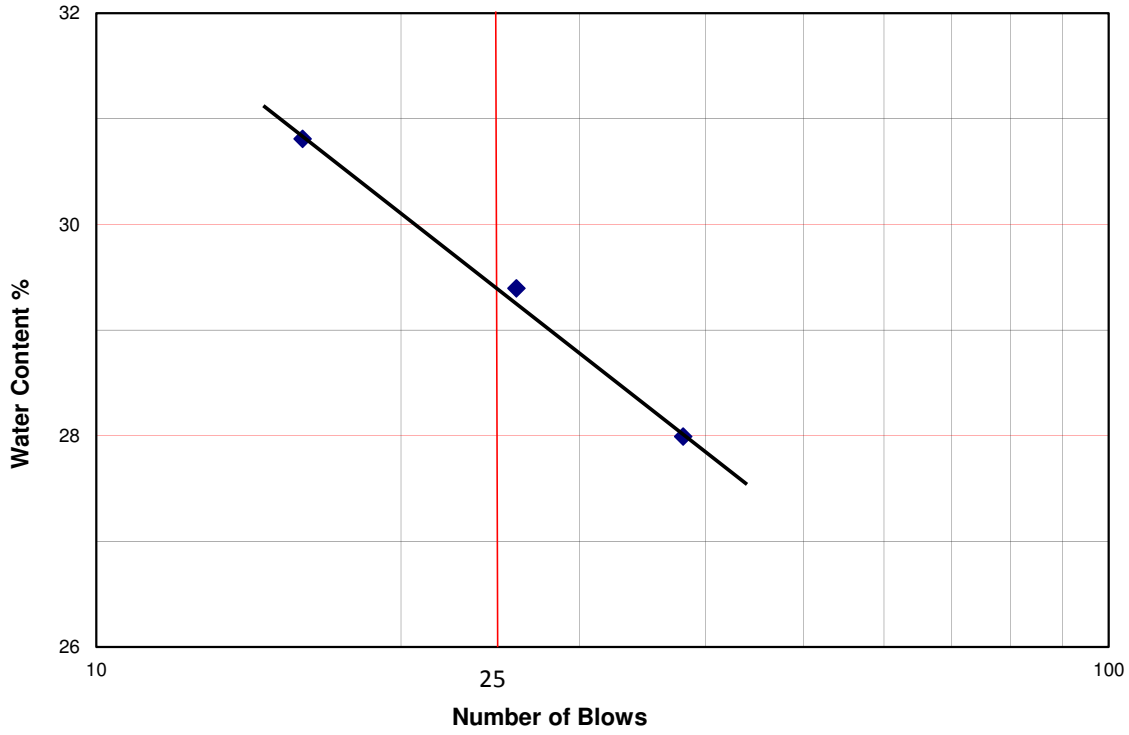
# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | : Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha | | | | | | | | | | |
| **Job No.** | : CM 19 01 03 | | | **Borehole No.** | : LBH-07-Opt.1 | | | **Date :** | 31-May-19 | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND F | SAND M | SAND C | GRAVEL F / GRAVEL C |
| **Bore Hole .** | LBH-07-Opt.1 | LBH-07-Opt.1 | LBH-07-Opt.1 | | | | | | | | |
| **Depth (m)** | 24.00-24.45 | 27.00-27.45 | 30.00-30.45 | | | | | | | | |
| **Sample Type** | SPT-15 | SPT-17 | SPT-19 | | | | | | | | |
| **Classification** | SP-SM | SP | SP-SM | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 95 | 98 | 94 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 5 | 2 | 6 | | | | | | | | |
| **D60 mm** | 0.230 | 0.290 | 0.290 | | | | | | | | |
| **D30 mm** | 0.180 | 0.200 | 0.190 | | | | | | | | |
| **D10 mm** | 0.098 | 0.150 | 0.098 | | | | | | | | |
| **Cu** | 2.35 | 1.93 | 2.96 | | | | | | | | |
| **Cc** | 1.44 | 0.92 | 1.27 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | | | | | | | | |




Checked By :

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 34.06 | 30.95 | 27.68 | | |
| Dry Weight + Can (g) | 29.36 | 26.10 | 23.41 | | |
| Can Weight (g) | 12.57 | 9.60 | 9.55 | | |
| Water Content, % | 28.0 | 29.4 | 30.8 | | |
| Number of Blows | 38 | 26 | 16 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 20.25 | 19.78 | 19.25 |
| Dry Weight + Can (g) | 18.71 | 18.32 | 18.36 |
| Can Weight (g) | 9.36 | 9.37 | 12.93 |
| Water Content, % | 16.5 | 16.3 | 16.4 |

| | |
|---|---|
| Liquid Limit % | 29.4 |
| Plastic Limit % | 16.4 |
| Plasticity Index % | 13.0 |

Preparation of Sample :
Dry State

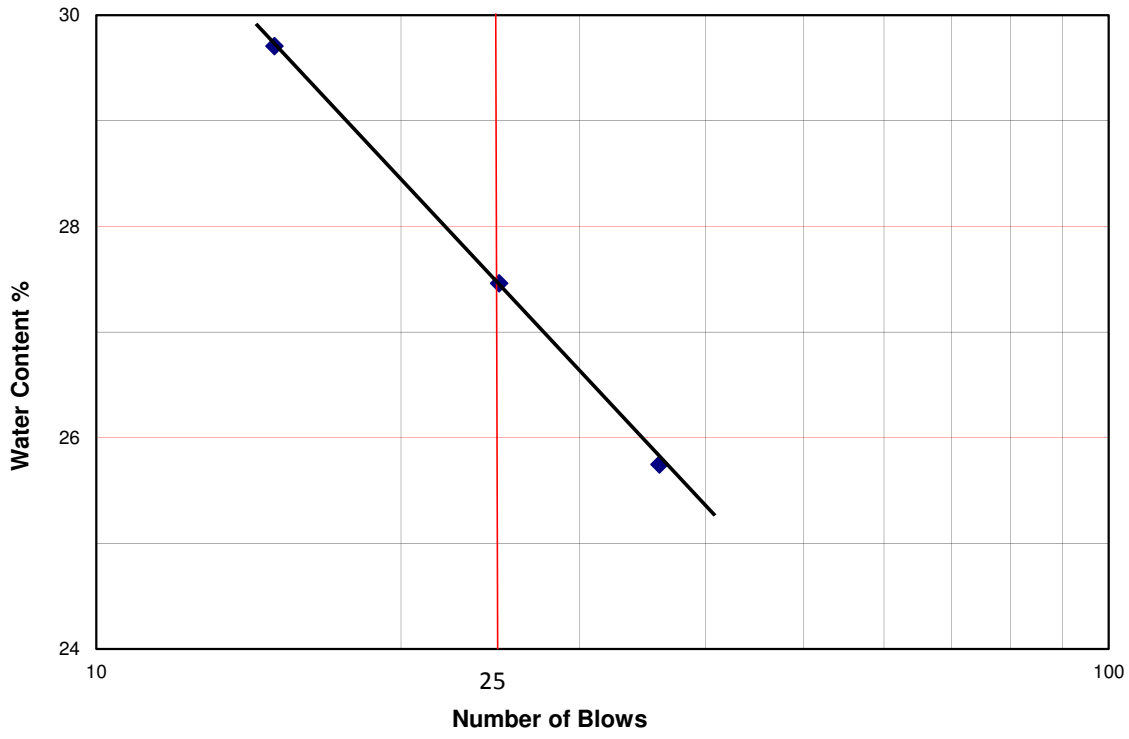
Sample Type: SPT-12

Borehole no.: LBH-07-Opt.1

Depth :18.00-18.45

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 35.45 | 34.22 | 31.79 | | |
| Dry Weight + Can (g) | 30.89 | 29.87 | 27.45 | | |
| Can Weight (g) | 13.18 | 14.03 | 12.84 | | |
| Water Content, % | 25.7 | 27.5 | 29.7 | | |
| Number of Blows | 36 | 25 | 15 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 22.65 | 19.88 | 15.48 |
| Dry Weight + Can (g) | 21.31 | 18.28 | 14.49 |
| Can Weight (g) | 12.60 | 7.84 | 8.07 |
| Water Content, % | 15.4 | 15.3 | 15.4 |

Liquid Limit % 27.5

Plastic Limit % 15.4

Plasticity Index % 12.1

Preparation of Sample :
Dry State

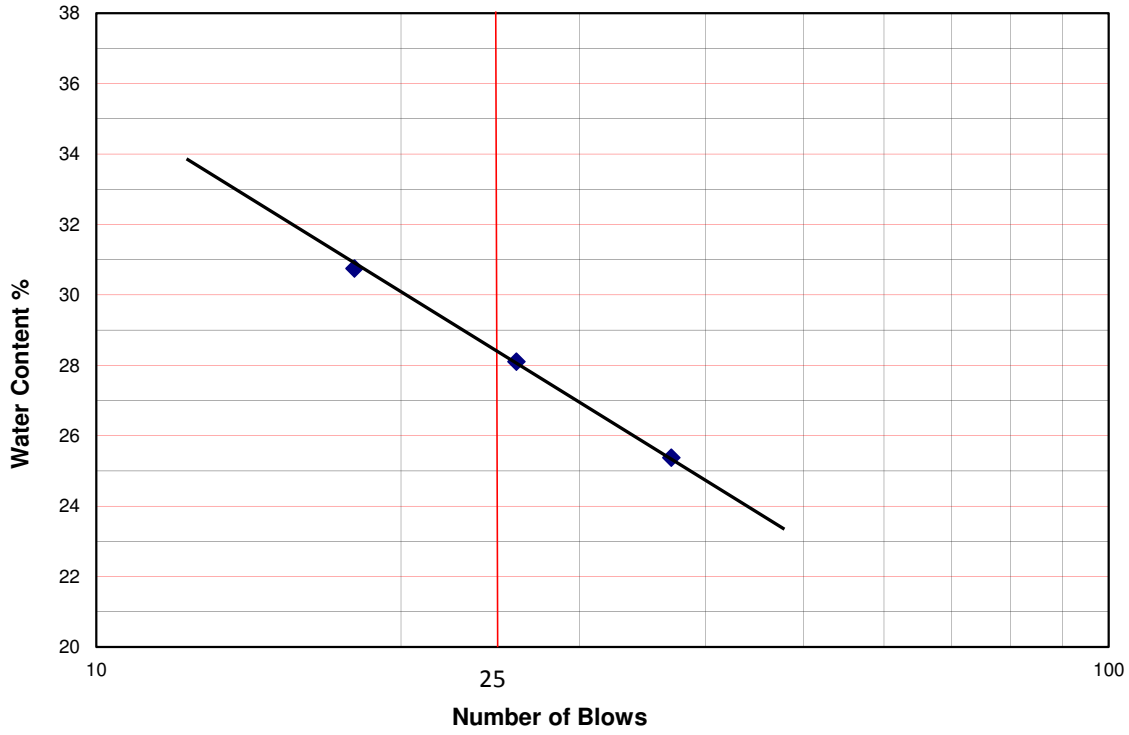
Sample Type: UDS-01

Borehole no.: LBH-07-Opt.1

Depth :19.50-20.00

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 27.34 | 27.11 | 29.49 | | |
| Dry Weight + Can (g) | 23.33 | 23.10 | 25.69 | | |
| Can Weight (g) | 7.53 | 8.83 | 13.33 | | |
| Water Content, % | 25.4 | 28.1 | 30.7 | | |
| Number of Blows | 37 | 26 | 18 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 17.88 | 18.59 | 19.02 |
| Dry Weight + Can (g) | 16.60 | 17.80 | 18.06 |
| Can Weight (g) | 8.50 | 12.79 | 12.05 |
| Water Content, % | 15.8 | 15.8 | 16.0 |

| | |
|---|---|
| Liquid Limit % | 28.4 |
| Plastic Limit % | 15.8 |
| Plasticity Index % | 12.6 |

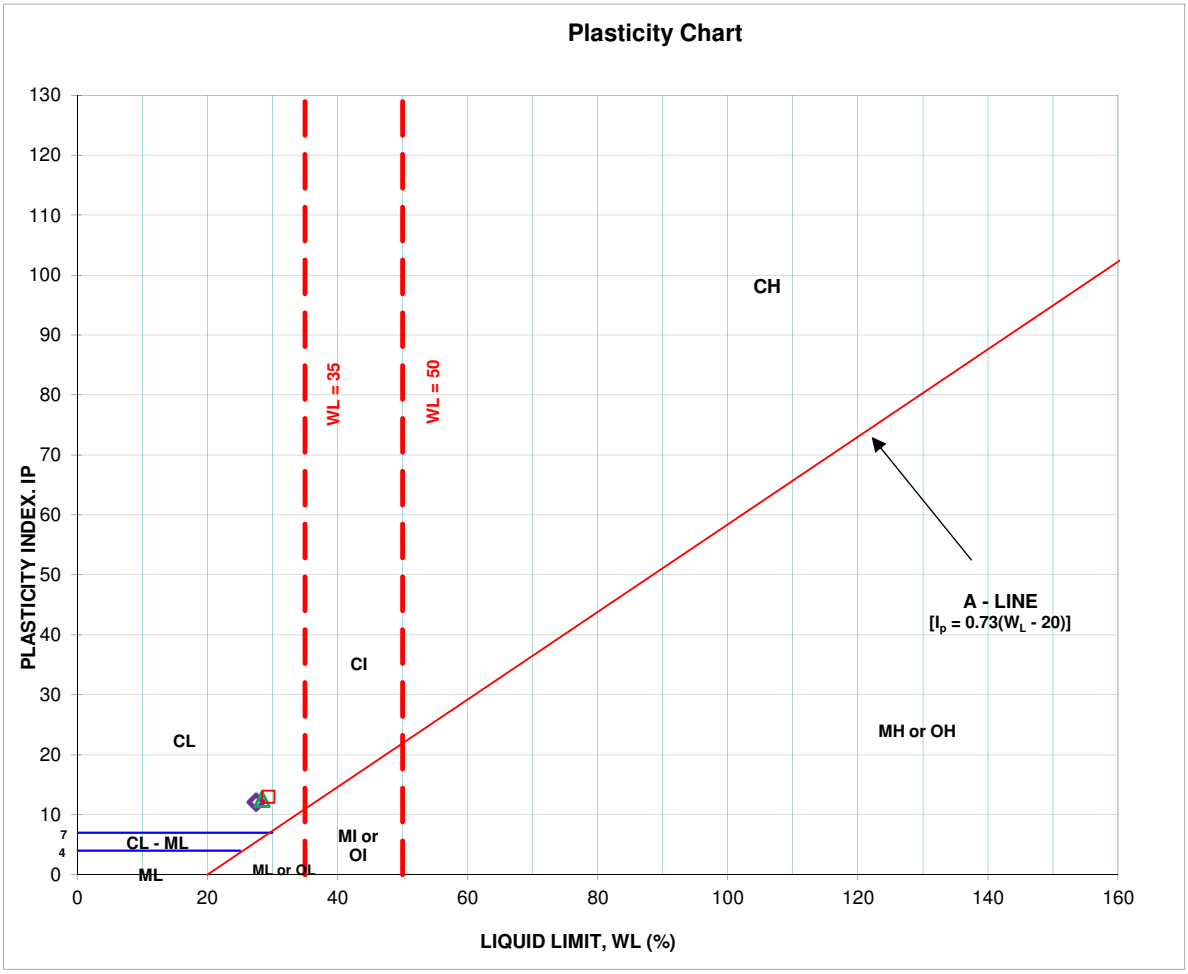
Preparation of Sample :
Dry State

Sample Type: SPT-13

Borehole no.: LBH-07-Opt.1

Depth :21.00-21.45

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.




| | Sample Type | Depth (m) | $W_L$ | $W_P$ | $I_P$ | Remarks |
|---|---|---|---|---|---|---|
| □ | SPT-12 | 18.00-18.45 | 29.4 | 16.4 | 13.0 | CL: Inorganic clays of low to medium plasticity. |
| ◇ | UDS-01 | 19.50-20.00 | 27.5 | 15.4 | 12.1 | CL: Inorganic clays of low to medium plasticity. |
| △ | SPT-13 | 21.00-21.45 | 28.4 | 15.8 | 12.6 | CL: Inorganic clays of low to medium plasticity. |
| ● | | | | | | |

| | | | |
|---|---|---|---|
| ML | Inorganic silts, very fine sands, rock flour, silty or clayey fine sands | MH | Inorganic silts, or diatomaceous fine sands or silts, elastic silts |
| CL | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays | CH | Inorganic clays of high plasticity, fat clays |
| OL | Organic silts and organic silty clays of low plasticity | OH | Organic silts and organic clays of medium t high plasticity |
| CI | Clays with Intermediate plasticity | MI | Silt with intermediate plasticity |

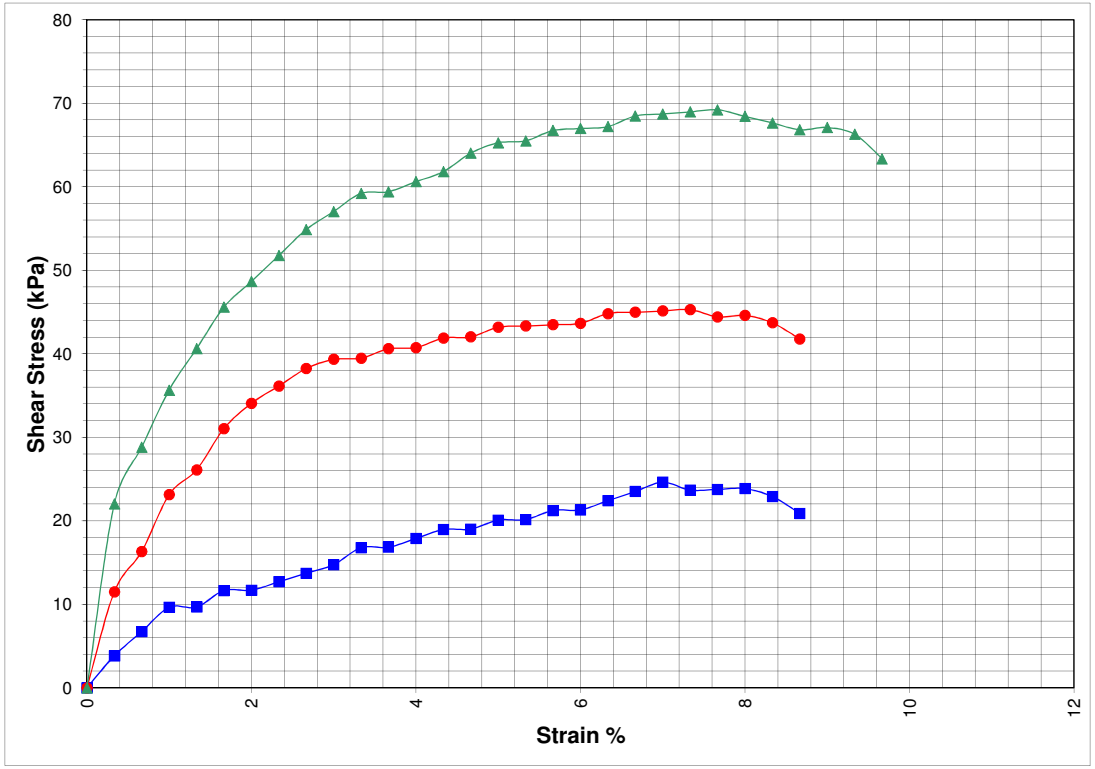
## PLASTICITY CHART (IS : 1498 - 1987)

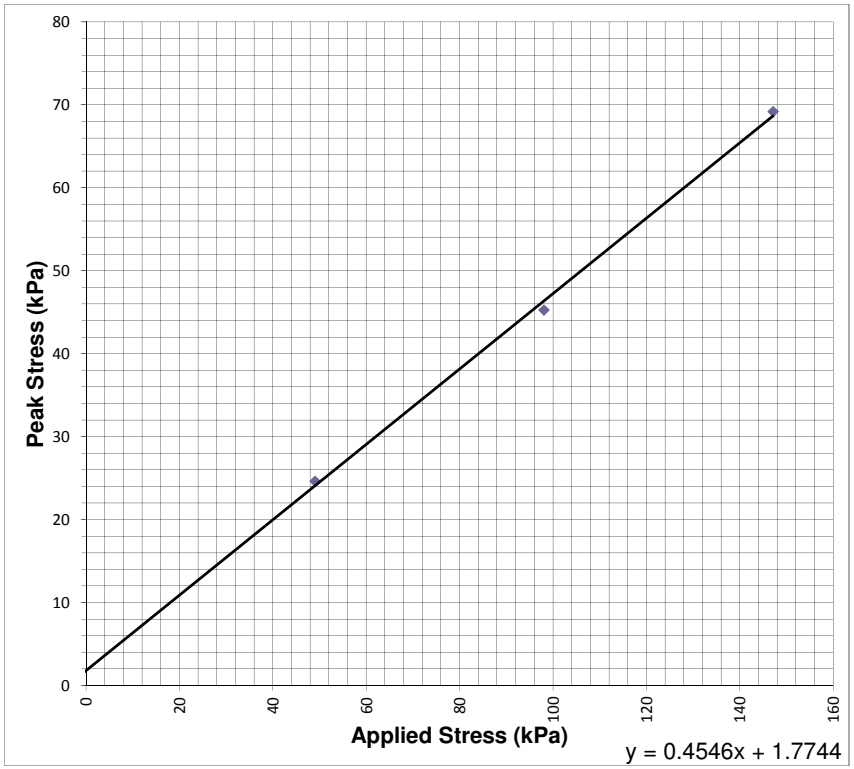
BOREHOLE NAME : LBH-07-Opt.1

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 25 |
| | Stage 2 | 98 | 45 |
| | Stage 3 | 147 | 69 |

| | | |
|---|---|---|
| Angle of Friction | **24.45** | ° |
| Apparent Cohesion | **1.77** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

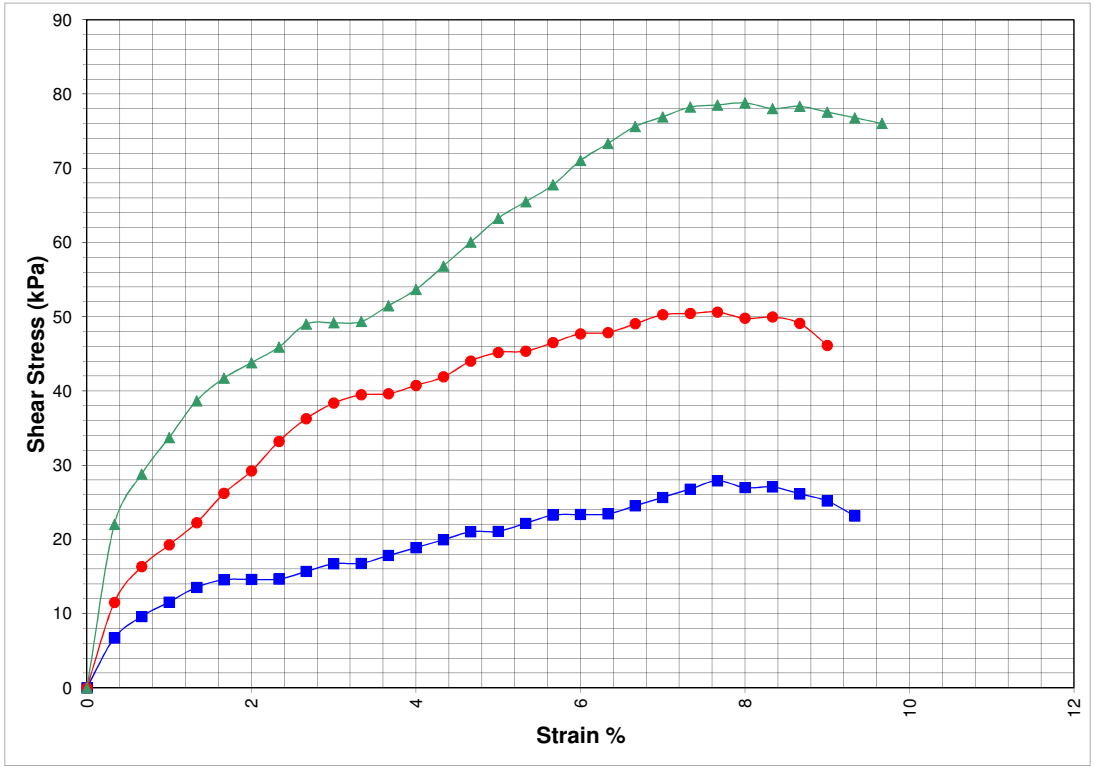
**Borehole: LBH-07-Opt.1**

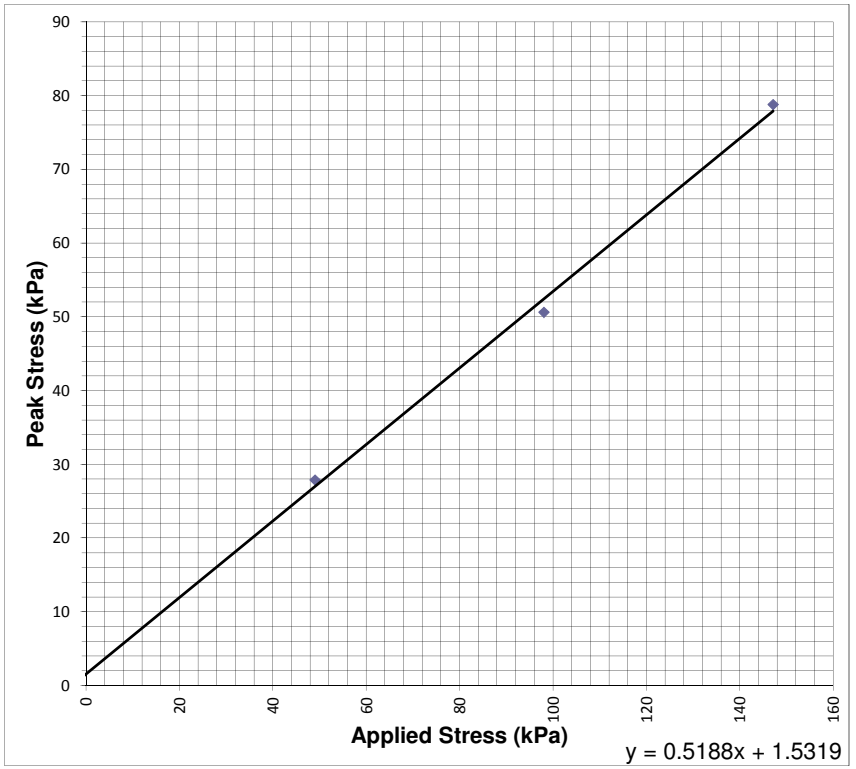
**Sample Type: DS-01**

**Depth: 0.00-0.50 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 51 |
| | Stage 3 | 147 | 79 |

| | | |
|---|---|---|
| Angle of Friction | **27.42** | ° |
| Apparent Cohesion | **1.53** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

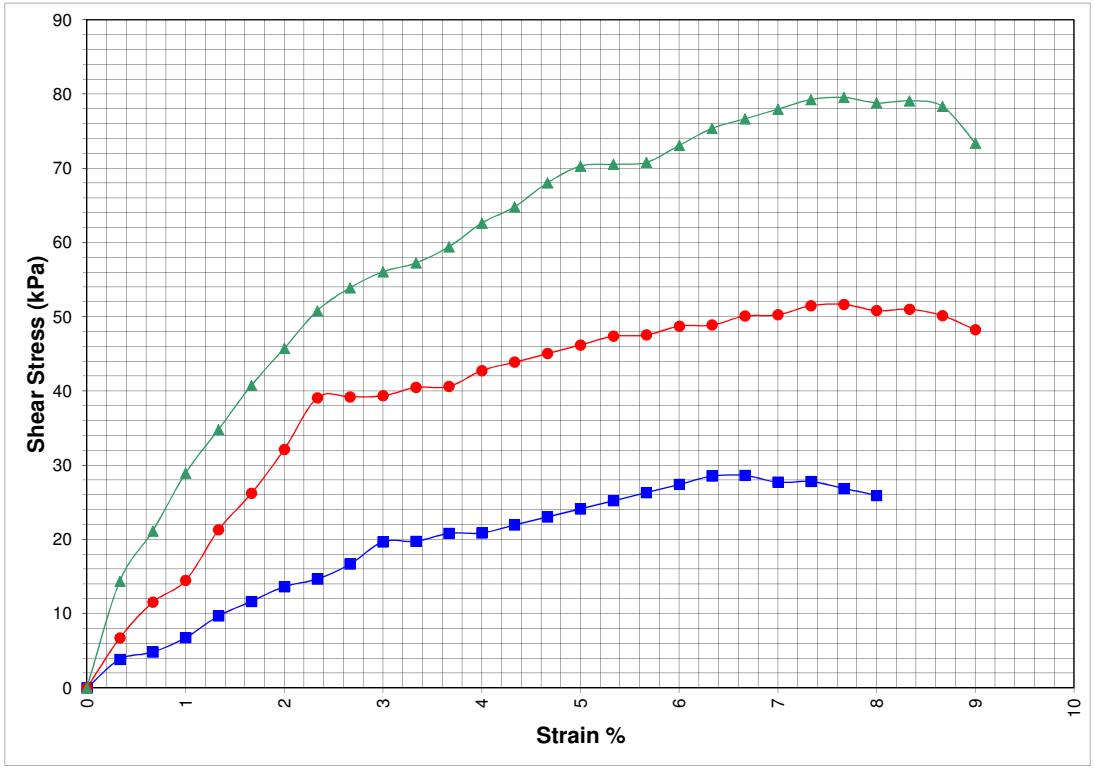
**Borehole: LBH-07-Opt.1**

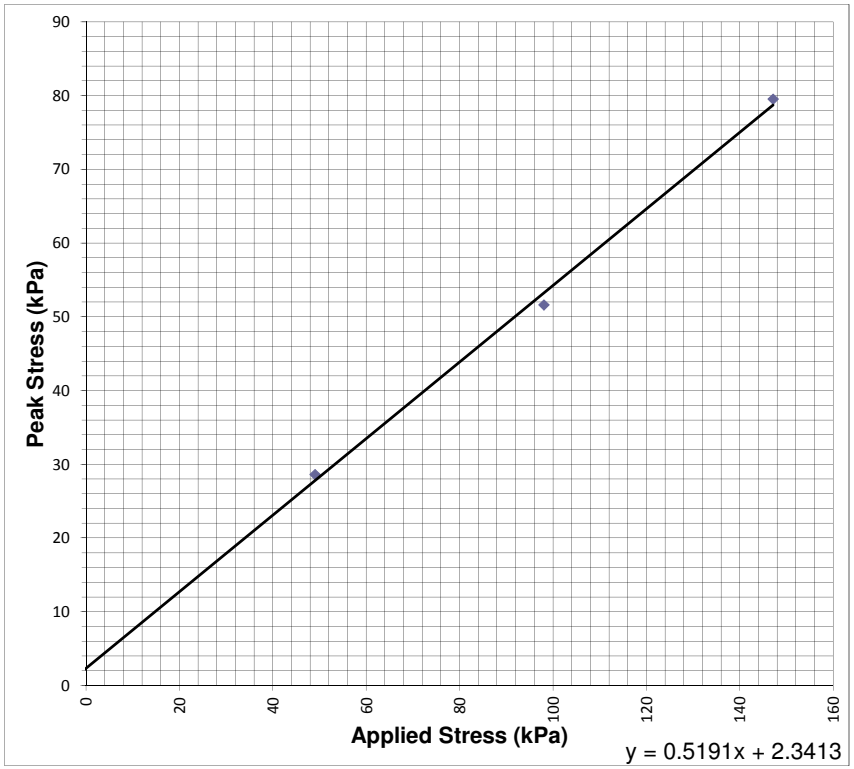
**Sample Type: SPT-03**

**Depth: 4.50-4.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 29 |
| | Stage 2 | 98 | 52 |
| | Stage 3 | 147 | 80 |

| | | |
|---|---|---|
| Angle of Friction | **27.43** | ° |
| Apparent Cohesion | **2.34** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

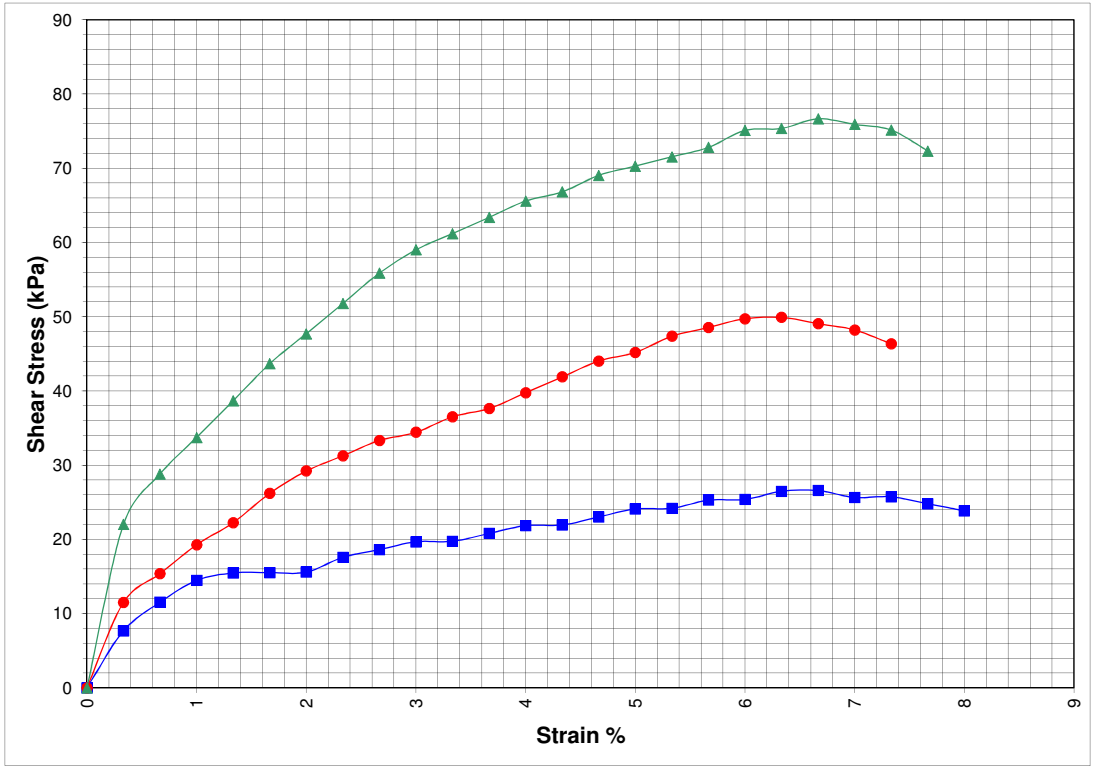
**Borehole: LBH-07-Opt.1**

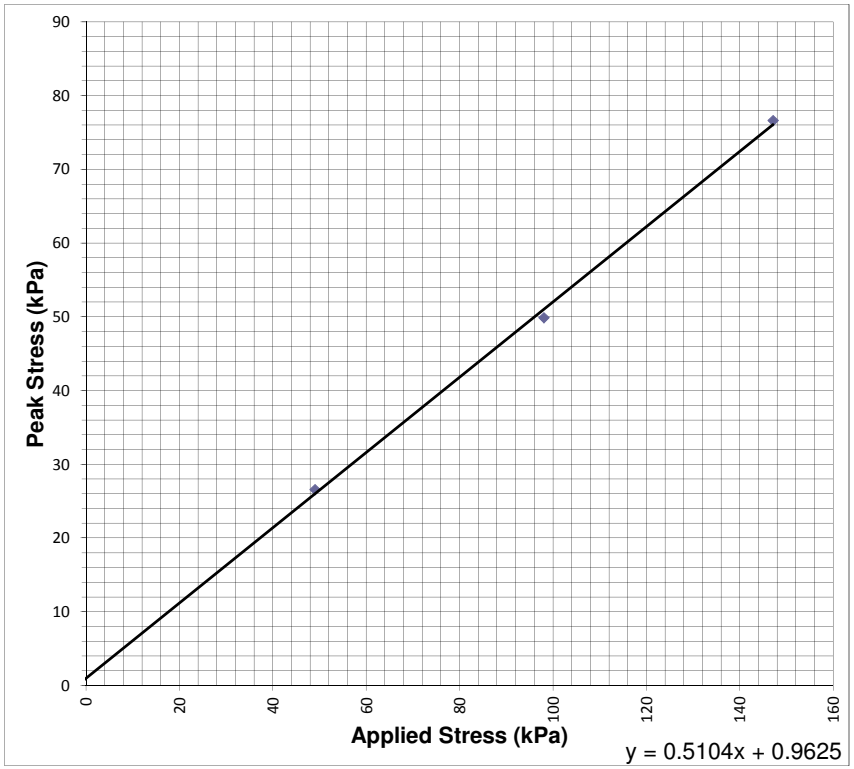
**Sample Type: SPT-04**

**Depth: 6.00-6.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 50 |
| | Stage 3 | 147 | 77 |

| | | |
|---|---|---|
| Angle of Friction | **27.04** | ° |
| Apparent Cohesion | **0.96** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

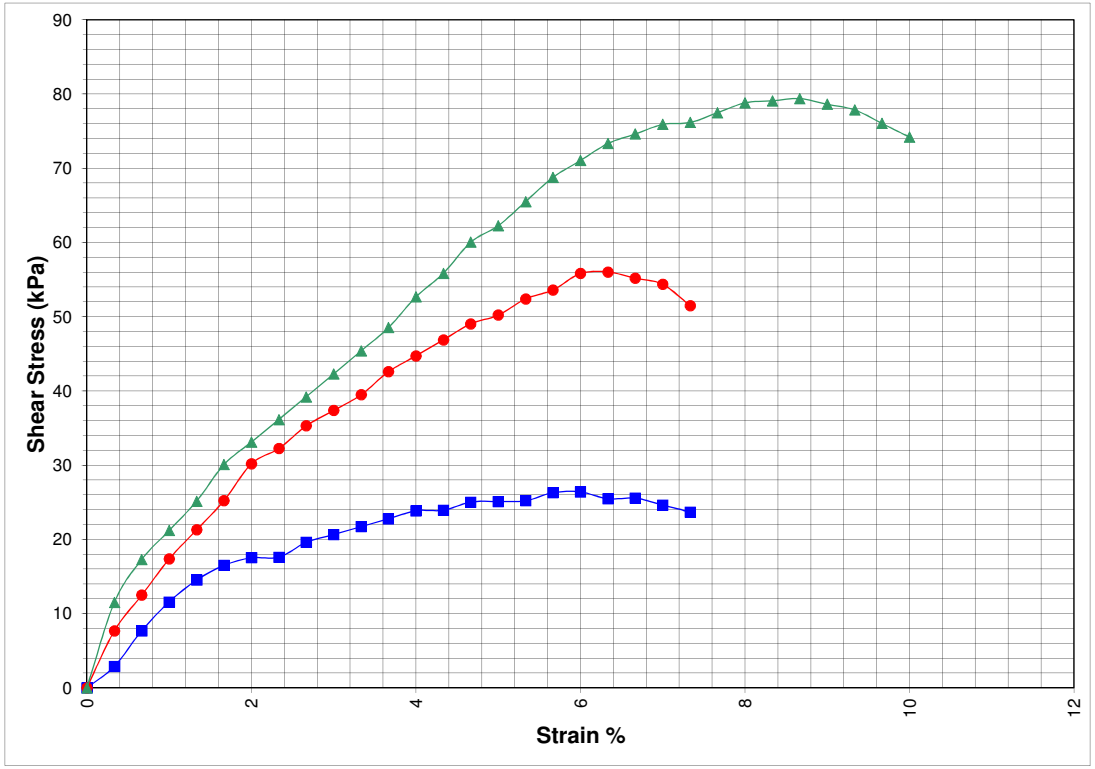
**Borehole: LBH-07-Opt.1**

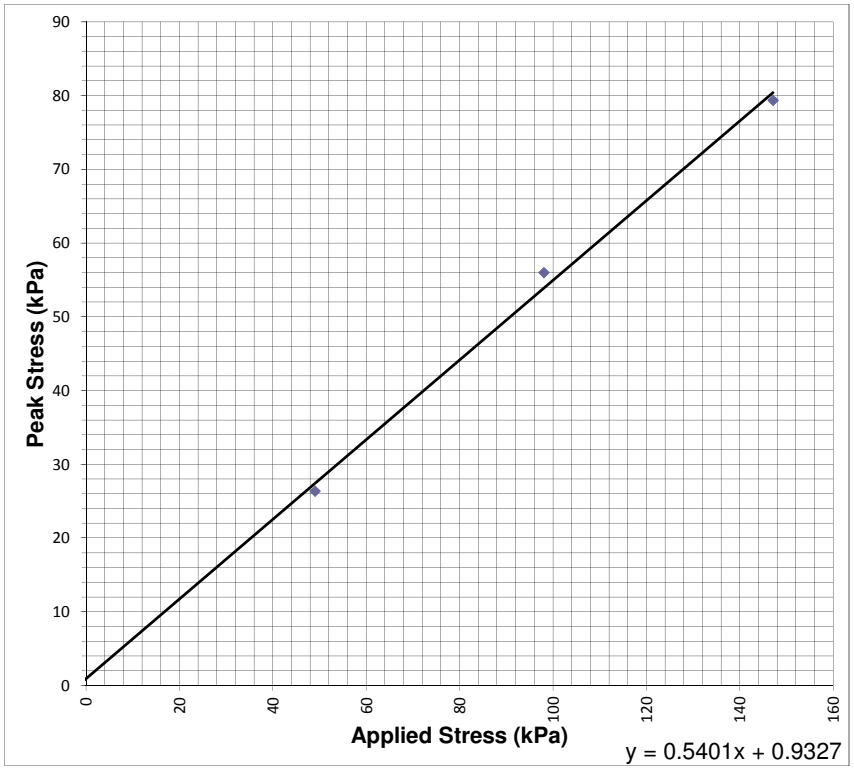
**Sample Type: SPT-07**

**Depth: 10.50-10.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 56 |
| | Stage 3 | 147 | 79 |

| | | |
|---|---|---|
| Angle of Friction | **28.37** | ° |
| Apparent Cohesion | **0.93** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

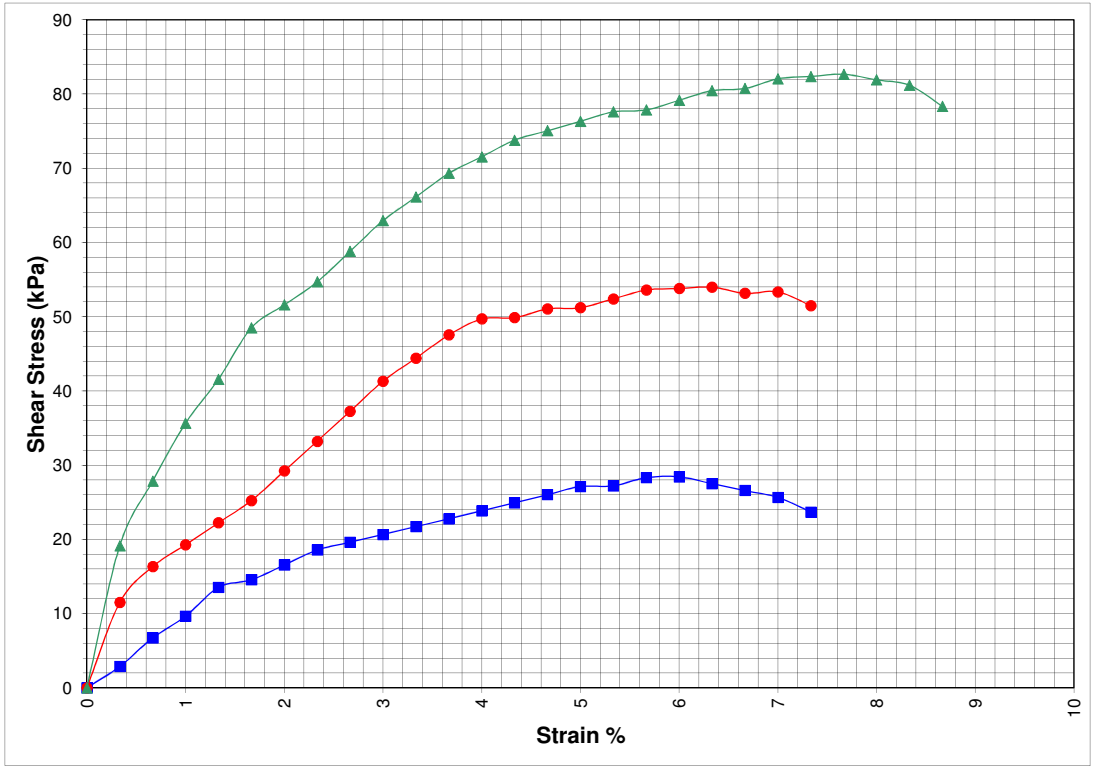
**Borehole: LBH-07-Opt.1**

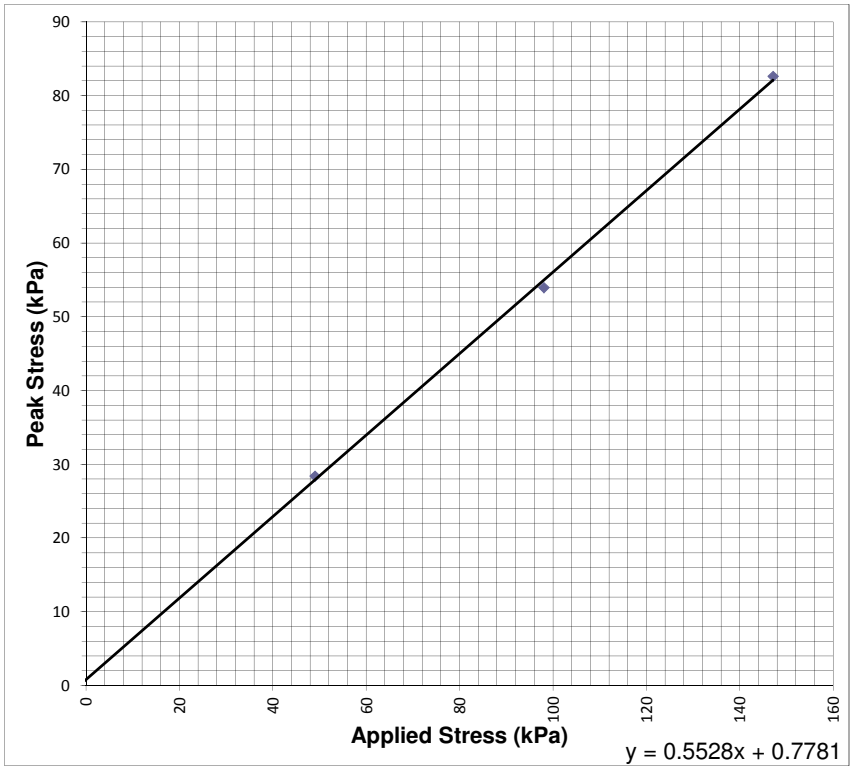
**Sample Type: SPT-08**

**Depth: 12.00-12.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 54 |
| | Stage 3 | 147 | 83 |

| | | |
|---|---|---|
| Angle of Friction | **28.93** | ° |
| Apparent Cohesion | **0.78** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

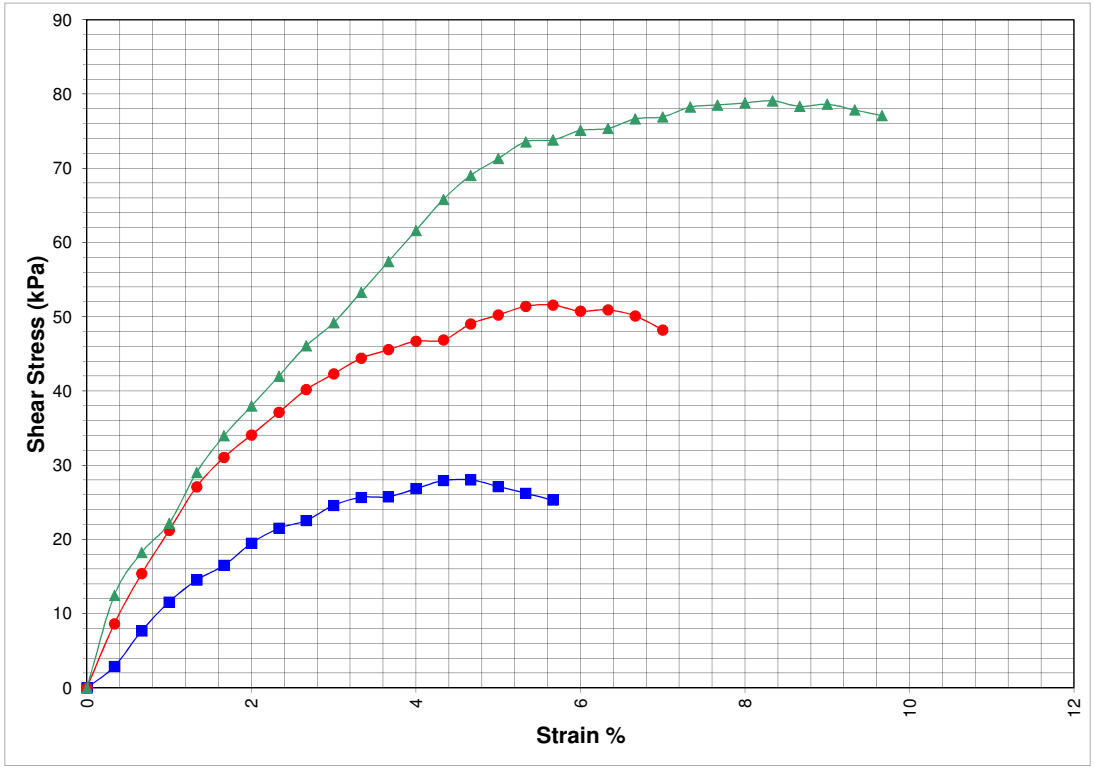
**Borehole: LBH-07-Opt.1**

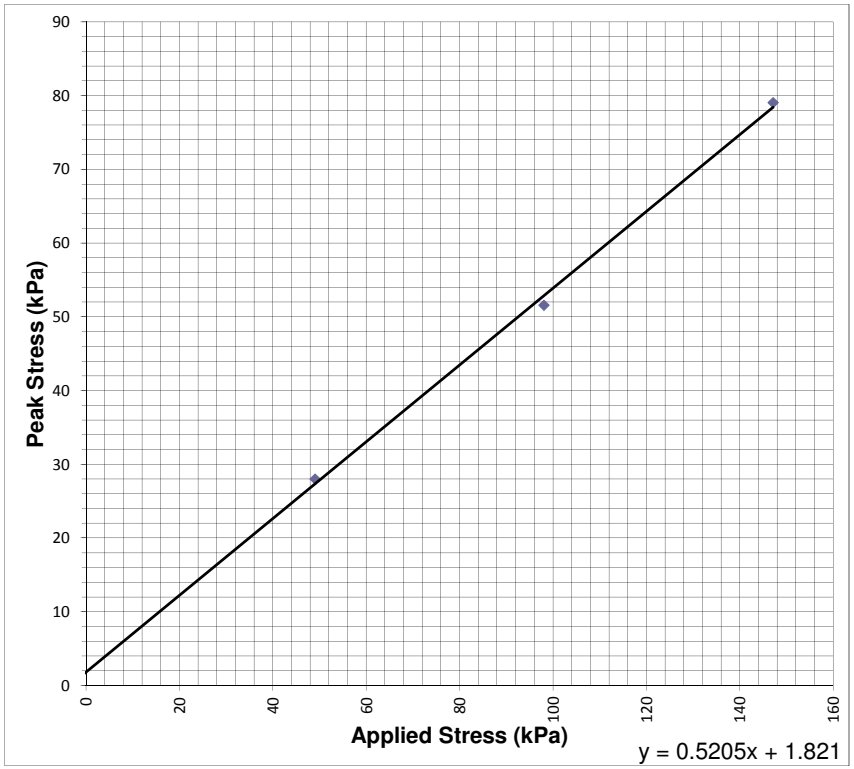
**Sample Type: SPT-09**

**Depth: 13.50-13.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 52 |
| | Stage 3 | 147 | 79 |

| | | |
|---|---|---|
| Angle of Friction | **27.50** | ° |
| Apparent Cohesion | **1.82** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

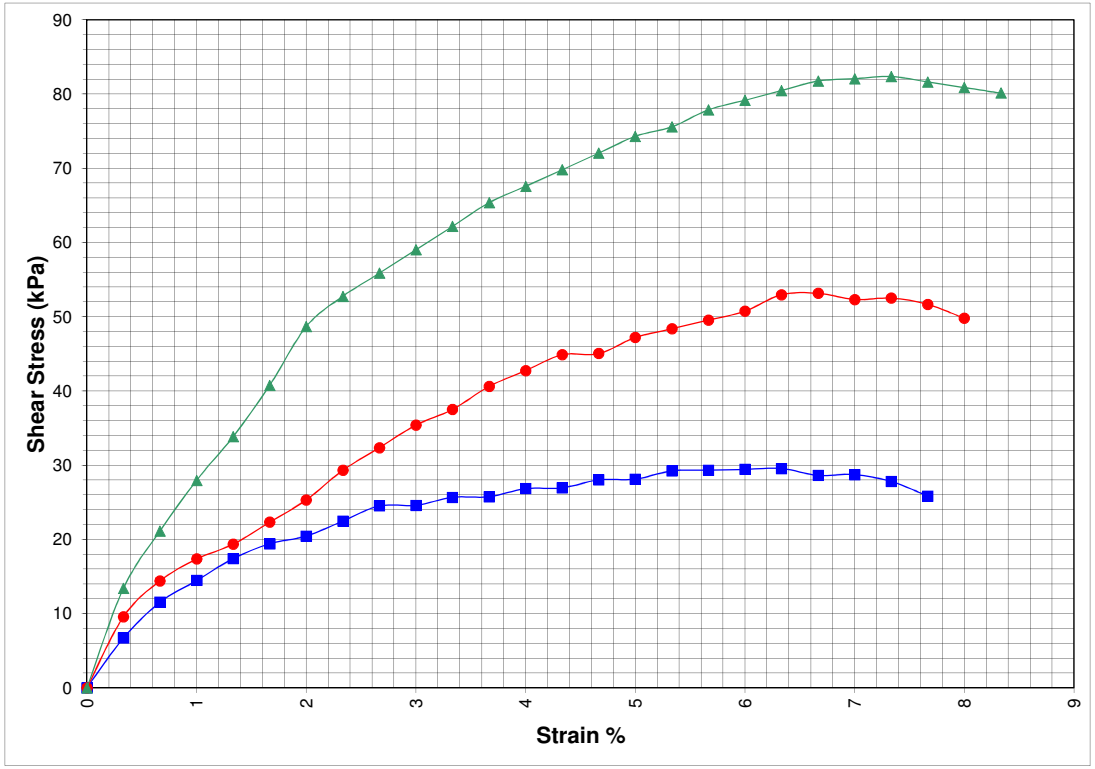
**Borehole: LBH-07-Opt.1**

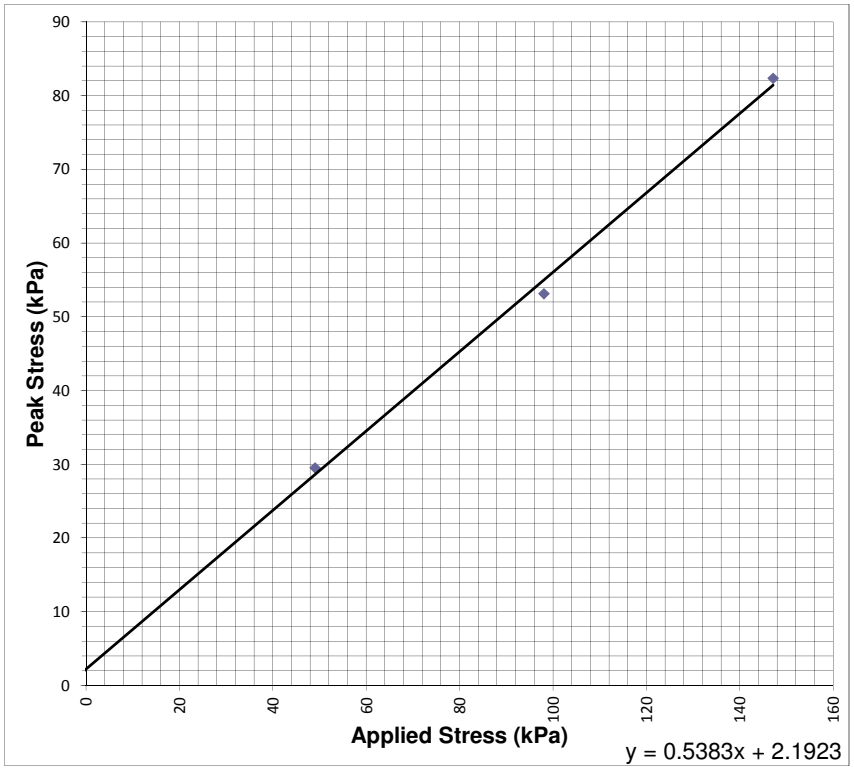
**Sample Type: SPT-11**

**Depth: 16.50-17.00 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 30 |
| | Stage 2 | 98 | 53 |
| | Stage 3 | 147 | 82 |

| | | |
|---|---|---|
| Angle of Friction | **28.29** | ° |
| Apparent Cohesion | **2.19** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

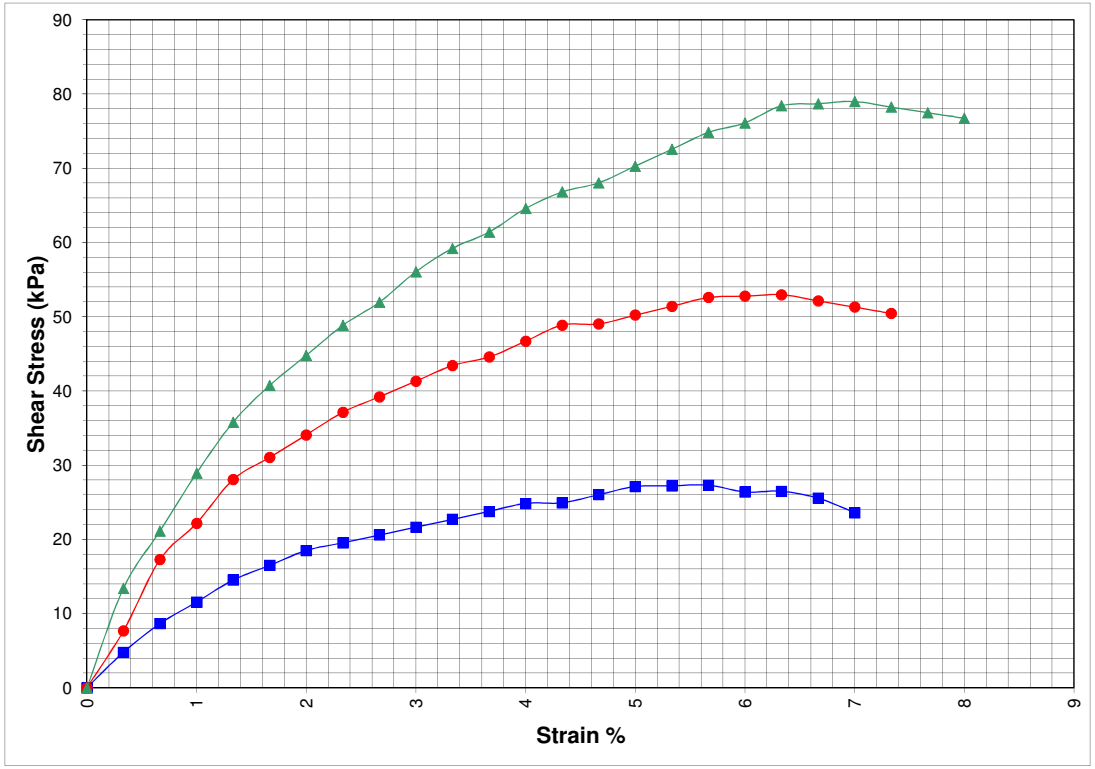
**Borehole: LBH-07-Opt.1**

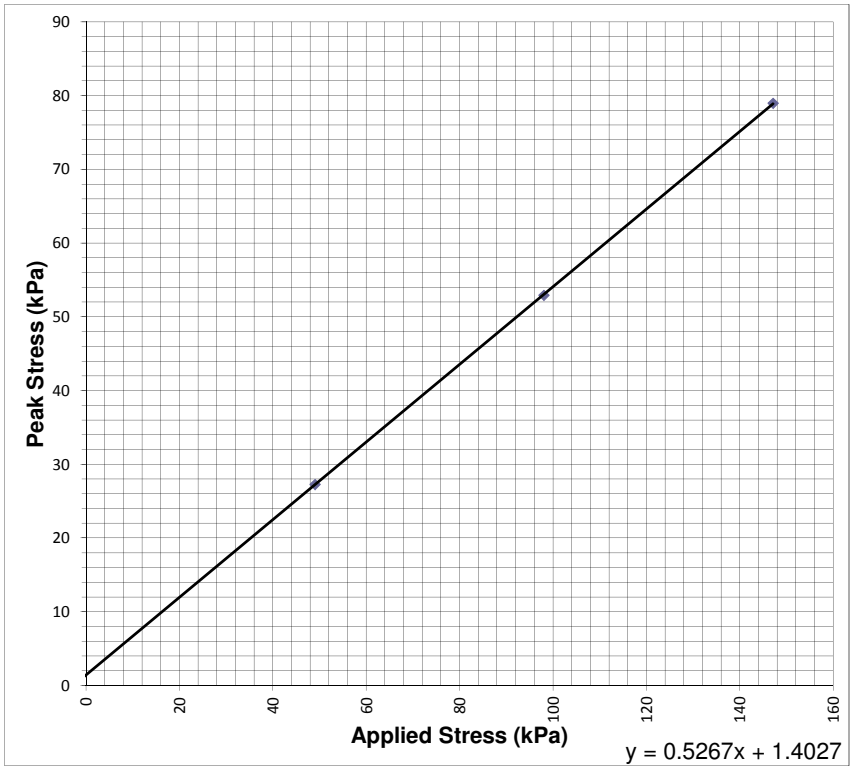
**Sample Type: SPT-14**

**Depth: 22.50-22.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 53 |
| | Stage 3 | 147 | 79 |

| | | |
|---|---|---|
| Angle of Friction | **27.78** | ° |
| Apparent Cohesion | **1.40** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

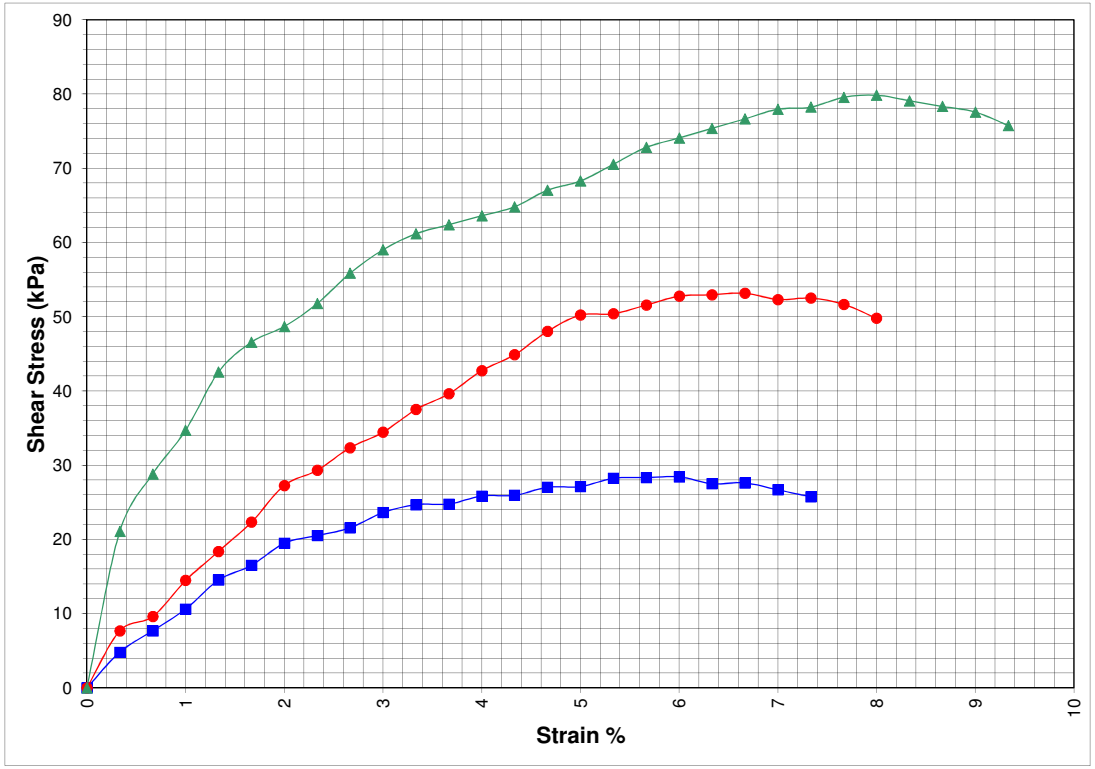
**Borehole: LBH-07-Opt.1**

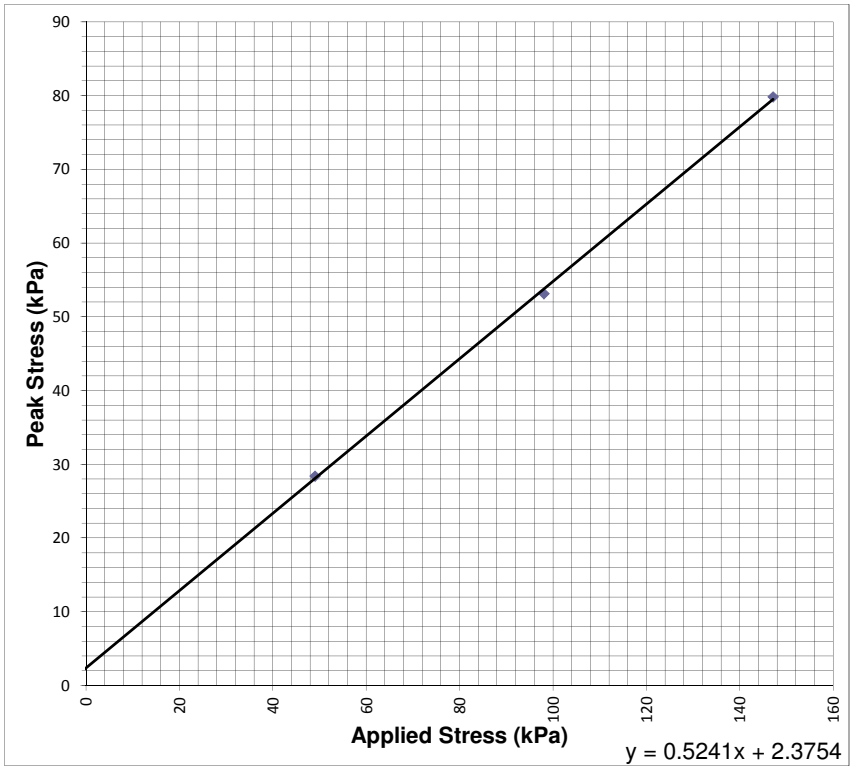
**Sample Type: SPT-16**

**Depth: 25.50-25.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 53 |
| | Stage 3 | 147 | 80 |

| | | |
|---|---|---|
| Angle of Friction | **27.66** | ° |
| Apparent Cohesion | **2.38** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

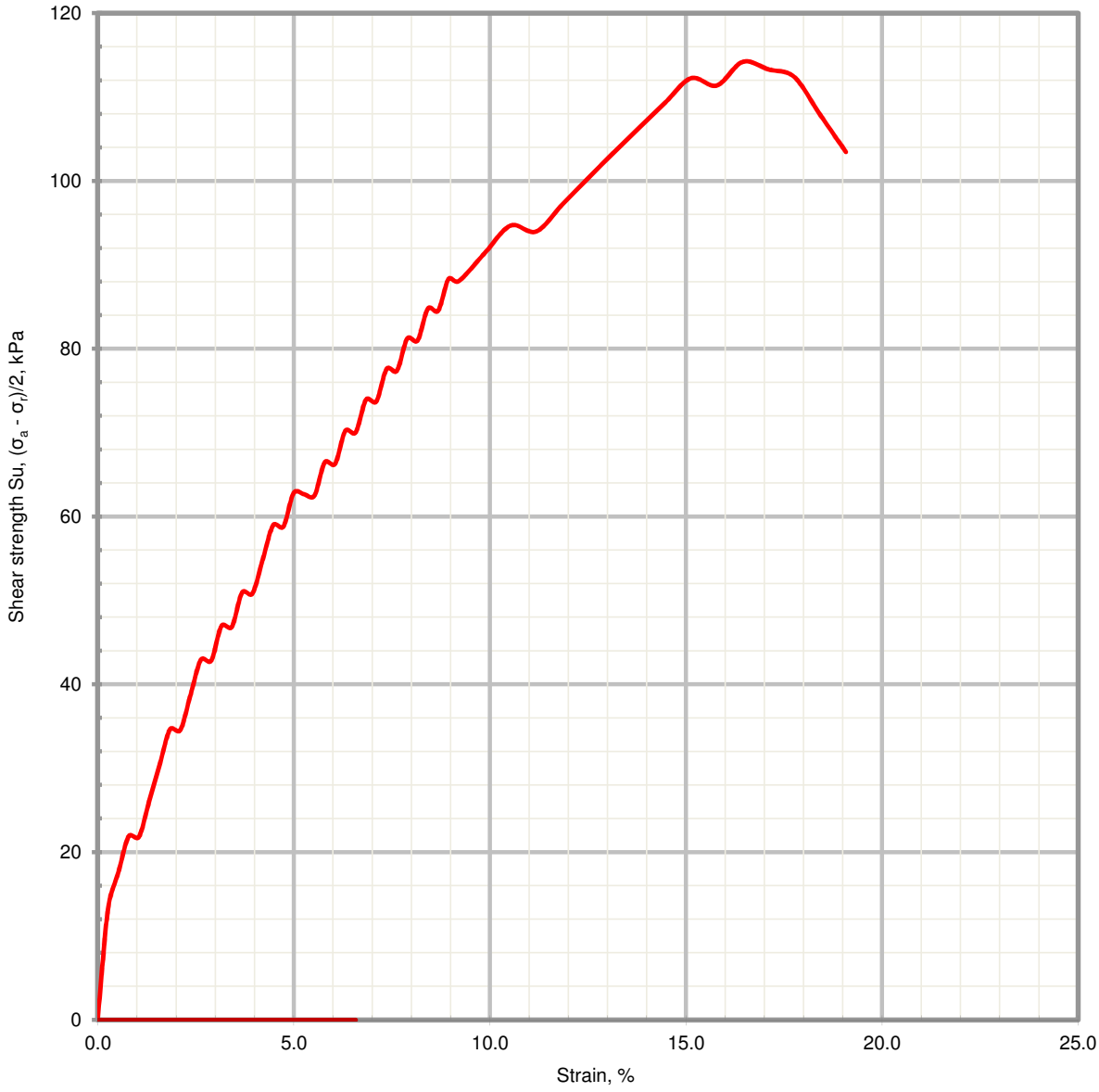
**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: LBH-07-Opt.1**

**Sample Type: SPT-18**

**Depth: 28.50-28.95 m**

## Stress - Strain Curves
## Unconsolidated Undrained Triaxial Compression Test




| Failure Type | |
|---|---|
| A | Bulge |
| B | Inclined Shear |
| C | Multiple Shear |
| D | Vertical Shear |

| Symbol | Sample No | Depth m | $\phi$ mm | Ht mm | W % | $\gamma'$ kN/m$^3$ | $\sigma_r$ kN/m$^2$ | $S_u$ kN/m$^2$ | $\varepsilon_f$ % | $\varepsilon_{50}$ % | Type of Failure |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | UDS-1 | 19.50-20.00 | 38 | 76 | 21.7 | 2.11 | 400.00 | 114.19 | 16.45 | 4.35 | A |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

**Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-1 | 0.00-0.50 | SP | | | | 0.04 | 13.26 | 3.20 | 13.25 | 2.62 | 0 | 99 | <--> | <--> | 1 | | | | | | | | | | | | | | | | | | |
| SPT-2 | 1.50-1.95 | | | | | 11.8 | 13.28 | 3.22 | 11.89 | 2.64 | | | | | | DST | | | 2.05 | 26.3 | | | | | | | | | | | | |
| SPT-3 | 3.00-3.45 | SP | | | | 19.5 | 15.17 | 5.11 | 12.70 | 2.61 | 0 | 99 | <--> | <--> | 1 | | | | | | | | | | | | | | | | | | |
| SPT-4 | 4.50-4.95 | | | | | 10.0 | 13.76 | 3.70 | 12.52 | 2.67 | | | | | | DST | | | 1.19 | 28.4 | | | | | | | | | | | | |
| SPT-5 | 6.00-6.45 | | | | | 12.4 | 13.40 | 3.34 | 11.92 | 2.65 | | | | | | DST | | | 1.97 | 27.5 | | | | | | | | | | | | |
| SPT-6 | 7.50-7.95 | SP | | | | 12.2 | 13.54 | 3.48 | 12.07 | 2.61 | 0 | 98 | <--> | <--> | 2 | | | | | | | | | | | | | | | | | | |
| SPT-7 | 9.00-9.45 | SP | | | | 10.1 | 13.49 | 3.43 | 12.25 | 2.62 | 0 | 98 | <--> | <--> | 2 | | | | | | | | | | | | | | | | | | |
| SPT-8 | 10.50-10.95 | | | | | 14.6 | 16.06 | 6.00 | 14.01 | 2.64 | | | | | | DST | | | 1.34 | 27.9 | | | | | | | | | | | | |
| SPT-9 | 12.00-12.45 | SP | | | | 18.3 | 15.34 | 5.28 | 12.97 | 2.61 | 0 | 98 | <--> | <--> | 2 | | | | | | | | | | | | | | | | | | |
| SPT-10 | 13.50-13.95 | SP | | | | 6.5 | 15.59 | 5.53 | 14.63 | 2.65 | 0 | 99 | <--> | <--> | 1 | | | | | | | | | | | | | | | | 8.40 | 0.30 | 1.00 | 2100 | 3540 |
| SPT-11 | 15.00-15.45 | | | | | 21.2 | 16.12 | 6.06 | 13.30 | 2.62 | | | | | | DST | | | 1.73 | 28.3 | | | | | | | | | | | | |
| SPT-12 | 16.50-16.95 | SP-SM | | | | 20.8 | 16.00 | 5.94 | 13.25 | 2.60 | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | | | | |
| SPT-13 | 18.00-18.45 | SP-SM | | | | 21.0 | 16.15 | 6.09 | 13.35 | 2.59 | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | | | | |
| SPT-14 | 19.50-19.95 | SP-SM | | | | 18.5 | 17.08 | 7.02 | 14.42 | 2.63 | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | | | | |
| SPT-15 | 21.00-21.45 | | | | | 18.3 | 16.14 | 6.08 | 13.64 | 2.62 | | | | | | DST | | | 2.15 | 27.3 | | | | | | | | | | | | |
| SPT-16 | 22.50-22.95 | SP-SM | | | | 17.5 | 15.98 | 5.92 | 13.60 | 2.62 | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | | | | |
| SPT-17 | 24.00-24.45 | SP-SM | | | | 15.0 | 16.03 | 5.97 | 13.94 | 2.61 | 0 | 92 | <--> | <--> | 8 | | | | | | | | | | | | | | | | | | |
| SPT-18 | 25.50-25.95 | | | | | 13.3 | 15.06 | 5.00 | 13.30 | 2.63 | | | | | | DST | | | 1.92 | 28.1 | | | | | | | | | | | | |
| SPT-19 | 27.00-27.45 | SP | | | | 7.0 | 13.51 | 3.45 | 12.63 | 2.64 | 0 | 99 | <--> | <--> | 1 | | | | | | | | | | | | | | | | | | |
| SPT-20 | 28.50-28.95 | | | | | 13.9 | 12.90 | 2.84 | 11.32 | 2.61 | | | | | | DST | | | 1.66 | 27.6 | | | | | | | | | | | | |
| SPT-21 | 30.00-30.45 | | | | | 20.6 | 12.95 | 2.89 | 10.75 | 2.62 | | | | | | DST | | | 2.25 | 28.4 | | | | | | | | | | | | |
| **END OF BOREHOLE** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

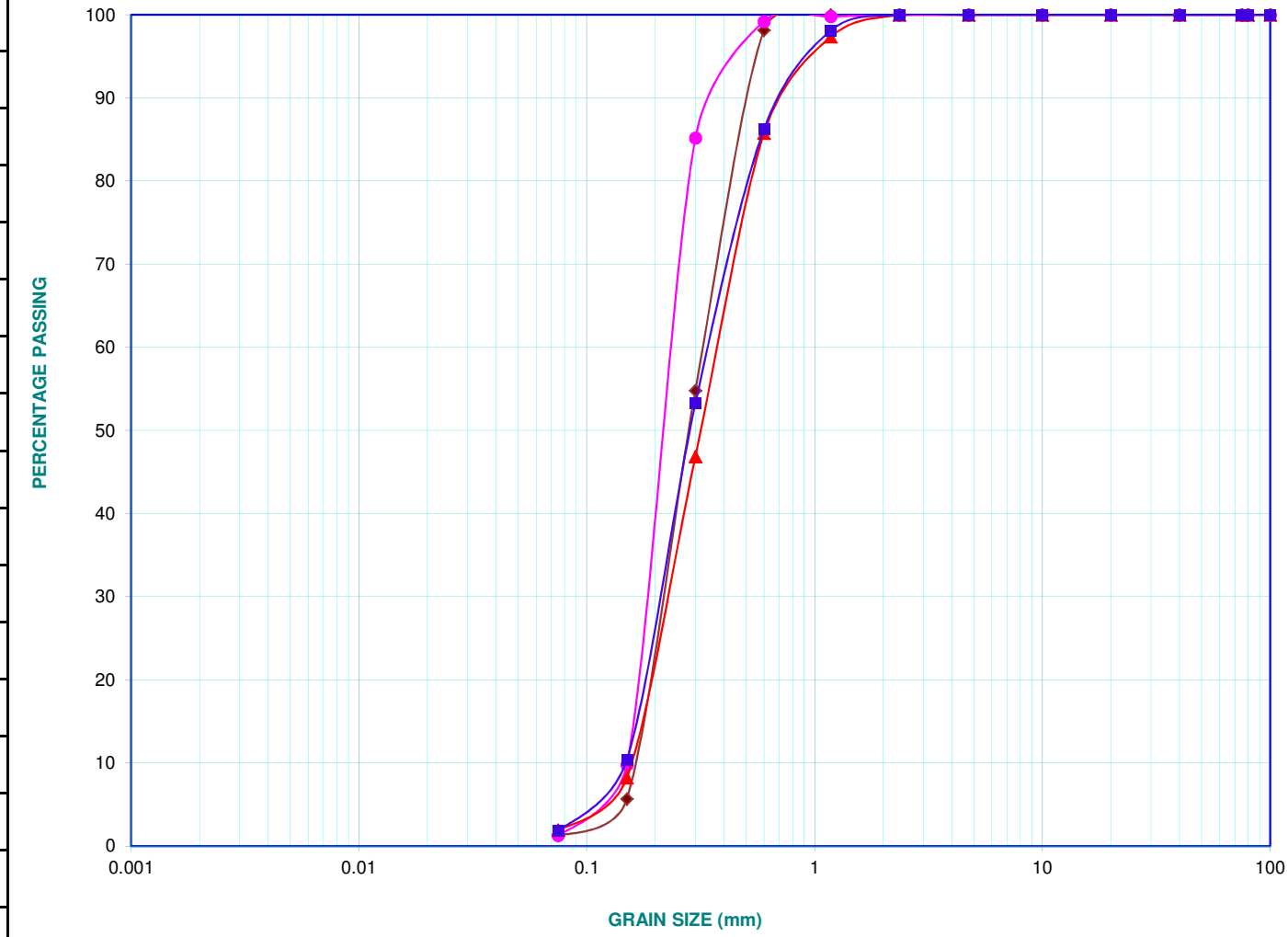
\# : Decayed Wood

**Failure Type**
A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha**
Project Code : **CM 19 01 03**
Borehole No. : **LBH-08**

# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | | **Borehole No.** | **: LBH-08** | | | | **Date :** | **31-May-19** | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | LBH-08 | LBH-08 | LBH-08 | LBH-08 | | | | | | | | |
| **Depth (m)** | 0.00-0.50 | 3.00-3.45 | 7.50-7.95 | 9.00-9.45 | | | | | | | | |
| **Sample Type** | SPT-1 | SPT-3 | SPT-6 | SPT-7 | | | | | | | | |
| **Classification** | SP | SP | SP | SP | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 99 | 99 | 98 | 98 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 1 | 1 | 2 | 2 | | | | | | | | |
| **D60 mm** | 0.330 | 0.230 | 0.390 | 0.350 | | | | | | | | |
| **D30 mm** | 0.220 | 0.190 | 0.230 | 0.210 | | | | | | | | |
| **D10 mm** | 0.160 | 0.150 | 0.160 | 0.150 | | | | | | | | |
| **Cu** | 2.06 | 1.53 | 2.44 | 2.33 | | | | | | | | |
| **Cc** | 0.92 | 1.05 | 0.85 | 0.84 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |

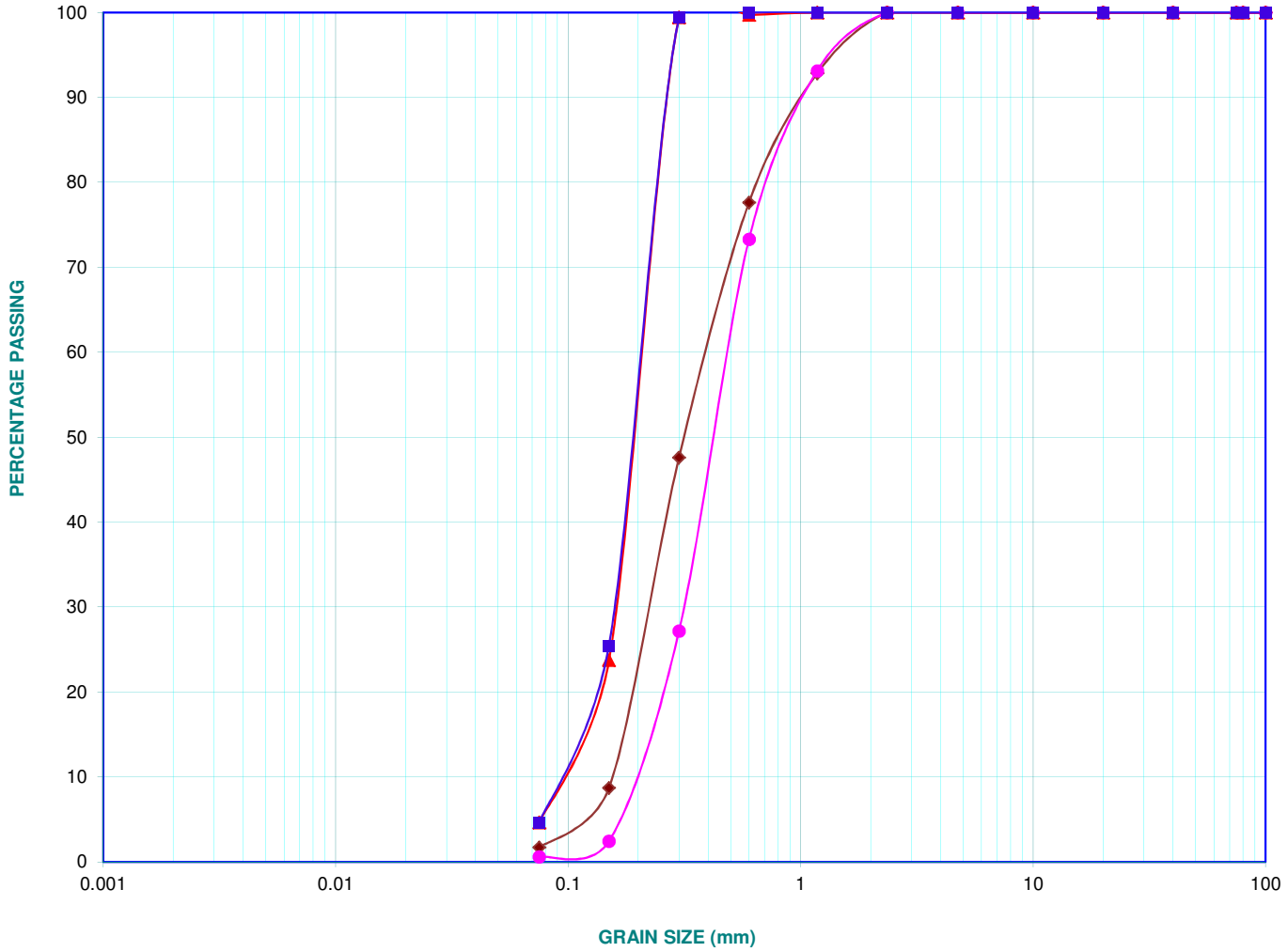



Checked By :

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: LBH-08** |
| **Date :** | **31-May-19** |

| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | LBH-08 | LBH-08 | LBH-08 | LBH-08 | | | | | | | | |
| **Depth (m)** | 12.00-12.45 | 13.50-13.95 | 16.50-16.95 | 18.00-18.45 | | | | | | | | |
| **Sample Type** | SPT-9 | SPT-10 | SPT-12 | SPT-13 | | | | | | | | |
| **Classification** | SP | SP | SP-SM | SP-SM | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 98 | 99 | 95 | 95 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 2 | 1 | 5 | 5 | | | | | | | | |
| **D60 mm** | 0.400 | 0.490 | 0.200 | 0.200 | | | | | | | | |
| **D30 mm** | 0.220 | 0.310 | 0.160 | 0.160 | | | | | | | | |
| **D10 mm** | 0.160 | 0.200 | 0.100 | 0.099 | | | | | | | | |
| **Cu** | 2.50 | 2.45 | 2.00 | 2.02 | | | | | | | | |
| **Cc** | 0.76 | 0.98 | 1.28 | 1.29 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |

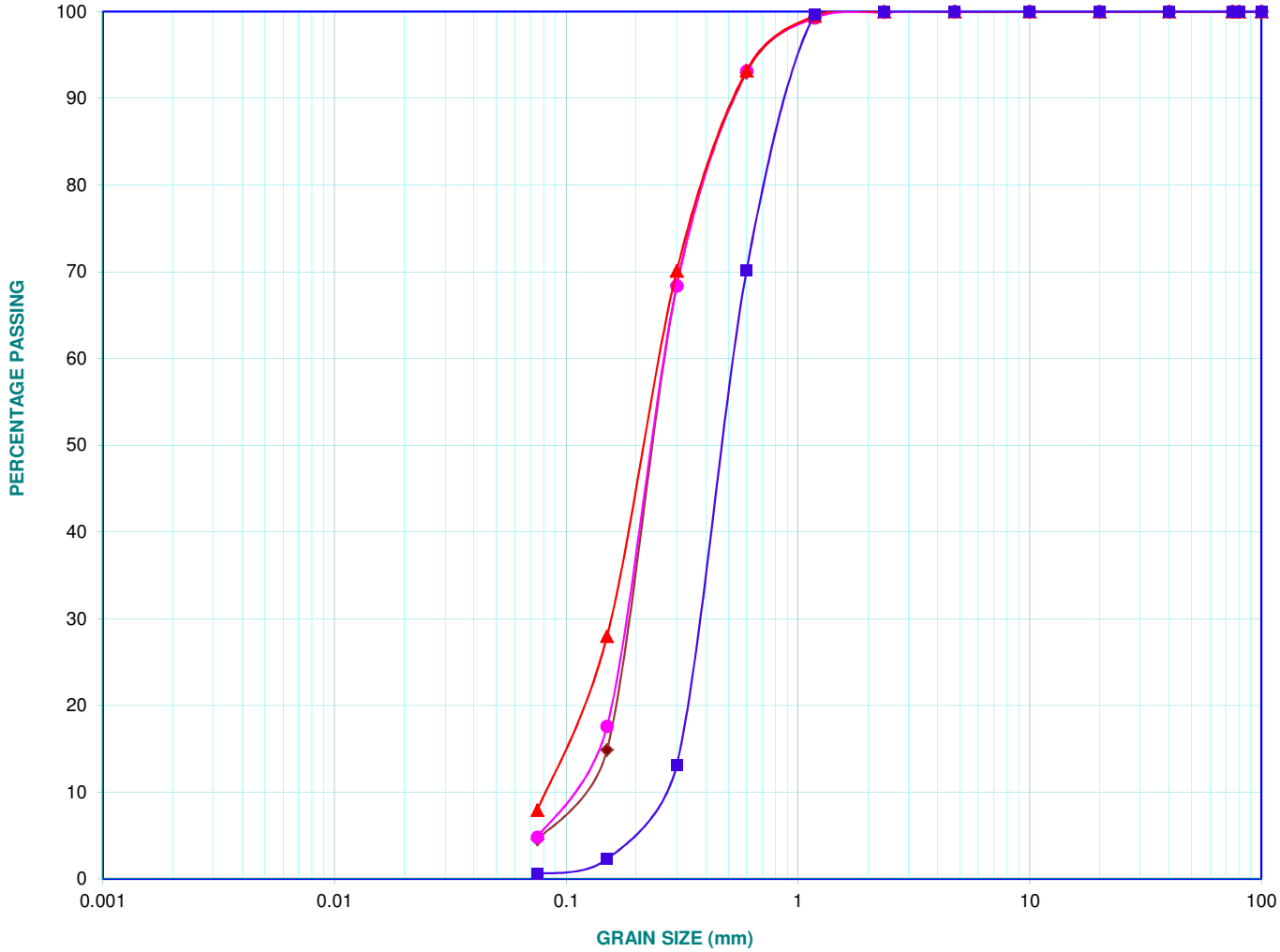



Checked By :

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: LBH-08** |
| **Date :** | **31-May-19** |

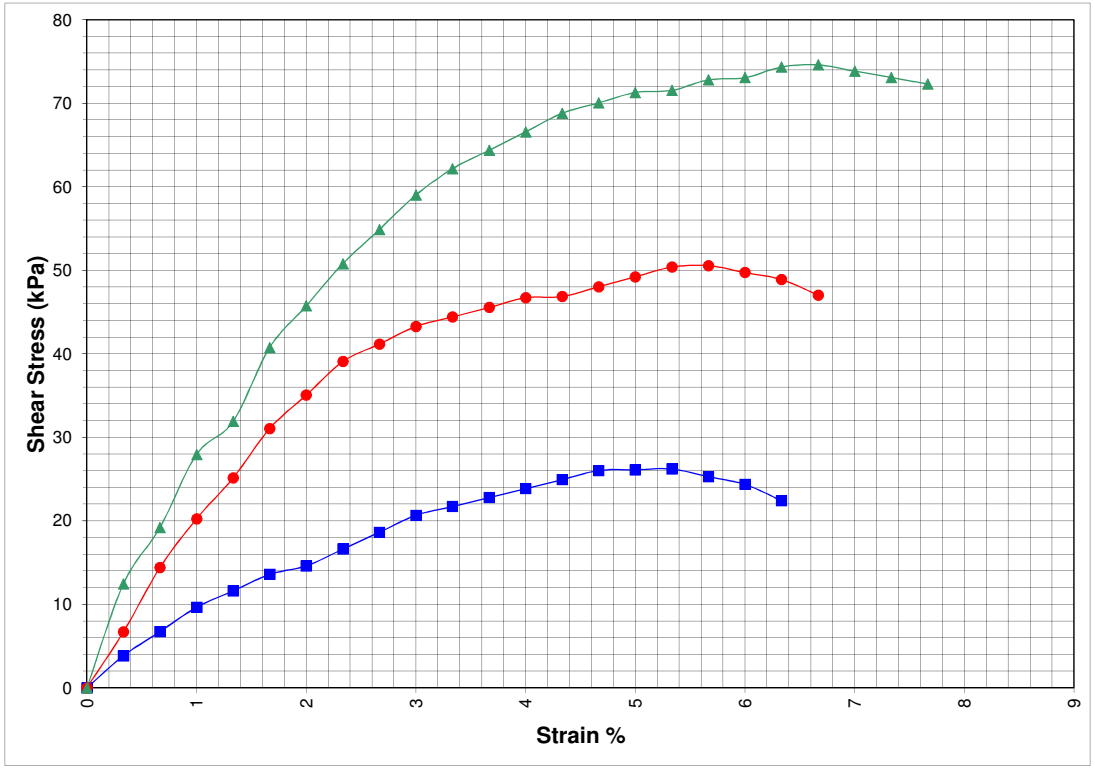
| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | LBH-08 | LBH-08 | LBH-08 | LBH-08 | | | | | | | | |
| **Depth (m)** | 19.50-19.95 | 22.50-22.95 | 24.00-24.45 | 27.00-27.45 | | | | | | | | |
| **Sample Type** | SPT-14 | SPT-16 | SPT-17 | SPT-19 | | | | | | | | |
| **Classification** | SP-SM | SP-SM | SP-SM | SP | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 95 | 95 | 92 | 99 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 5 | 5 | 8 | 1 | | | | | | | | |
| **D60 mm** | 0.260 | 0.280 | 0.250 | 0.510 | | | | | | | | |
| **D30 mm** | 0.190 | 0.180 | 0.160 | 0.390 | | | | | | | | |
| **D10 mm** | 0.130 | 0.110 | 0.080 | 0.2800 | | | | | | | | |
| **Cu** | 2.00 | 2.55 | 3.13 | 1.82 | | | | | | | | |
| **Cc** | 1.07 | 1.05 | 1.28 | 1.07 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |

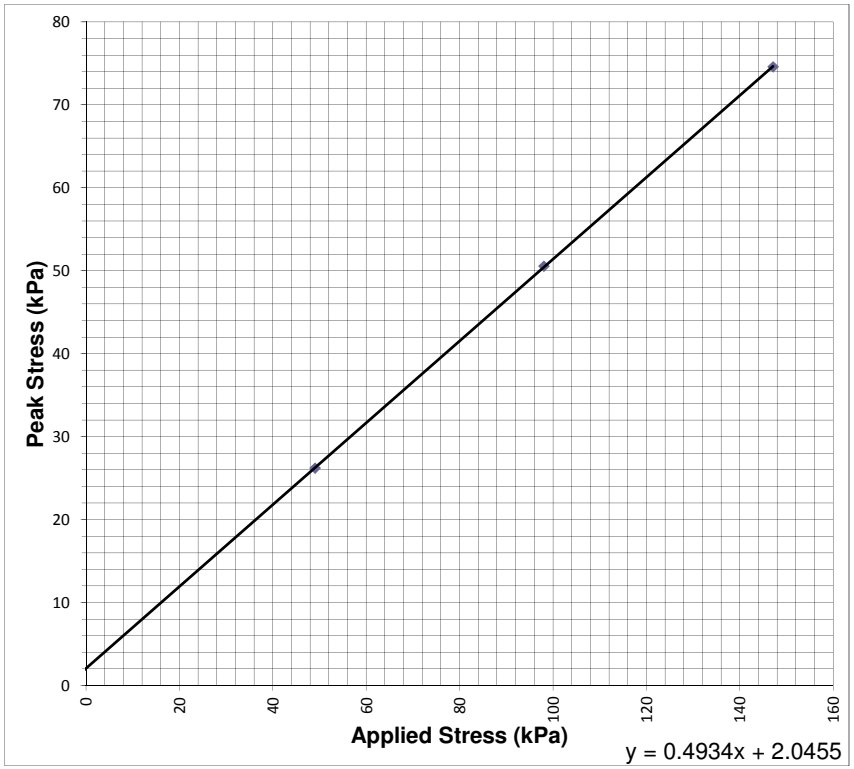



Checked By :

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 51 |
| | Stage 3 | 147 | 75 |

| | | |
|---|---|---|
| Angle of Friction | **26.26** | ° |
| Apparent Cohesion | **2.05** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

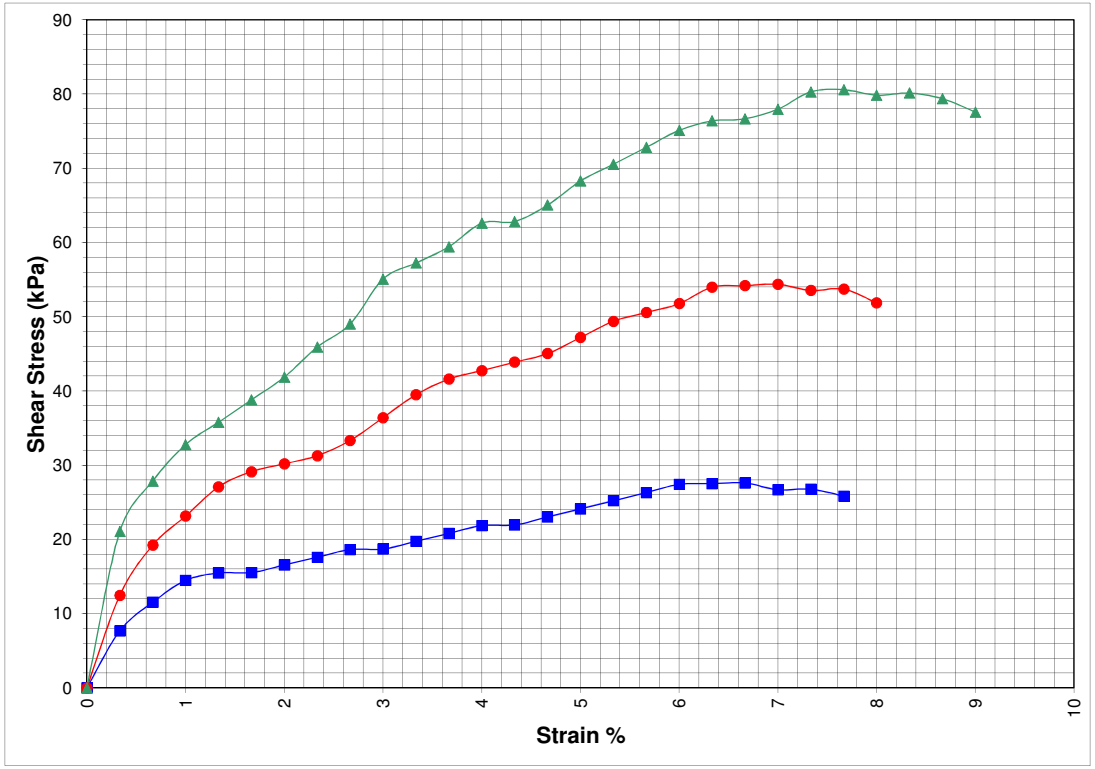
**Borehole: LBH-08**

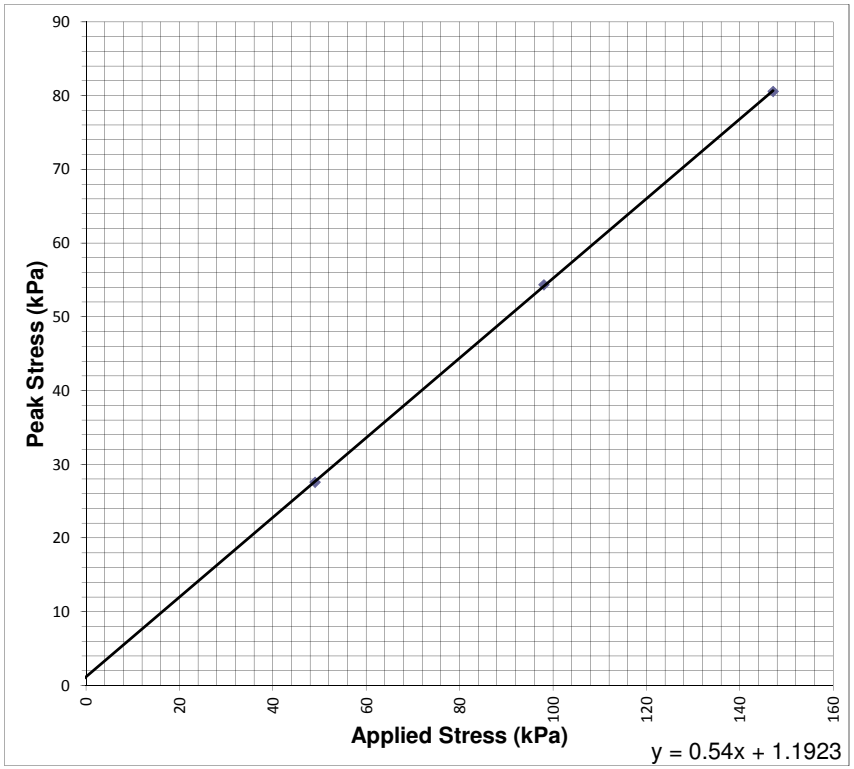
**Sample Type: SPT-02**

**Depth: 1.50-1.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 54 |
| | Stage 3 | 147 | 81 |

| | | |
|---|---|---|
| Angle of Friction | **28.37** | ° |
| Apparent Cohesion | **1.19** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

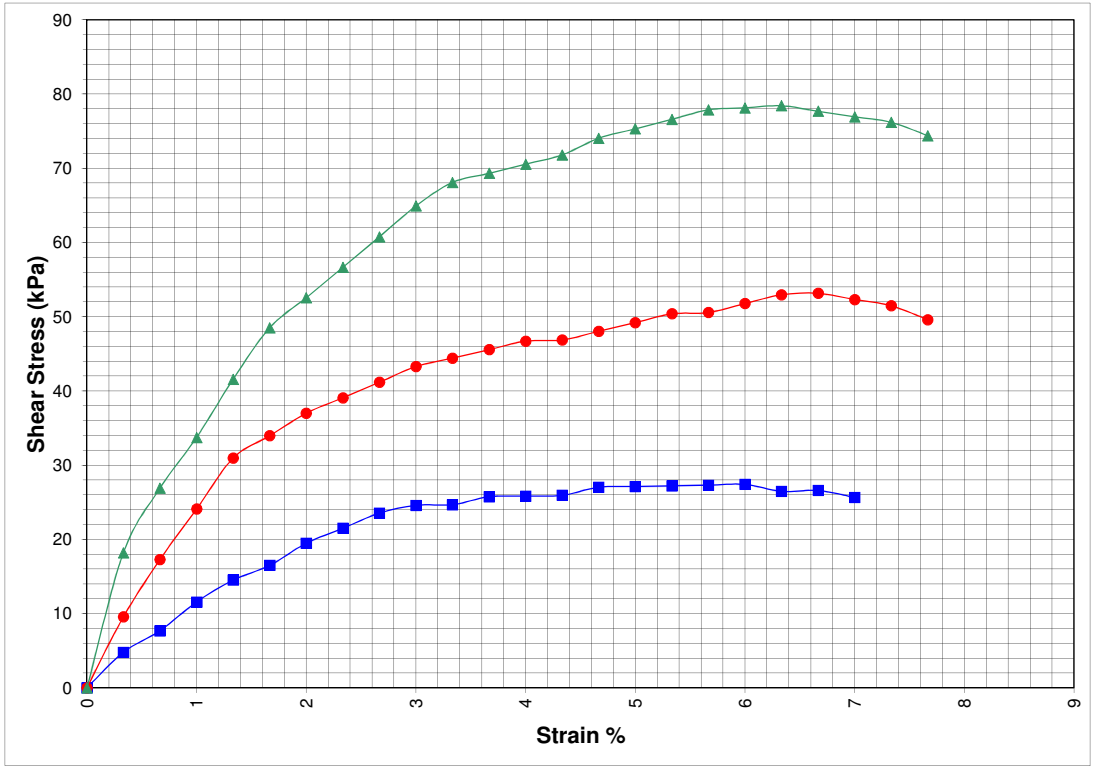
**Borehole: LBH-08**

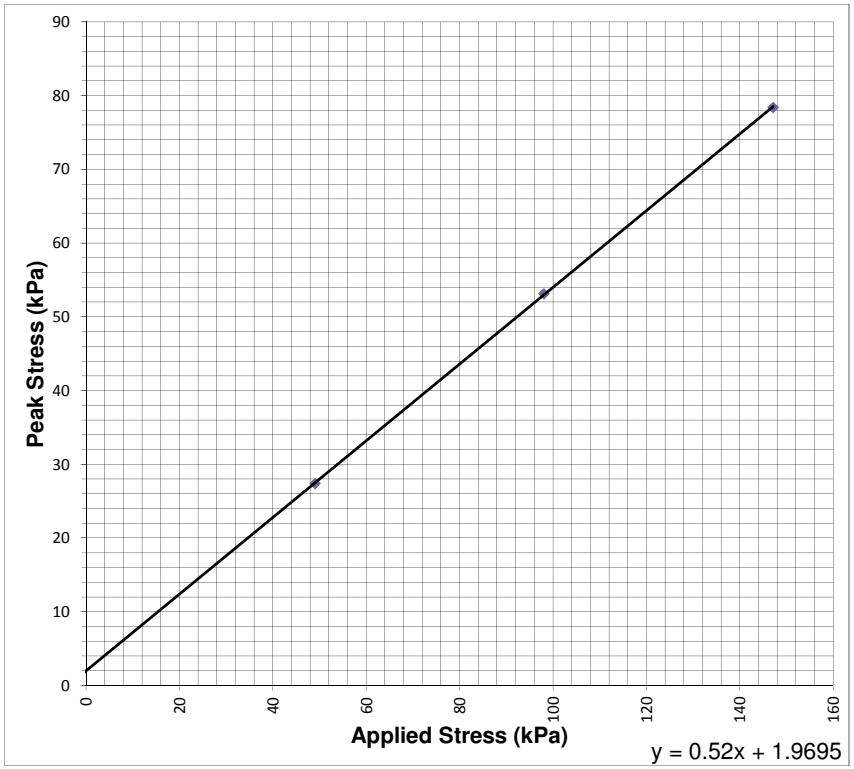
**Sample Type: SPT-04**

**Depth: 4.50-4.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 53 |
| | Stage 3 | 147 | 78 |

| | | |
|---|---|---|
| Angle of Friction | **27.47** | ° |
| Apparent Cohesion | **1.97** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

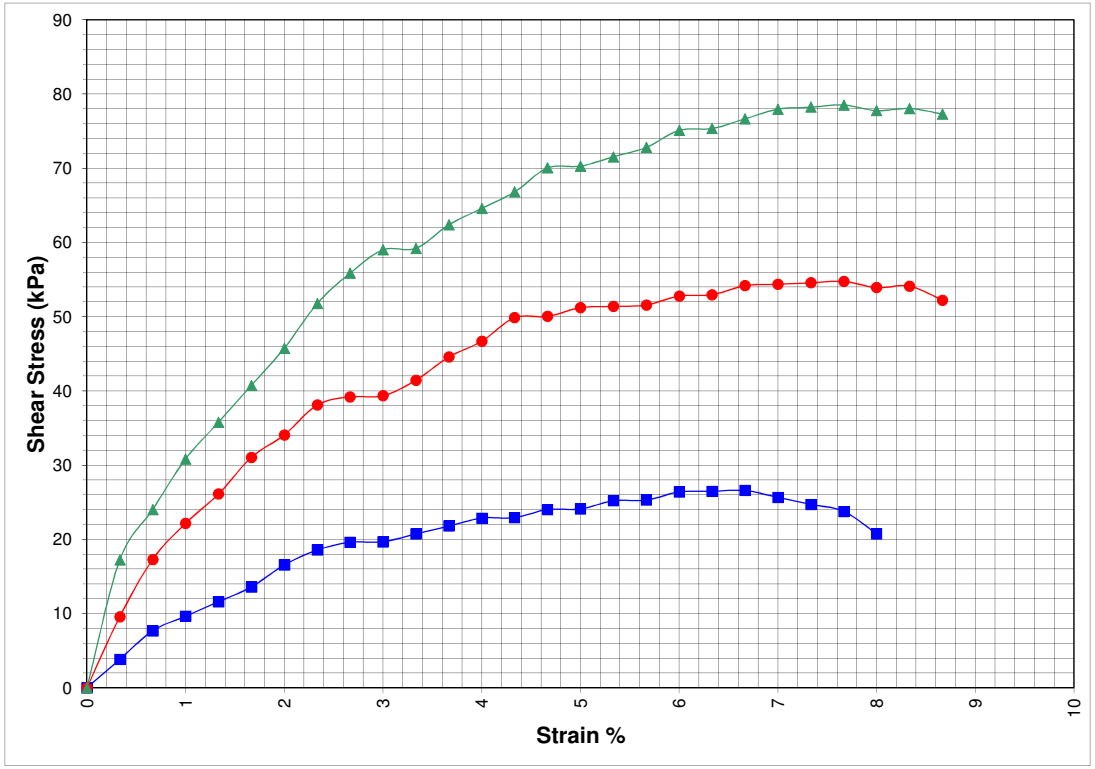
**Borehole: LBH-08**

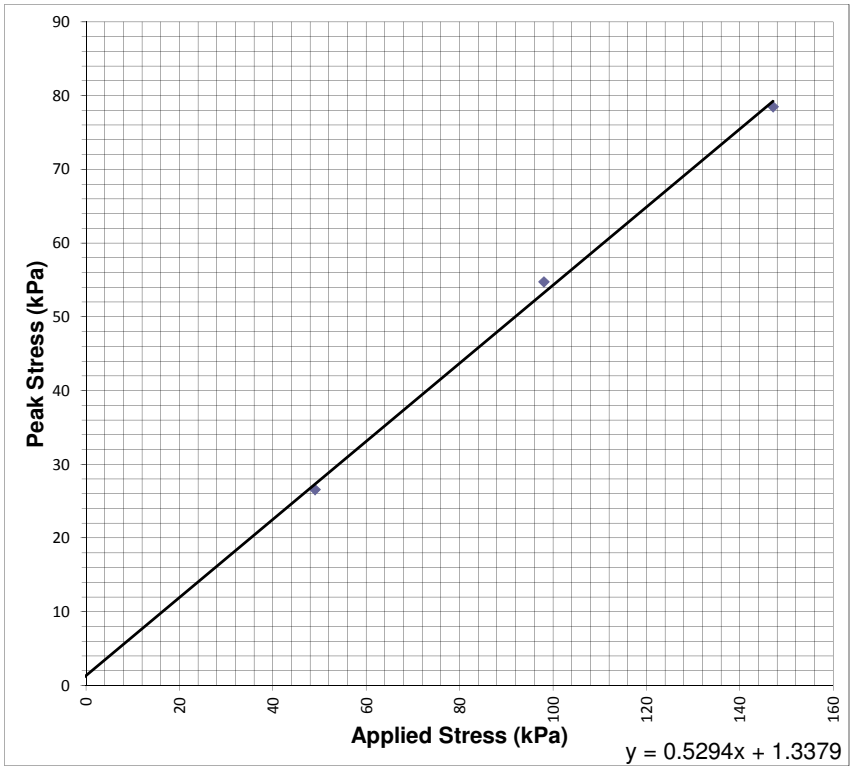
**Sample Type: SPT-05**

**Depth: 6.00-6.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 55 |
| | Stage 3 | 147 | 79 |

| | | |
|---|---|---|
| Angle of Friction | **27.90** | ° |
| Apparent Cohesion | **1.34** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

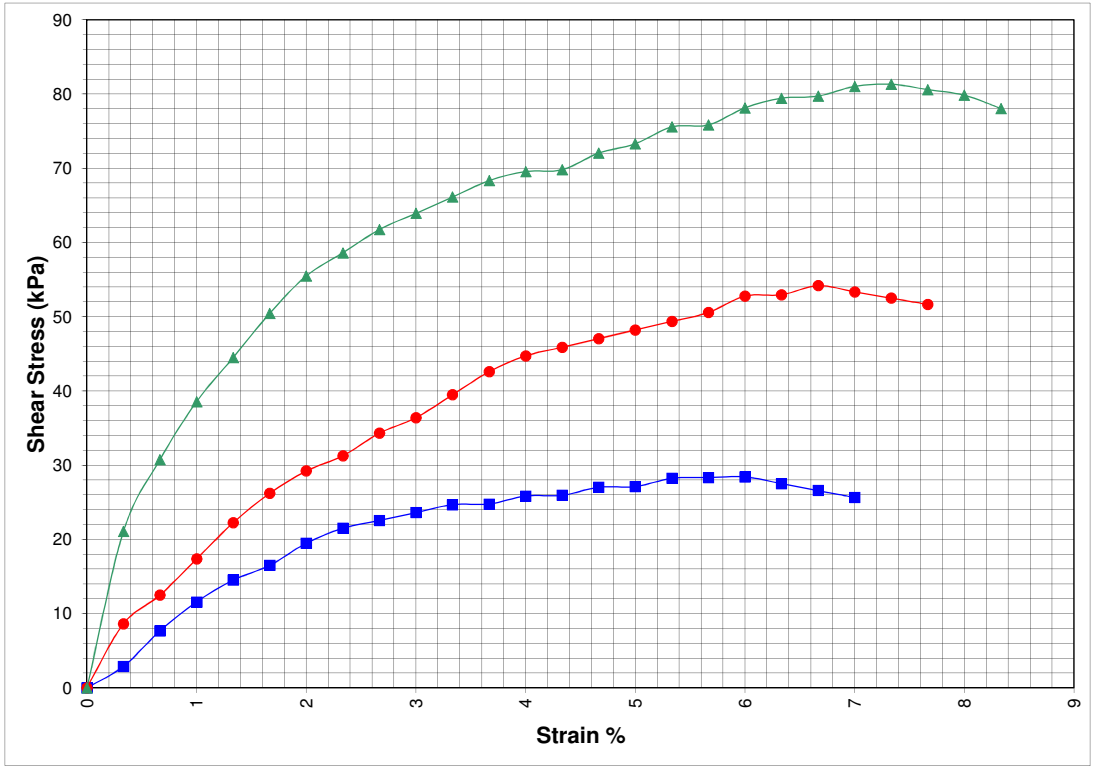
**Borehole: LBH-08**

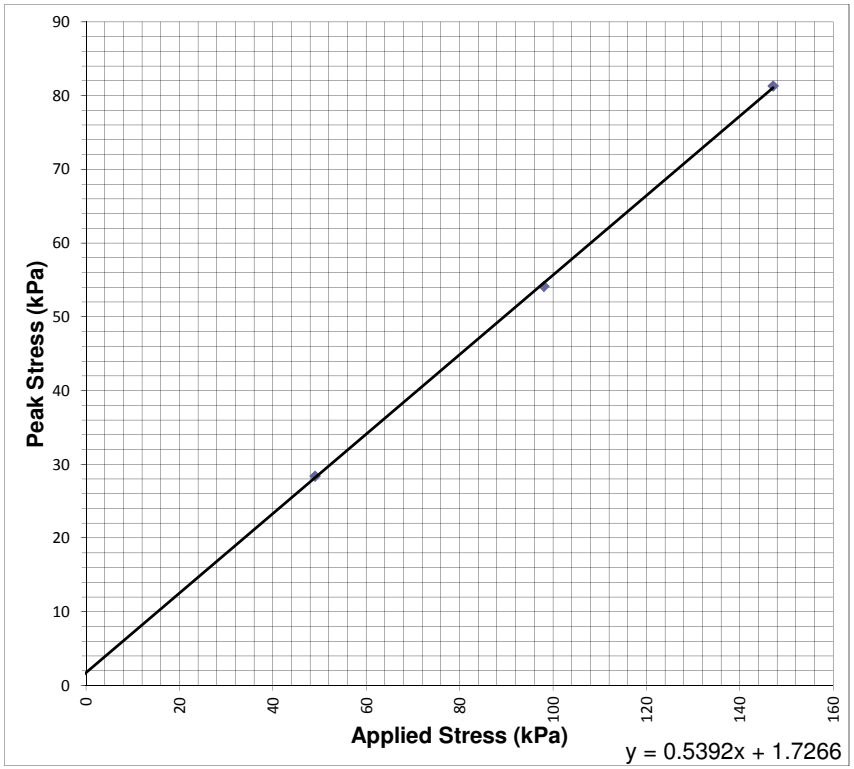
**Sample Type: SPT-08**

**Depth: 10.50-10.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 54 |
| | Stage 3 | 147 | 81 |

| | | |
|---|---|---|
| Angle of Friction | **28.33** | ° |
| Apparent Cohesion | **1.73** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

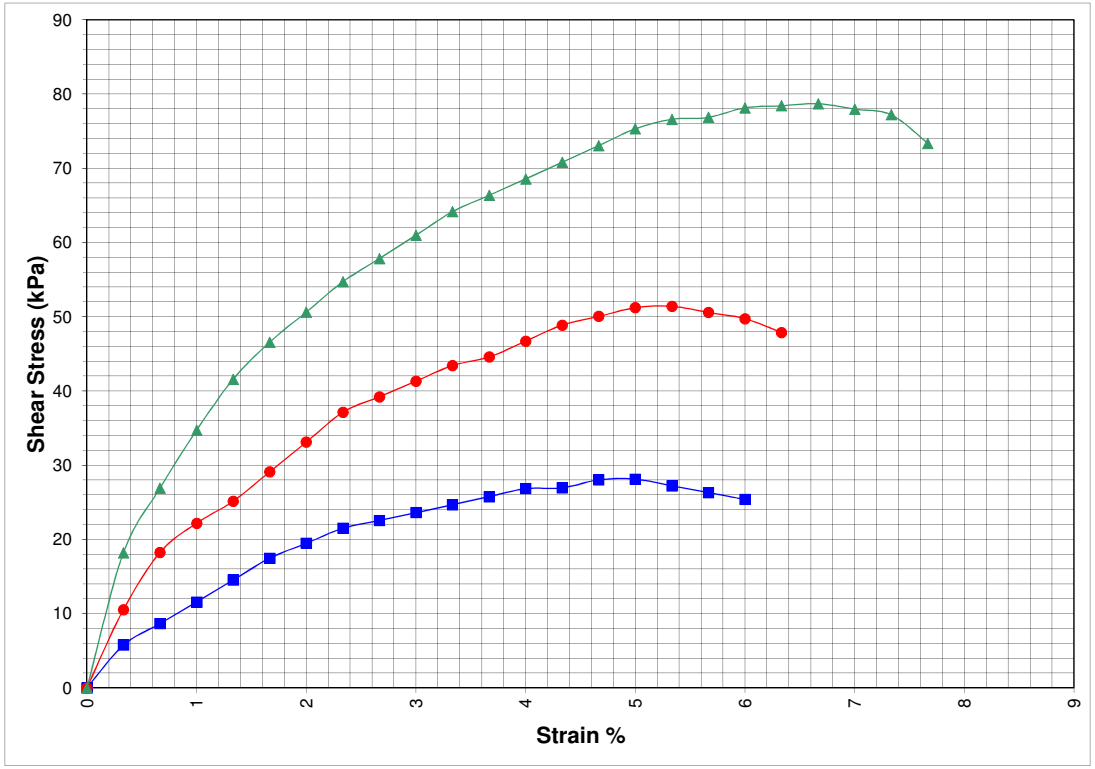
**Borehole: LBH-08**

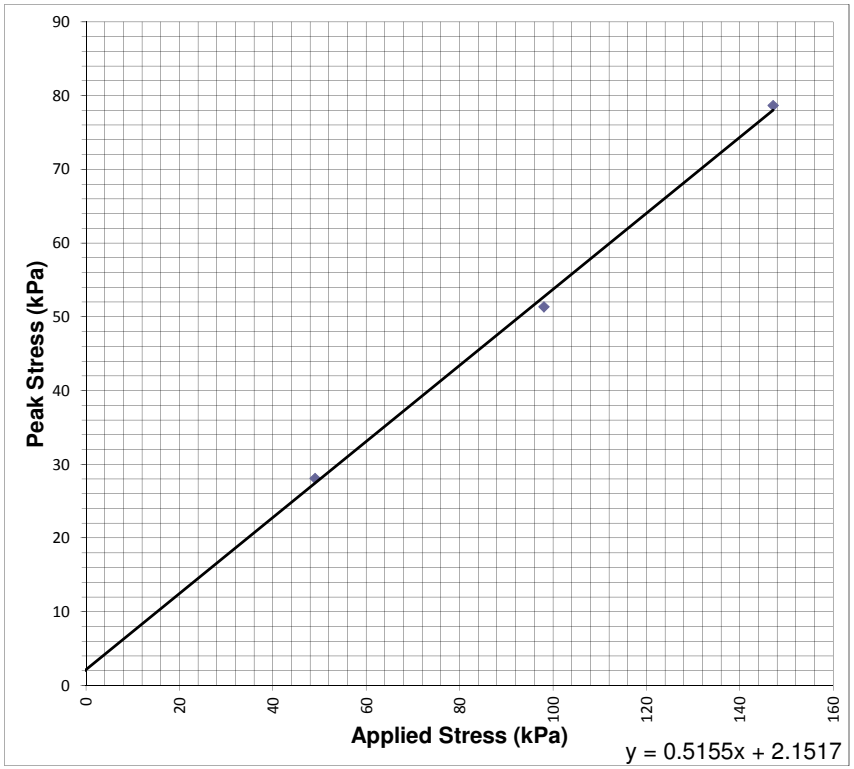
**Sample Type: SPT-11**

**Depth: 15.00-15.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 51 |
| | Stage 3 | 147 | 79 |

| | | |
|---|---|---|
| Angle of Friction | **27.27** | ° |
| Apparent Cohesion | **2.15** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

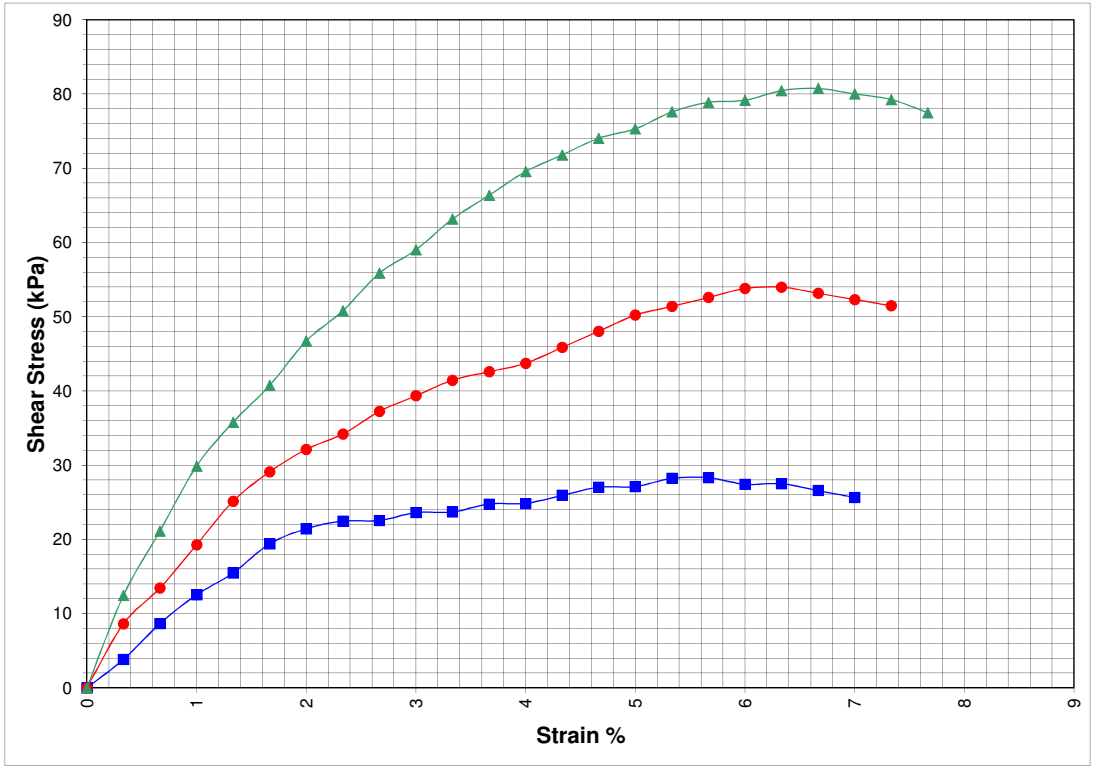
**Borehole: LBH-08**

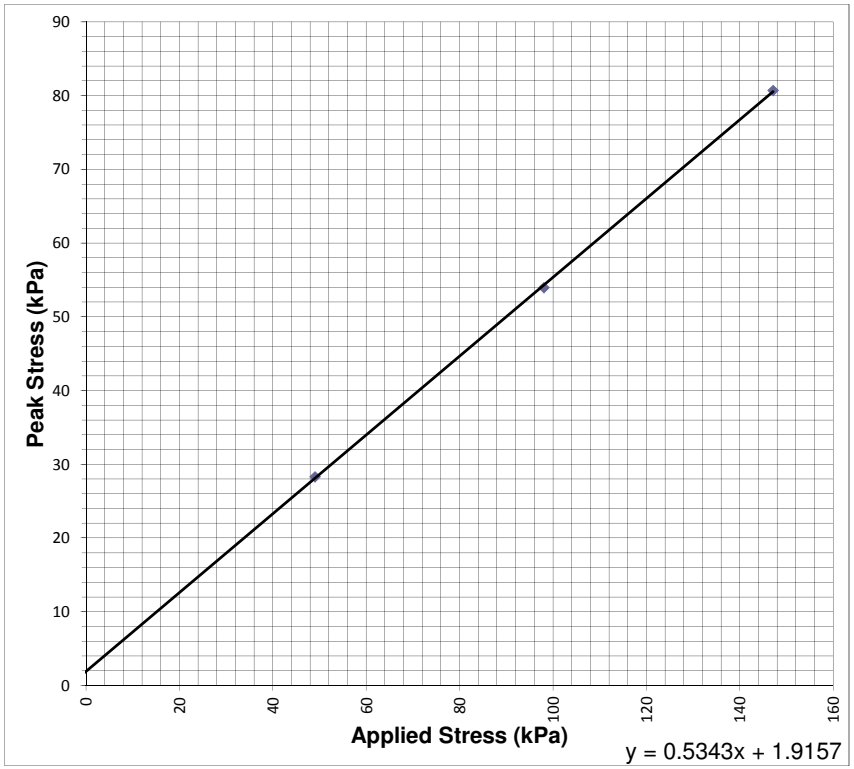
**Sample Type: SPT-15**

**Depth: 21.00-21.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 54 |
| | Stage 3 | 147 | 81 |

| | | |
|---|---|---|
| Angle of Friction | **28.12** | ° |
| Apparent Cohesion | **1.92** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

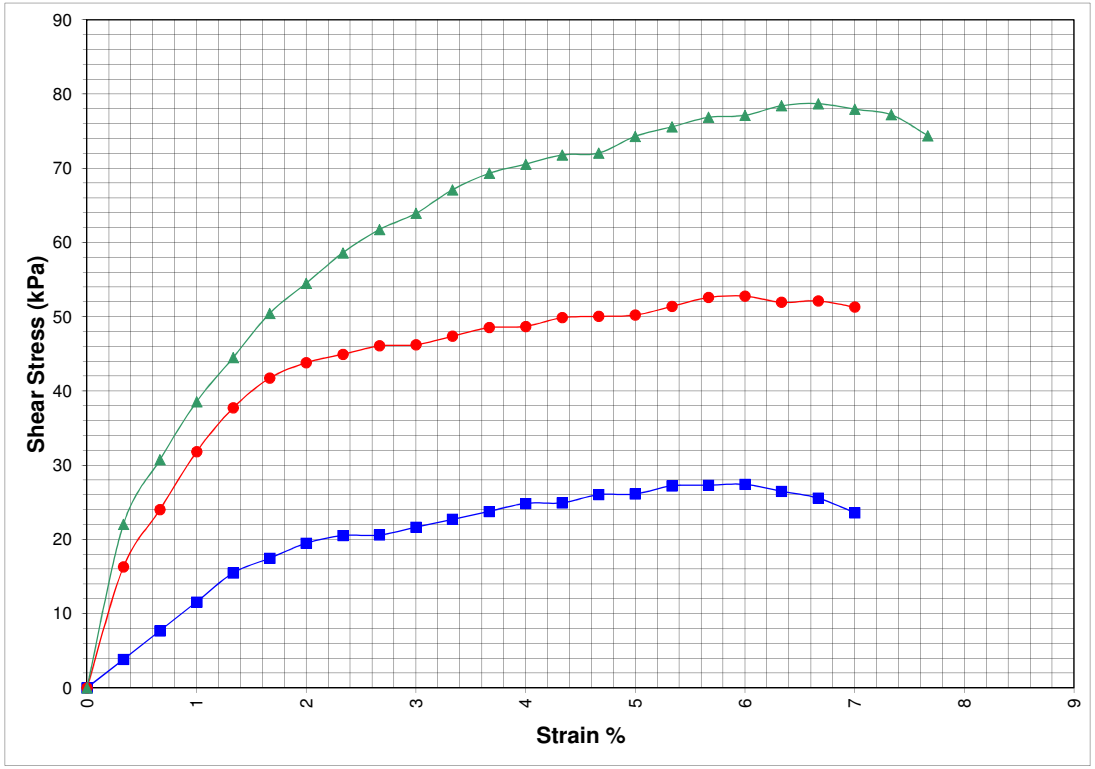
**Borehole: LBH-08**

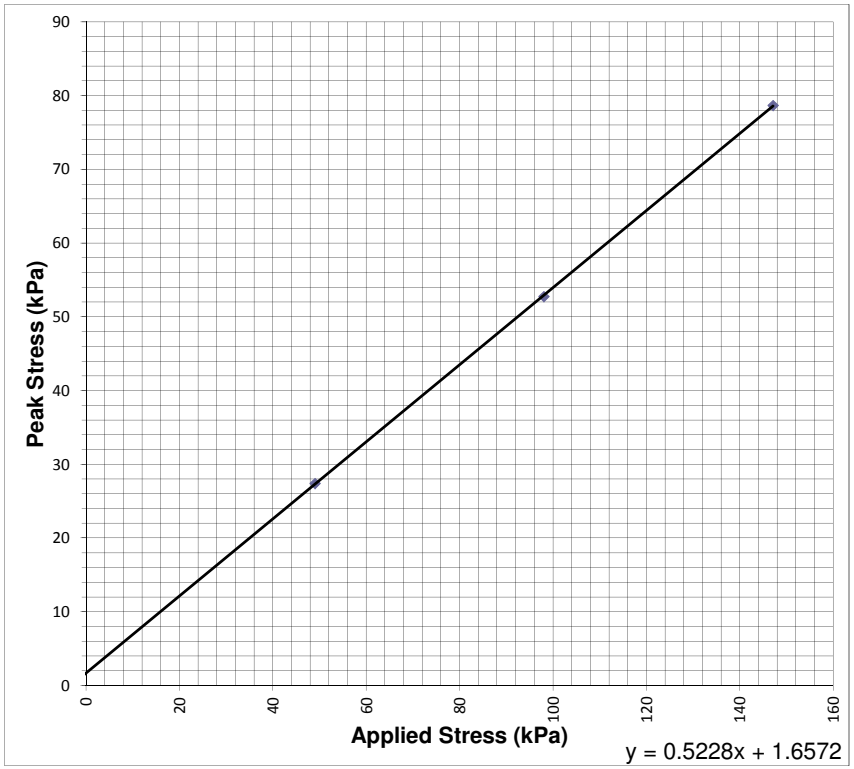
**Sample Type: SPT-18**

**Depth: 25.50-25.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 53 |
| | Stage 3 | 147 | 79 |

| | | |
|---|---|---|
| Angle of Friction | **27.60** | ° |
| Apparent Cohesion | **1.66** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

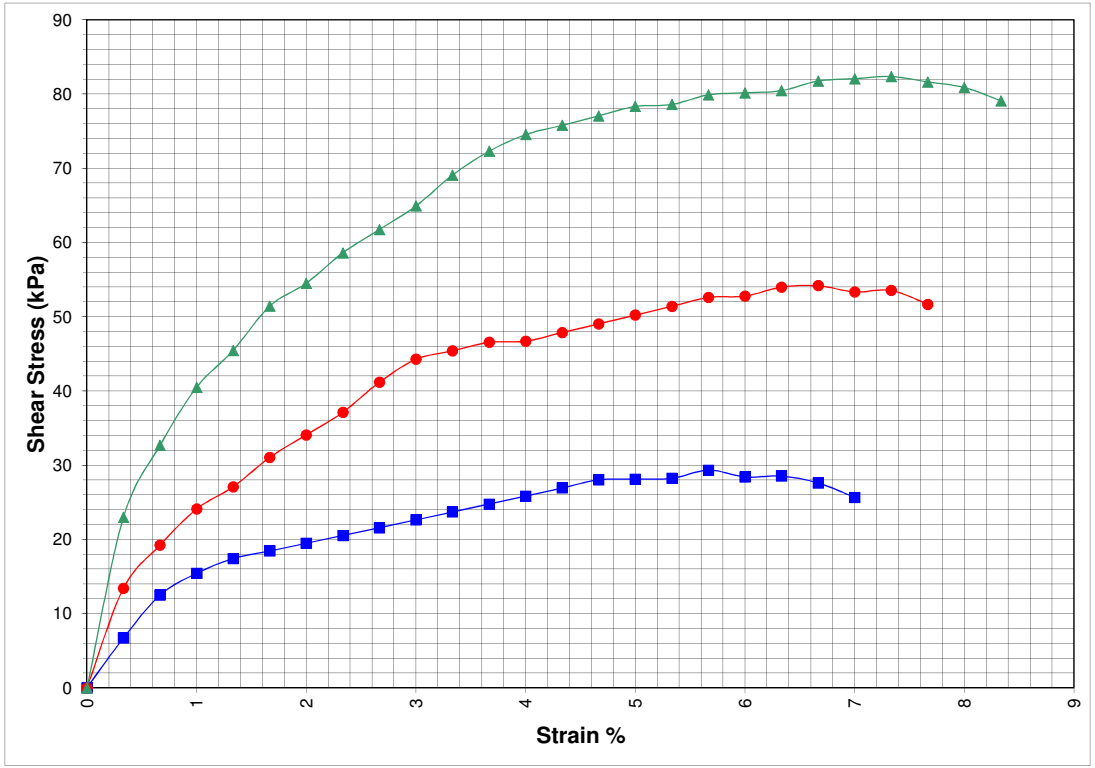
**Borehole: LBH-08**

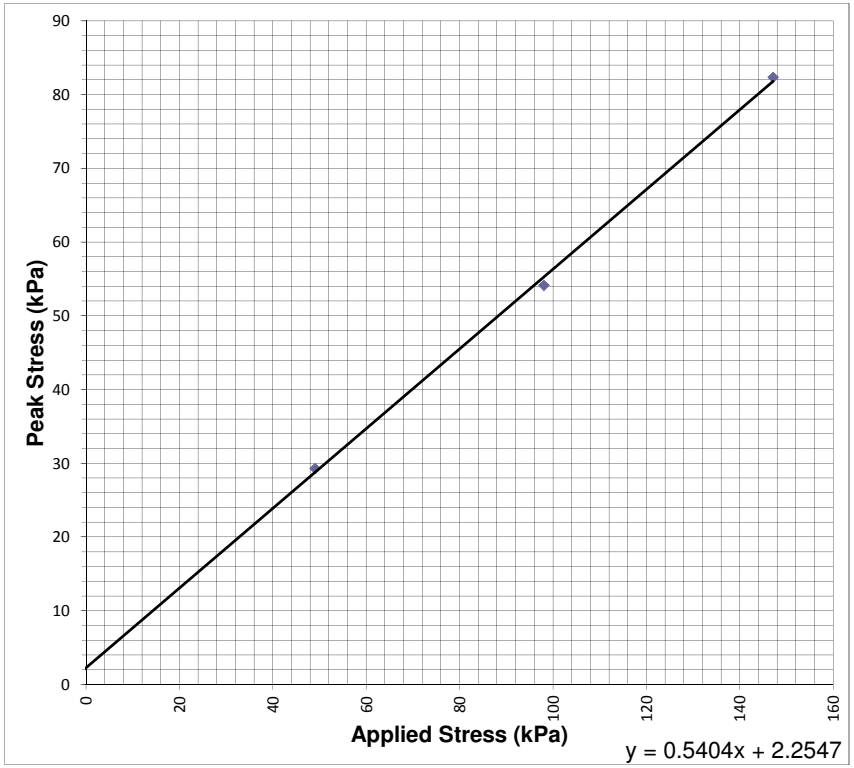
**Sample Type: SPT-20**

**Depth: 28.50-28.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 29 |
| | Stage 2 | 98 | 54 |
| | Stage 3 | 147 | 82 |

| | | |
|---|---|---|
| Angle of Friction | **28.39** | ° |
| Apparent Cohesion | **2.25** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: LBH-08**

**Sample Type: SPT-21**

**Depth: 30.00-30.45 m**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-1 | 0.00-0.20 | SP-SM | | | | 18.8 | 16.82 | 6.76 | 14.15 | 2.63 | 0 | 89 | <--> | <--> | 11 | | | | | | | | | | | | | | | | | | |
| SPT-2 | 1.50-1.70 | SP-SM | | | | 19.4 | 18.91 | 8.85 | 15.83 | 2.64 | 0 | 92 | <--> | <--> | 8 | | | | | | | | | | | | | | | | | | |
| SPT-3 | 3.00-3.30 | | | | | 15.3 | 18.74 | 8.68 | 16.26 | | | | | | | DST | | | 1.17 | 30.7 | | | | | | | | | | | | |
| SPT-4 | 4.50-4.75 | SP | | | | 20.6 | 18.10 | 8.04 | 15.01 | | 0 | 96 | <--> | <--> | 4 | | | | | | | | | | | | | | | | | | |
| SPT-5 | 6.00-6.15 | | | | | 20.2 | 16.72 | 6.66 | 13.91 | 2.60 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-6 | 7.50-7.70 | | | | | 22.5 | 18.50 | 8.44 | 15.09 | 2.61 | | | | | | DST | | | 1.20 | 31.4 | | | | | | | | | | | | |
| SPT-7 | 9.00-9.30 | | | | | 16.0 | 18.30 | 8.24 | 15.77 | 2.63 | | | | | | | | | | | | | | | | | | | | 8.97 | 1.00 | 2.00 | 100 | 8850 |
| SPT-8 | 10.50-10.70 | SP | | | | 20.8 | 18.57 | 8.51 | 15.37 | | 0 | 96 | <--> | <--> | 4 | | | | | | | | | | | | | | | | | | |
| SPT-9 | 12.00-12.30 | | | | | 20.9 | 18.58 | 8.52 | 15.37 | | | | | | | DST | | | 1.58 | 29.7 | | | | | | | | | | | | |
| SPT-10 | 13.50-13.70 | SP | | | | 18.4 | 18.30 | 8.24 | 15.46 | | 0 | 99 | <--> | <--> | 1 | | | | | | | | | | | | | | | | | | |
| SPT-11 | 15.00-15.45 | CL | 28.0 | 12.9 | 15.1 | 27.2 | 19.73 | 9.67 | 15.50 | 2.58 | 0 | 49 | 39 | 12 | 51 | | | | | | | | | 10.0 | | | | | | | | |
| SPT-12 | 16.50-16.75 | SP-SM | | | | 16.0 | 18.05 | 7.99 | 15.55 | | 0 | 92 | <--> | <--> | 8 | | | | | | | | | | | | | | | | | | |
| SPT-13 | 18.00-18.30 | SP | | | | 19.3 | 18.00 | 7.94 | 15.08 | | 0 | 97 | <--> | <--> | 3 | | | | | | | | | | | | | | | | | | |
| SPT-14 | 19.50-19.70 | | | | | 19.3 | 17.55 | 7.49 | 14.71 | | | | | | | DST | | | 1.52 | 27.7 | | | | | | | | | | | | |
| SPT-15 | 21.00-21.25 | SP-SM | | | | 18.2 | 17.60 | 7.54 | 14.89 | | 0 | 92 | <--> | <--> | 8 | | | | | | | | | | | | | | | | | | |
| SPT-16 | 22.50-22.70 | | | | | 20.0 | 17.70 | 7.64 | 14.75 | | | | | | | DST | | | 1.92 | 25.9 | | | | | | | | | | | | |
| SPT-17 | 24.00-24.30 | SP-SM | | | | 20.2 | 17.98 | 7.92 | 14.96 | | 0 | 93 | <--> | <--> | 7 | | | | | | | | | | | | | | | | 8.60 | 0.90 | 2.00 | 200 | 5310 |
| SPT-18 | 25.50-25.75 | SP-SM | | | | 20.5 | 17.57 | 7.51 | 14.58 | 2.61 | 0 | 91 | <--> | <--> | 9 | | | | | | | | | | | | | | | | | | |
| SPT-19 | 27.00-27.20 | SP-SM | | | | 21.9 | 16.56 | 6.50 | 13.58 | | 0 | 91 | <--> | <--> | 9 | | | | | | | | | | | | | | | | | | |
| SPT-20 | 28.50-28.80 | | | | | 21.2 | 18.43 | 8.37 | 15.20 | 2.60 | | | | | | DST | | | 1.89 | 26.7 | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

\# : Decayed Wood

**Failure Type**

A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-09**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density ($kN/m^3$) | Submerged Unit Weight ($kN/m^3$) | Dry Density ($kN/m^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-21 | 30.00-30.20 | SP | | | | 7.9 | 14.79 | 4.73 | 13.70 | | 0 | 96 | <--> | <--> | 4 | | | | | | | | | | | | | | | | | | |
| SPT-22 | 32.00-32.15 | SP | | | | 10.4 | 13.67 | 3.61 | 12.39 | | 0 | 96 | <--> | <--> | 4 | | | | | | | | | | | | | | | | | | |
| SPT-23 | 33.50-33.70 | | | | | 5.0 | 13.69 | 3.63 | 13.04 | 2.64 | | | | | | DST | | | 1.44 | 26.2 | | | | | | | | | | | | |
| SPT-24 | 35.00-35.25 | | | | | 5.1 | 13.01 | 2.95 | 12.38 | 2.65 | | | | | | | | | | | | | | | | | | | | | | |
| SPT-25 | 36.50-36.70 | SP | | | | 15.0 | 15.29 | 5.23 | 13.30 | | 0 | 96 | <--> | <--> | 4 | | | | | | | | | | | | | | | | | | |
| SPT-26 | 38.00-38.25 | | | | | 12.0 | 13.64 | 3.58 | 12.18 | | | | | | | DST | | | 1.88 | 27.4 | | | | | | | | | | | | |
| SPT-27 | 40.00-40.15 | SP-SM | | | | 14.2 | 14.40 | 4.34 | 12.61 | | 0 | 92 | <--> | <--> | 8 | | | | | | | | | | | | | | | | | | |
| **END OF BOREHOLE** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

\# : Decayed Wood

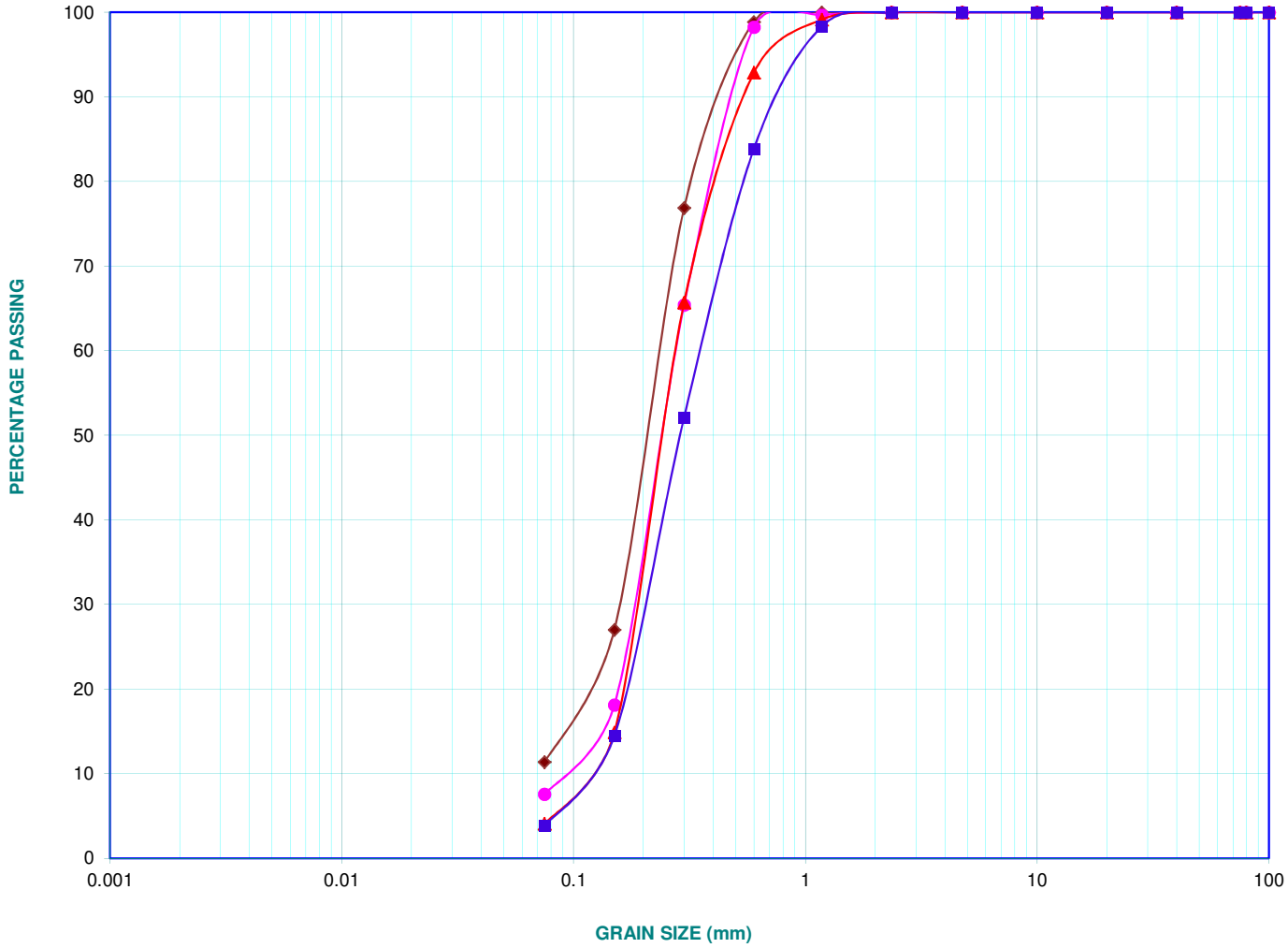
**Failure Type**

A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-09**

# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | **Borehole No.** | **: MBH-09** | | | **Date :** | **7-Jun-19** | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | . | SAND F | SAND M | SAND C | GRAVEL F | GRAVEL C |
| **Bore Hole .** | MBH-09 | MBH-09 | MBH-09 | MBH-09 | | | | | | | | |
| **Depth (m)** | 0.00-0.20 | 1.50-1.70 | 4.50-4.75 | 10.50-10.70 | | | | | | | | |
| **Sample Type** | SPT-01 | SPT-02 | SPT-04 | SPT-08 | | | | | | | | |
| **Classification** | SP-SM | SP-SM | SP | SP | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 89 | 92 | 96 | 96 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 11 | 8 | 4 | 4 | | | | | | | | |
| **D60 mm** | 0.230 | 0.290 | 0.290 | 0.350 | | | | | | | | |
| **D30 mm** | 0.170 | 0.190 | 0.190 | 0.210 | | | | | | | | |
| **D10 mm** | 0.075 | 0.099 | 0.130 | 0.130 | | | | | | | | |
| **Cu** | 3.07 | 2.93 | 2.23 | 2.69 | | | | | | | | |
| **Cc** | 1.68 | 1.26 | 0.96 | 0.97 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |

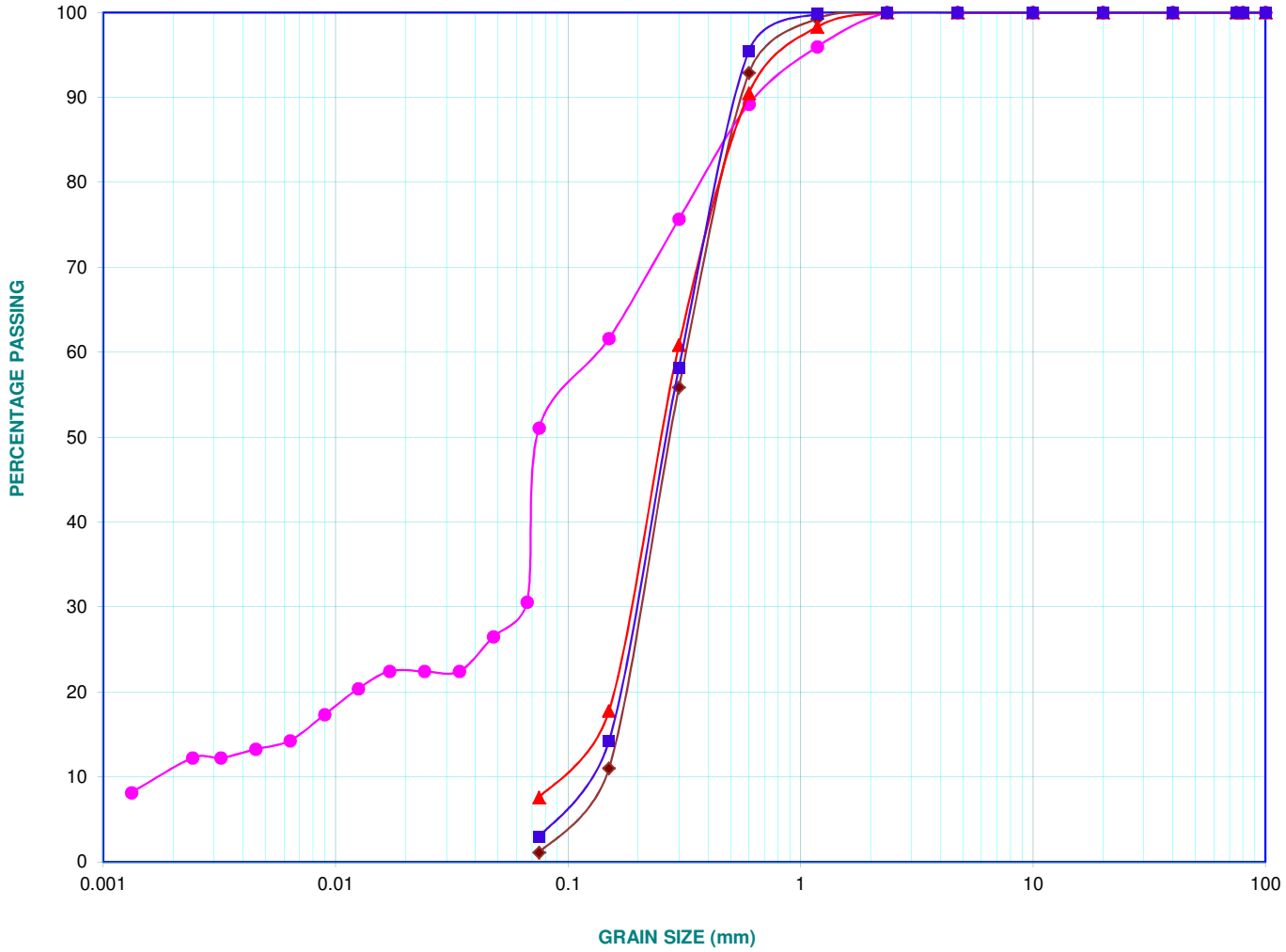



Checked By :

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-09** |
| **Date :** | **7-Jun-19** |

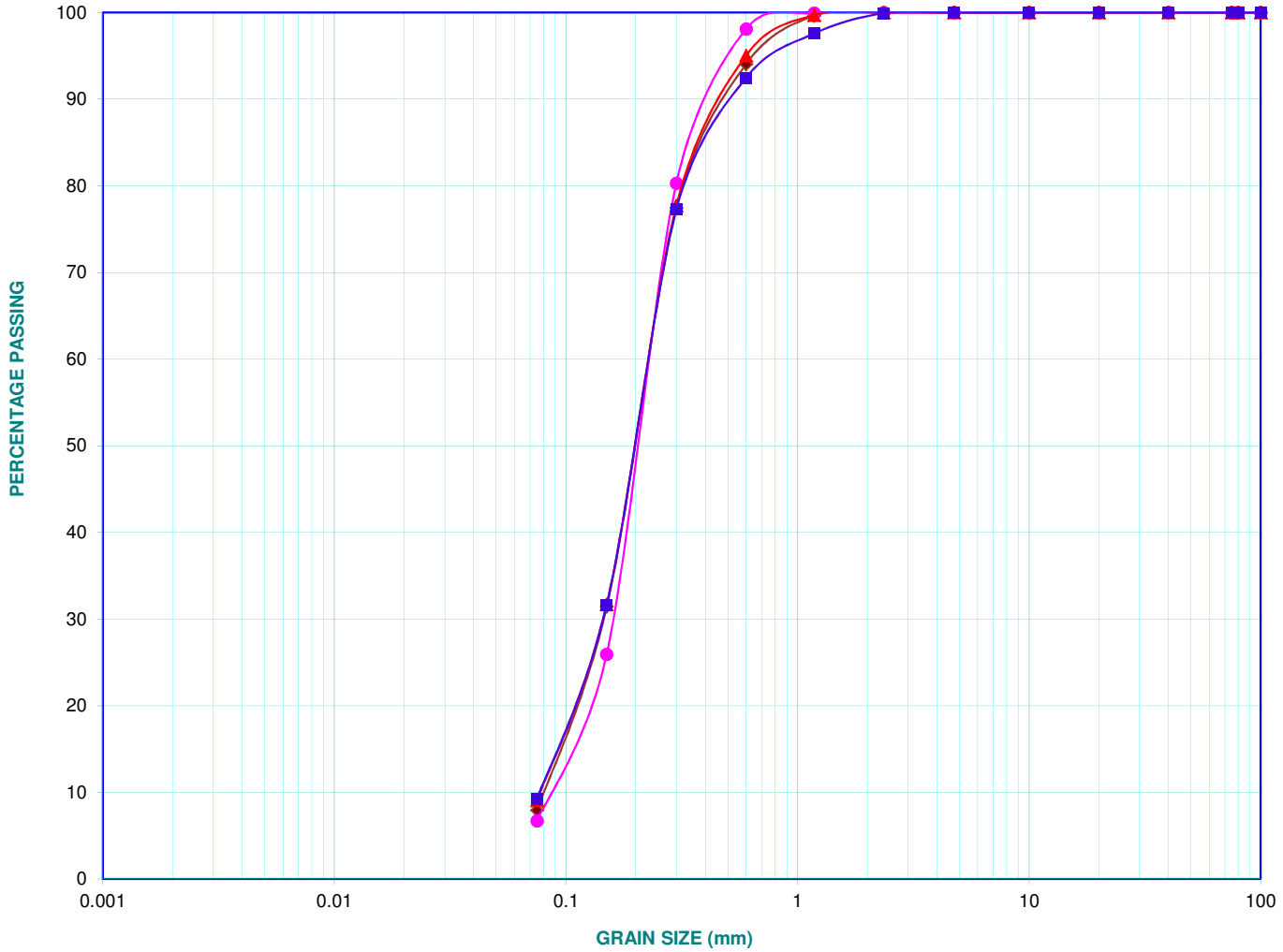
| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-09 | MBH-09 | MBH-09 | MBH-09 | | | | | | | | |
| **Depth (m)** | 13.50-13.70 | 15.00-15.45 | 16.50-16.75 | 18.00-18.30 | | | | | | | | |
| **Sample Type** | SPT-10 | SPT-11 | SPT-12 | SPT-13 | | | | | | | | |
| **Classification** | SP | CL | SP-SM | SP | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 99 | 49 | 92 | 97 | | | | | | | | |
| **Silt %** | <----> | 39 | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | 12 | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 1 | 51 | 8 | 3 | | | | | | | | |
| **D60 mm** | 0.310 | 0.150 | 0.300 | 0.300 | | | | | | | | |
| **D30 mm** | 0.200 | 0.067 | 0.190 | 0.200 | | | | | | | | |
| **D10 mm** | 0.150 | 0.002 | 0.099 | 0.140 | | | | | | | | |
| **Cu** | 2.07 | 78.95 | 3.03 | 2.14 | | | | | | | | |
| **Cc** | 0.86 | 15.75 | 1.22 | 0.95 | | | | | | | | |
| **Liquid Limit %** | --- | 28.0 | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | 12.9 | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | 15.1 | --- | --- | | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | : Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha | | | | | | | | | | |
| **Job No.** | : CM 19 01 03 | | | | **Borehole No.** | : MBH-09 | | | **Date :** | 7-Jun-19 | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND F | SAND M | SAND C | GRAVEL F / GRAVEL C |
| **Bore Hole .** | MBH-09 | MBH-09 | MBH-09 | MBH-09 | | | | | | | |
| **Depth (m)** | 21.00-21.25 | 24.00-24.30 | 25.50-25.75 | 27.00-27.20 | | | | | | | |
| **Sample Type** | SPT-15 | SPT-17 | SPT-18 | SPT-19 | | | | | | | |
| **Classification** | SP-SM | SP-SM | SP-SM | SP-SM | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | |
| **Sand %** | 92 | 93 | 91 | 91 | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | |
| **Fines % (Silt+Clay)** | 8 | 7 | 9 | 9 | | | | | | | |
| **D60 mm** | 0.220 | 0.220 | 0.220 | 0.220 | | | | | | | |
| **D30 mm** | 0.150 | 0.170 | 0.150 | 0.150 | | | | | | | |
| **D10 mm** | 0.080 | 0.090 | 0.078 | 0.078 | | | | | | | |
| **Cu** | 2.75 | 2.44 | 2.82 | 2.821 | | | | | | | |
| **Cc** | 1.28 | 1.46 | 1.31 | 1.311 | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | |

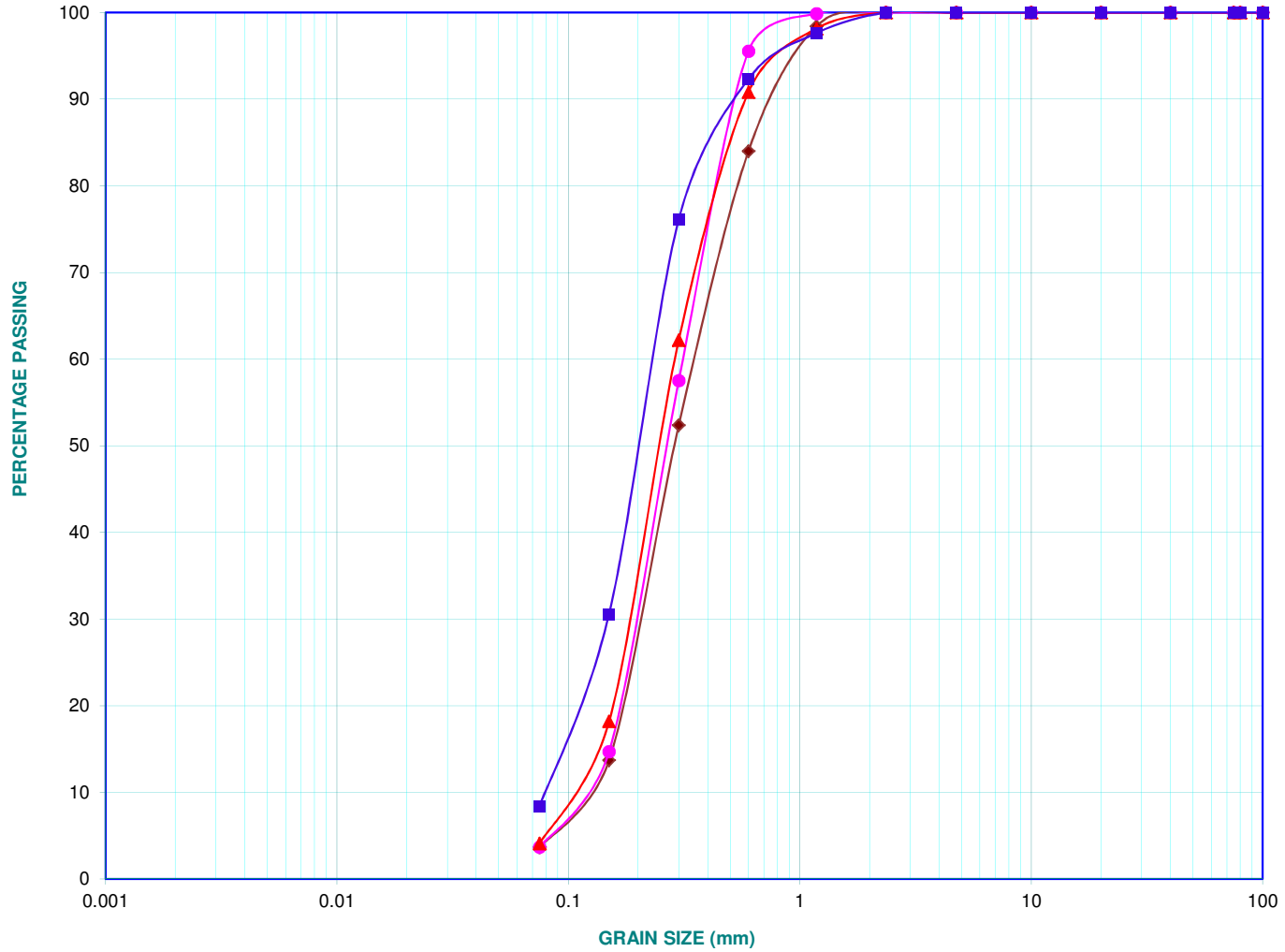



Checked By :

# GRAIN SIZE ANALYSIS

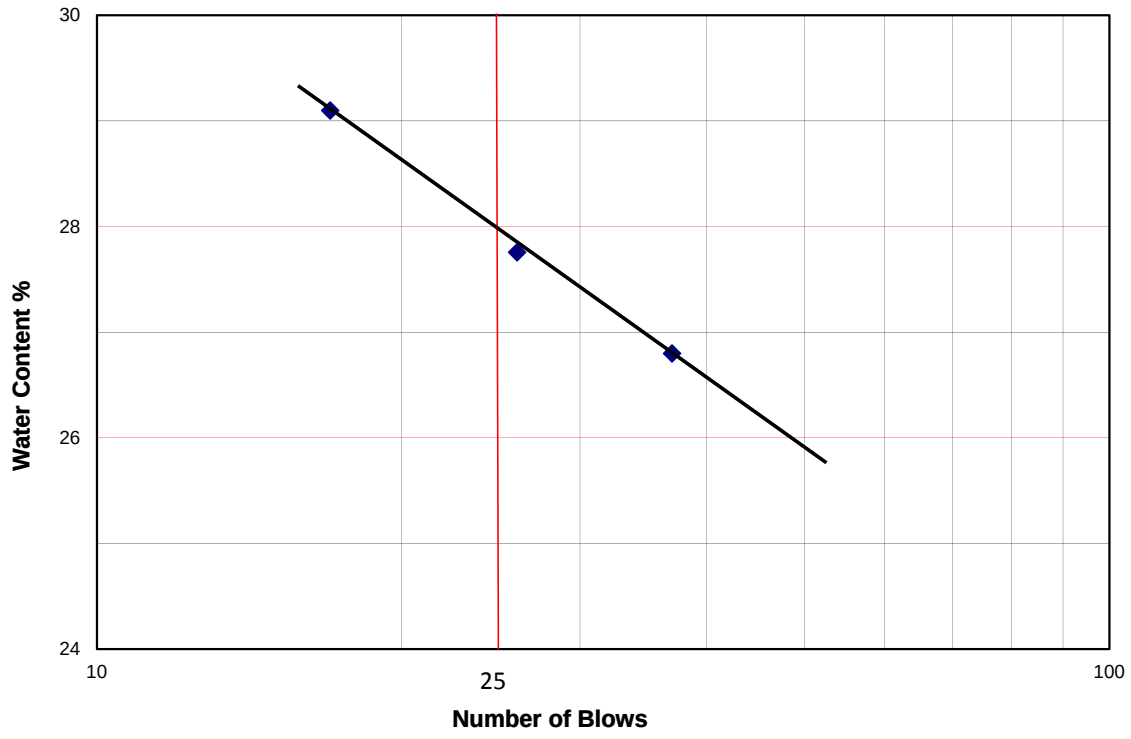
| | |
|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-09** |
| **Date :** | **7-Jun-19** |

| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-09 | MBH-09 | MBH-09 | MBH-09 | | | | | | | | |
| **Depth (m)** | 30.00-30.20 | 32.00-32.15 | 36.50-36.70 | 40.00-40.15 | | | | | | | | |
| **Sample Type** | SPT-21 | SPT-22 | SPT-25 | SPT-27 | | | | | | | | |
| **Classification** | SP | SP | SP | SP-SM | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 96 | 96 | 96 | 92 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 4 | 4 | 4 | 8 | | | | | | | | |
| **D60 mm** | 0.350 | 0.300 | 0.290 | 0.220 | | | | | | | | |
| **D30 mm** | 0.200 | 0.200 | 0.190 | 0.150 | | | | | | | | |
| **D10 mm** | 0.130 | 0.120 | 0.110 | 0.080 | | | | | | | | |
| **Cu** | 2.69 | 2.50 | 2.64 | 2.75 | | | | | | | | |
| **Cc** | 0.88 | 1.11 | 1.13 | 1.28 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |




Checked By :

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 32.39 | 36.83 | 33.81 | | |
| Dry Weight + Can (g) | 27.99 | 31.69 | 29.14 | | |
| Can Weight (g) | 11.57 | 13.17 | 13.09 | | |
| Water Content, % | 26.8 | 27.8 | 29.1 | | |
| Number of Blows | 37 | 26 | 17 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 20.35 | 18.28 | 15.31 |
| Dry Weight + Can (g) | 19.11 | 17.23 | 14.63 |
| Can Weight (g) | 9.51 | 9.22 | 9.24 |
| Water Content, % | 12.9 | 13.1 | 12.6 |

| | |
|---|---|
| Liquid Limit % | 28.0 |
| Plastic Limit % | 12.9 |
| Plasticity Index % | 15.1 |

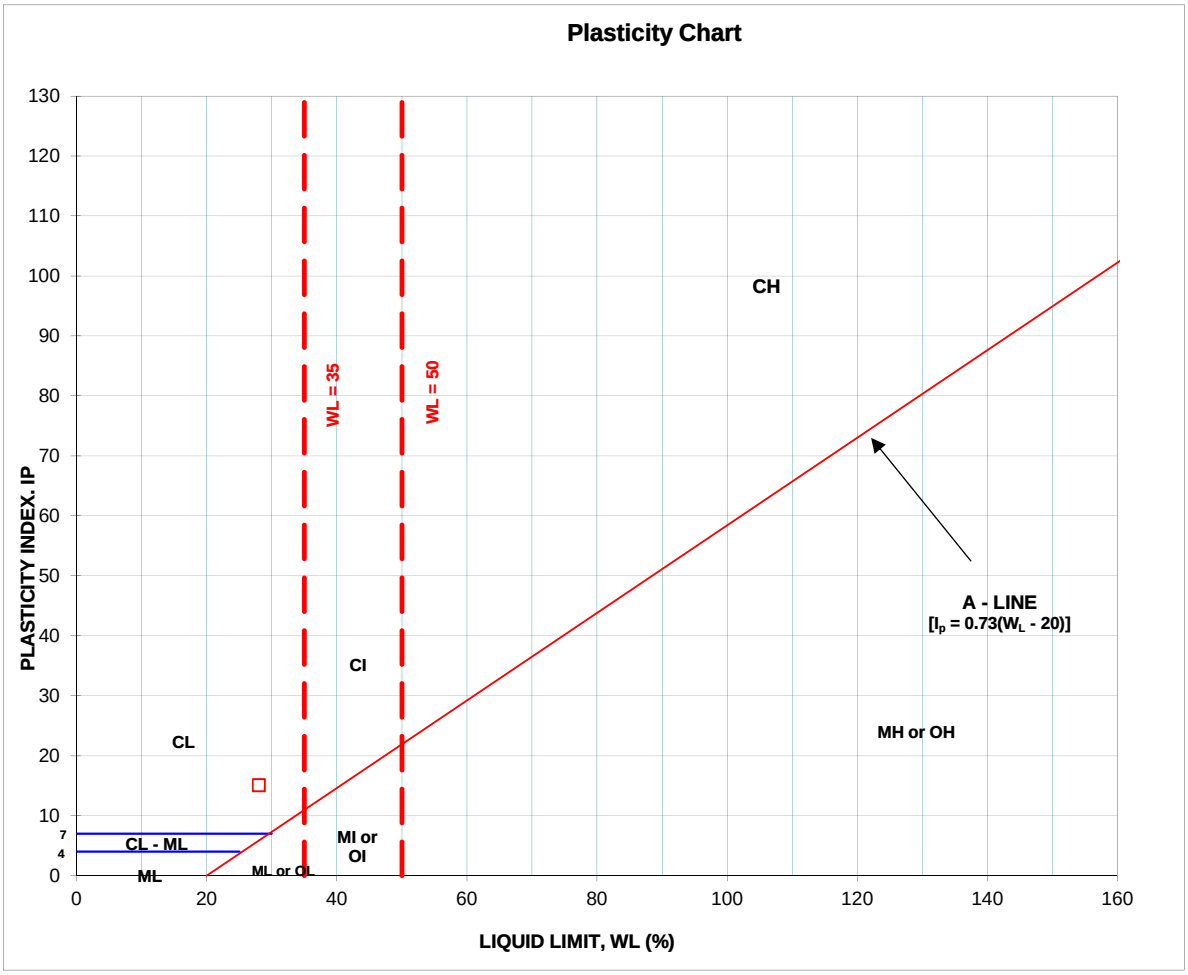
Preparation of Sample :
Dry State

Sample Type: SPT-11

Borehole no.: MBH-9

Depth :15.00-15.45

Project: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.




| | Sample Type | Depth (m) | $W_L$ | $W_P$ | $I_P$ | Remarks |
|---|---|---|---|---|---|---|
| □ | SPT-11 | 15.00-15.45 | 28.0 | 12.9 | 15.1 | CL: Inorganic clays of low to medium plasticity. |
| ◇ | | | | | | |
| △ | | | | | | |
| ● | | | | | | |
| + | | | | | | |
| ■ | | | | | | |

| | | | |
|---|---|---|---|
| ML | Inorganic silts, very fine sands, rock flour, silty or clayey fine sands | MH | Inorganic silts, or diatomaceous fine sands or silts, elastic silts |
| CL | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays | CH | Inorganic clays of high plasticity, fat clays |
| OL | Organic silts and organic silty clays of low plasticity | OH | Organic silts and organic clays of medium t high plasticity |
| CI | Clays with Intermediate plasticity | MI | Silt with intermediate plasticity |

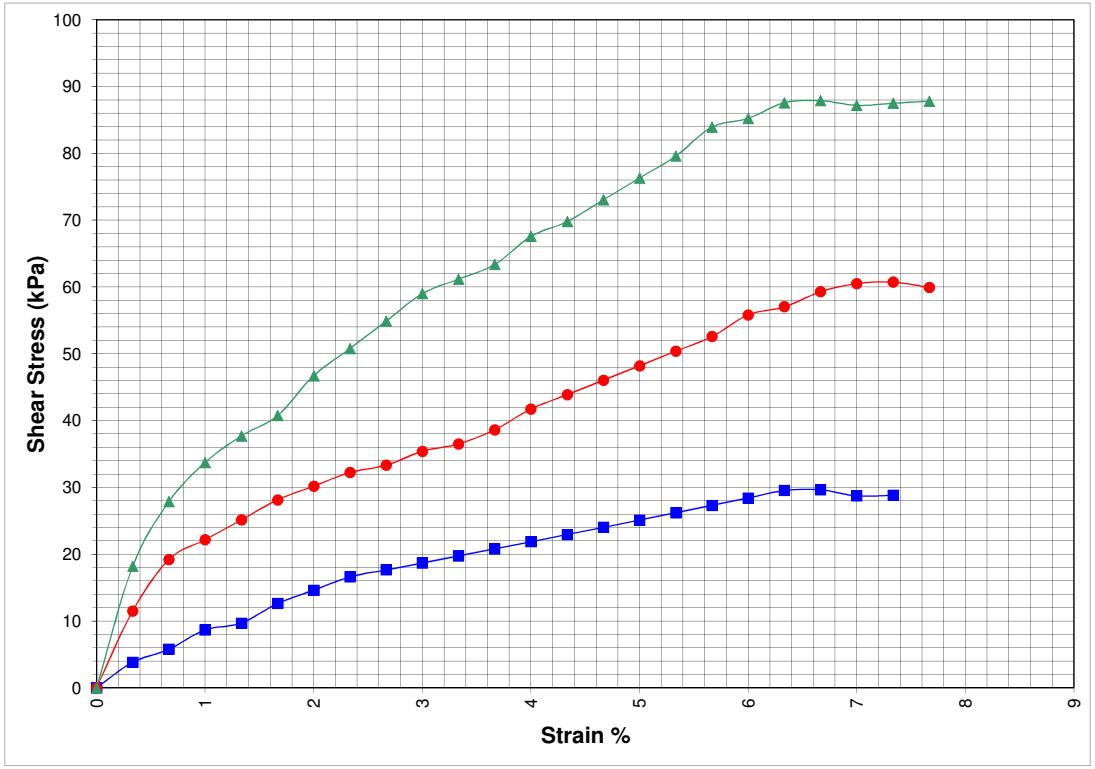
## PLASTICITY CHART (IS : 1498 - 1987)

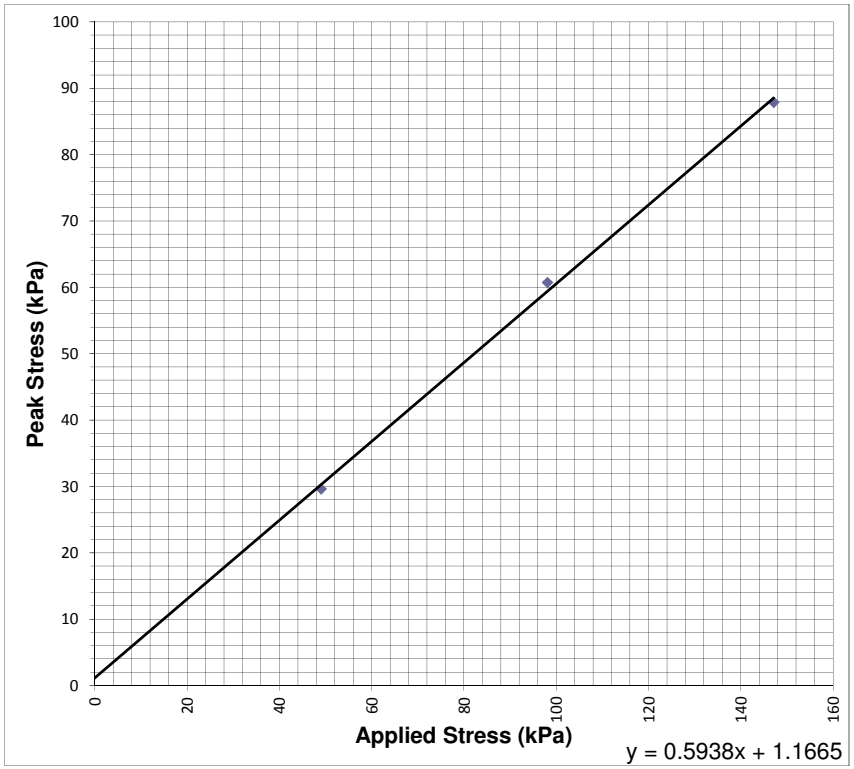
BOREHOLE NAME : MBH-9

**Project: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 30 |
| | Stage 2 | 98 | 61 |
| | Stage 3 | 147 | 88 |

| | | |
|---|---|---|
| Angle of Friction | **30.70** | ° |
| Apparent Cohesion | **1.17** | kPa |

k

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

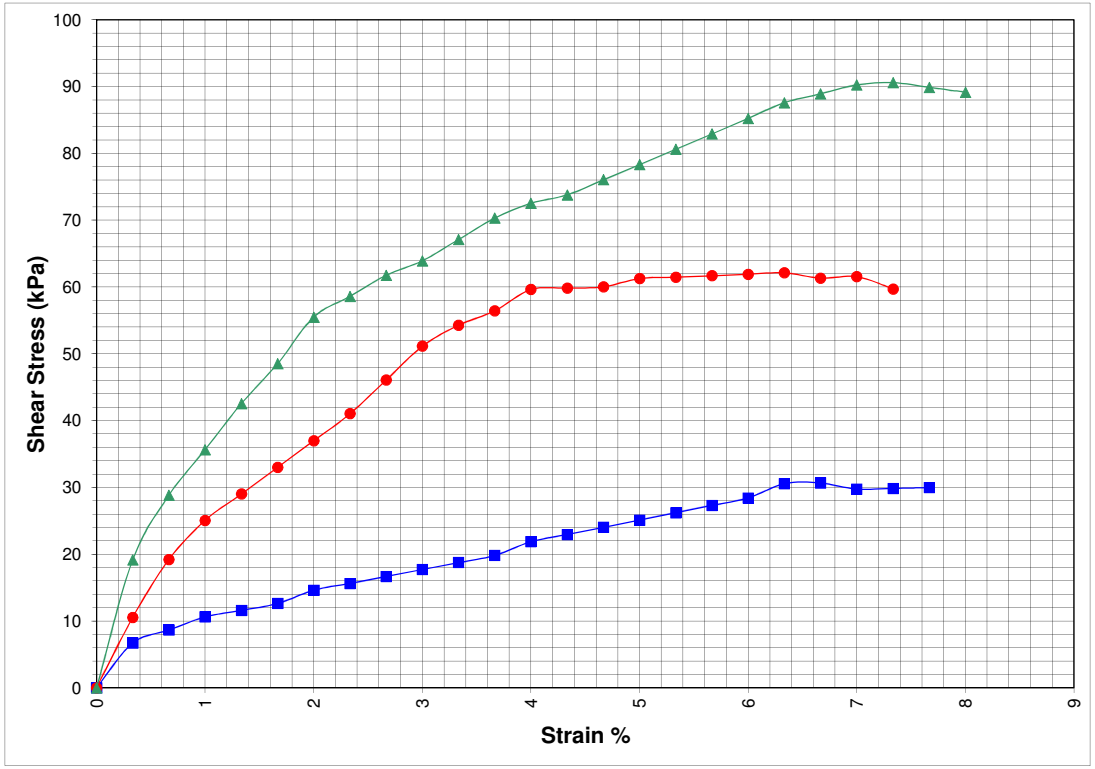
**Borehole: MBH-09**

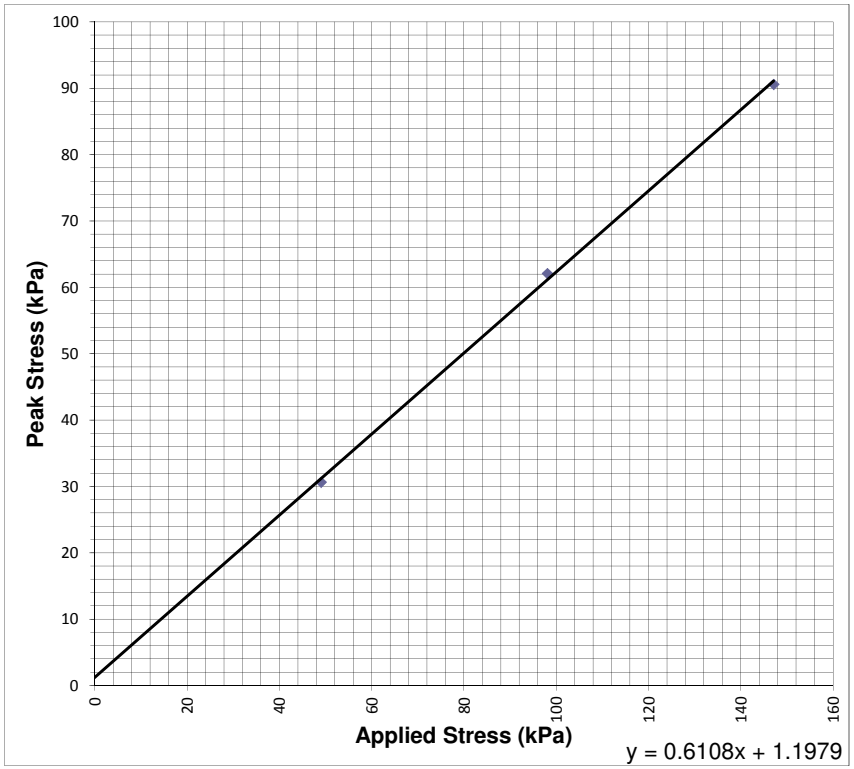
**Sample Type: SPT-03**

**Depth: 3.00-3.30 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 31 |
| | Stage 2 | 98 | 62 |
| | Stage 3 | 147 | 91 |

| | | |
|---|---|---|
| Angle of Friction | **31.42** | ° |
| Apparent Cohesion | **1.20** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

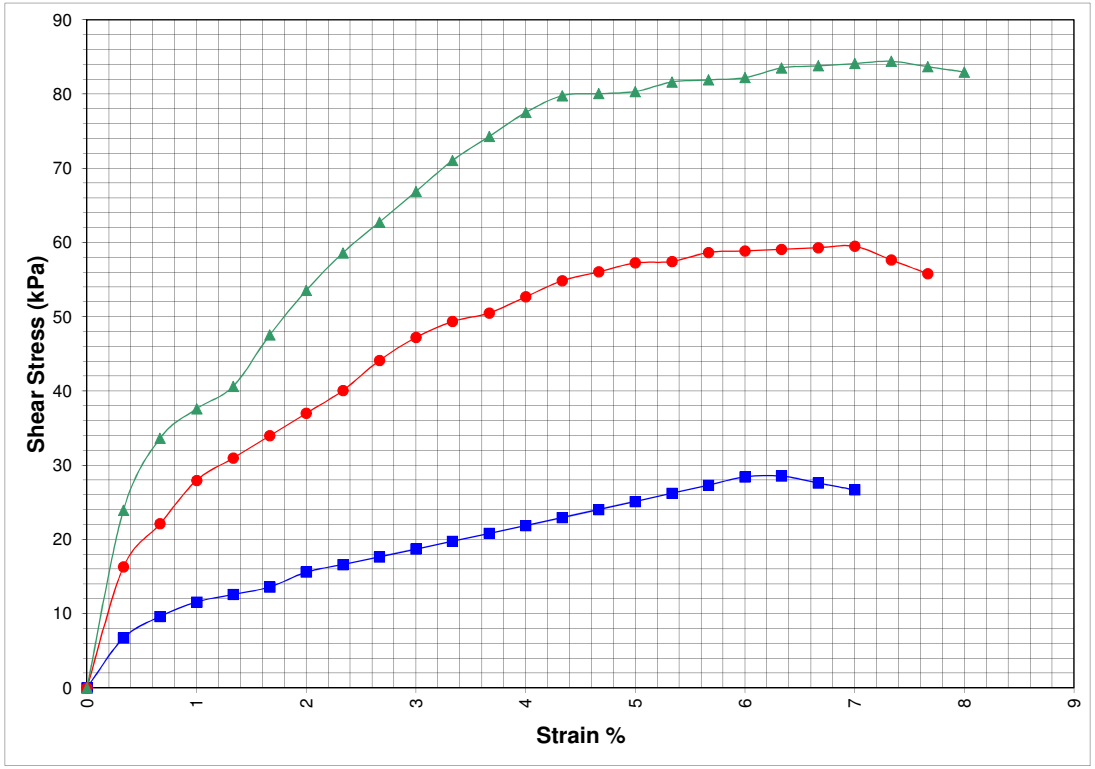
**Borehole: MBH-09**

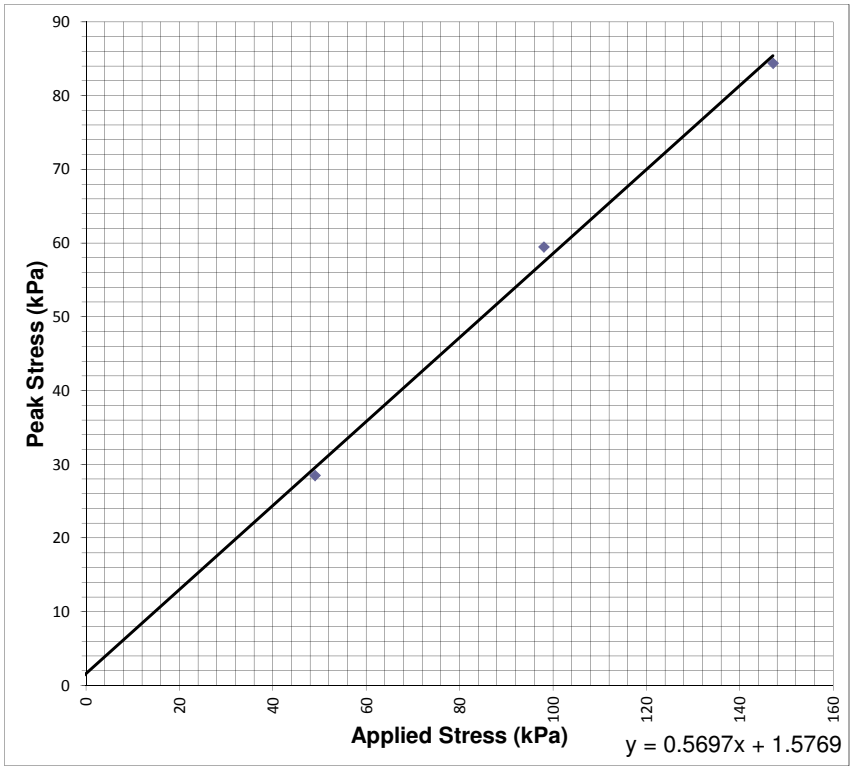
**Sample Type: SPT-06**

**Depth: 7.50-7.70 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 29 |
| | Stage 2 | 98 | 59 |
| | Stage 3 | 147 | 84 |

| | | |
|---|---|---|
| Angle of Friction | **29.67** | ° |
| Apparent Cohesion | **1.58** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

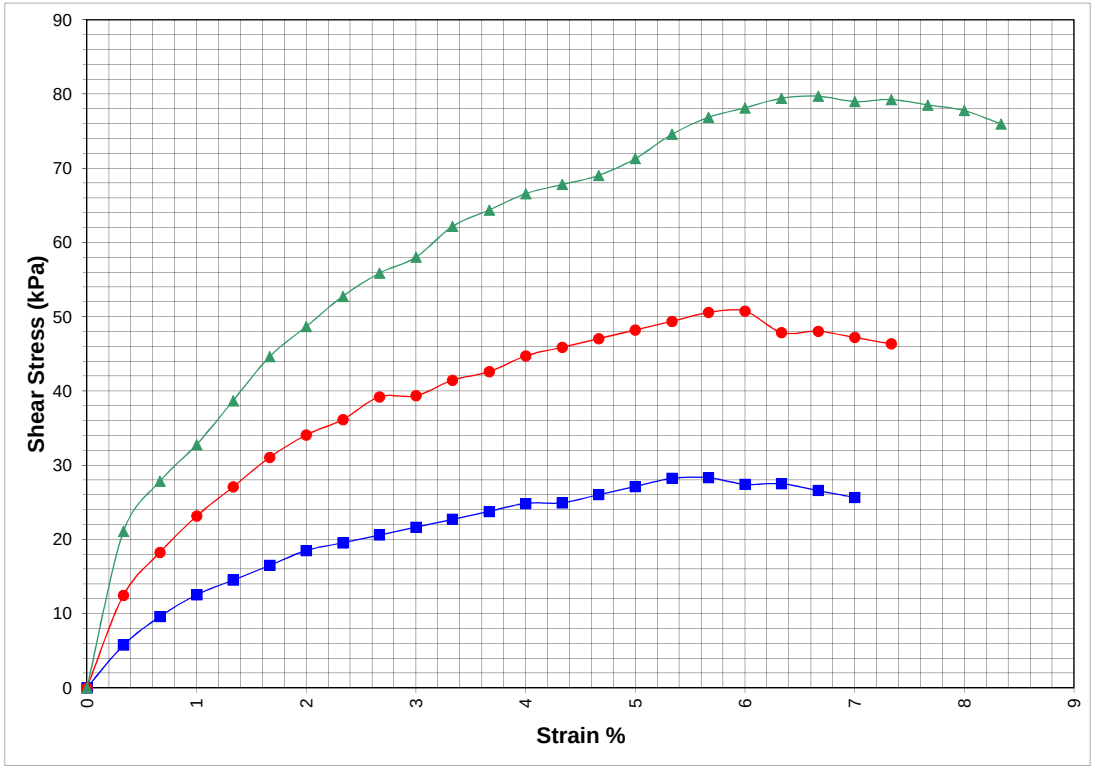
**Borehole: MBH-09**

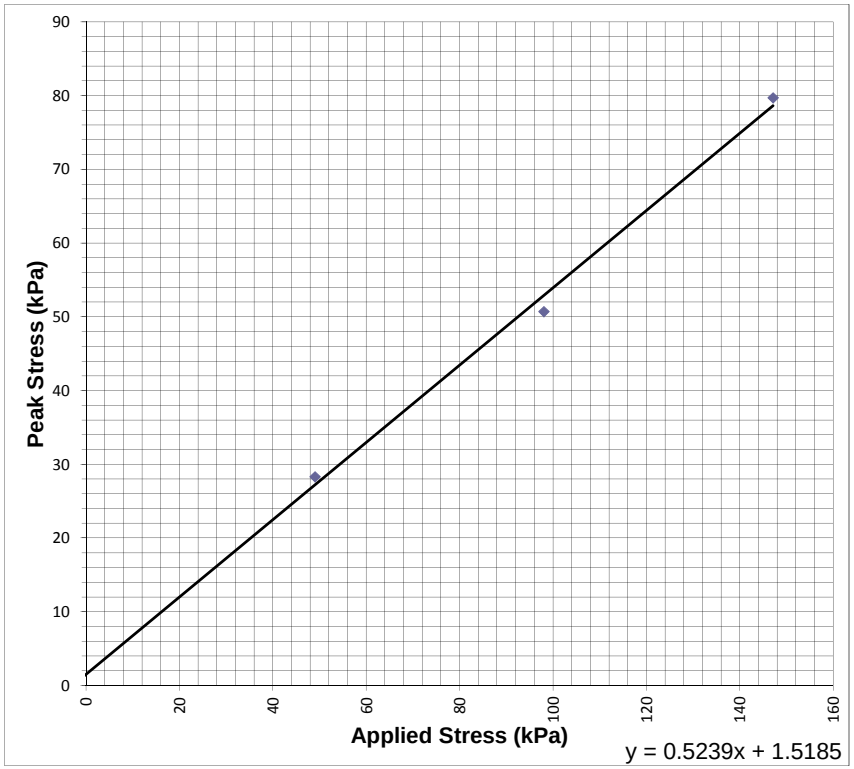
**Sample Type: SPT-09**

**Depth: 12.00-12.30 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 51 |
| | Stage 3 | 147 | 80 |

| | | |
|---|---|---|
| Angle of Friction | **27.65** | ° |
| Apparent Cohesion | **1.52** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

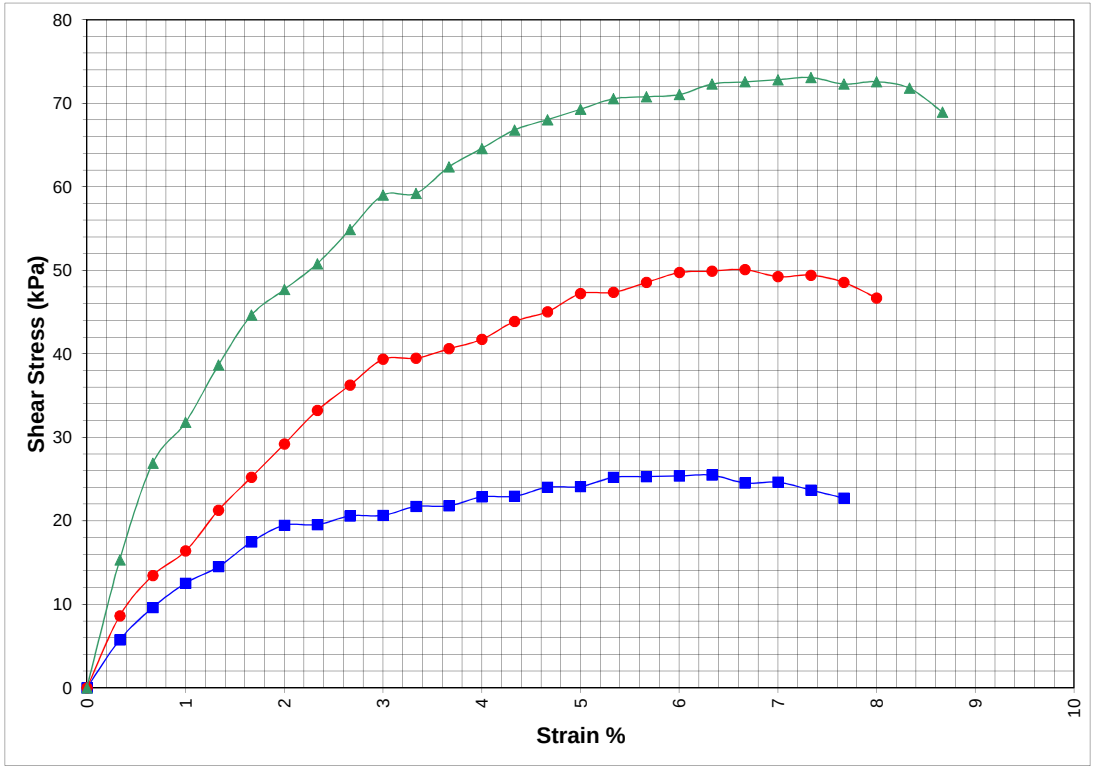
**Borehole: MBH-09**

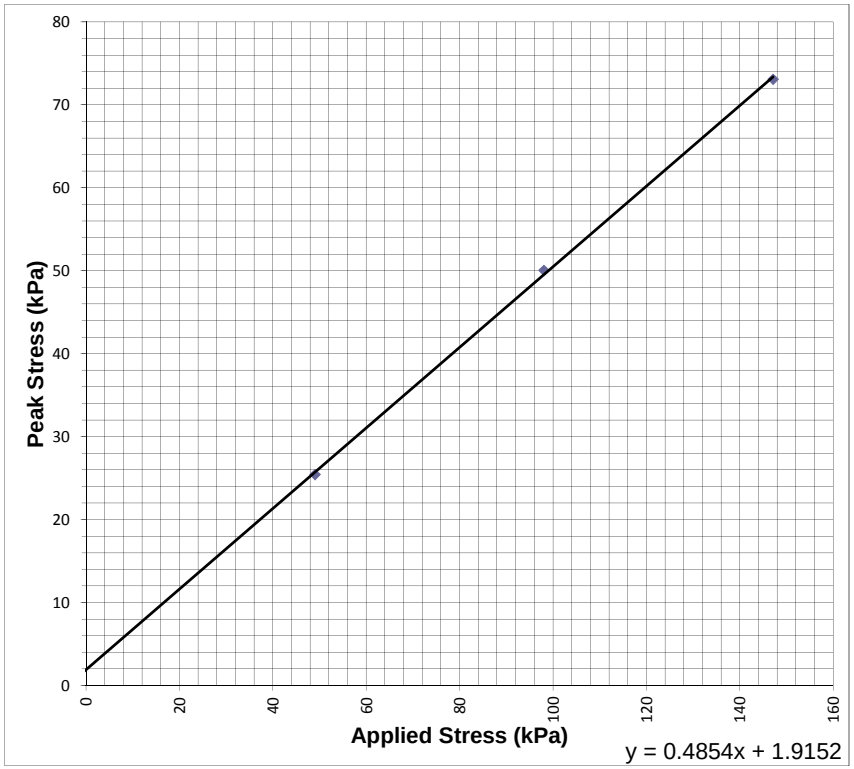
**Sample Type: SPT-14**

**Depth: 19.50-19.70 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 25 |
| | Stage 2 | 98 | 50 |
| | Stage 3 | 147 | 73 |

| | | |
|---|---|---|
| Angle of Friction | **25.89** | ° |
| Apparent Cohesion | **1.92** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

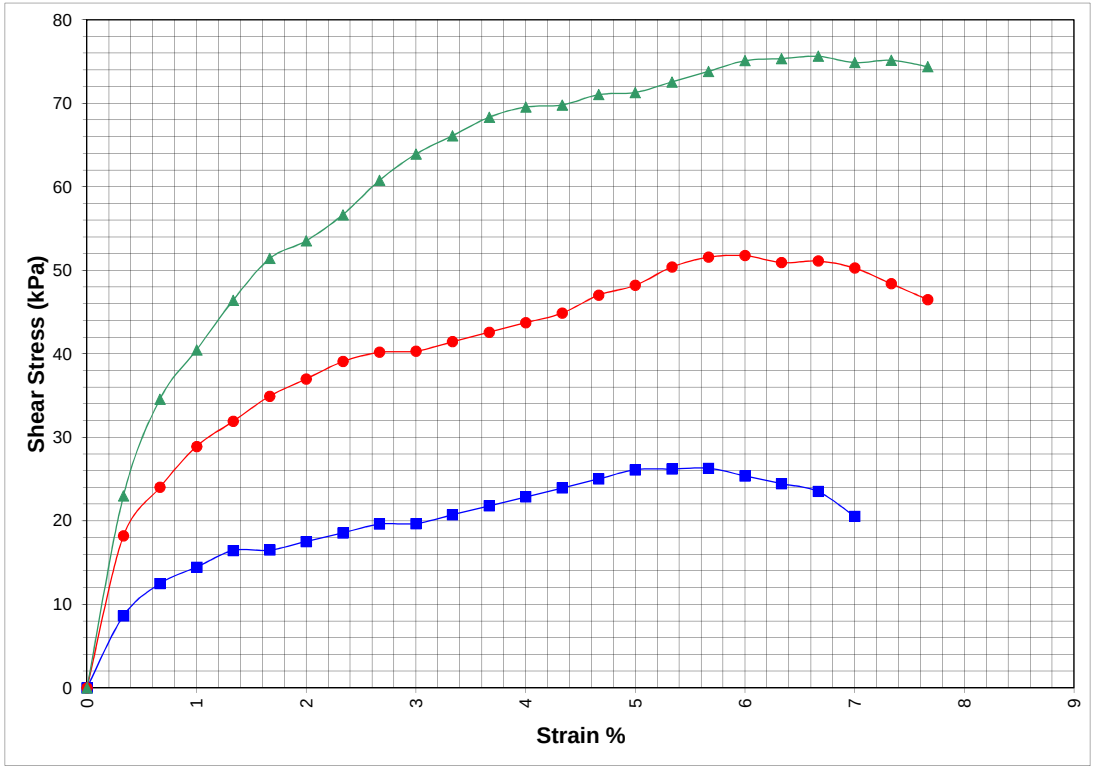
**Borehole: MBH-09**

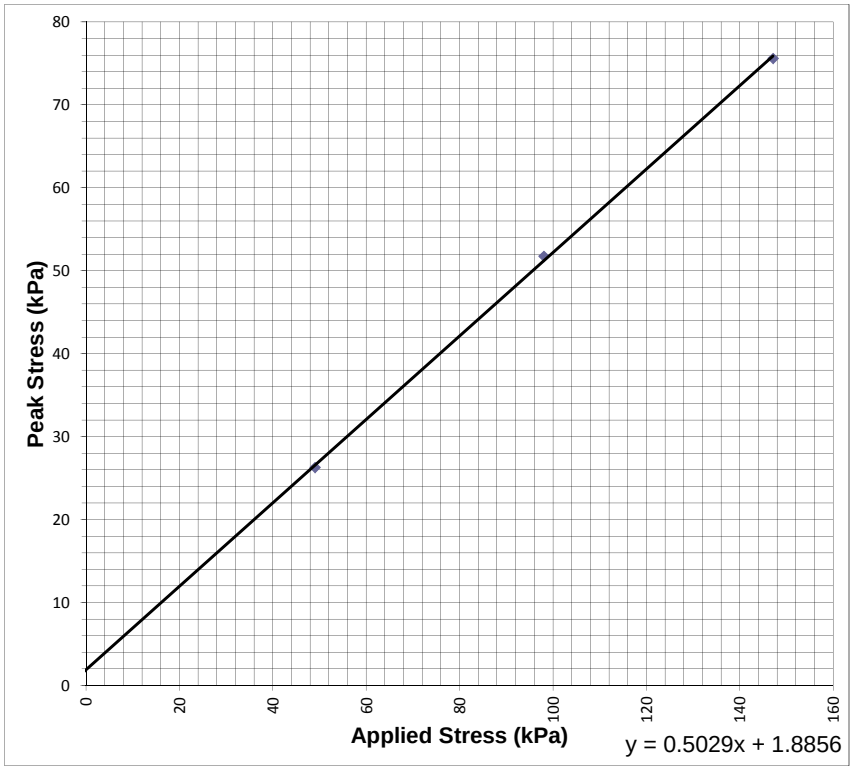
**Sample Type: SPT-16**

**Depth: 22.50-22.70 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 52 |
| | Stage 3 | 147 | 76 |

| | | |
|---|---|---|
| Angle of Friction | **26.70** | ° |
| Apparent Cohesion | **1.89** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

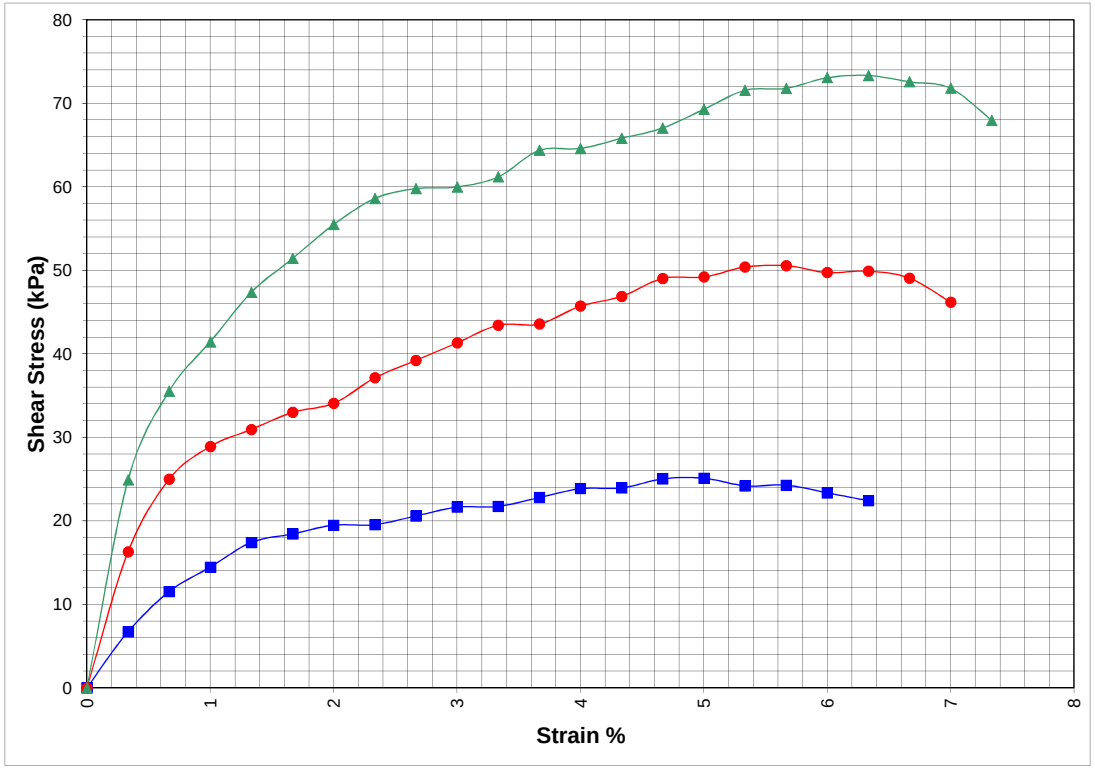
**Borehole: MBH-09**

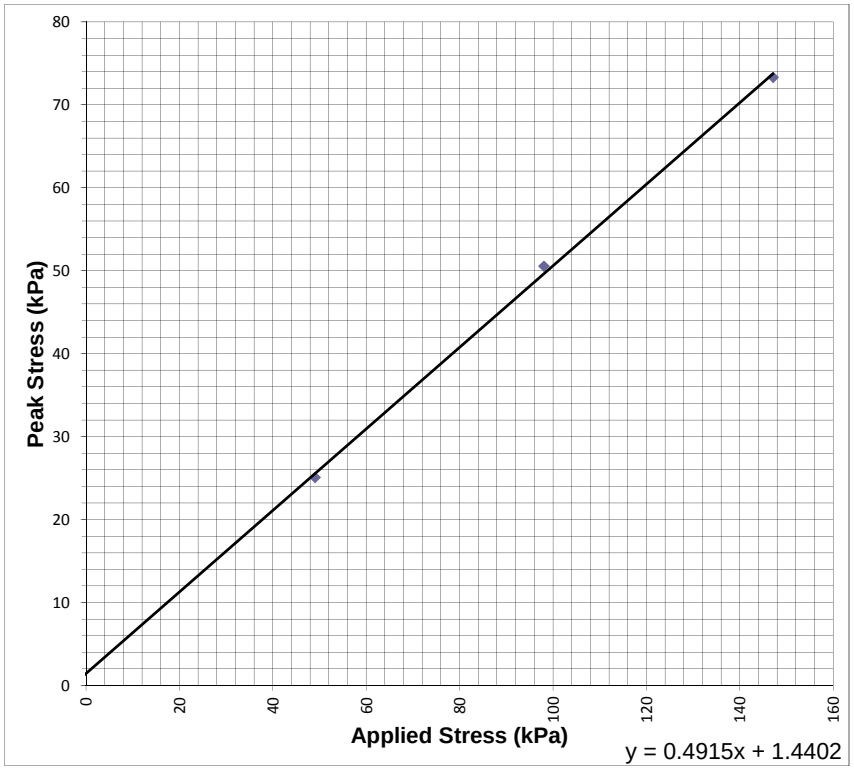
**Sample Type: SPT-20**

**Depth: 28.50-28.80 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 25 |
| | Stage 2 | 98 | 51 |
| | Stage 3 | 147 | 73 |

| | | |
|---|---|---|
| Angle of Friction | **26.17** | ° |
| Apparent Cohesion | **1.44** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

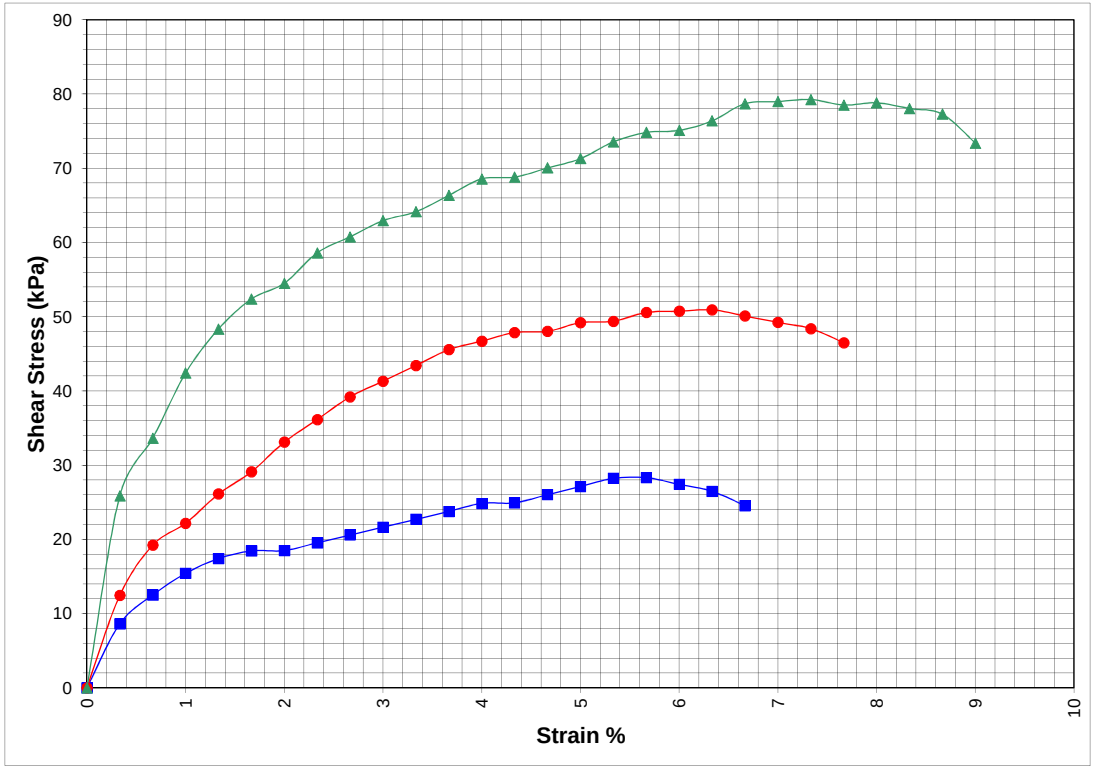
**Borehole: MBH-09**

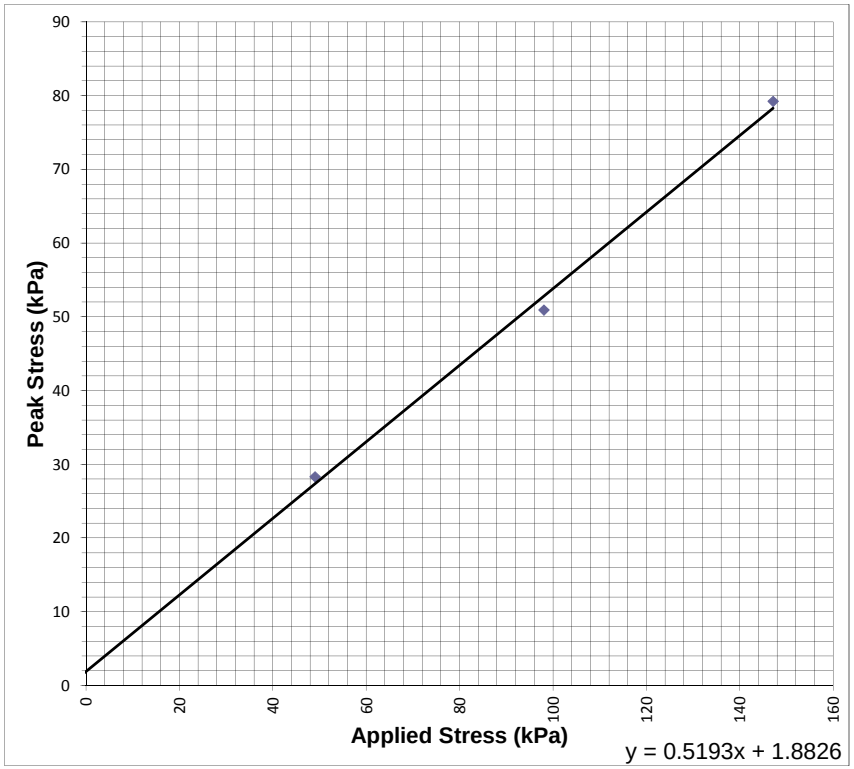
**Sample Type: SPT-23**

**Depth: 33.50-33.70 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 51 |
| | Stage 3 | 147 | 79 |

| | | |
|---|---|---|
| Angle of Friction | **27.44** | ° |
| Apparent Cohesion | **1.88** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: MBH-09**

**Sample Type: SPT-26**

**Depth: 38.00-38.25 m**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-1 | 0.00-0.30 | SP-SM | | | | 18.7 | 18.50 | 8.44 | 15.58 | 2.61 | 0 | 93 | <--> | <--> | 7 | | | | | | | | | | | | | | | | | | |
| SPT-2 | 1.50-1.80 | SP-SM | | | | 17.1 | 19.23 | 9.17 | 16.42 | 2.64 | 0 | 89 | <--> | <--> | 11 | | | | | | | | | | | | | | | | | | |
| SPT-3 | 3.00-3.15 | | | | | 16.0 | 17.47 | 7.41 | 15.05 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-4 | 4.50-4.62 | | | | | 17.9 | 17.38 | 7.32 | 14.74 | 2.65 | | | | | | | | | | | | | | | | | | | | | | |
| SPT-5 | 6.00-6.28 | | | | | 22.0 | 17.77 | 7.71 | 14.56 | | | | | | | DST | | | 2.38 | 28.6 | | | | | | | | | | | | |
| SPT-6 | 7.50-7.70 | SM / SC | | | | 18.6 | 18.72 | 8.66 | 15.79 | | 0 | 87 | <--> | <--> | 13 | | | | | | | | | | | | | | | | | | |
| SPT-7 | 9.00-9.25 | SM / SC | | | | 22.0 | 18.36 | 8.30 | 15.05 | 2.60 | 0 | 83 | <--> | <--> | 17 | | | | | | | | | | | | | | | | | | |
| SPT-8 | 10.50-10.80 | | | | | 19.5 | 17.76 | 7.70 | 14.86 | | | | | | | DST | | | 1.56 | 29.3 | | | | | | | | | | | | |
| SPT-9 | 12.00-12.25 | SP-SM | | | | 19.1 | 17.76 | 7.70 | 14.92 | | 0 | 91 | <--> | <--> | 9 | | | | | | | | | | | | | | | | | | |
| SPT-10 | 13.50-13.95 | | | | | 18.8 | 19.19 | 9.13 | 16.15 | 2.63 | | | | | | DST | | | 1.58 | 28.7 | | | | | | | | | | | | |
| SPT-11 | 15.00-15.45 | SP-SM | | | | 14.5 | 18.90 | 8.84 | 16.50 | | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | | 8.45 | 0.70 | 1.00 | 1000 | 7080 |
| SPT-12 | 16.50-16.95 | | | | | 14.8 | 19.16 | 9.10 | 16.69 | | | | | | | DST | | | 1.44 | 27.5 | | | | | | | | | | | | |
| SPT-13 | 18.00-18.45 | SP-SM | | | | 16.0 | 17.43 | 7.37 | 15.03 | | 0 | 93 | <--> | <--> | 7 | | | | | | | | | | | | | | | | | | |
| SPT-14 | 19.50-19.80 | | | | | 19.2 | 18.03 | 7.97 | 15.13 | 2.62 | | | | | | | | | | | | | | | | | | | | | | |
| SPT-15 | 21.00-21.30 | SP-SM | | | | 18.6 | 17.52 | 7.46 | 14.76 | | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | | 8.60 | 0.40 | 1.00 | 1500 | 10620 |
| SPT-16 | 22.50-22.80 | | | | | 19.7 | 19.59 | 9.53 | 16.36 | 2.61 | | | | | | DST | | | 2.12 | 26.4 | | | | | | | | | | | | |
| SPT-17 | 24.00-24.30 | SP-SM | | | | 20.6 | 18.43 | 8.37 | 15.28 | | 0 | 90 | <--> | <--> | 10 | | | | | | | | | | | | | | | | | | |
| SPT-18 | 25.50-25.75 | | | | | 20.1 | 18.88 | 8.82 | 15.72 | 2.62 | | | | | | | | | | | | | | | | | | | | | | |
| SPT-19 | 27.00-27.20 | | | | | 17.7 | 18.85 | 8.79 | 16.02 | | | | | | | DST | | | 2.05 | 29.4 | | | | | | | | | | | | |
| SPT-20 | 28.50-28.80 | SP-SM | | | | 15.7 | 18.73 | 8.67 | 16.19 | | 0 | 91 | <--> | <--> | 9 | | | | | | | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

\# : Decayed Wood

**Failure Type**

A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-10**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density ($kN/m^3$) | Submerged Unit Weight ($kN/m^3$) | Dry Density ($kN/m^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-21 | 30.00-30.40 | SP | | | | 14.2 | 17.91 | 7.85 | 15.68 | 2.65 | 0 | 96 | <--> | <--> | 4 | | | | | | | | | | | | | | | | | | |
| SPT-22 | 31.50-31.70 | | | | | 14.7 | 17.56 | 7.50 | 15.31 | | | | | | | DST | | | 1.48 | 30.3 | | | | | | | | | | | | |
| SPT-23 | 33.00-33.30 | SP | | | | 15.5 | 18.06 | 8.00 | 15.64 | | 0 | 96 | <--> | <--> | 4 | | | | | | | | | | | | | | | | | | |
| SPT-24 | 34.50-34.80 | | | | | 16.9 | 18.17 | 8.11 | 15.54 | | | | | | | DST | | | 1.21 | 30.6 | | | | | | | | | | | | |
| SPT-25 | 36.00-36.20 | SP-SM | | | | 16.7 | 18.10 | 8.04 | 15.51 | 2.62 | 0 | 91 | <--> | <--> | 9 | | | | | | | | | | | | | | | | | | |
| SPT-26 | 37.50-37.65 | | | | | 16.6 | 18.28 | 8.22 | 15.68 | | | | | | | DST | | | 1.55 | 29.4 | | | | | | | | | | | | |
| SPT-27 | 39.00-39.35 | SP-SM | | | | 15.9 | 18.25 | 8.19 | 15.75 | | 0 | 92 | <--> | <--> | 8 | | | | | | | | | | | | | | | | | | |
| SPT-28 | 40.00- 40.25 | SP-SM | | | | 16.3 | 17.32 | 7.26 | 14.89 | 2.65 | 0 | 92 | <--> | <--> | 8 | | | | | | | | | | | | | | | | | | |
| **END OF BOREHOLE** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
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NP : Non Plastic
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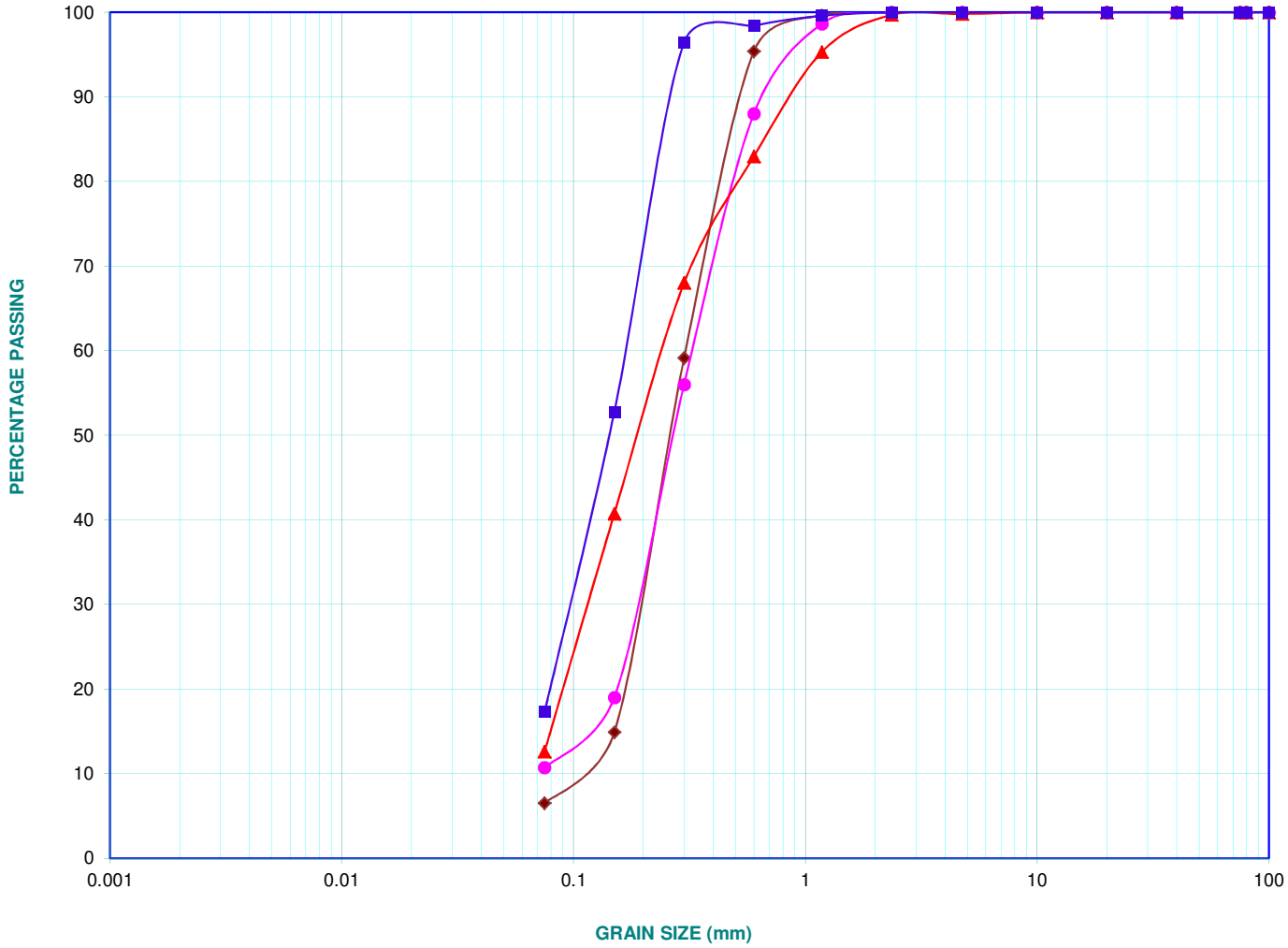
**Failure Type**

A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-10**

# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | **Borehole No.** | **: MBH-10** | | | | **Date :** | **7-Jun-19** | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | . | SAND F | SAND M | SAND C | GRAVEL F / GRAVEL C |
| **Bore Hole .** | MBH-10 | MBH-10 | MBH-10 | MBH-10 | | | | | | | |
| **Depth (m)** | 0.00-0.30 | 1.50-1.80 | 7.50-7.70 | 9.00-9.25 | | | | | | | |
| **Sample Type** | SPT-01 | SPT-02 | SPT-06 | SPT-07 | | | | | | | |
| **Classification** | SP-SM | SP-SM | SM / SC | SM / SC | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | |
| **Sand %** | 93 | 89 | 87 | 83 | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | |
| **Fines % (Silt+Clay)** | 7 | 11 | 13 | 17 | | | | | | | |
| **D60 mm** | 0.300 | 0.320 | | | | | | | | | |
| **D30 mm** | 0.199 | 0.200 | | | | | | | | | |
| **D10 mm** | 0.110 | 0.075 | | | | | | | | | |
| **Cu** | 2.73 | 4.27 | | | | | | | | | |
| **Cc** | 1.20 | 1.67 | | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | |

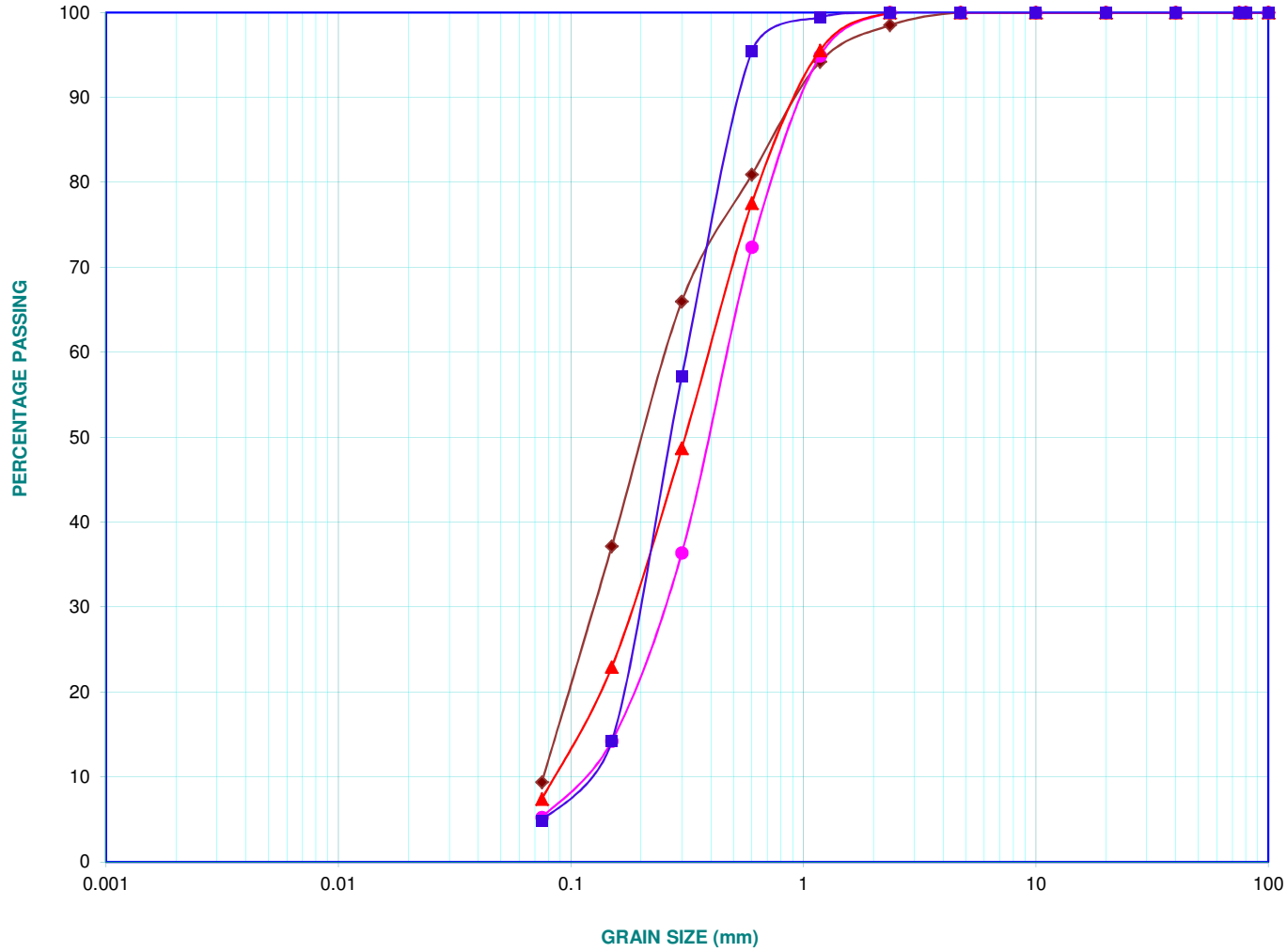



Checked By :

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-10** |
| **Date :** | **7-Jun-19** |

| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-10 | MBH-10 | MBH-10 | MBH-10 | | | | | | | | |
| **Depth (m)** | 12.00-12.25 | 15.00-15.45 | 18.00-18.45 | 21.00-21.30 | | | | | | | | |
| **Sample Type** | SPT-09 | SPT-11 | SPT-13 | SPT-15 | | | | | | | | |
| **Classification** | SP-SM | SP-SM | SP-SM | SP-SM | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 91 | 95 | 93 | 95 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 9 | 5 | 7 | 5 | | | | | | | | |
| **D60 mm** | 0.260 | 0.480 | 0.400 | 0.310 | | | | | | | | |
| **D30 mm** | 0.120 | 0.260 | 0.190 | 0.200 | | | | | | | | |
| **D10 mm** | 0.075 | 0.120 | 0.089 | 0.130 | | | | | | | | |
| **Cu** | 3.47 | 4.00 | 4.49 | 2.38 | | | | | | | | |
| **Cc** | 0.74 | 1.17 | 1.01 | 0.99 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |

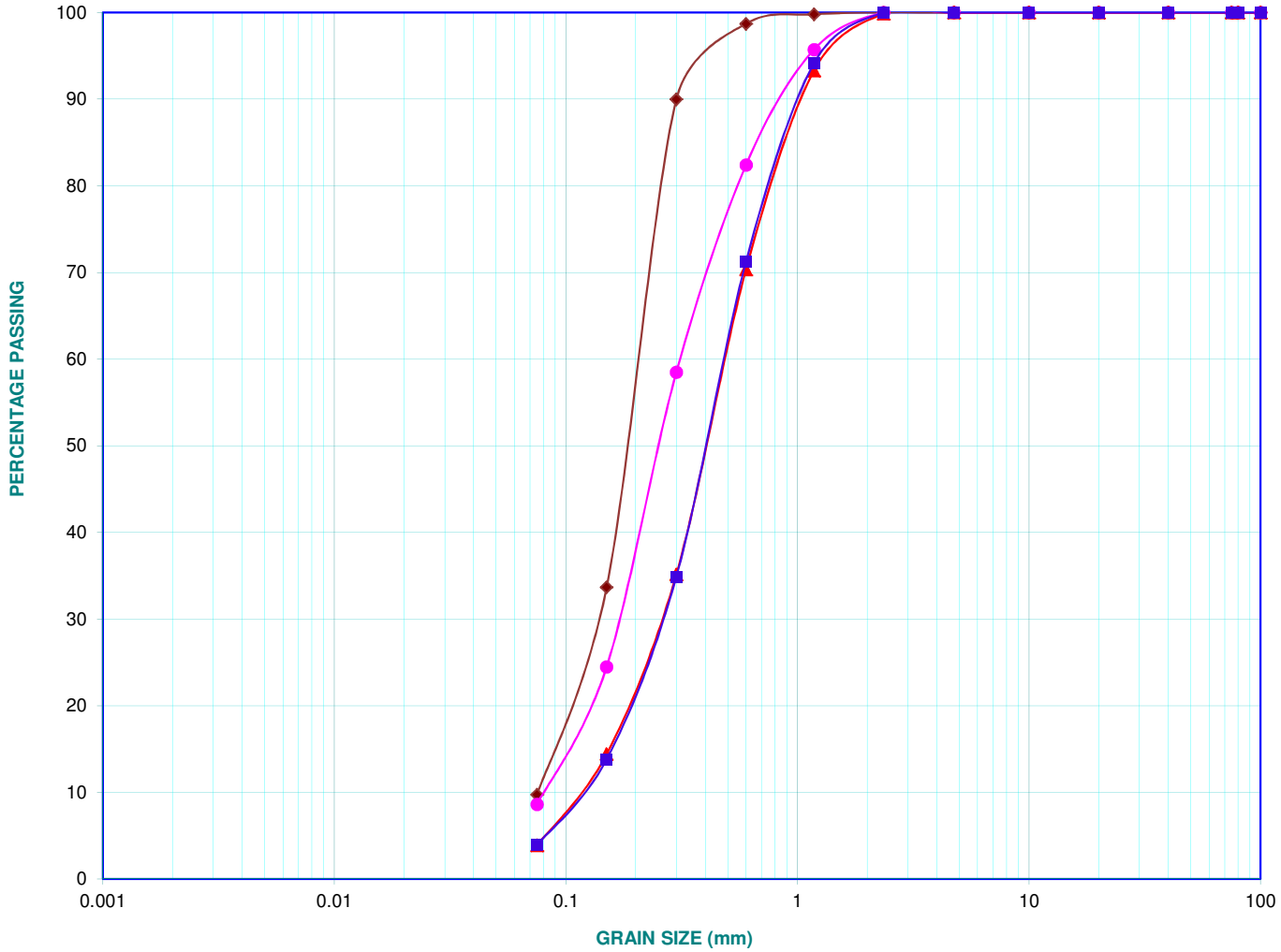



Checked By :

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-10** |
| **Date :** | **7-Jun-19** |

| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-10 | MBH-10 | MBH-10 | MBH-10 | | | | | | | | |
| **Depth (m)** | 24.00-24.30 | 28.50-28.80 | 30.00-30.40 | 33.00-33.30 | | | | | | | | |
| **Sample Type** | SPT-17 | SPT-20 | SPT-21 | SPT-23 | | | | | | | | |
| **Classification** | SP-SM | SP-SM | SP | SP | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 90 | 91 | 96 | 96 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 10 | 9 | 4 | 4 | | | | | | | | |
| **D60 mm** | 0.200 | 0.300 | 0.500 | 0.500 | | | | | | | | |
| **D30 mm** | 0.150 | 0.180 | 0.280 | 0.280 | | | | | | | | |
| **D10 mm** | 0.075 | 0.080 | 0.120 | 0.120 | | | | | | | | |
| **Cu** | 2.67 | 3.75 | 4.17 | 4.167 | | | | | | | | |
| **Cc** | 1.50 | 1.35 | 1.31 | 1.307 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |

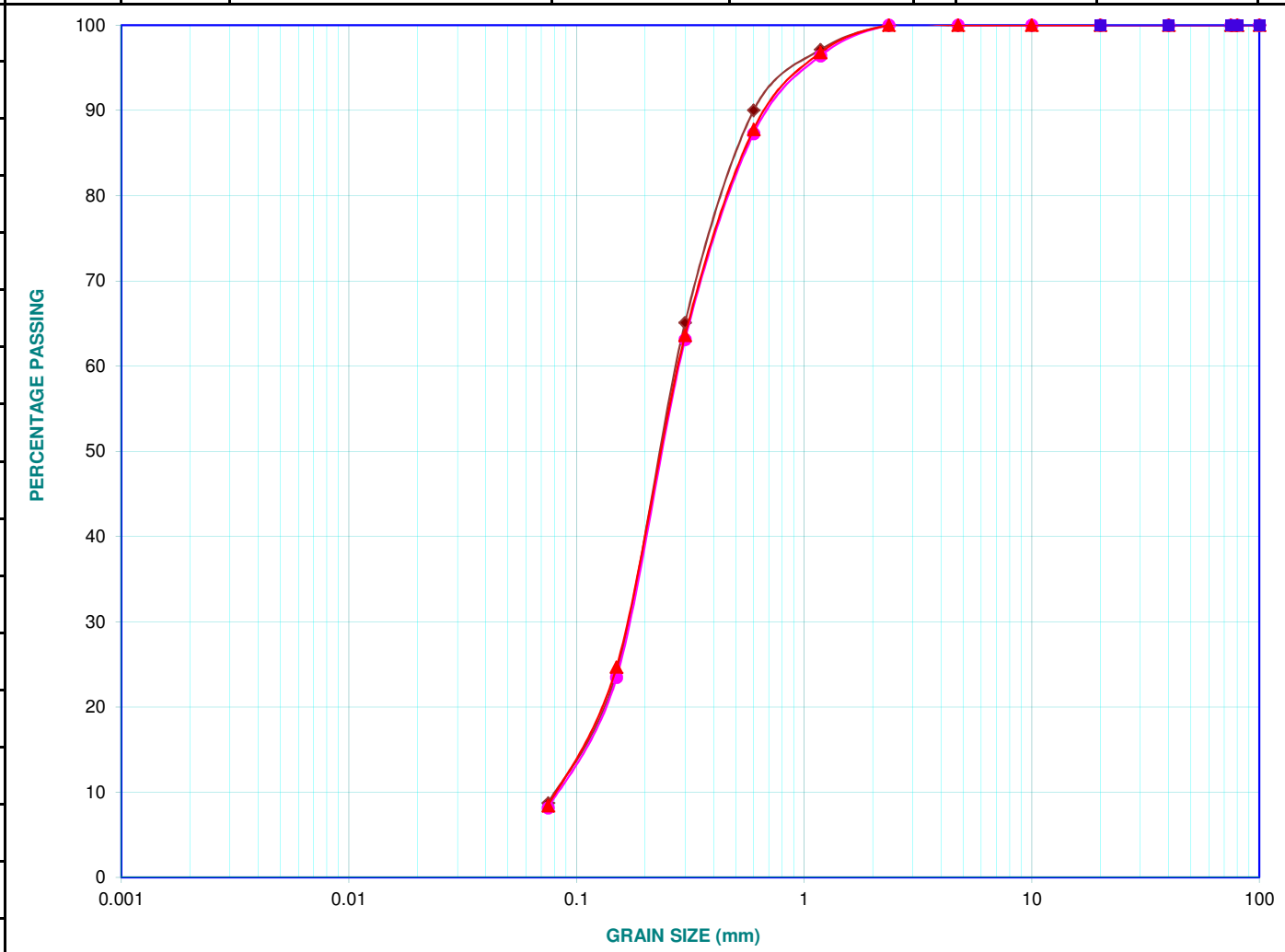



Checked By :

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-10** |
| **Date :** | **7-Jun-19** |

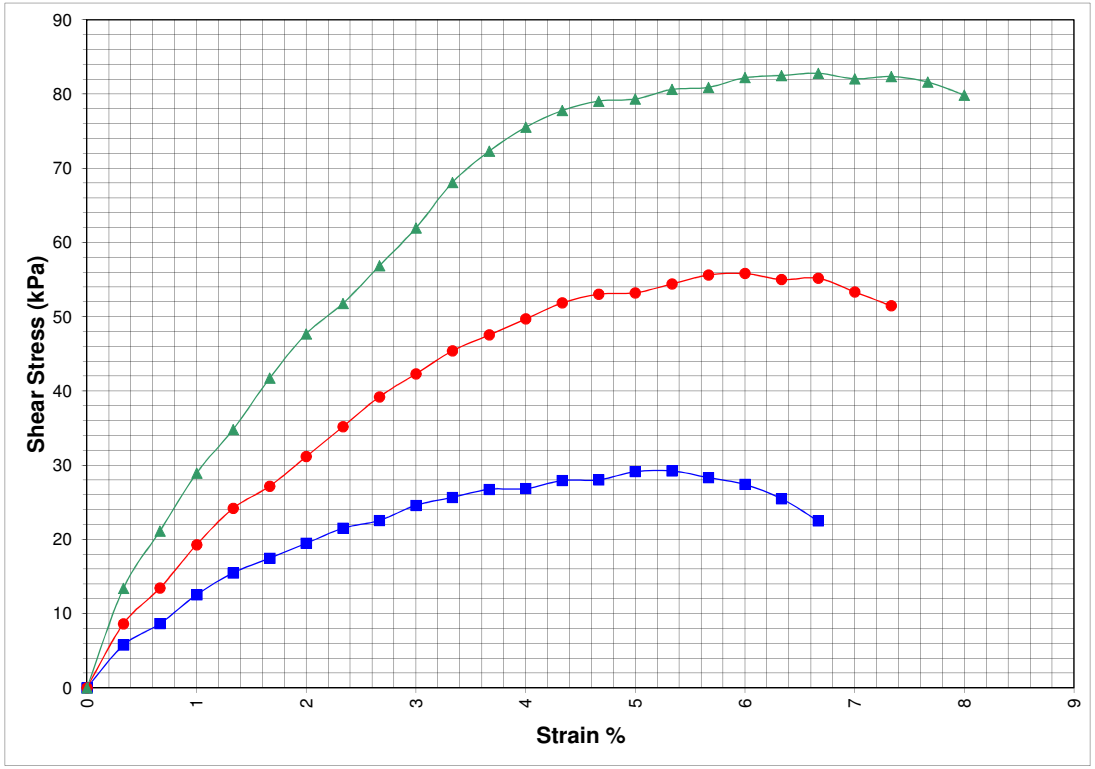
| Symbol | | | | |
|---|---|---|---|---|
| Bore Hole . | MBH-10 | MBH-10 | MBH-10 | |
| Depth (m) | 36.00-36.20 | 39.00-39.35 | 40.00-40.25 | |
| Sample Type | SPT-25 | SPT-27 | SPT-28 | |
| Classification | SP-SM | SP-SM | SP-SM | |
| Gravel % | 0 | 0 | 0 | |
| Sand % | 91 | 92 | 92 | |
| Silt % | <----> | <----> | <----> | |
| Clay % | <----> | <----> | <----> | |
| Fines % (Silt+Clay) | 9 | 8 | 8 | |
| D60 mm | 0.270 | 0.280 | 0.280 | |
| D30 mm | 0.180 | 0.180 | 0.180 | |
| D10 mm | 0.080 | 0.081 | 0.080 | |
| Cu | 3.38 | 3.46 | 3.50 | |
| Cc | 1.50 | 1.43 | 1.45 | |
| Liquid Limit % | --- | --- | --- | |
| Plastic Limit % | --- | --- | --- | |
| Plasticity Index | --- | --- | --- | |

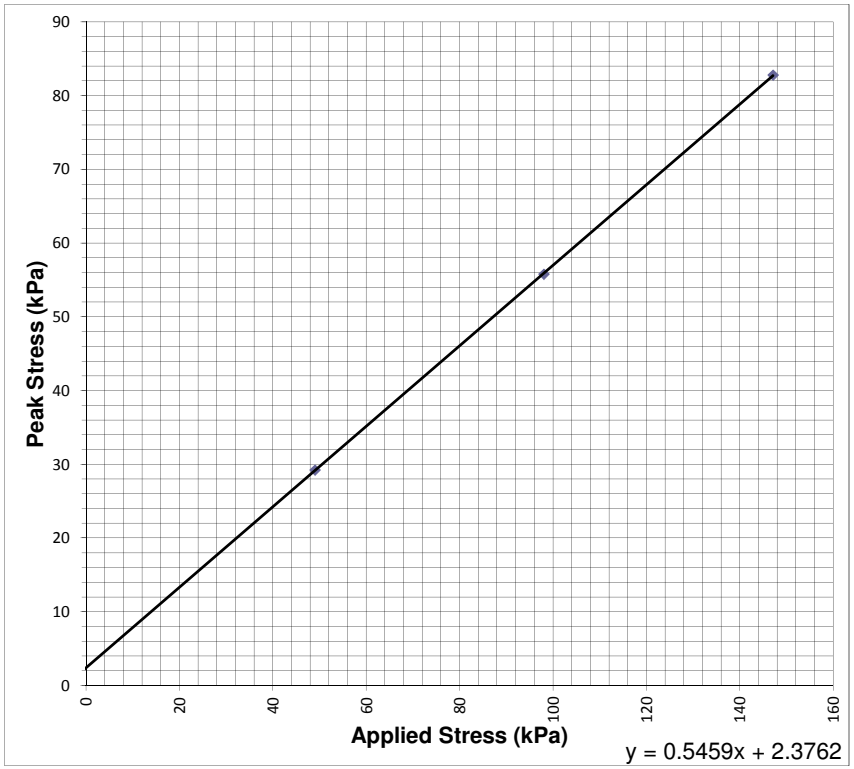



Checked By :

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 29 |
| | Stage 2 | 98 | 56 |
| | Stage 3 | 147 | 83 |

| | | |
|---|---|---|
| Angle of Friction | **28.63** | ° |
| Apparent Cohesion | **2.38** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

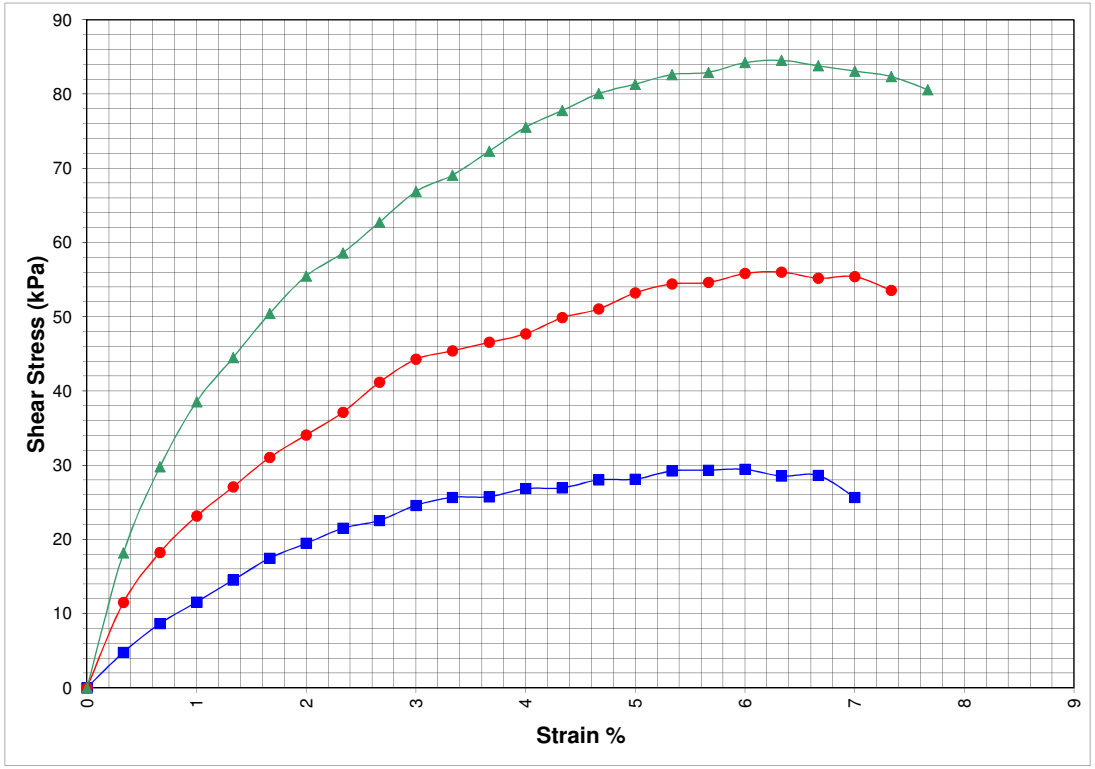
**Borehole: MBH-10**

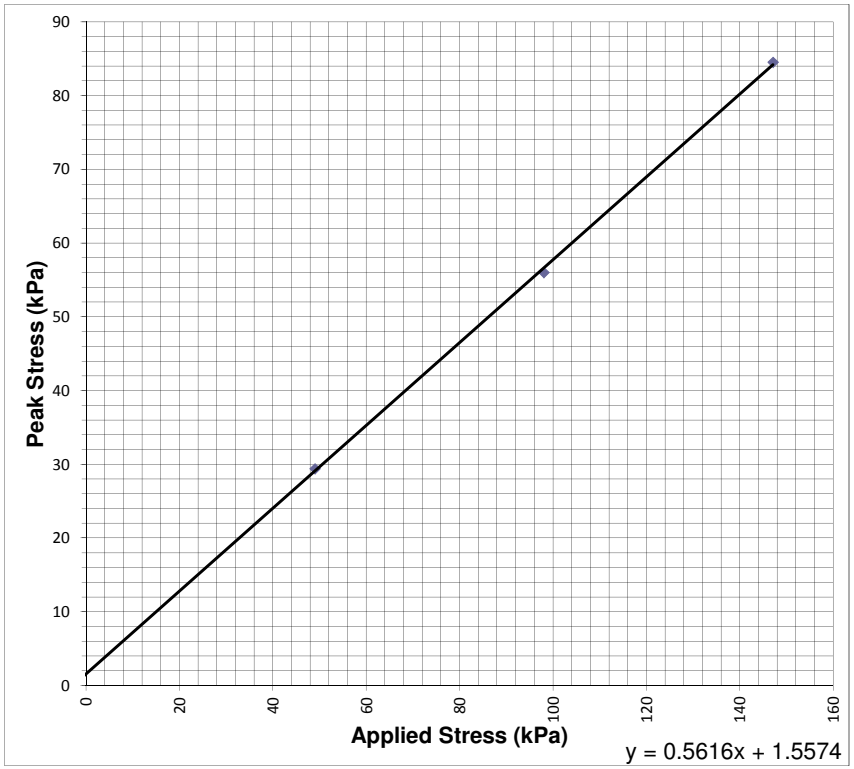
**Sample Type: SPT-05**

**Depth: 6.00-6.28 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 29 |
| | Stage 2 | 98 | 56 |
| | Stage 3 | 147 | 85 |

| | | |
|---|---|---|
| Angle of Friction | **29.32** | ° |
| Apparent Cohesion | **1.56** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

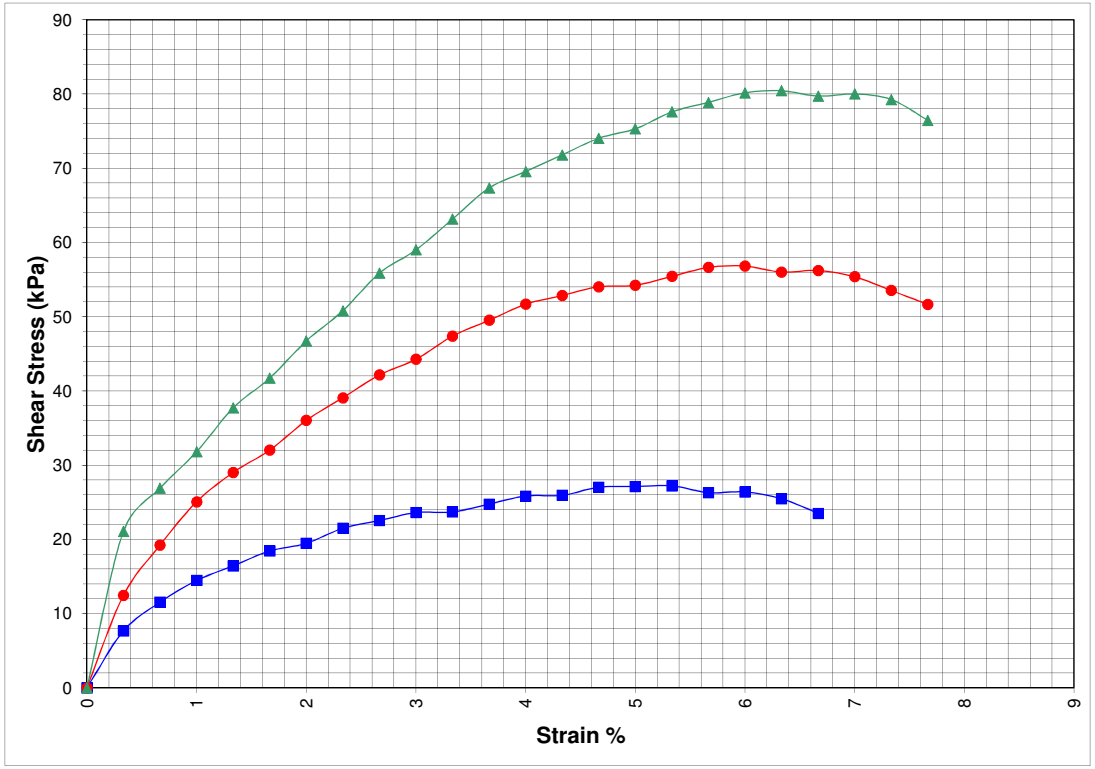
**Borehole: MBH-10**

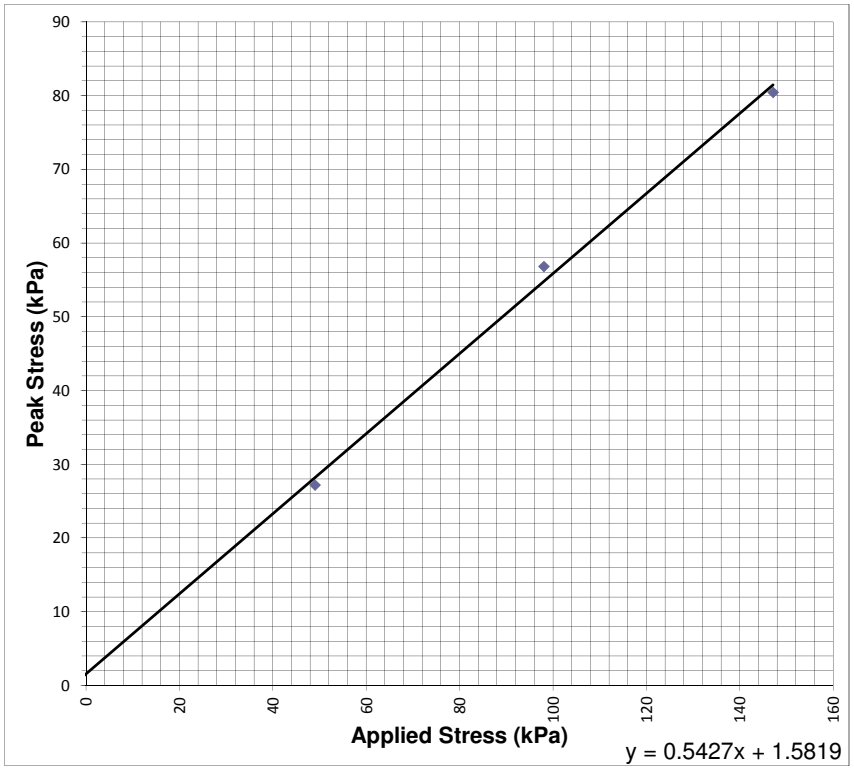
**Sample Type: SPT-08**

**Depth: 10.50-10.80 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 57 |
| | Stage 3 | 147 | 80 |

| | | |
|---|---|---|
| Angle of Friction | **28.69** | ° |
| Apparent Cohesion | **1.58** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

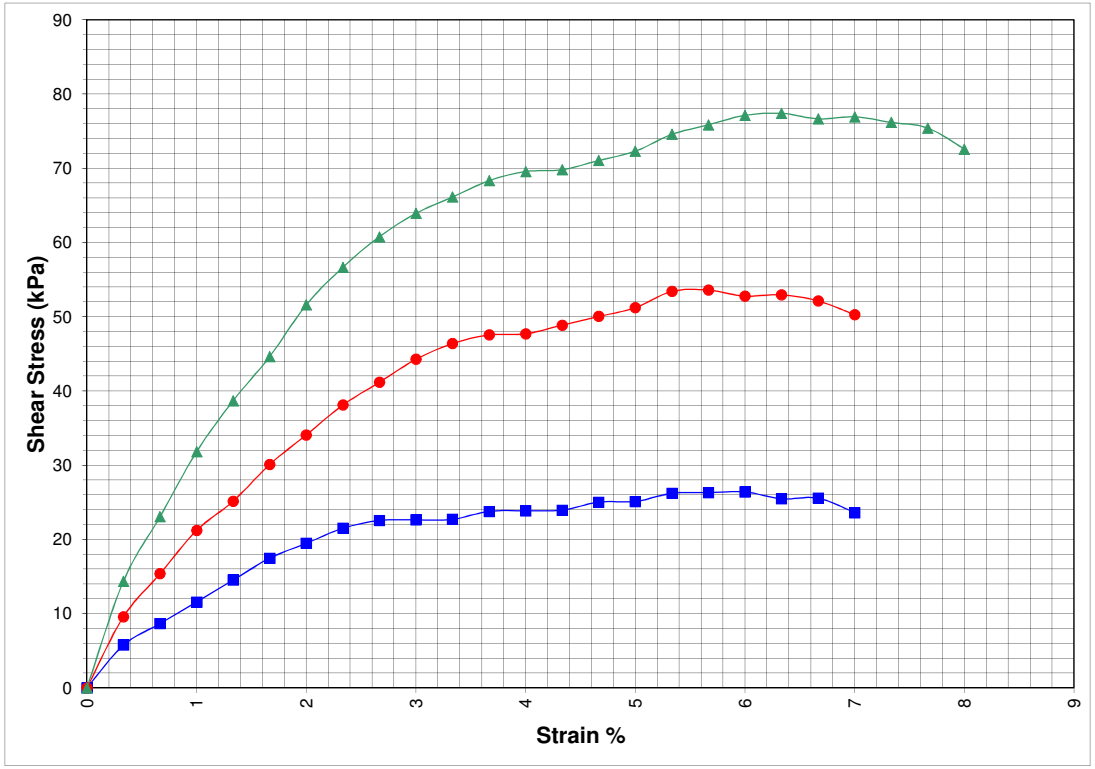
**Borehole: MBH-10**

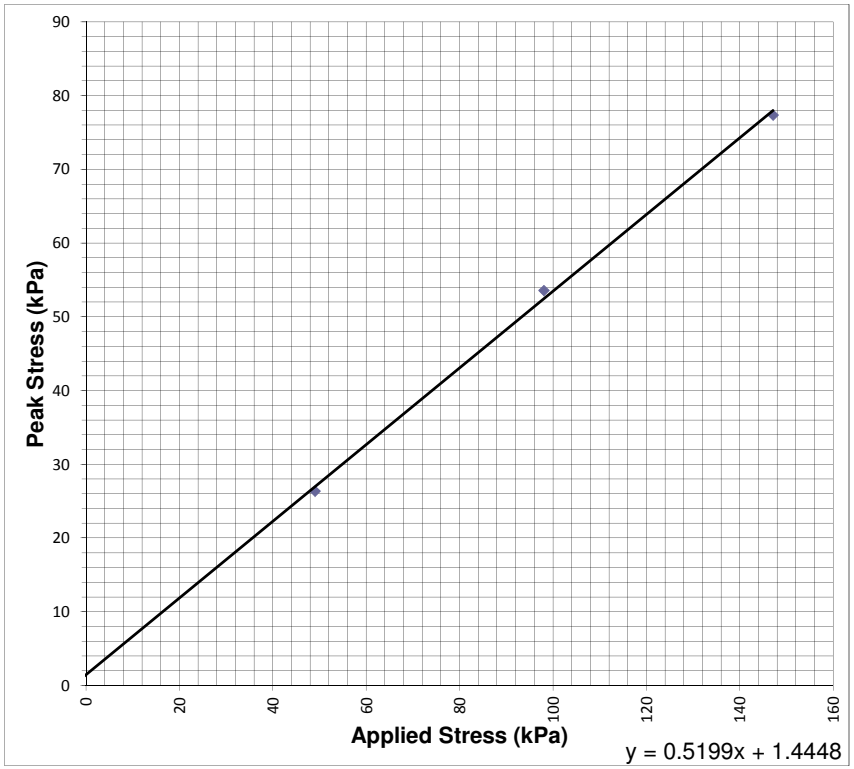
**Sample Type: SPT-10**

**Depth: 13.50-13.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 54 |
| | Stage 3 | 147 | 77 |

| | | |
|---|---|---|
| Angle of Friction | **27.47** | ° |
| Apparent Cohesion | **1.44** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

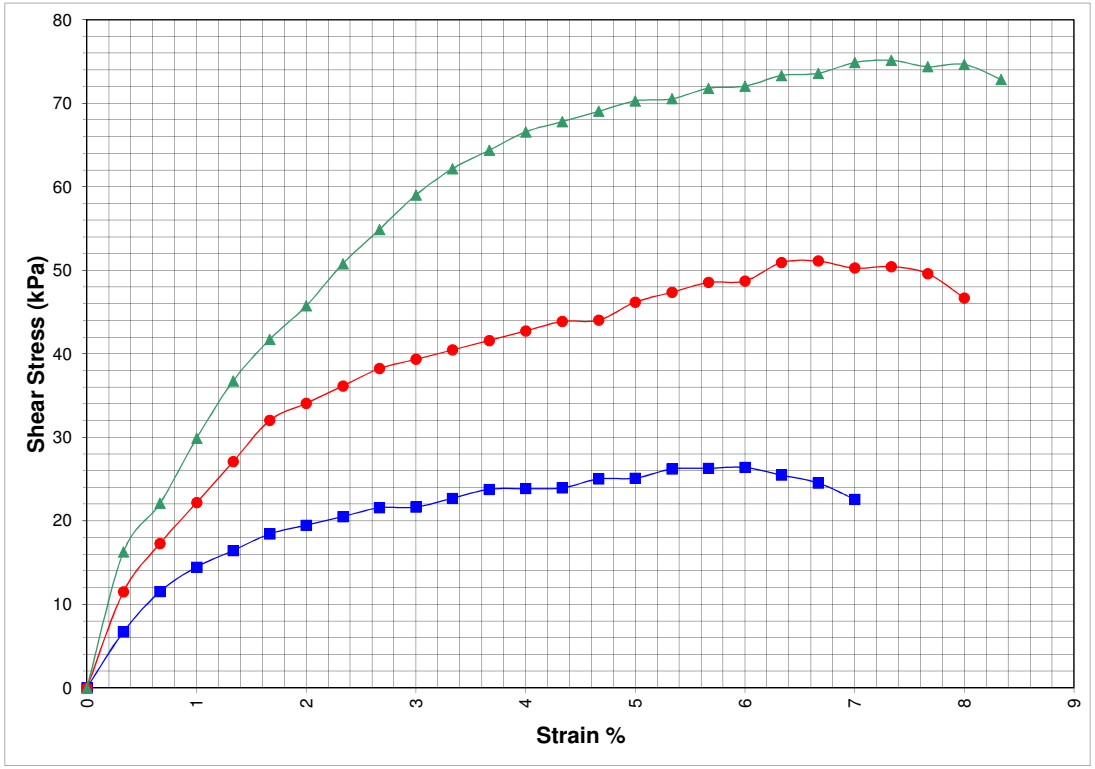
**Borehole: MBH-10**

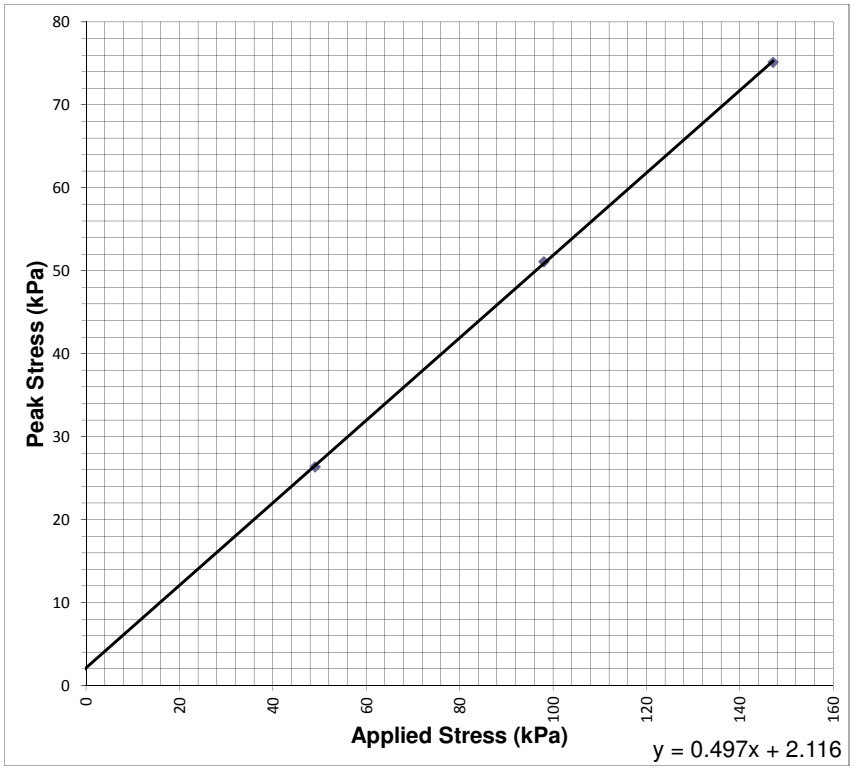
**Sample Type: SPT-12**

**Depth: 16.50-16.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 51 |
| | Stage 3 | 147 | 75 |

| | | |
|---|---|---|
| Angle of Friction | **26.43** | ° |
| Apparent Cohesion | **2.12** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

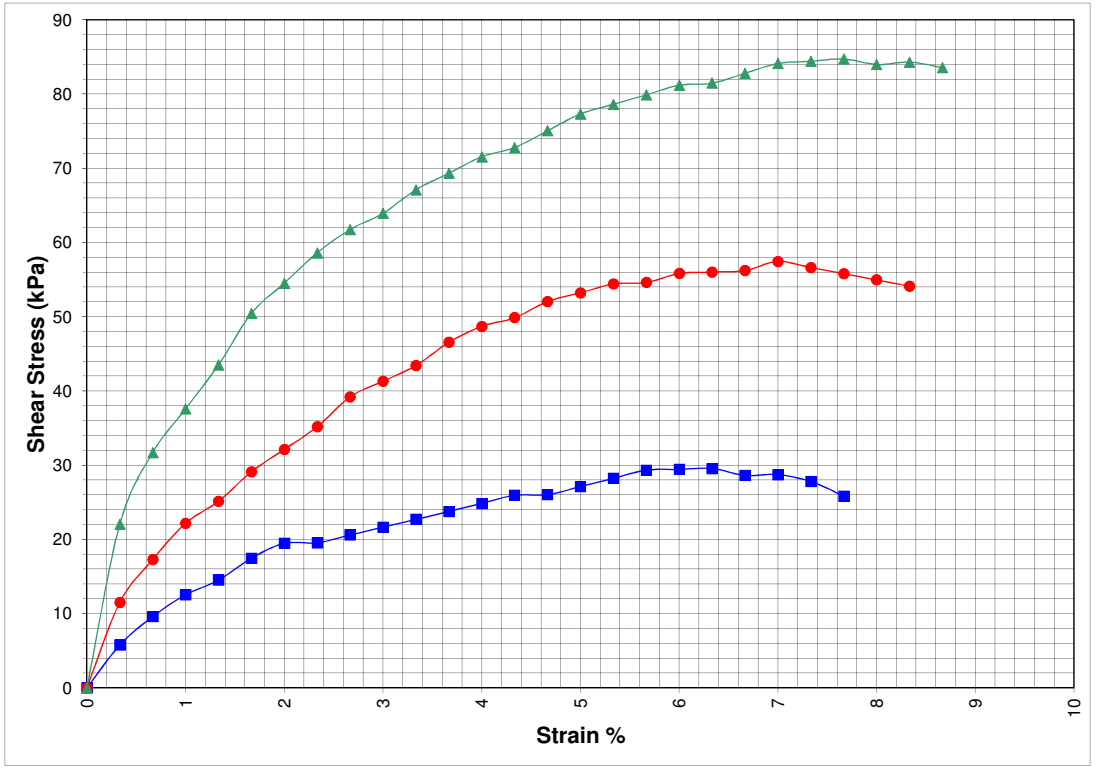
**Borehole: MBH-10**

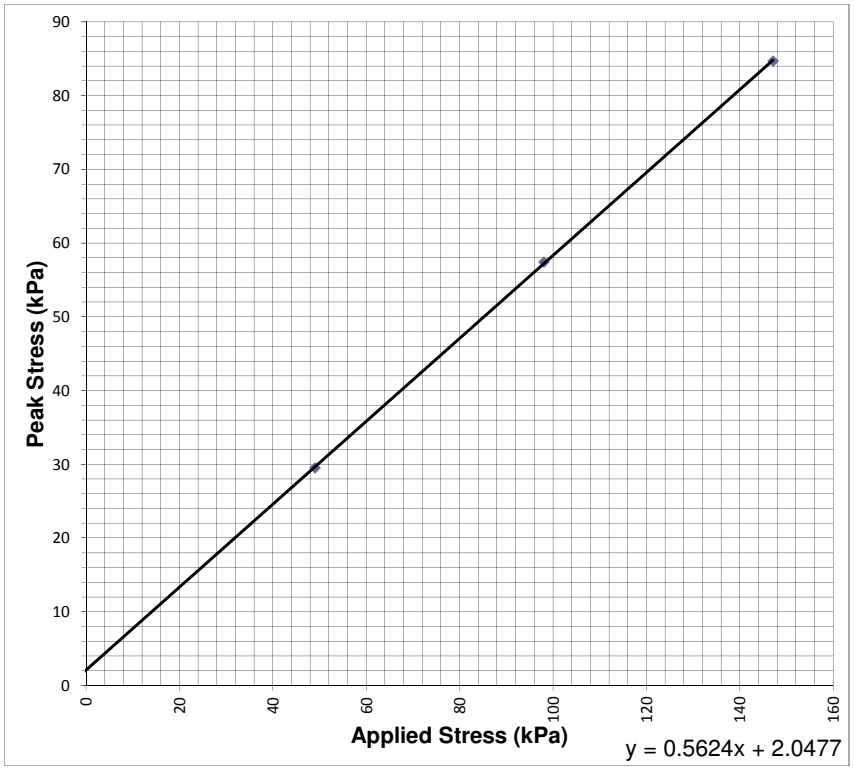
**Sample Type: SPT-16**

**Depth: 22.50-22.80 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 30 |
| | Stage 2 | 98 | 57 |
| | Stage 3 | 147 | 85 |

| | | |
|---|---|---|
| Angle of Friction | **29.35** | ° |
| Apparent Cohesion | **2.05** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

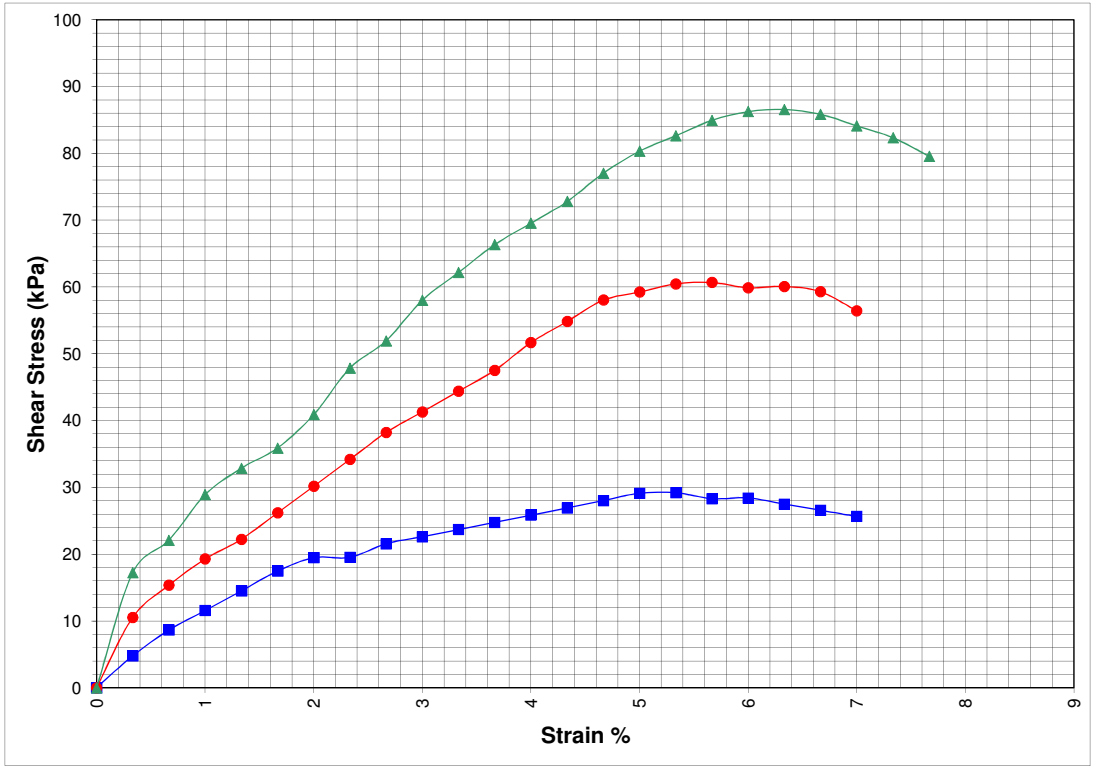
**Borehole: MBH-10**

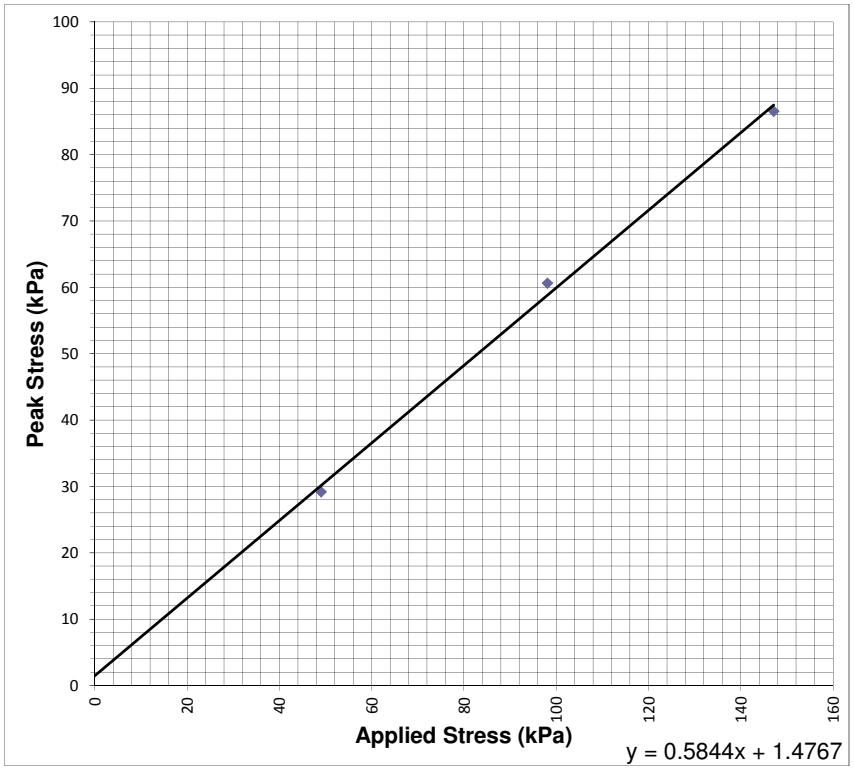
**Sample Type: SPT-19**

**Depth: 27.00-27.20 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 29 |
| | Stage 2 | 98 | 61 |
| | Stage 3 | 147 | 87 |

| | | |
|---|---|---|
| Angle of Friction | **30.30** | ° |
| Apparent Cohesion | **1.48** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

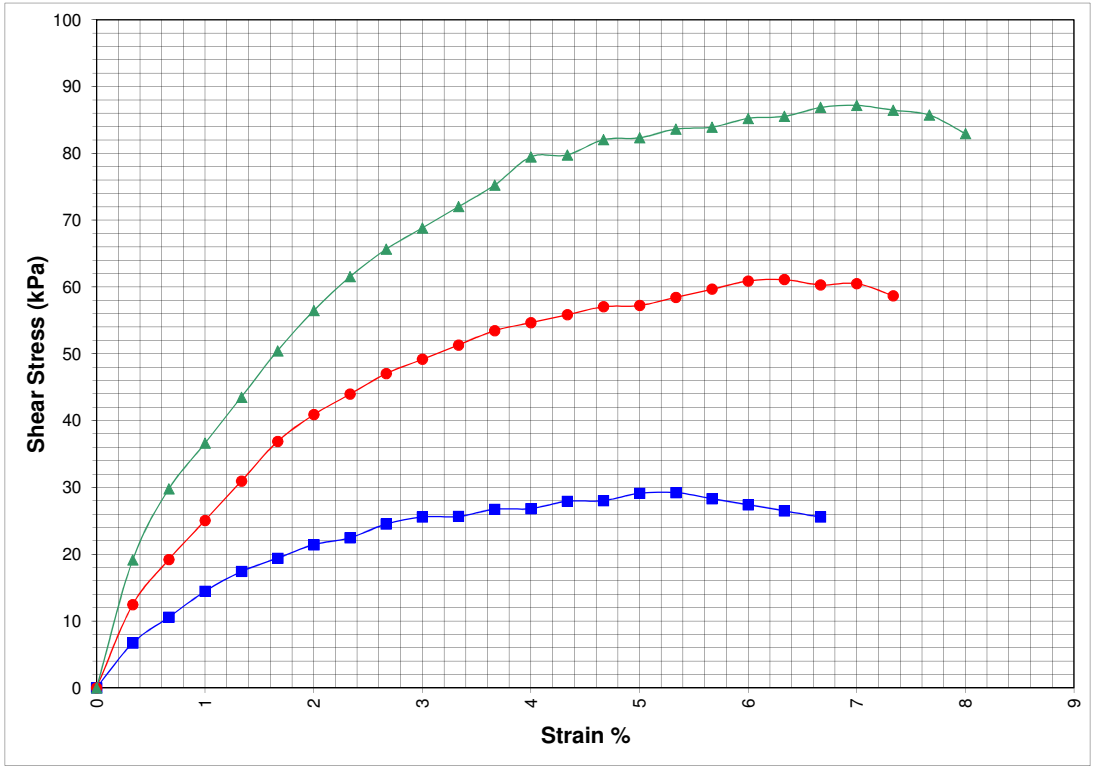
**Borehole: MBH-10**

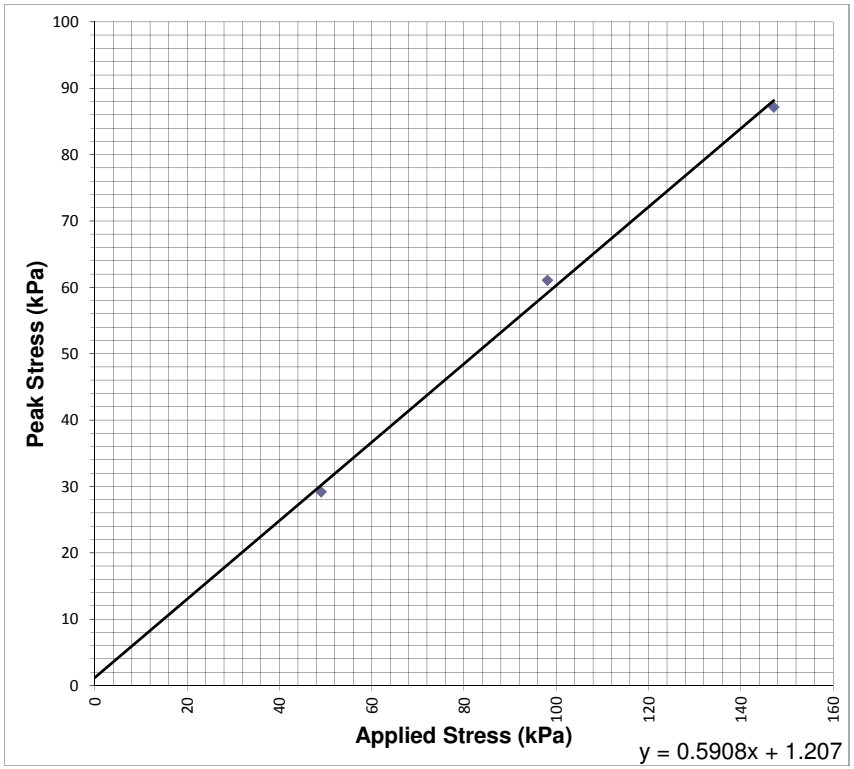
**Sample Type: SPT-22**

**Depth: 31.50-31.70 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 29 |
| | Stage 2 | 98 | 61 |
| | Stage 3 | 147 | 87 |

| | | |
|---|---|---|
| Angle of Friction | **30.57** | ° |
| Apparent Cohesion | **1.21** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

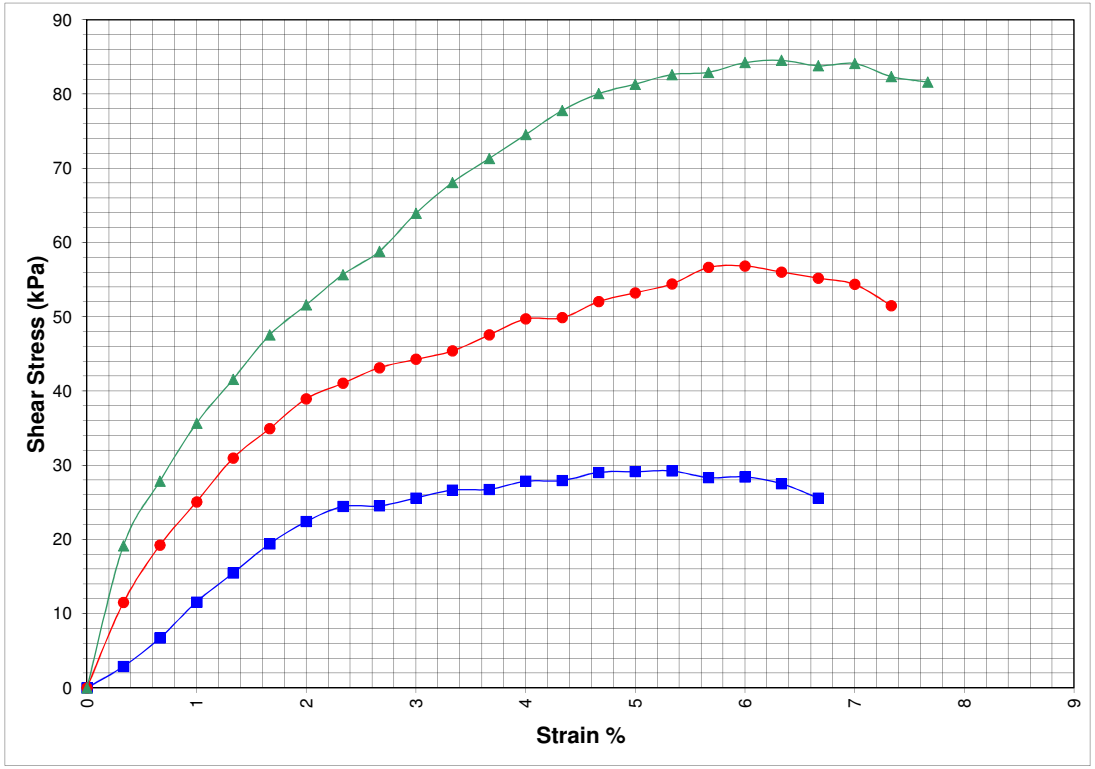
**Borehole: MBH-10**

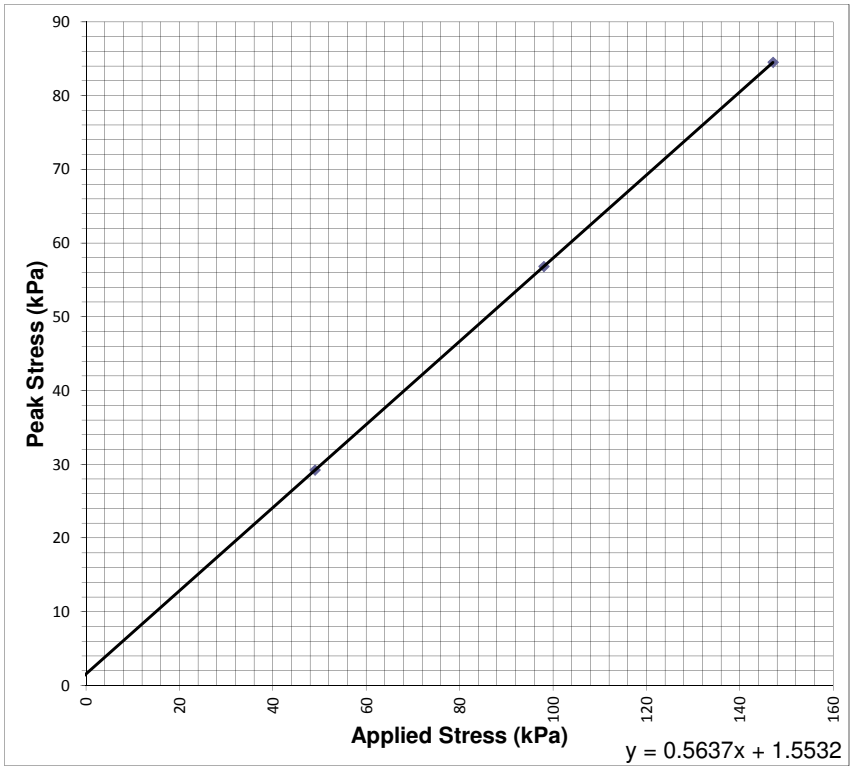
**Sample Type: SPT-24**

**Depth: 34.50-34.80 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 29 |
| | Stage 2 | 98 | 57 |
| | Stage 3 | 147 | 85 |

| | | |
|---|---|---|
| Angle of Friction | **29.41** | ° |
| Apparent Cohesion | **1.55** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: MBH-10**

**Sample Type: SPT-26**

**Depth: 37.50-37.65 m**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-1 | 0.00-0.18 | SP-SM | | | | 19.3 | 19.33 | 9.27 | 16.21 | 2.62 | 0 | 89 | <--> | <--> | 11 | | | | | | | | | | | | | | | | | | |
| SPT-2 | 1.50-1.75 | | | | | 19.4 | 17.73 | 7.67 | 14.85 | 2.59 | | | | | | DST | | | 0.72 | 32.4 | | | | | | | | | | | | |
| SPT-3 | 3.00-3.22 | SP | | | | 11.6 | 15.73 | 5.67 | 14.09 | | 0 | 98 | <--> | <--> | 2 | | | | | | | | | | | | | | | | | |
| SPT-4 | 4.50-4.65 | SP | | | | 16.9 | 15.76 | 5.70 | 13.48 | | 0 | 97 | <--> | <--> | 3 | | | | | | | | | | | | | | | | | |
| SPT-5 | 6.00-6.18 | | | | | 15.1 | 17.43 | 7.37 | 15.15 | 2.63 | | | | | | DST | | | 1.65 | 31.8 | | | | | | | | | | | | |
| SPT-6 | 7.50-7.70 | SP | | | | 15.4 | 17.45 | 7.39 | 15.12 | | 0 | 97 | <--> | <--> | 3 | | | | | | | | | | | | | | 8.05 | 0.80 | 2.00 | 700 | 10620 |
| SPT-7 | 9.00-9.30 | SP | | | | 15.5 | 17.83 | 7.77 | 15.43 | 2.63 | 0 | 96 | <--> | <--> | 4 | | | | | | | | | | | | | | | | | |
| SPT-8 | 10.50-10.75 | | | | | 18.3 | 17.80 | 7.74 | 15.04 | | | | | | | DST | | | 1.55 | 29.3 | | | | | | | | | | | | |
| SPT-9 | 12.00-12.28 | | | | | 19.5 | 19.13 | 9.07 | 16.02 | 2.63 | | | | | | | | | | | | | | | | | | | | | | |
| SPT-10 | 13.50-13.75 | | | | | 18.0 | 19.15 | 9.09 | 16.24 | | | | | | | DST | | | 1.76 | 28.8 | | | | | | | | | | | | |
| SPT-11 | 15.00-15.22 | SP-SM | | | | 15.4 | 17.80 | 7.74 | 15.42 | 2.64 | 0 | 92 | <--> | <--> | 8 | | | | | | | | | | | | | | | | | |
| SPT-12 | 16.50-16.80 | SP-SM | | | | 19.3 | 17.79 | 7.73 | 14.91 | | 0 | 91 | <--> | <--> | 9 | | | | | | | | | | | | | | | | | |
| SPT-13 | 18.00-18.28 | | | | | 20.4 | 17.80 | 7.74 | 14.78 | | | | | | | DST | | | 1.60 | 30.2 | | | | | | | | | | | | |
| SPT-14 | 19.50-19.75 | | | | | 18.9 | 17.80 | 7.74 | 14.96 | 2.62 | | | | | | | | | | | | | | | | | | | 8.34 | 1.00 | 2.00 | 1400 | 5310 |
| SPT-15 | 21.00-21.25 | SP | | | | 20.6 | 18.08 | 8.02 | 15.00 | | 0 | 96 | <--> | <--> | 4 | | | | | | | | | | | | | | | | | |
| SPT-16 | 22.50-22.72 | | | | | 23.0 | 18.06 | 8.00 | 14.69 | 2.60 | | | | | | | | | | | | | | | | | | | | | | |
| SPT-17 | 24.00-24.20 | | | | | 22.7 | 18.04 | 7.98 | 14.70 | | | | | | | DST | | | 1.90 | 29.7 | | | | | | | | | | | | |
| SPT-18 | 25.50-25.70 | SP-SM | | | | 23.4 | 18.53 | 8.47 | 15.02 | | 0 | 91 | <--> | <--> | 9 | | | | | | | | | | | | | | | | | |
| SPT-19 | 27.00-27.18 | | | | | 23.6 | 18.08 | 8.02 | 14.63 | 2.59 | | | | | | | | | | | | | | | | | | | | | | |
| SPT-20 | 28.50-28.70 | SP-SM | | | | 19.9 | 18.53 | 8.47 | 15.46 | | 0 | 90 | <--> | <--> | 10 | | | | | | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

\# : Decayed Wood

**Failure Type**

A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-11**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-21 | 30.00-30.22 | | | | | 20.8 | 17.80 | 7.74 | 14.73 | | | | | | | DST | | | 1.67 | 30.2 | | | | | | | | | | | | | |
| SPT-22 | 31.50-31.70 | SP-SM | | | | 17.8 | 18.81 | 8.75 | 15.97 | | 0 | 92 | <--> | <--> | 8 | | | | | | | | | | | | | | | | | | |
| SPT-23 | 33.00-33.15 | | | | | 16.7 | 18.81 | 8.75 | 16.11 | 2.62 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-24 | 34.50-34.75 | | | | | 17.1 | 18.11 | 8.05 | 15.46 | | | | | | | DST | | | 1.20 | 30.4 | | | | | | | | | | | | | |
| SPT-25 | 36.00-36.20 | SP-SM | | | | 23.6 | 17.98 | 7.92 | 14.55 | | 0 | 91 | <--> | <--> | 9 | | | | | | | | | | | | | | | | | | |
| SPT-26 | 38.00-38.24 | | | | | 22.9 | 18.31 | 8.25 | 14.89 | | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-27 | 40.00-40.18 | | | | | 22.4 | 17.59 | 7.53 | 14.37 | | | | | | | DST | | | 1.49 | 29.7 | | | | | | | | | | | | | |
| **END OF BOREHOLE** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

\# : Decayed Wood

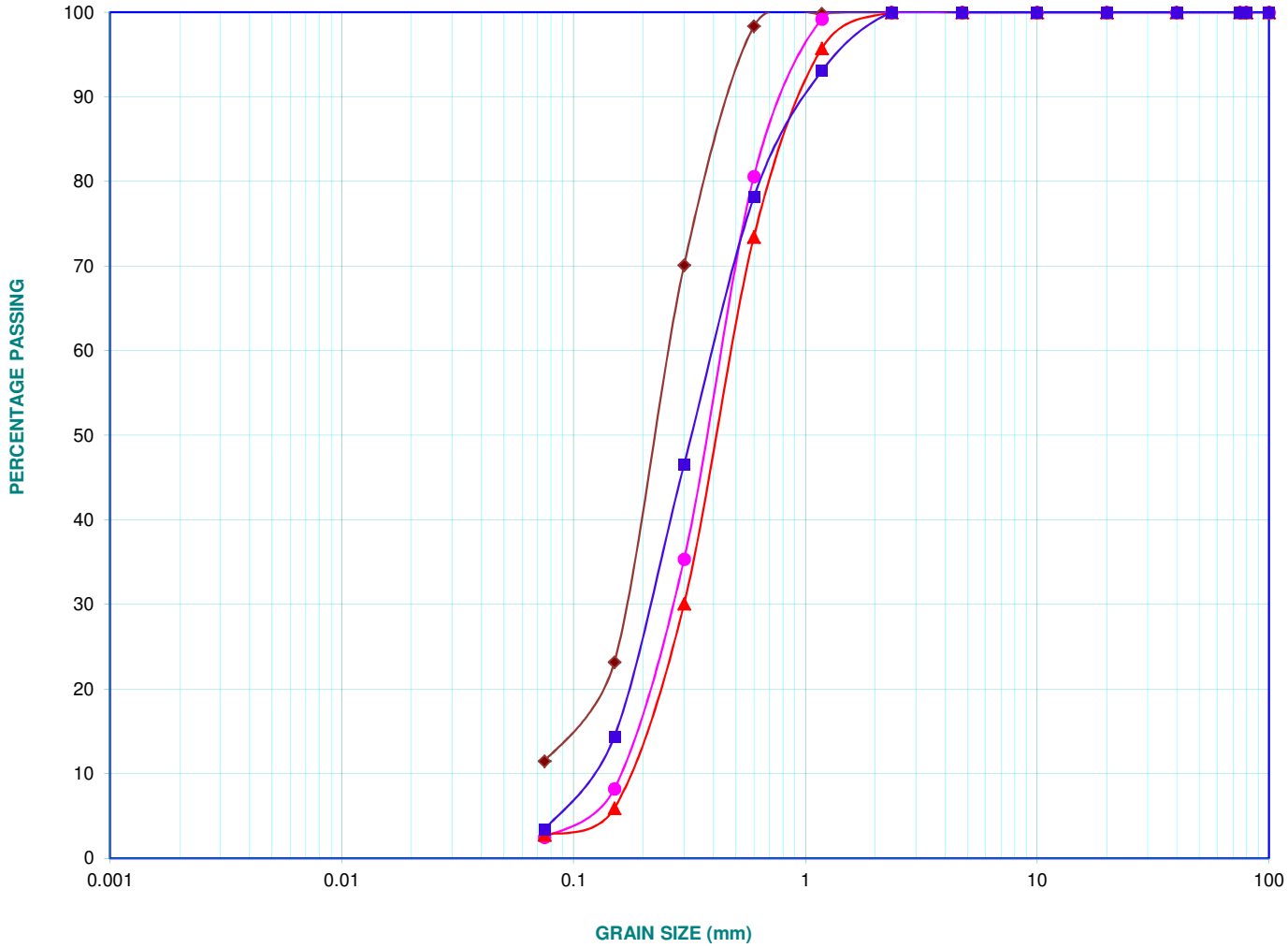
**Failure Type**

A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-11**

# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | **Borehole No.** | **: MBH-11** | | | | **Date :** | **15-Jun-19** | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-11 | MBH-11 | MBH-11 | MBH-11 | | | | | | | | |
| **Depth (m)** | 0.00.0.18 | 3.00-3.22 | 4.50-4.65 | 7.50-7.70 | | | | | | | | |
| **Sample Type** | SPT-01 | SPT-03 | SPT-04 | SPT-06 | | | | | | | | |
| **Classification** | SP-SM | SP | SP | SP | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 89 | 98 | 97 | 97 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 11 | 2 | 3 | 3 | | | | | | | | |
| **D60 mm** | | 0.420 | 0.500 | 0.400 | | | | | | | | |
| **D30 mm** | | 0.280 | 0.300 | 0.210 | | | | | | | | |
| **D10 mm** | | 0.170 | 0.190 | 0.130 | | | | | | | | |
| **Cu** | --- | 2.47 | 2.63 | 3.08 | | | | | | | | |
| **Cc** | --- | 1.10 | 0.95 | 0.85 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |




Checked By :

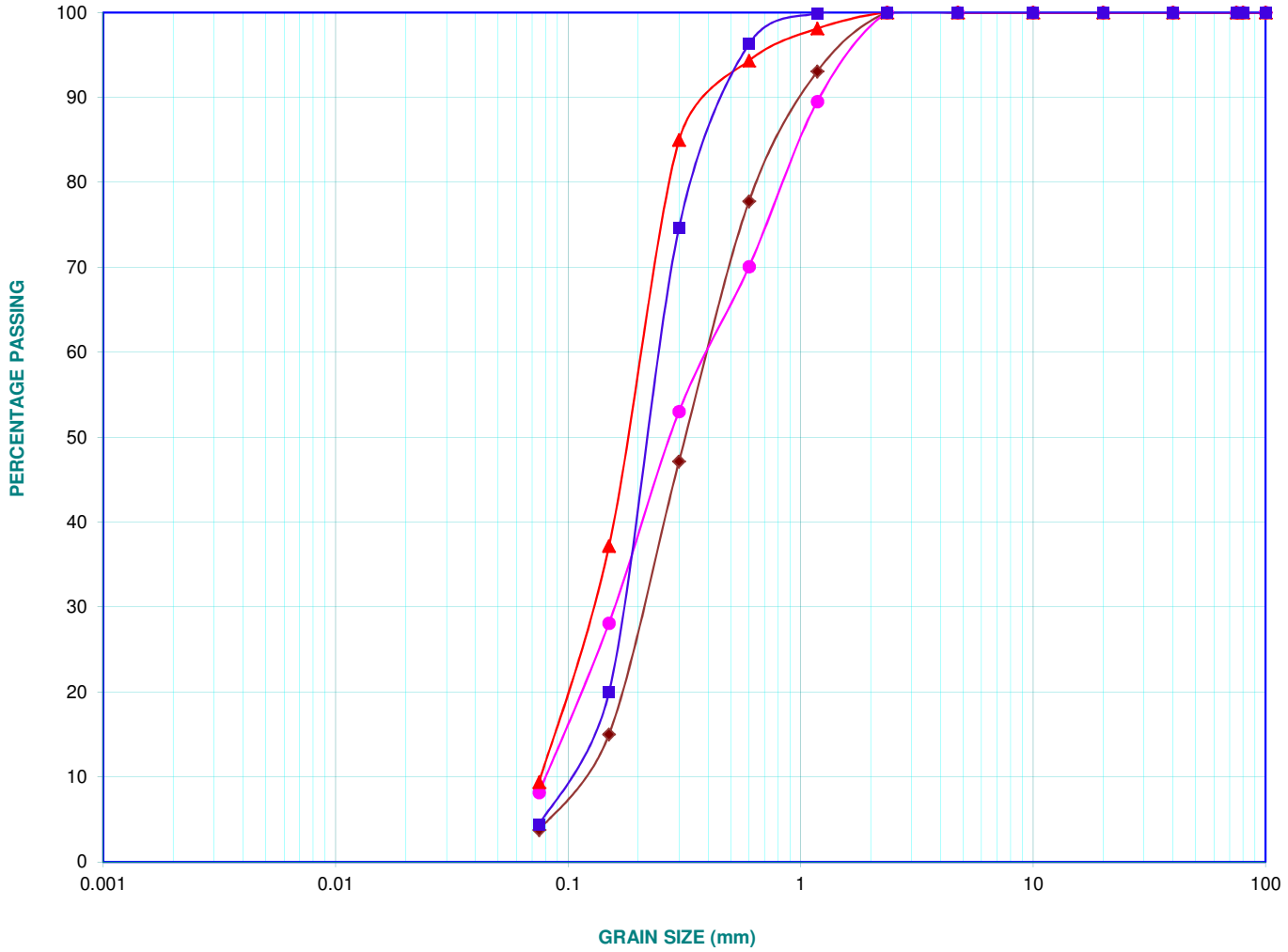
# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Job No.** | **: CM 19 01 03** | | **Borehole No.** | **: MBH-11** | | **Date :** | **15-Jun-19** |

| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |

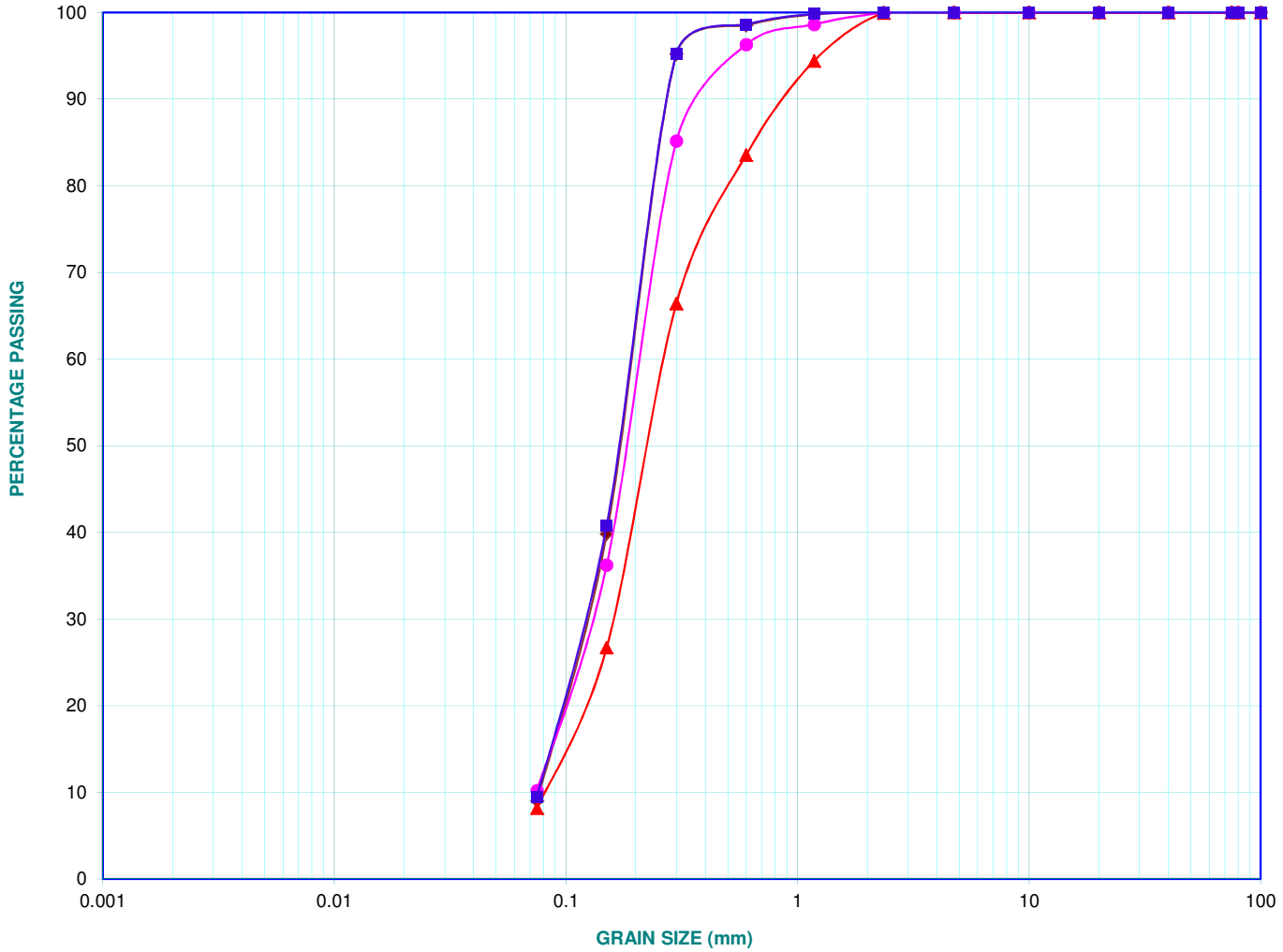
| | | | | |
|---|---|---|---|---|
| **Bore Hole .** | MBH-11 | MBH-11 | MBH-11 | MBH-11 |
| **Depth (m)** | 9.00-9.30 | 15.00-15.22 | 16.50-16.80 | 21.00-21.25 |
| **Sample Type** | SPT-07 | SPT-11 | SPT-12 | SPT-15 |
| **Classification** | SP | SP-SM | SP-SM | SP |
| **Gravel %** | 0 | 0 | 0 | 0 |
| **Sand %** | 96 | 92 | 91 | 96 |
| **Silt %** | <----> | <----> | <----> | <----> |
| **Clay %** | <----> | <----> | <----> | <----> |
| **Fines % (Silt+Clay)** | 4 | 8 | 9 | 4 |
| **D60 mm** | 0.400 | 0.400 | 0.200 | 0.250 |
| **D30 mm** | 0.210 | 0.160 | 0.130 | 0.180 |
| **D10 mm** | 0.120 | 0.080 | 0.080 | 0.100 |
| **Cu** | 3.33 | 5.00 | 2.50 | 2.50 |
| **Cc** | 0.92 | 0.80 | 1.06 | 1.30 |
| **Liquid Limit %** | --- | --- | --- | --- |
| **Plastic Limit %** | --- | --- | --- | --- |
| **Plasticity Index** | --- | --- | --- | --- |




Checked By :

# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | **Borehole No.** | **: MBH-11** | | | | **Date :** | **15-Jun-19** | | |
| **Symbol** | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-11 | MBH-11 | MBH-11 | MBH-11 | | | | | | | | |
| **Depth (m)** | 25.50-25.70 | 28.50-28.70 | 31.50-31.70 | 36.00-36.20 | | | | | | | | |
| **Sample Type** | SPT-18 | SPT-20 | SPT-22 | SPT-25 | | | | | | | | |
| **Classification** | SP-SM | SP-SM | SP-SM | SP-SM | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 91 | 90 | 92 | 91 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 9 | 10 | 8 | 9 | | | | | | | | |
| **D60 mm** | 0.200 | 0.210 | 0.280 | 0.200 | | | | | | | | |
| **D30 mm** | 0.120 | 0.130 | 0.180 | 0.120 | | | | | | | | |
| **D10 mm** | 0.080 | 0.075 | 0.080 | 0.080 | | | | | | | | |
| **Cu** | 2.50 | 2.80 | 3.50 | 2.50 | | | | | | | | |
| **Cc** | 0.90 | 1.07 | 1.45 | 0.90 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |

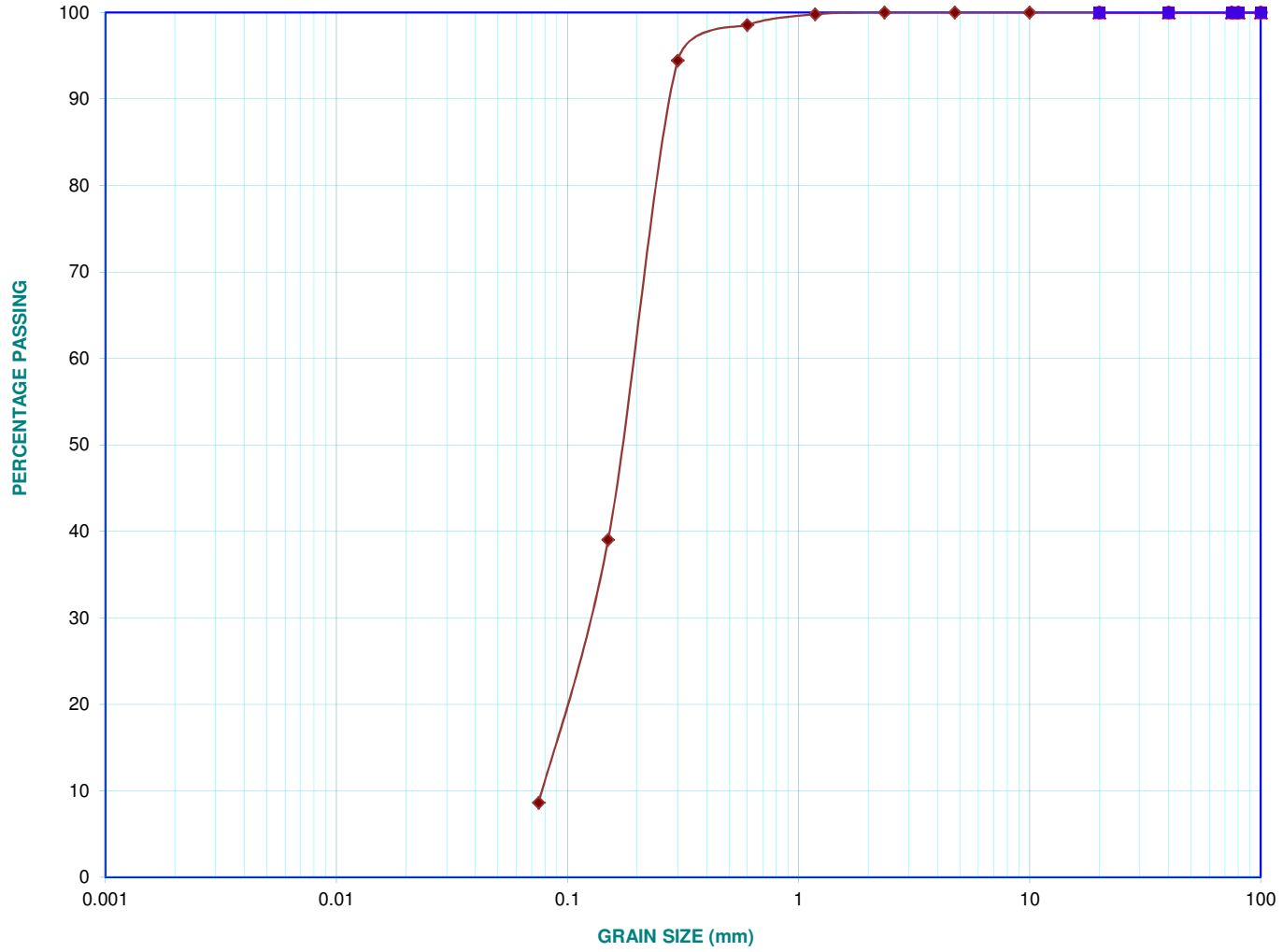



Checked By :

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-11** |
| **Date :** | **15-Jun-19** |

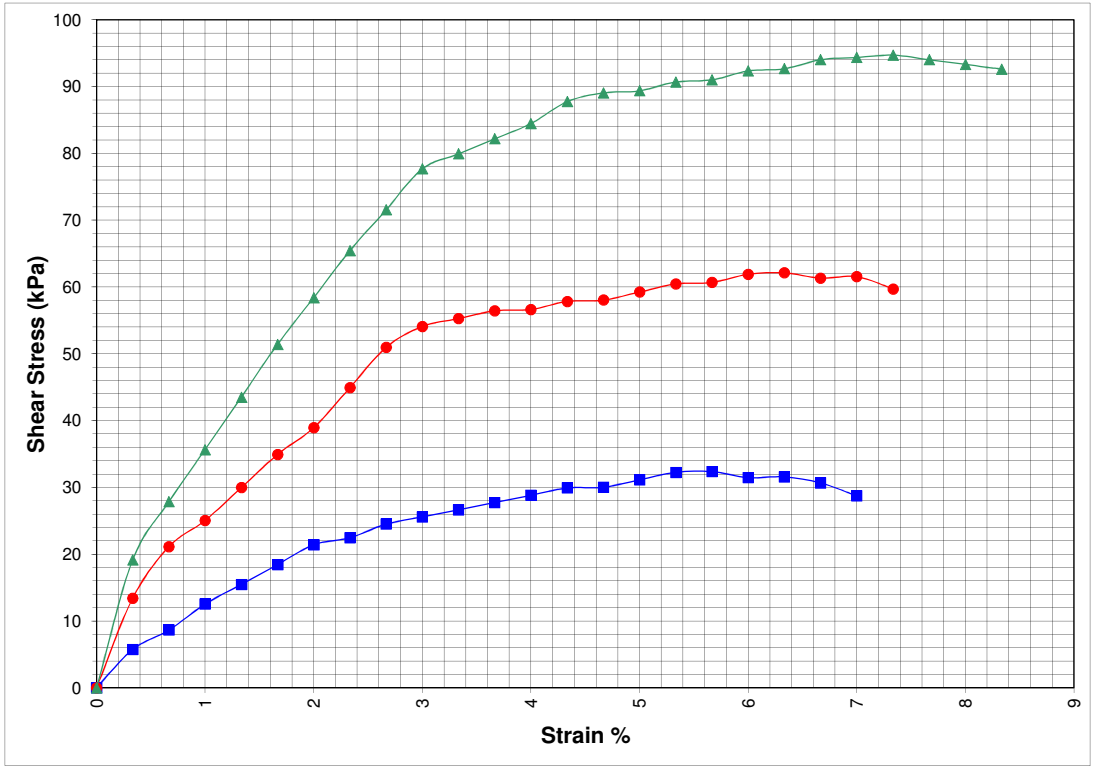
| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| Bore Hole . | MBH-11 | | | | | | | | | | | |
| Depth (m) | 38.00-38.24 | | | | | | | | | | | |
| Sample Type | SPT-26 | | | | | | | | | | | |
| Classification | SP-SM | | | | | | | | | | | |
| Gravel % | 0 | | | | | | | | | | | |
| Sand % | 91 | | | | | | | | | | | |
| Silt % | <----> | | | | | | | | | | | |
| Clay % | <----> | | | | | | | | | | | |
| Fines % (Silt+Clay) | 9 | | | | | | | | | | | |
| D60 mm | 0.200 | | | | | | | | | | | |
| D30 mm | 0.120 | | | | | | | | | | | |
| D10 mm | 0.079 | | | | | | | | | | | |
| Cu | 2.53 | | | | | | | | | | | |
| Cc | 0.91 | | | | | | | | | | | |
| Liquid Limit % | --- | | | | | | | | | | | |
| Plastic Limit % | --- | | | | | | | | | | | |
| Plasticity Index | --- | | | | | | | | | | | |

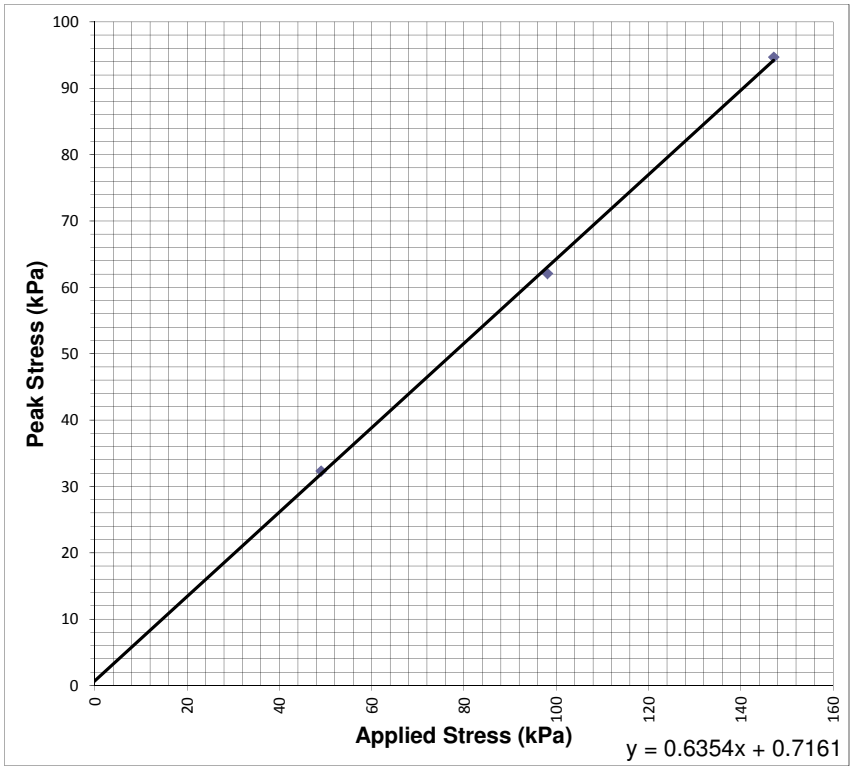



Checked By :

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 32 |
| | Stage 2 | 98 | 62 |
| | Stage 3 | 147 | 95 |

| | | |
|---|---|---|
| Angle of Friction | **32.43** | ° |
| Apparent Cohesion | **0.72** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

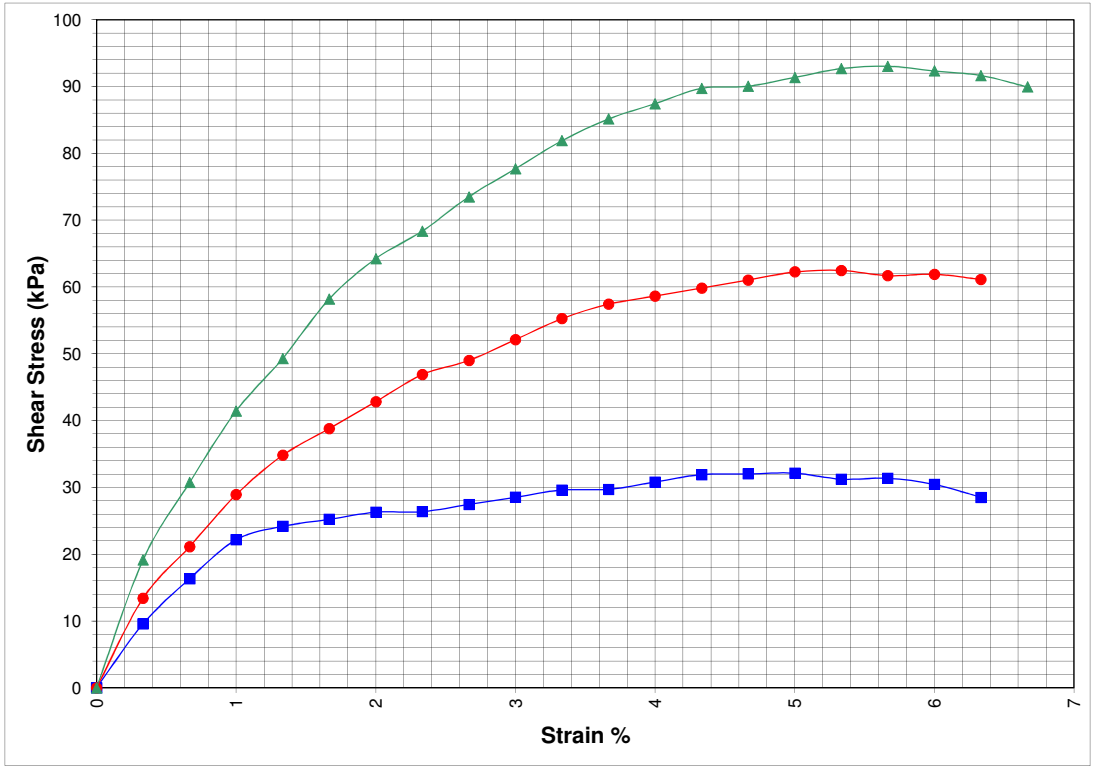
**Borehole: MBH-11**

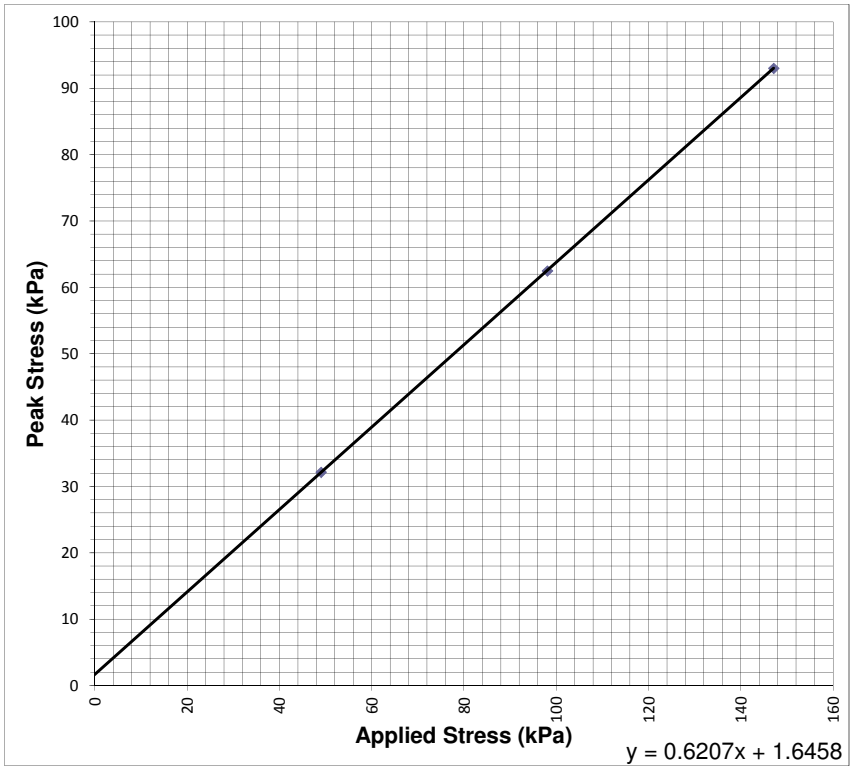
**Sample Type: SPT-02**

**Depth: 1.50-1.75 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 32 |
| | Stage 2 | 98 | 62 |
| | Stage 3 | 147 | 93 |

| | | |
|---|---|---|
| Angle of Friction | **31.83** | ° |
| Apparent Cohesion | **1.65** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

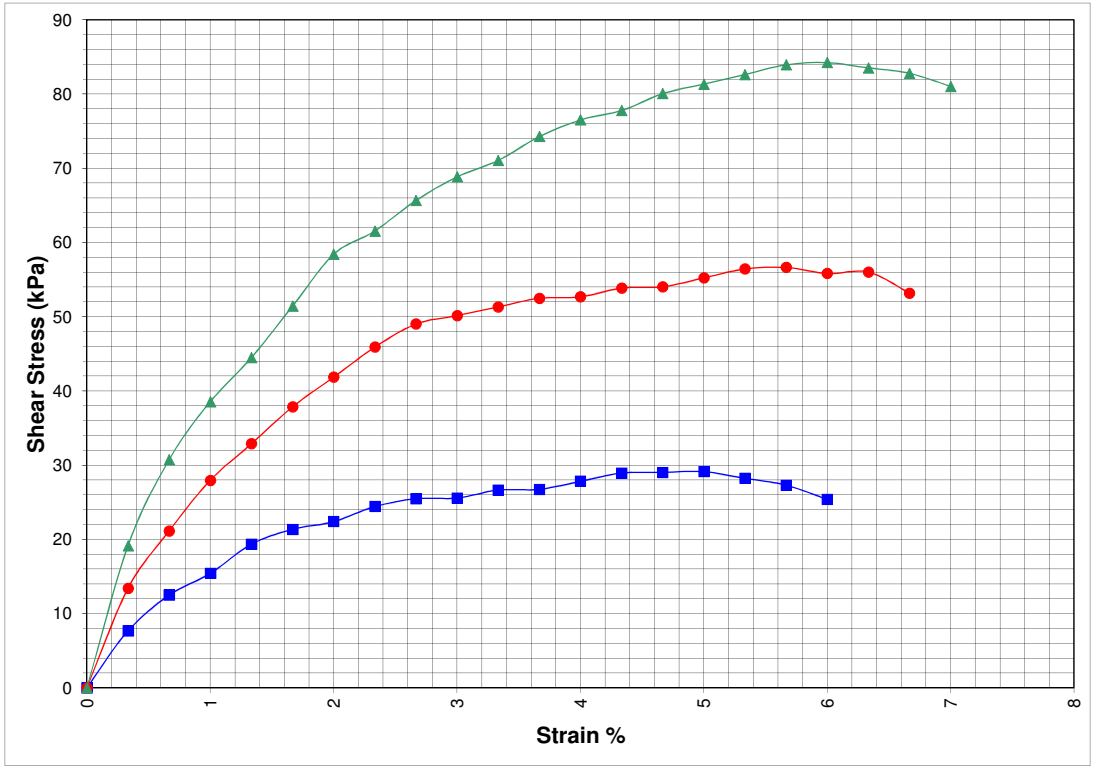
**Borehole: MBH-11**

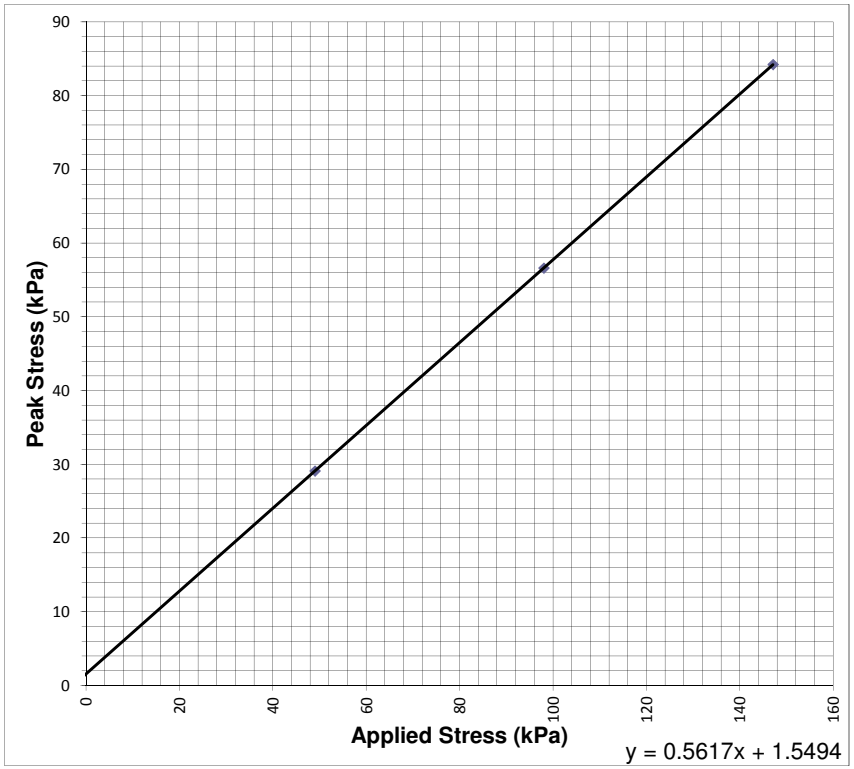
**Sample Type: SPT-05**

**Depth: 6.00-6.18 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 29 |
| | Stage 2 | 98 | 57 |
| | Stage 3 | 147 | 84 |

| | | |
|---|---|---|
| Angle of Friction | **29.32** | ° |
| Apparent Cohesion | **1.55** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

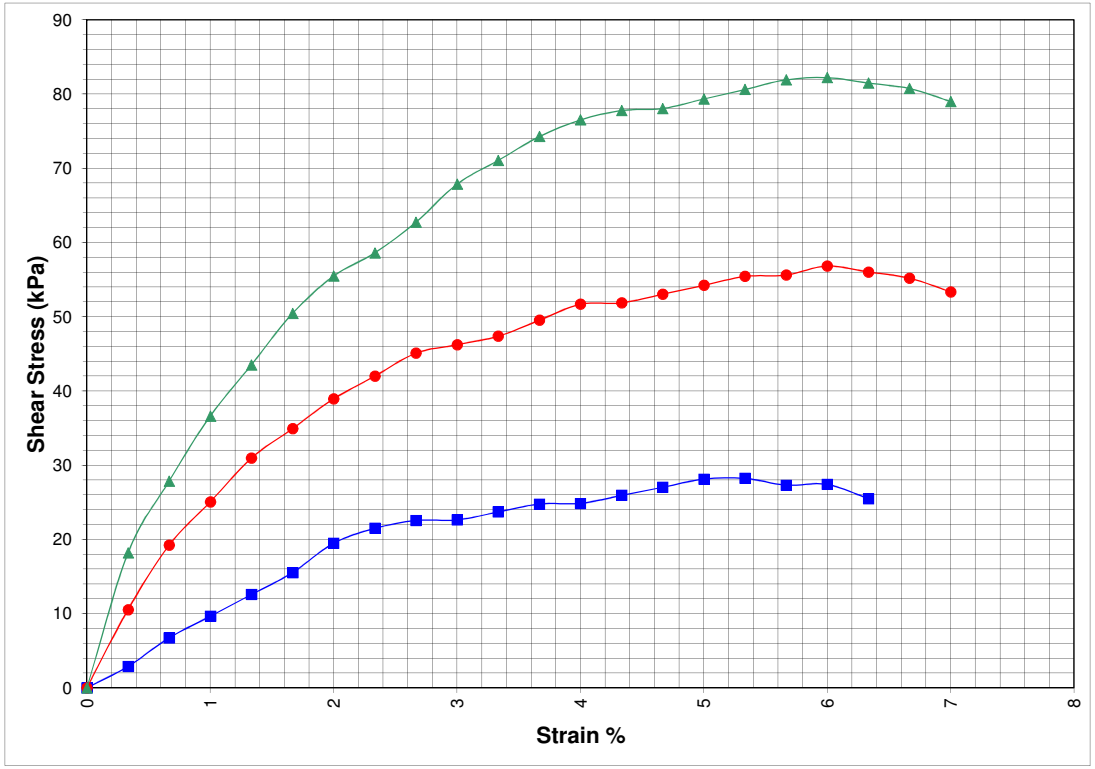
**Borehole: MBH-11**

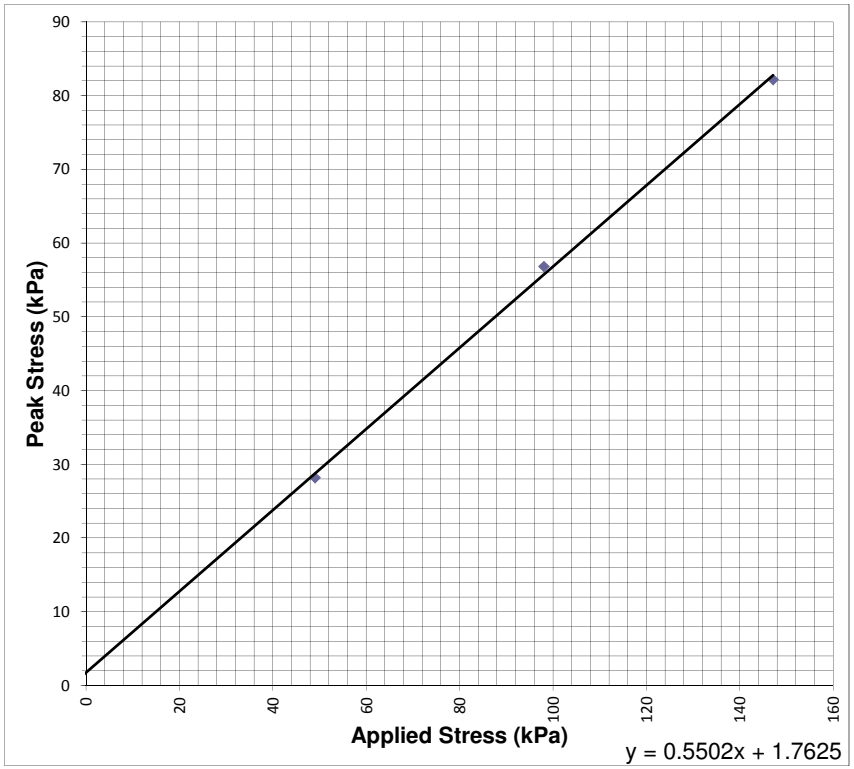
**Sample Type: SPT-08**

**Depth: 10.50-10.75 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 57 |
| | Stage 3 | 147 | 82 |

| | | |
|---|---|---|
| Angle of Friction | **28.82** | ° |
| Apparent Cohesion | **1.76** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

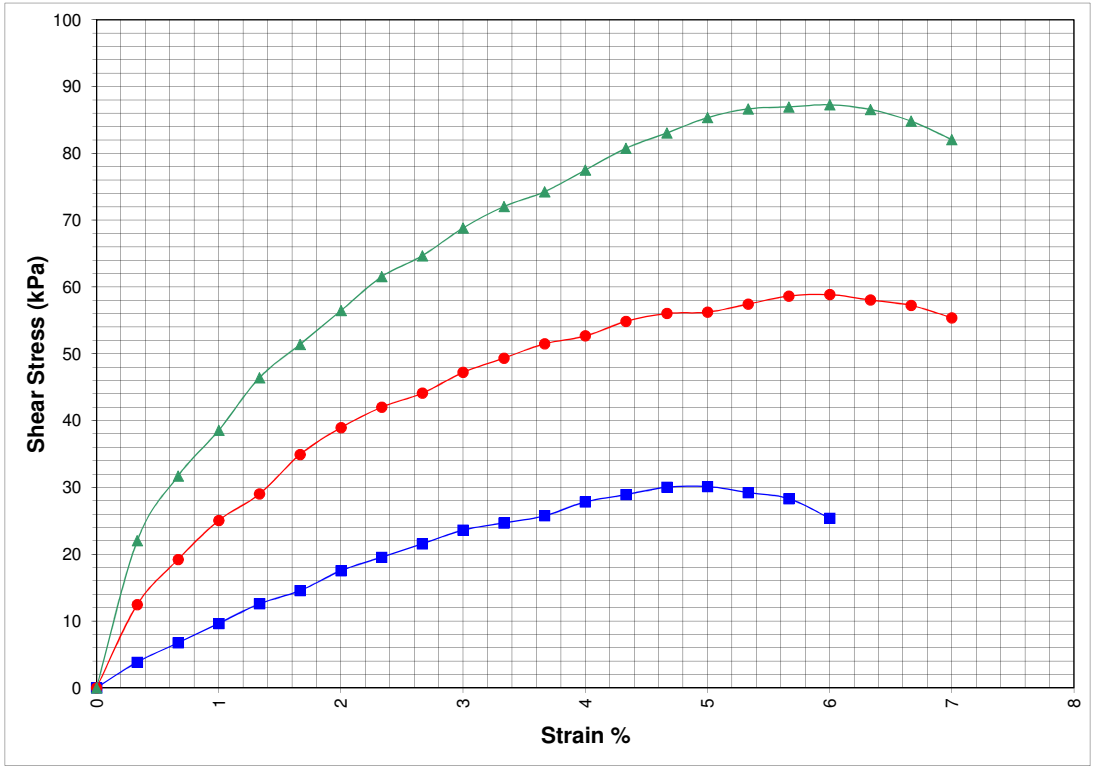
**Borehole: MBH-11**

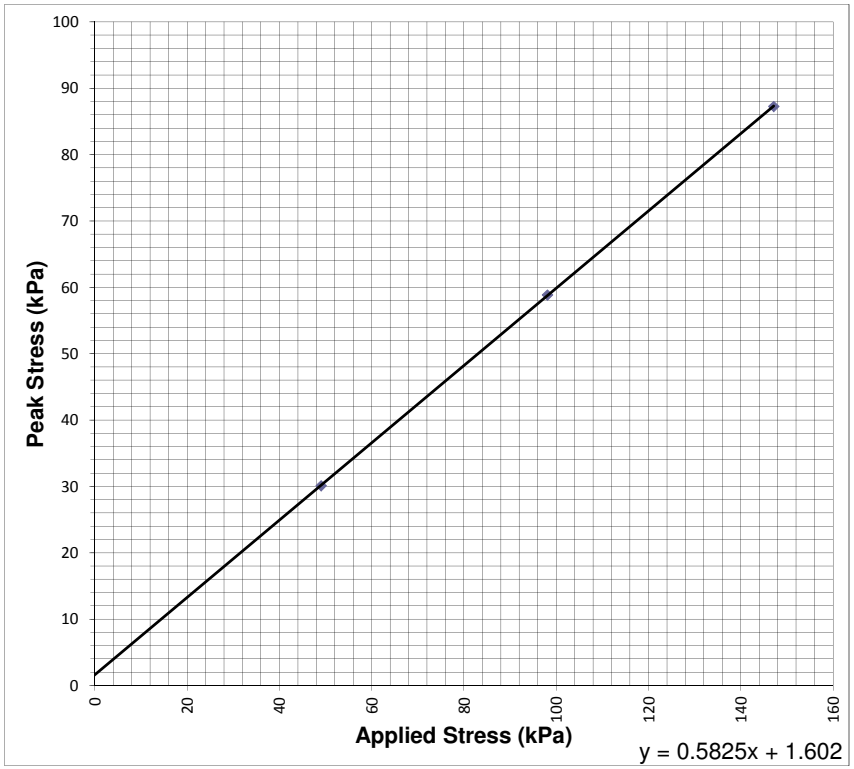
**Sample Type: SPT-10**

**Depth: 13.50-13.75 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 30 |
| | Stage 2 | 98 | 59 |
| | Stage 3 | 147 | 87 |

| | | |
|---|---|---|
| Angle of Friction | **30.22** | ° |
| Apparent Cohesion | **1.60** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

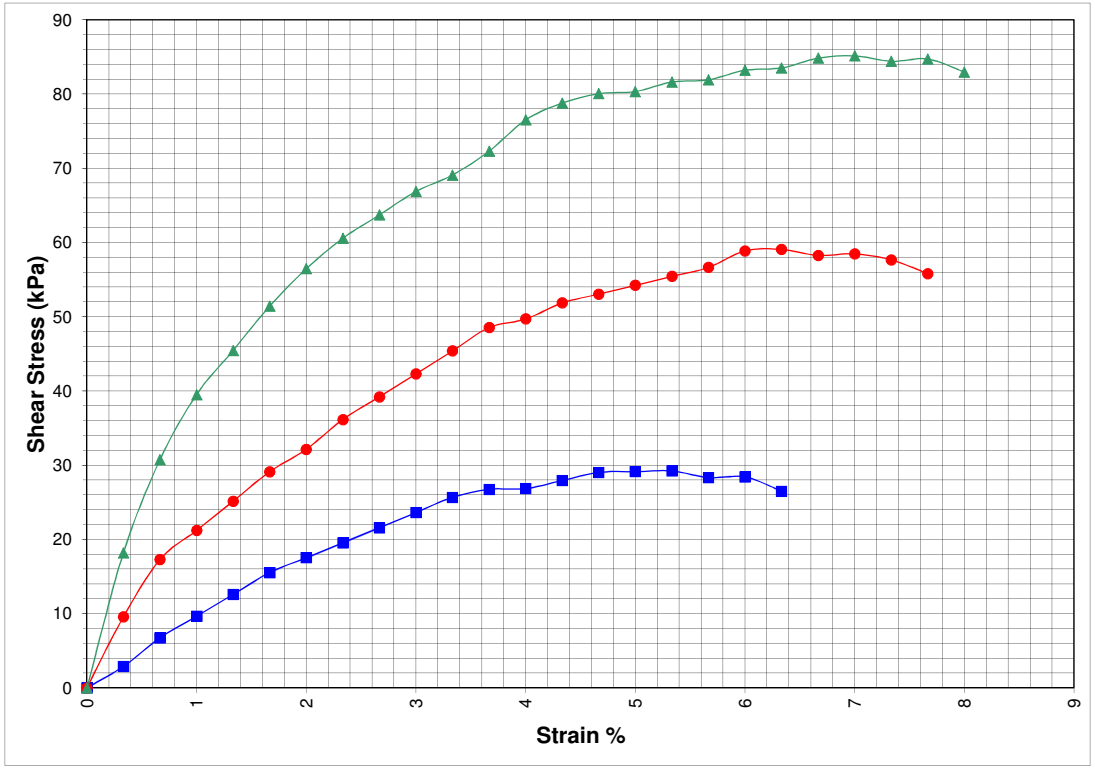
**Borehole: MBH-11**

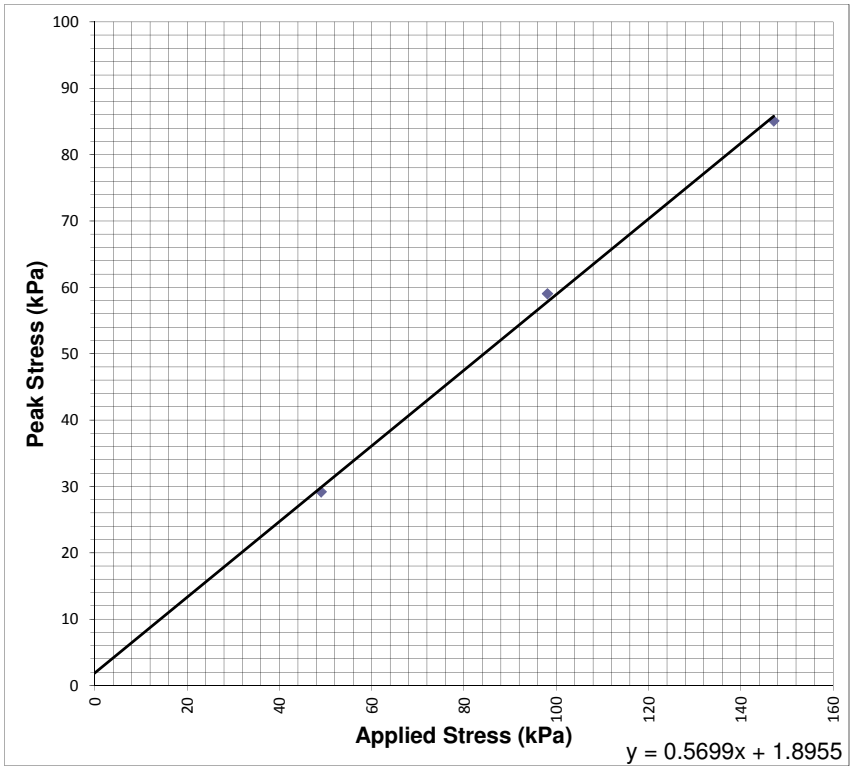
**Sample Type: SPT-13**

**Depth: 18.00-18.28 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 29 |
| | Stage 2 | 98 | 59 |
| | Stage 3 | 147 | 85 |

| | | |
|---|---|---|
| Angle of Friction | **29.68** | ° |
| Apparent Cohesion | **1.90** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

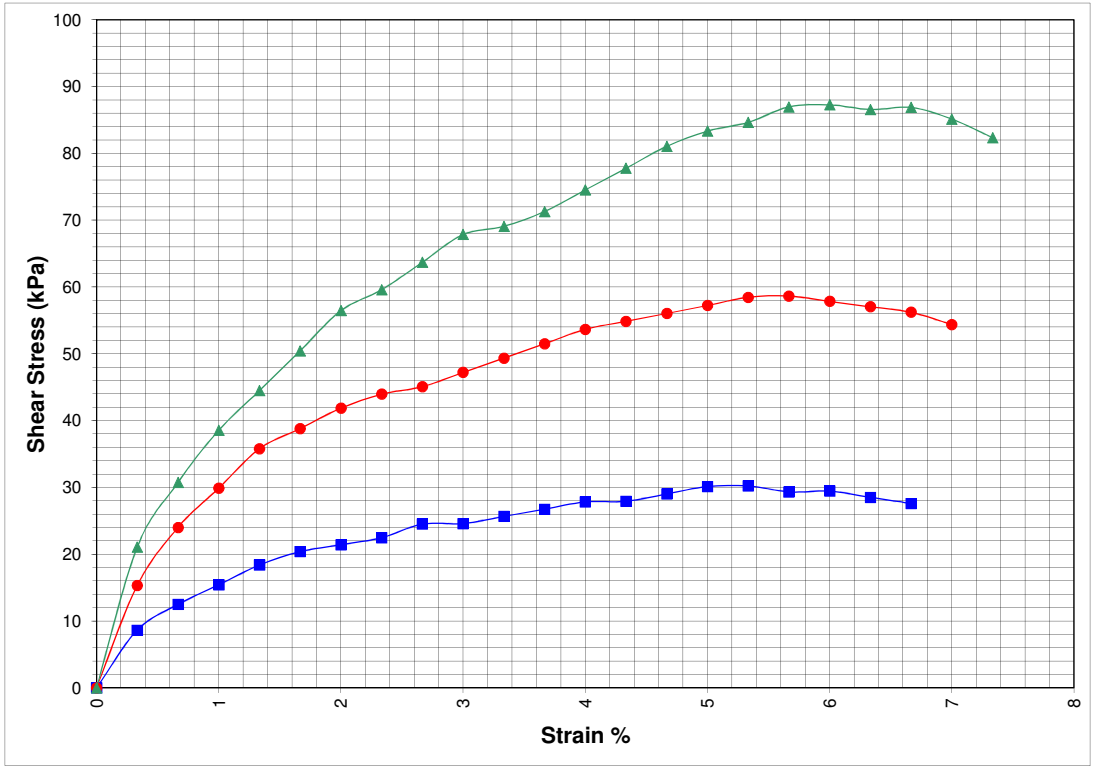
**Borehole: MBH-11**

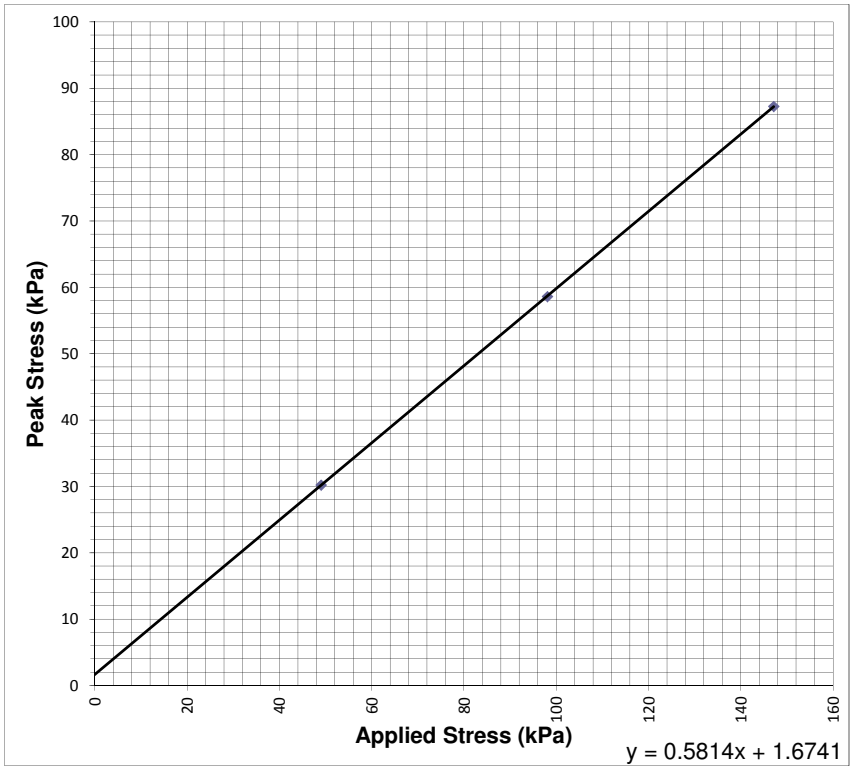
**Sample Type: SPT-17**

**Depth: 24.00-24.20 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 30 |
| | Stage 2 | 98 | 59 |
| | Stage 3 | 147 | 87 |

| | | |
|---|---|---|
| Angle of Friction | **30.17** | ° |
| Apparent Cohesion | **1.67** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

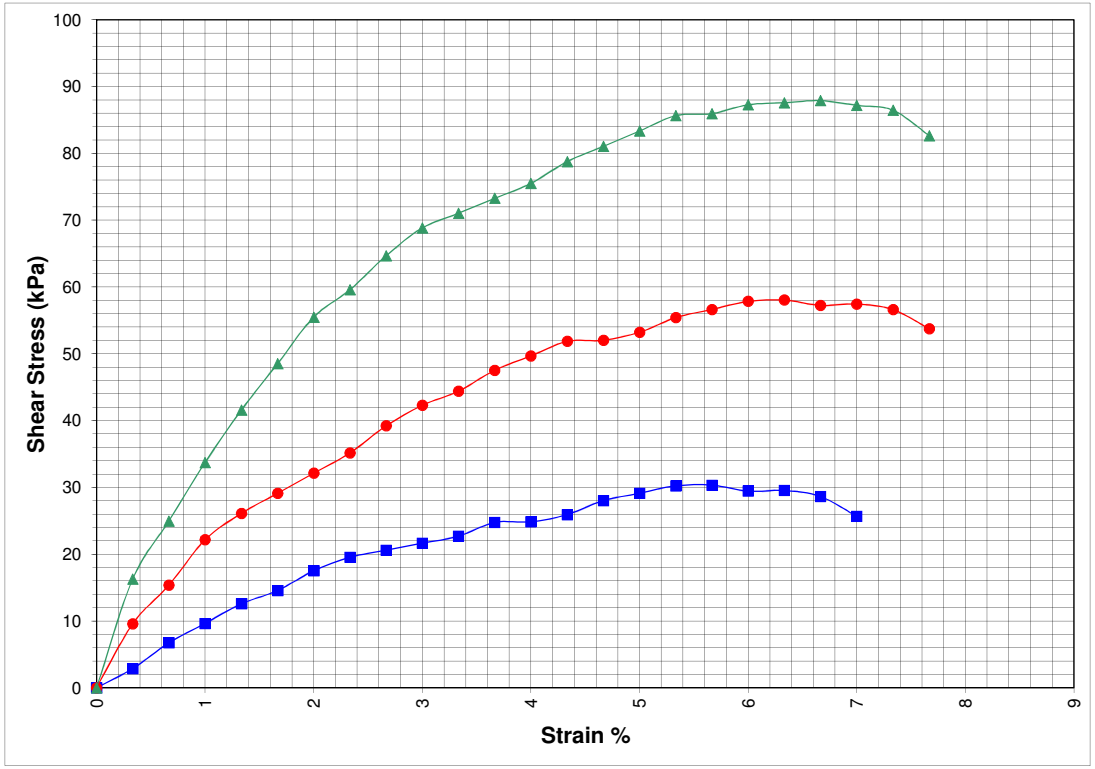
**Borehole: MBH-11**

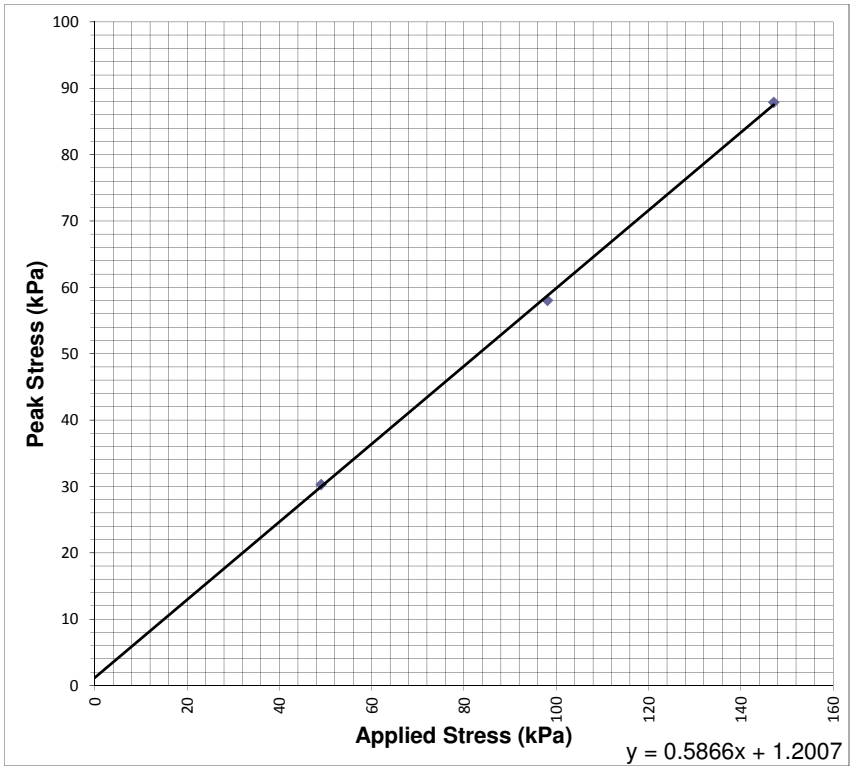
**Sample Type: SPT-21**

**Depth: 30.00-30.22 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 30 |
| | Stage 2 | 98 | 58 |
| | Stage 3 | 147 | 88 |

| | | |
|---|---|---|
| Angle of Friction | **30.40** | ° |
| Apparent Cohesion | **1.20** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

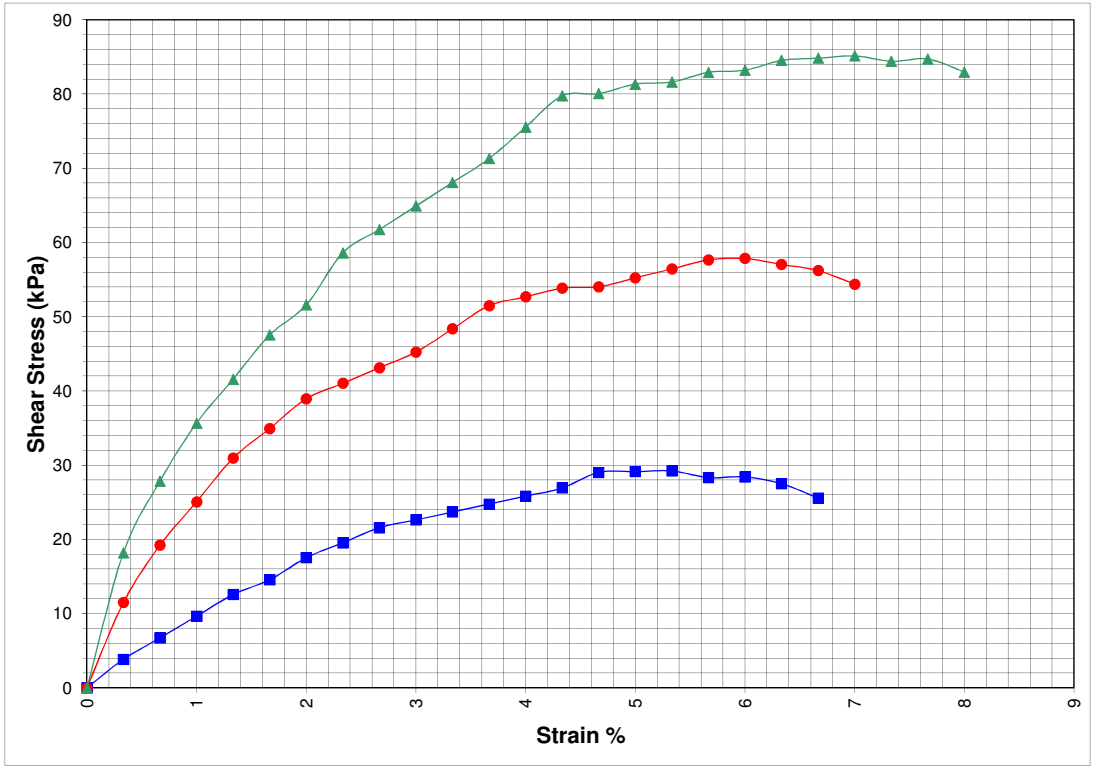
**Borehole: MBH-11**

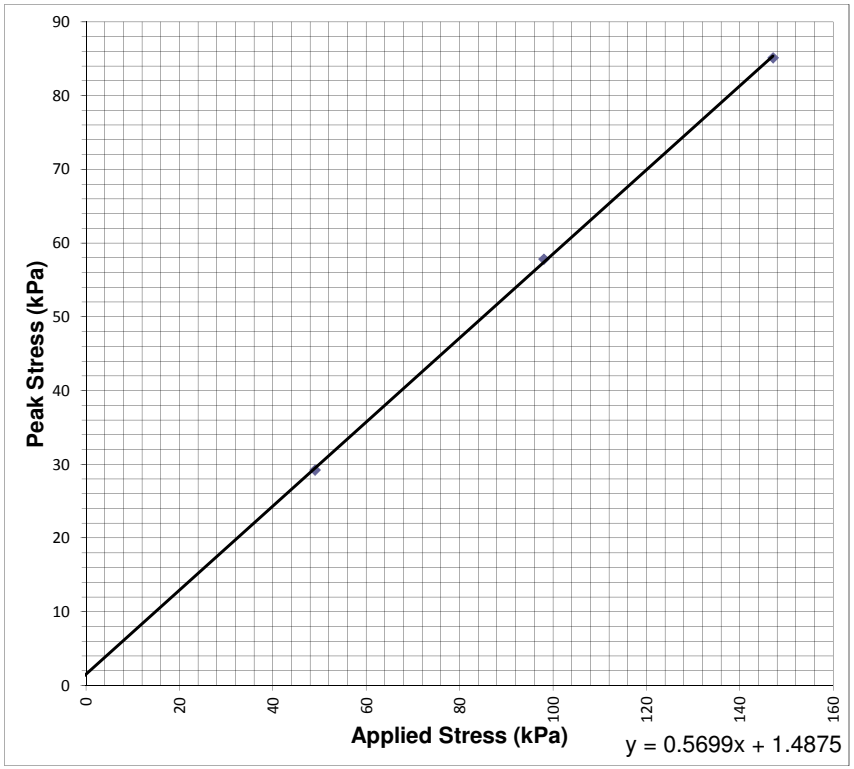
**Sample Type: SPT-24**

**Depth: 34.50-34.75 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 29 |
| | Stage 2 | 98 | 58 |
| | Stage 3 | 147 | 85 |

| | | |
|---|---|---|
| Angle of Friction | **29.68** | ° |
| Apparent Cohesion | **1.49** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: MBH-11**

**Sample Type: SPT-27**

**Depth: 40.00-40.18 m**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-1 | 0.00-0.25 | | | | | 19.3 | 17.24 | 7.18 | 14.46 | 2.66 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-2 | 1.50-1.65 | SP-SM | | | | 16.3 | 15.40 | 5.34 | 13.24 | | 0 | 90 | <--> | <--> | 10 | | | | | | | | | | | | | | 8.68 | 3.40 | 1.00 | 2500 | 12390 |
| SPT-3 | 3.00-3.25 | | | | | 18.2 | 18.53 | 8.47 | 15.68 | 2.61 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-4 | 4.50-4.75 | | | | | 18.7 | 18.90 | 8.84 | 15.92 | | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-5 | 6.00-6.30 | | | | | 14.9 | 17.97 | 7.91 | 15.63 | | | | | | | DST | | | 1.65 | 25.6 | | | | | | | | | | | | |
| SPT-6 | 7.50-7.80 | SM / SC | | | | 23.4 | 17.48 | 7.42 | 14.17 | | 0 | 84 | <--> | <--> | 16 | | | | | | | | | | | | | | | | | | |
| SPT-7 | 9.00-9.25 | | | | | 20.7 | 16.61 | 6.55 | 13.76 | | | | | | | DST | | | 1.52 | 24.9 | | | | | | | | | | | | |
| SPT-8 | 10.50-10.80 | SP-SM | | | | 20.4 | 17.11 | 7.05 | 14.21 | 2.59 | 0 | 92 | <--> | <--> | 8 | | | | | | | | | | | | | | | | | | |
| SPT-9 | 12.00-12.30 | | | | | 20.6 | 18.24 | 8.18 | 15.12 | 2.64 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-10 | 13.50-13.75 | | | | | 20.5 | 17.48 | 7.42 | 14.51 | | | | | | | DST | | | 2.63 | 27.5 | | | | | | | | | | | | |
| SPT-11 | 15.00-15.30 | SP-SM | | | | 21.3 | 17.43 | 7.37 | 14.37 | | 0 | 94 | <--> | <--> | 6 | | | | | | | | | | | | | | | | | | |
| SPT-12 | 16.50-16.75 | | | | | 22.5 | 17.86 | 7.80 | 14.58 | | | | | | | DST | | | 1.97 | 27.9 | | | | | | | | | | | | |
| SPT-13 | 18.00-18.30 | SM / SC | | | | 23.3 | 17.86 | 7.80 | 14.49 | 2.64 | 0 | 82 | <--> | <--> | 18 | | | | | | | | | | | | | | | | | | |
| SPT-14 | 19.50-19.75 | | | | | 22.2 | 18.20 | 8.14 | 14.89 | | | | | | | | | | | | | | | | | | | | 8.60 | 1.60 | 1.00 | 1100 | 5310 |
| SPT-15 | 21.00-21.25 | SP-SM | | | | 20.8 | 18.27 | 8.21 | 15.12 | | 0 | 92 | <--> | <--> | 8 | | | | | | | | | | | | | | | | | | |
| SPT-16 | 22.50-22.80 | | | | | 20.2 | 17.41 | 7.35 | 14.49 | 2.66 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-17 | 24.00-24.20 | | | | | 22.8 | 18.22 | 8.16 | 14.84 | | | | | | | DST | | | 2.38 | 26.5 | | | | | | | | | | | | |
| SPT-18 | 25.50-25.70 | SM / SC | | | | 25.6 | 17.80 | 7.74 | 14.18 | | 0 | 81 | <--> | <--> | 19 | | | | | | | | | | | | | | | | | | |
| SPT-19 | 27.00-27.25 | | | | | 19.7 | 18.04 | 7.98 | 15.07 | | | | | | | DST | | | 1.50 | 27.3 | | | | | | | | | | | | |
| SPT-20 | 28.50-28.65 | | | | | 24.1 | 17.95 | 7.89 | 14.47 | 2.63 | | | | | | | | | | | | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

\# : Decayed Wood

**Failure Type**

A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-12**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density ($kN/m^3$) | Submerged Unit Weight ($kN/m^3$) | Dry Density ($kN/m^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-21 | 30.00-30.15 | | | | | 24.6 | 18.11 | 8.05 | 14.53 | 2.64 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-22 | 31.50-31.70 | | | | | 22.4 | 17.57 | 7.51 | 14.35 | | | | | | | DST | | | 1.42 | 26.7 | | | | | | | | | | | | | |
| SPT-23 | 33.00-33.15 | SM / SC | | | | 24.2 | 17.41 | 7.35 | 14.02 | | 0 | 83 | <--> | <--> | 17 | | | | | | | | | | | | | | | | | | |
| SPT-24 | 34.50-34.60 | | | | | 24.4 | 17.40 | 7.34 | 13.99 | | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-25 | 36.00-36.10 | SM / SC | | | | 23.9 | 18.24 | 8.18 | 14.72 | | 0 | 84 | <--> | <--> | 16 | | | | | | | | | | | | | | | | | | |
| SPT-26 | 37.50-37.60 | | | | | 14.8 | 15.35 | 5.29 | 13.37 | 2.62 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-27 | 39.00-39.10 | | | | | 23.6 | 16.87 | 6.81 | 13.65 | | | | | | | | | | | | | | | | | | | | | | | | |
| **END OF BOREHOLE** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

\# : Decayed Wood

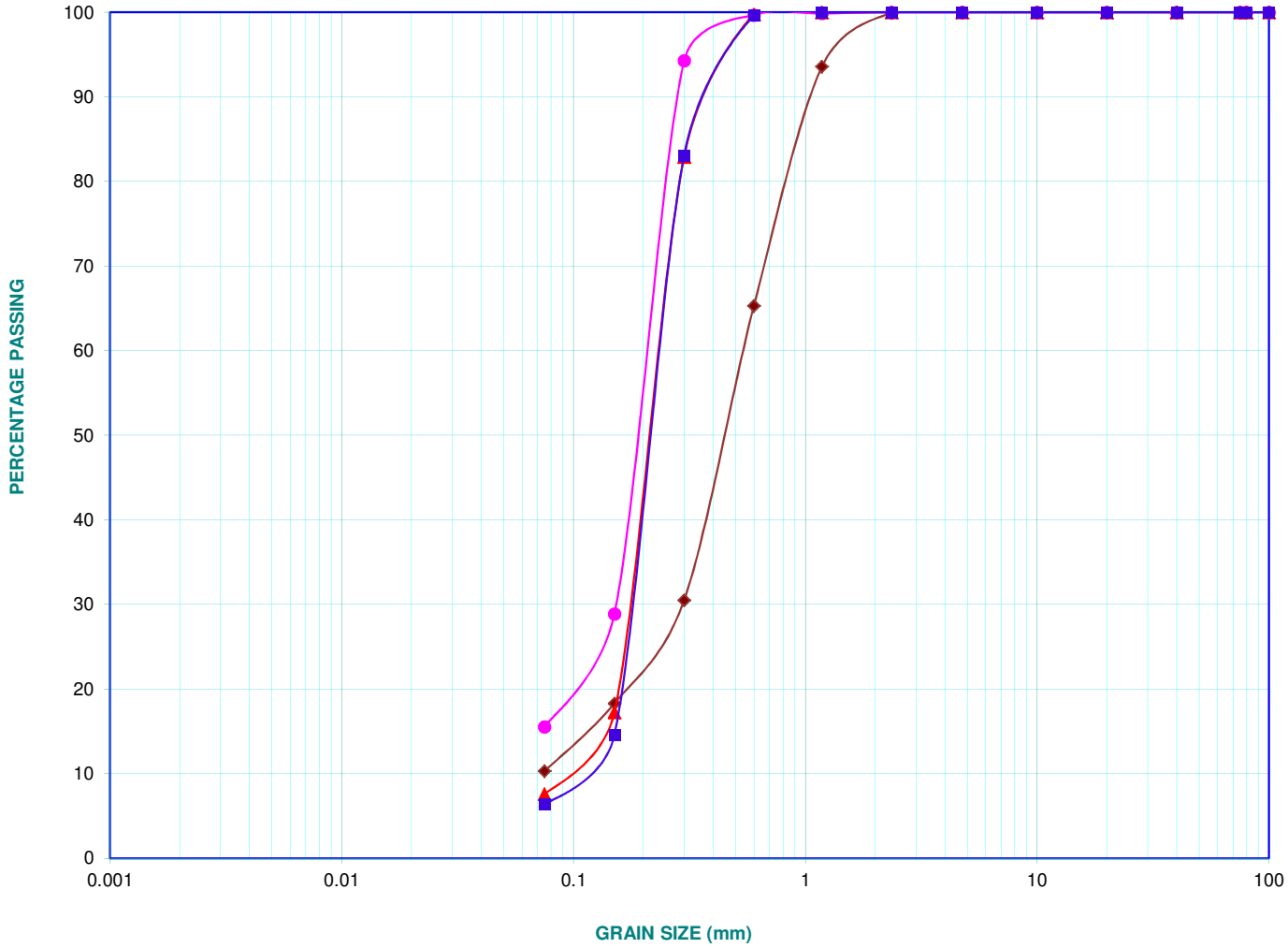
**Failure Type**

A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-12**

# GRAIN SIZE ANALYSIS

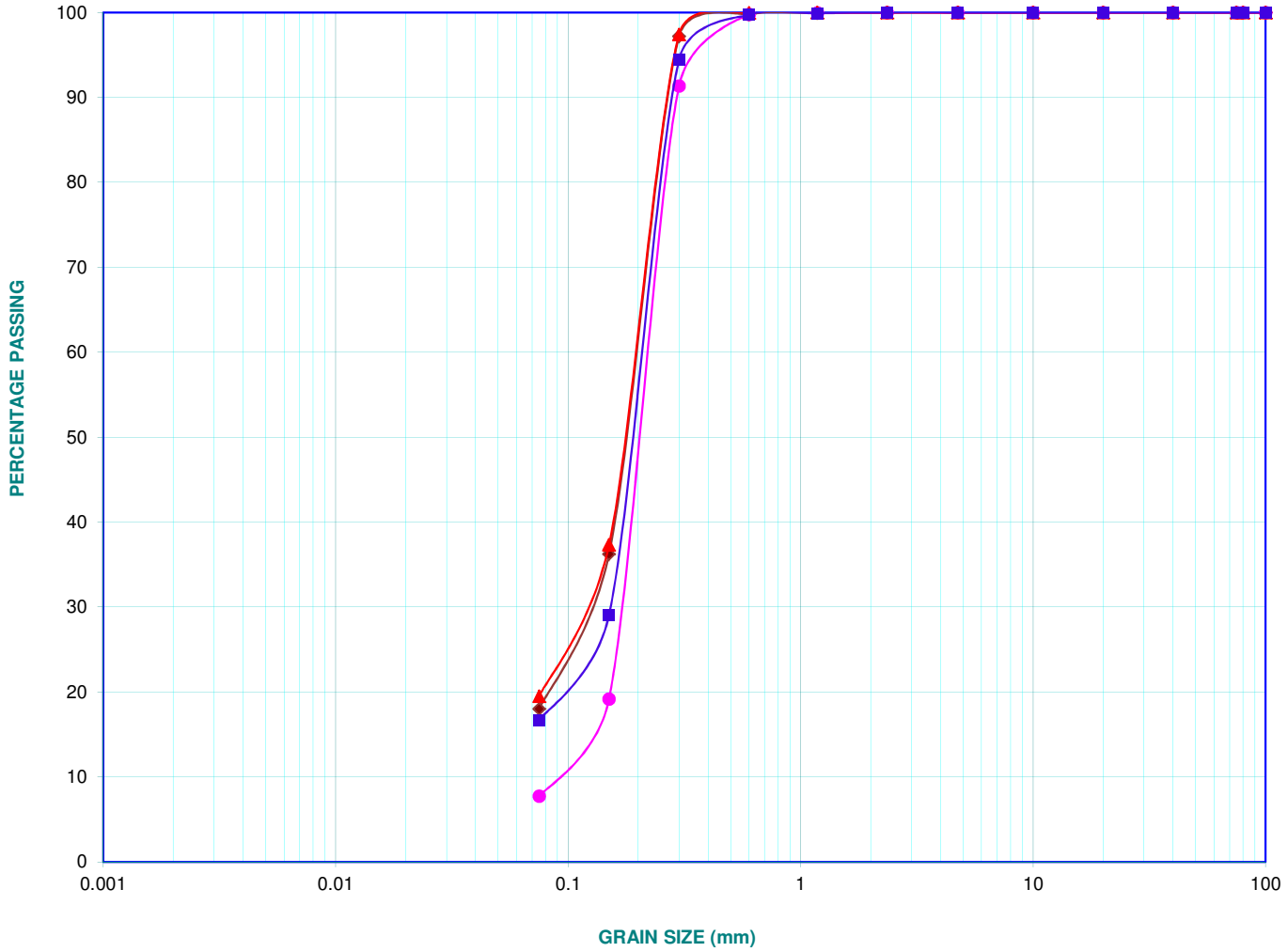
| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | : Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha | | | | | | | | | | |
| **Job No.** | : CM 19 01 03 | | | **Borehole No.** | : MBH-12 | | | **Date :** | 7-Jun-19 | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | . | SAND F | SAND M | SAND C | GRAVEL F / GRAVEL C |
| **Bore Hole .** | MBH-12 | MBH-12 | MBH-12 | MBH-12 | | | | | | | |
| **Depth (m)** | 1.50-1.65 | 7.50-7.80 | 10.50-10.80 | 15.00-15.30 | | | | | | | |
| **Sample Type** | SPT-02 | SPT-06 | SPT-08 | SPT-11 | | | | | | | |
| **Classification** | SP-SM | SM / SC | SP-SM | SP-SM | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | |
| **Sand %** | 90 | 84 | 92 | 94 | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | |
| **Fines % (Silt+Clay)** | 10 | 16 | 8 | 6 | | | | | | | |
| **D60 mm** | 0.550 | | 0.240 | 0.240 | | | | | | | |
| **D30 mm** | 0.300 | | 0.180 | 0.180 | | | | | | | |
| **D10 mm** | 0.075 | | 0.100 | 0.120 | | | | | | | |
| **Cu** | 7.33 | | 2.40 | 2.00 | | | | | | | |
| **Cc** | 2.18 | | 1.35 | 1.13 | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | **Borehole No.** | **: MBH-12** | | | | | **Date :** | **7-Jun-19** | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-12 | MBH-12 | MBH-12 | MBH-12 | | | | | | | | |
| **Depth (m)** | 18.00-18.30 | 21.00-21.25 | 25.50-25.70 | 33.00-33.15 | | | | | | | | |
| **Sample Type** | SPT-13 | SPT-15 | SPT-18 | SPT-23 | | | | | | | | |
| **Classification** | SM / SC | SP-SM | SM / SC | SM / SC | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 82 | 92 | 81 | 83 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 18 | 8 | 19 | 17 | | | | | | | | |
| **D60 mm** | | 0.220 | | | | | | | | | | |
| **D30 mm** | | 0.180 | | | | | | | | | | |
| **D10 mm** | | 0.095 | | | | | | | | | | |
| **Cu** | | 2.32 | | | | | | | | | | |
| **Cc** | | 1.55 | | | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |

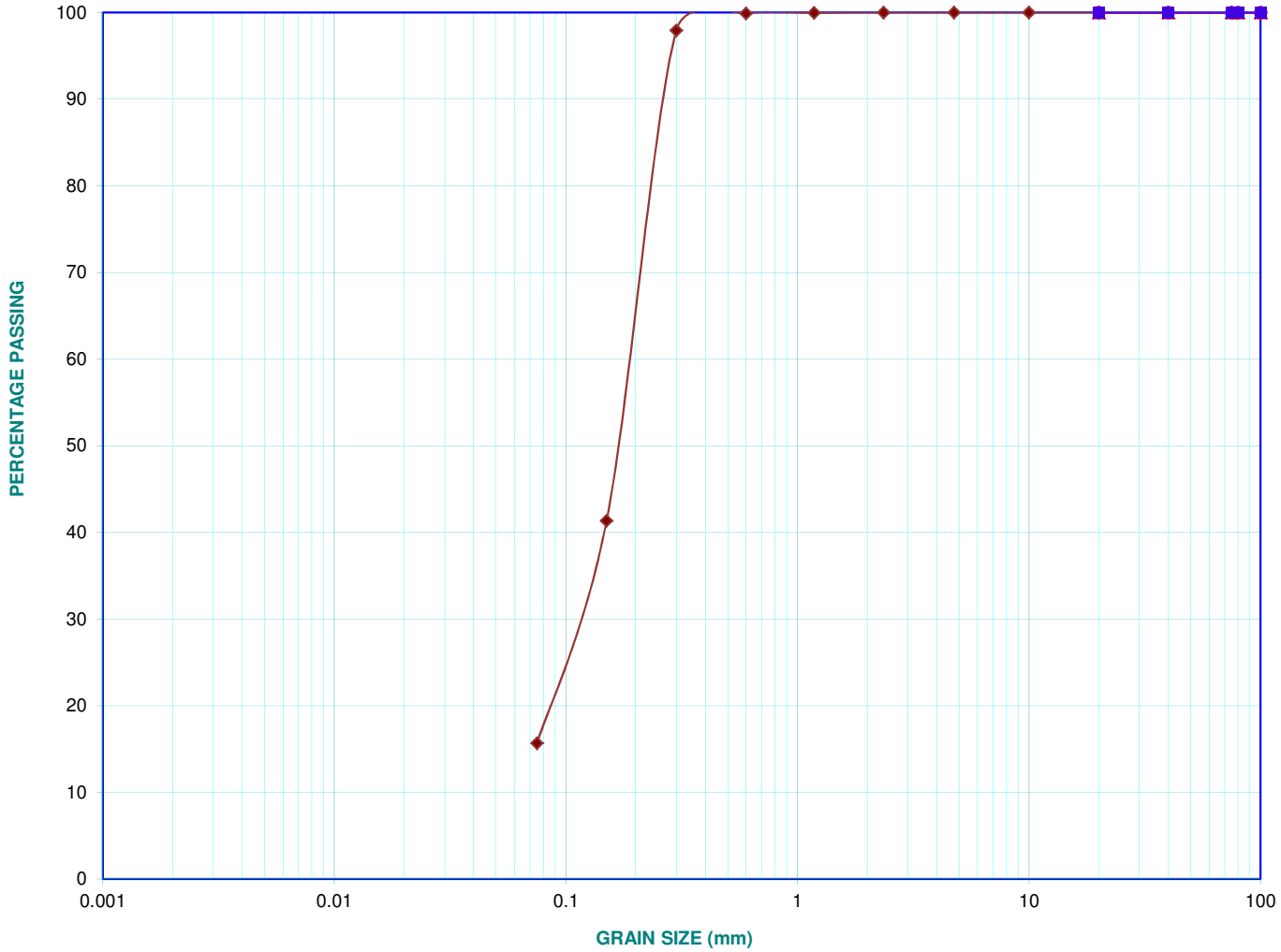



Checked By :

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-12** |
| **Date :** | **7-Jun-19** |

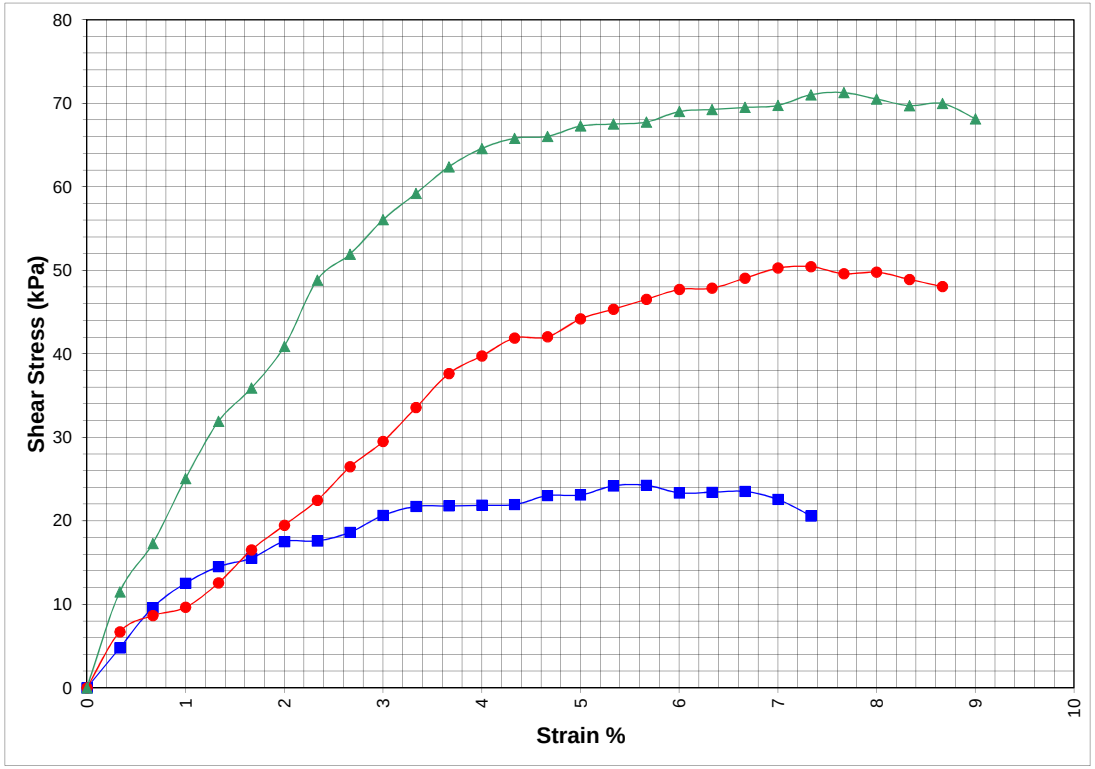
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Symbol** | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-12 | | | | | | | | | | | |
| **Depth (m)** | 36.00-36.10 | | | | | | | | | | | |
| **Sample Type** | SPT-25 | | | | | | | | | | | |
| **Classification** | SM / SC | | | | | | | | | | | |
| **Gravel %** | 0 | | | | | | | | | | | |
| **Sand %** | 84 | | | | | | | | | | | |
| **Silt %** | <----> | | | | | | | | | | | |
| **Clay %** | <----> | | | | | | | | | | | |
| **Fines % (Silt+Clay)** | 16 | | | | | | | | | | | |
| **D60 mm** | | | | | | | | | | | | |
| **D30 mm** | | | | | | | | | | | | |
| **D10 mm** | | | | | | | | | | | | |
| **Cu** | | | | | | | | | | | | |
| **Cc** | | | | | | | | | | | | |
| **Liquid Limit %** | --- | | | | | | | | | | | |
| **Plastic Limit %** | --- | | | | | | | | | | | |
| **Plasticity Index** | --- | | | | | | | | | | | |

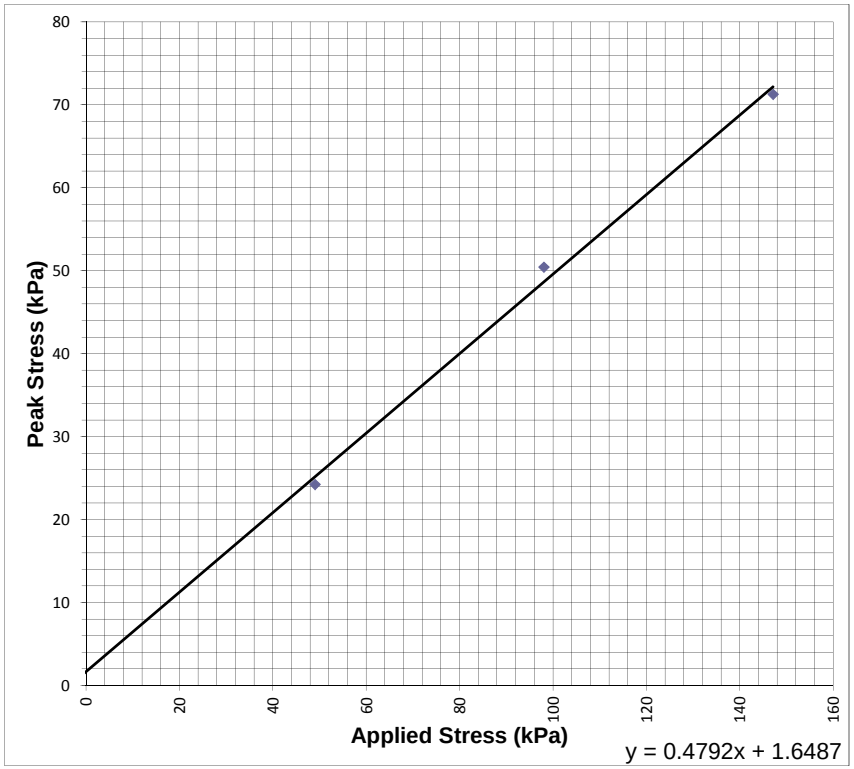



Checked By :

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 24 |
| | Stage 2 | 98 | 50 |
| | Stage 3 | 147 | 71 |

| | | |
|---|---|---|
| Angle of Friction | **25.60** | ° |
| Apparent Cohesion | **1.65** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

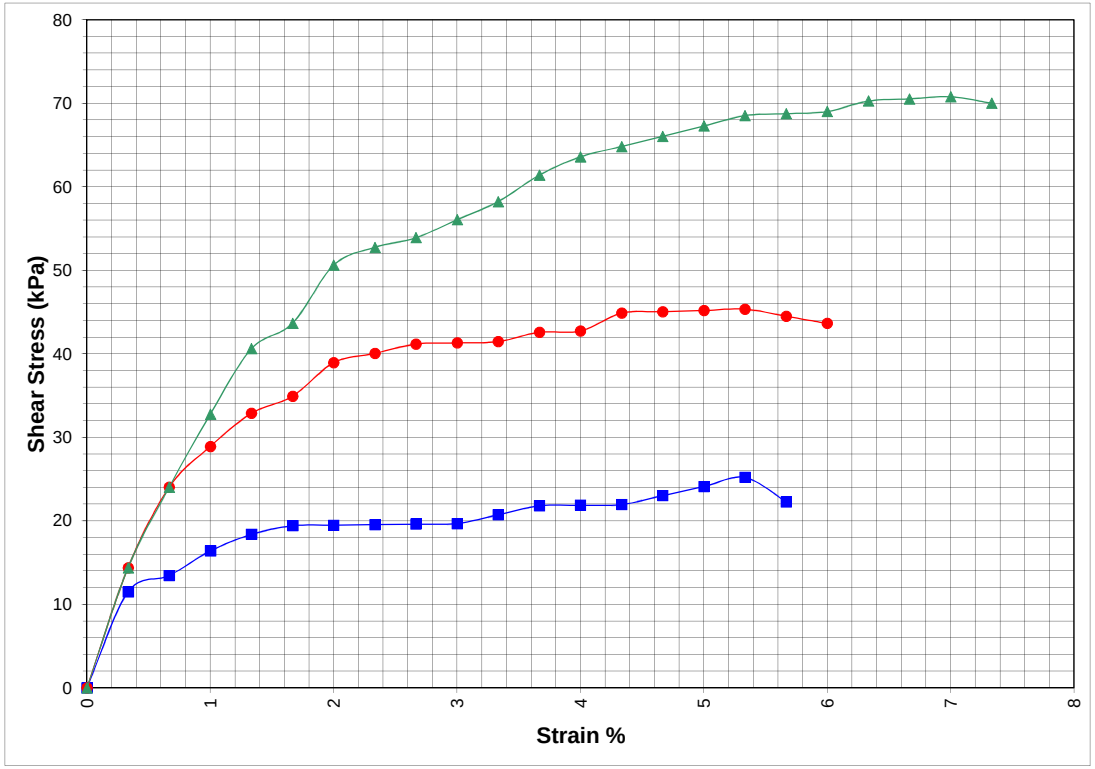
**Borehole: MBH-12**

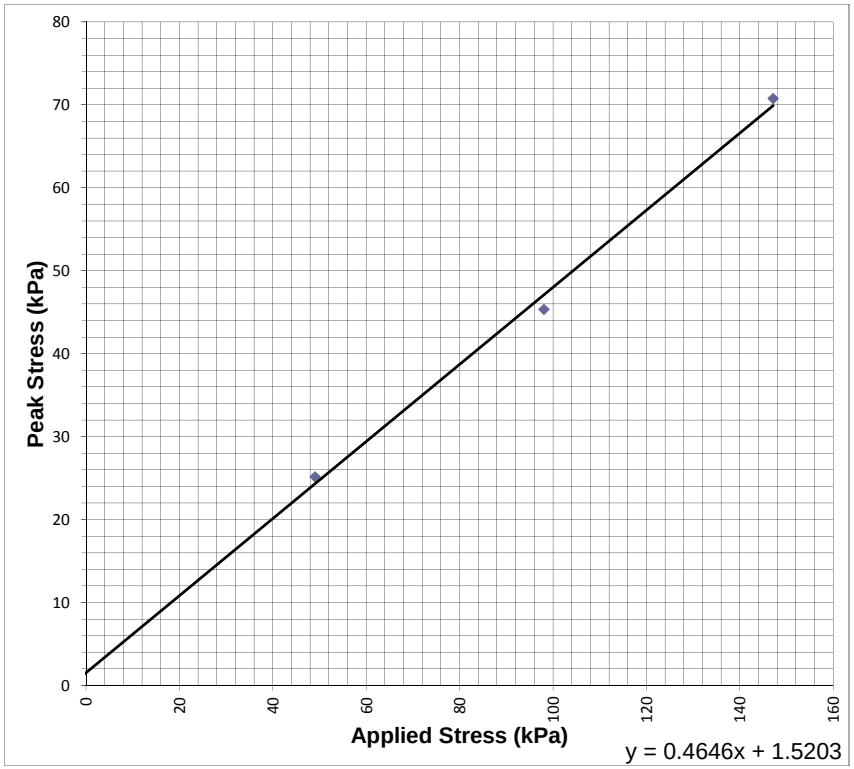
**Sample Type: SPT-05**

**Depth: 6.00-6.30 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 25 |
| | Stage 2 | 98 | 45 |
| | Stage 3 | 147 | 71 |

| | | |
|---|---|---|
| Angle of Friction | **24.92** | ° |
| Apparent Cohesion | **1.52** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

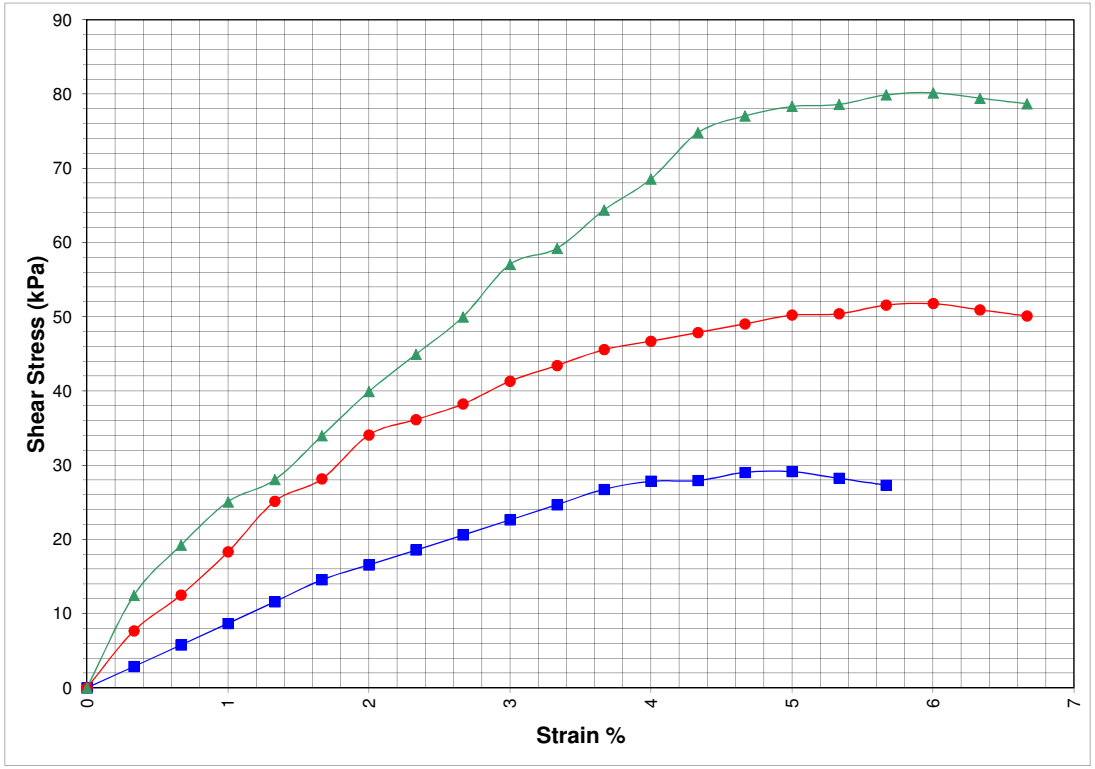
**Borehole: MBH-12**

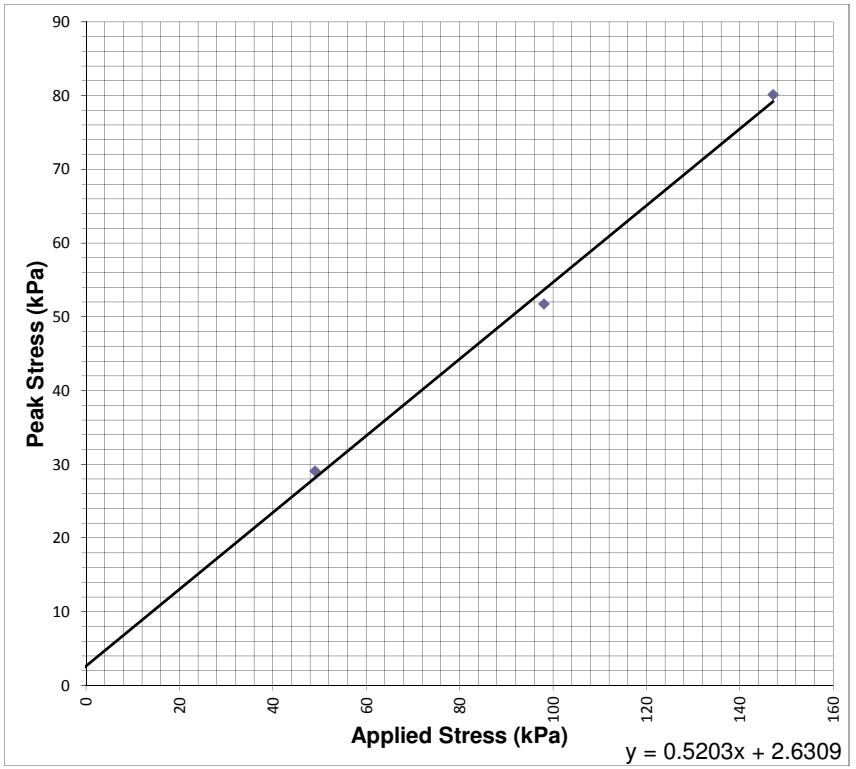
**Sample Type: SPT-07**

**Depth: 9.00-9.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 29 |
| | Stage 2 | 98 | 52 |
| | Stage 3 | 147 | 80 |

| | | |
|---|---|---|
| Angle of Friction | **27.5** | ° |
| Apparent Cohesion | **2.63** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

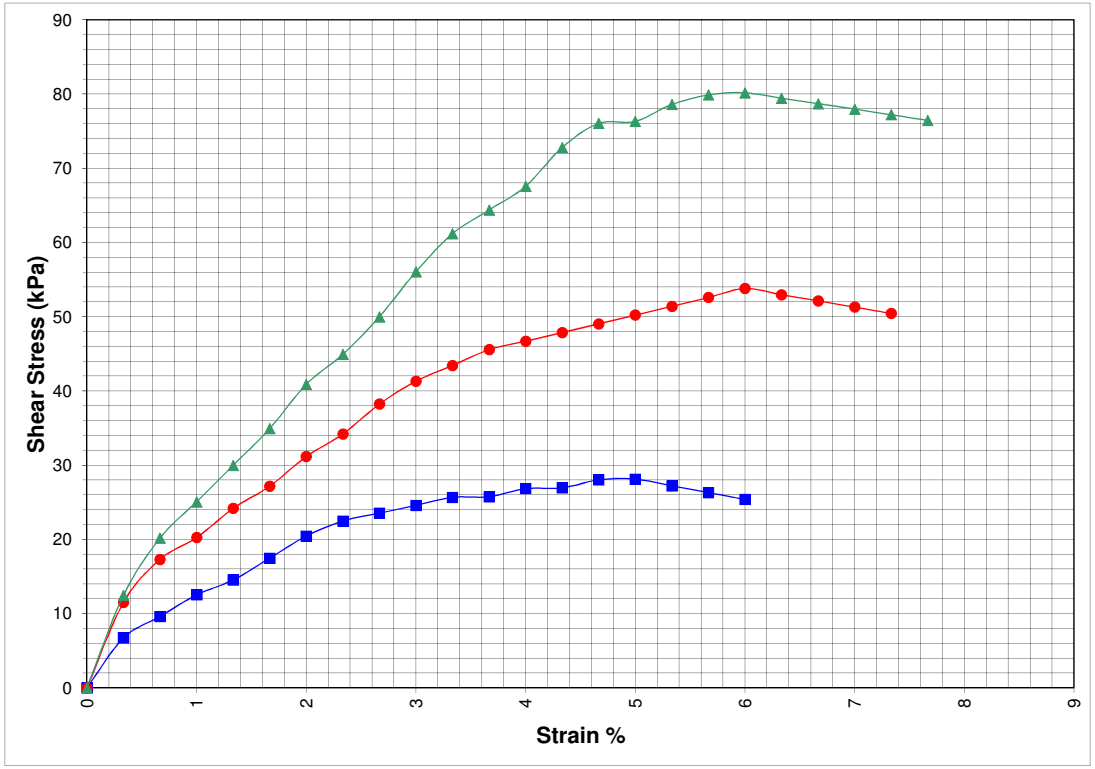
**Borehole: MBH-12**

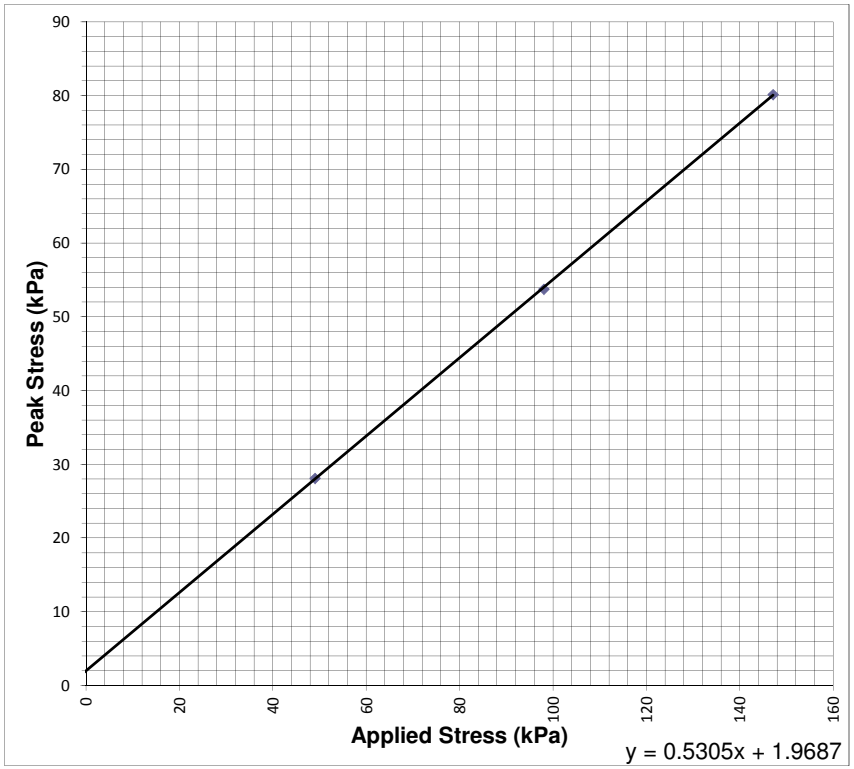
**Sample Type: SPT-10**

**Depth: 13.50-13.75 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 54 |
| | Stage 3 | 147 | 80 |

| | | |
|---|---|---|
| Angle of Friction | **27.9** | ° |
| Apparent Cohesion | **1.97** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

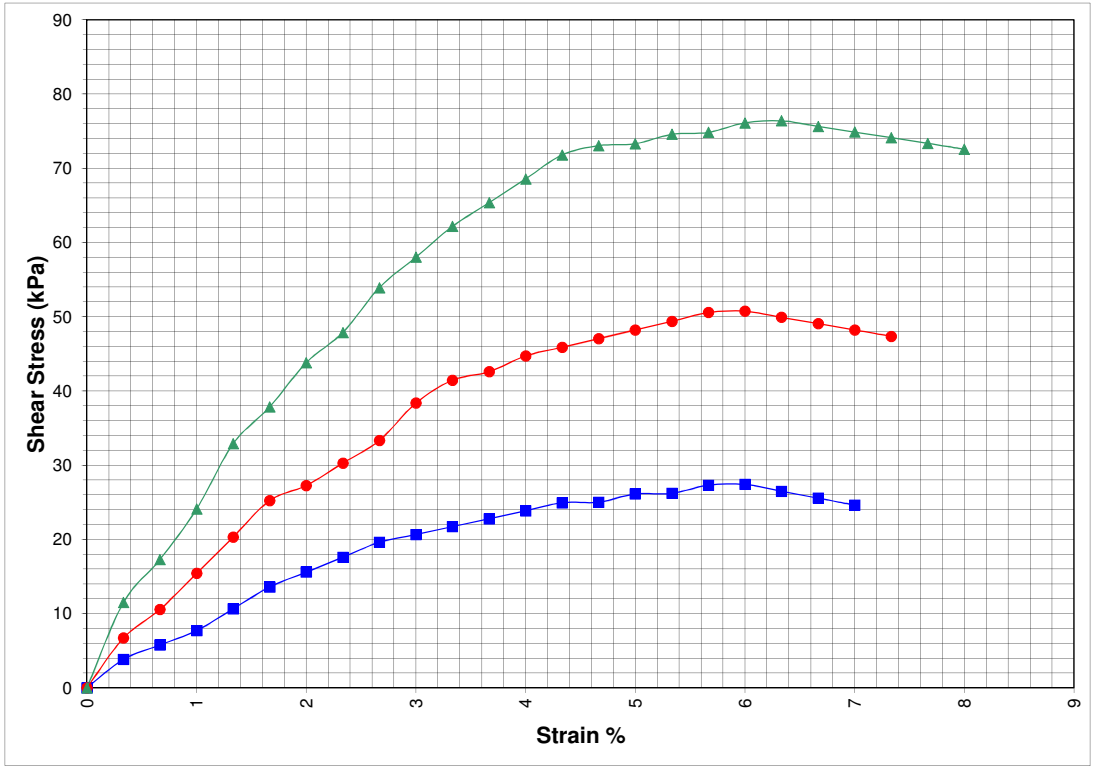
**Borehole: MBH-12**

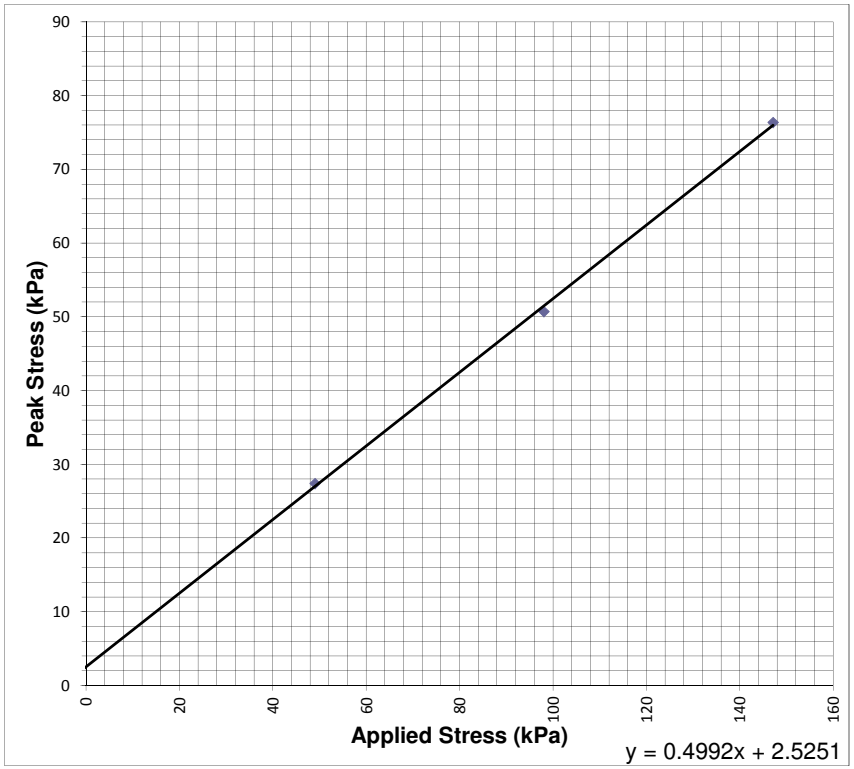
**Sample Type: SPT-12**

**Depth: 16.50-16.75 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 51 |
| | Stage 3 | 147 | 76 |

| | | |
|---|---|---|
| Angle of Friction | **26.5** | ° |
| Apparent Cohesion | **2.38** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

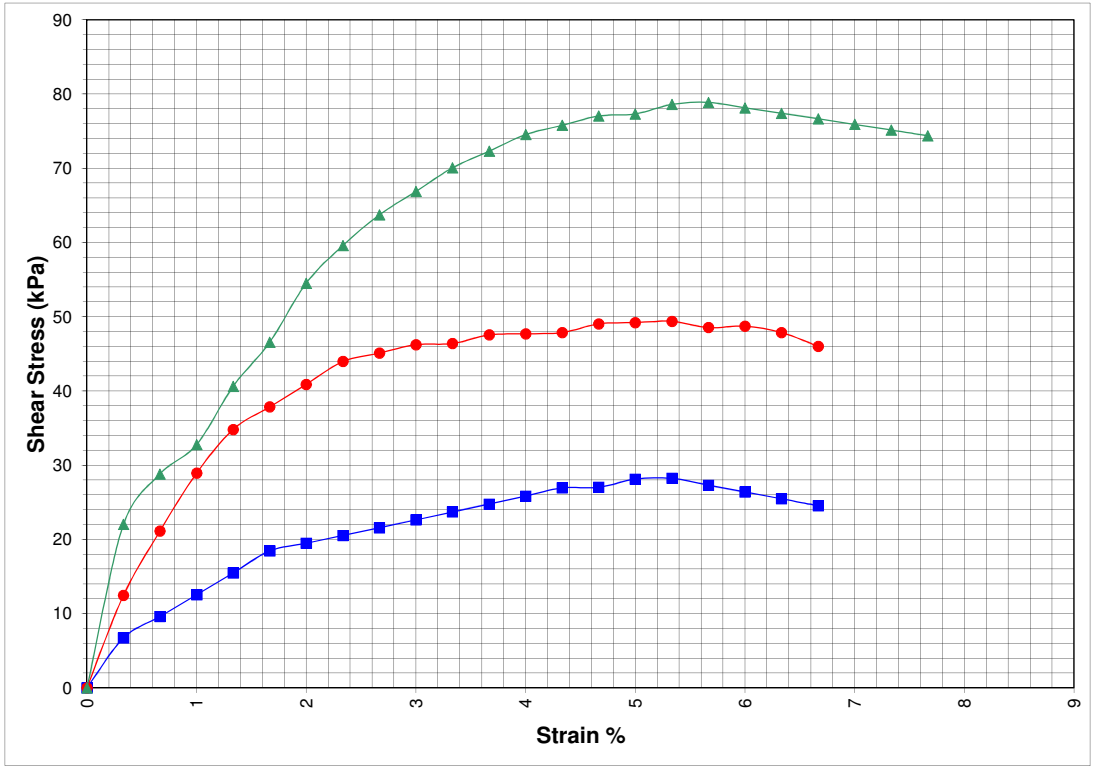
**Borehole: MBH-12**

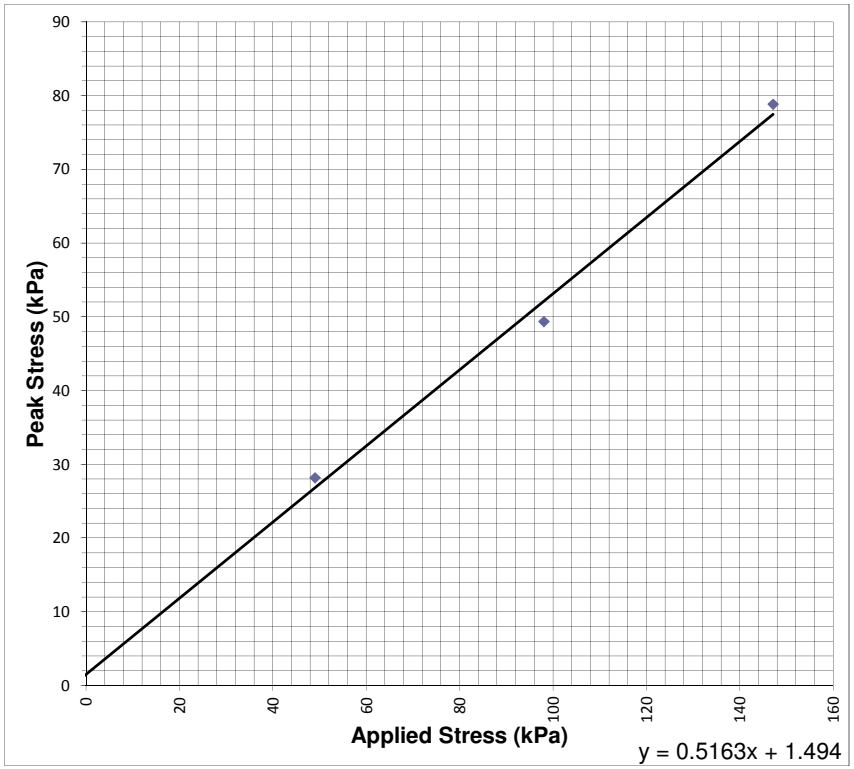
**Sample Type: SPT-17**

**Depth: 24.00-24.20 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 49 |
| | Stage 3 | 147 | 79 |

| | | |
|---|---|---|
| Angle of Friction | **27.31** | ° |
| Apparent Cohesion | **1.50** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

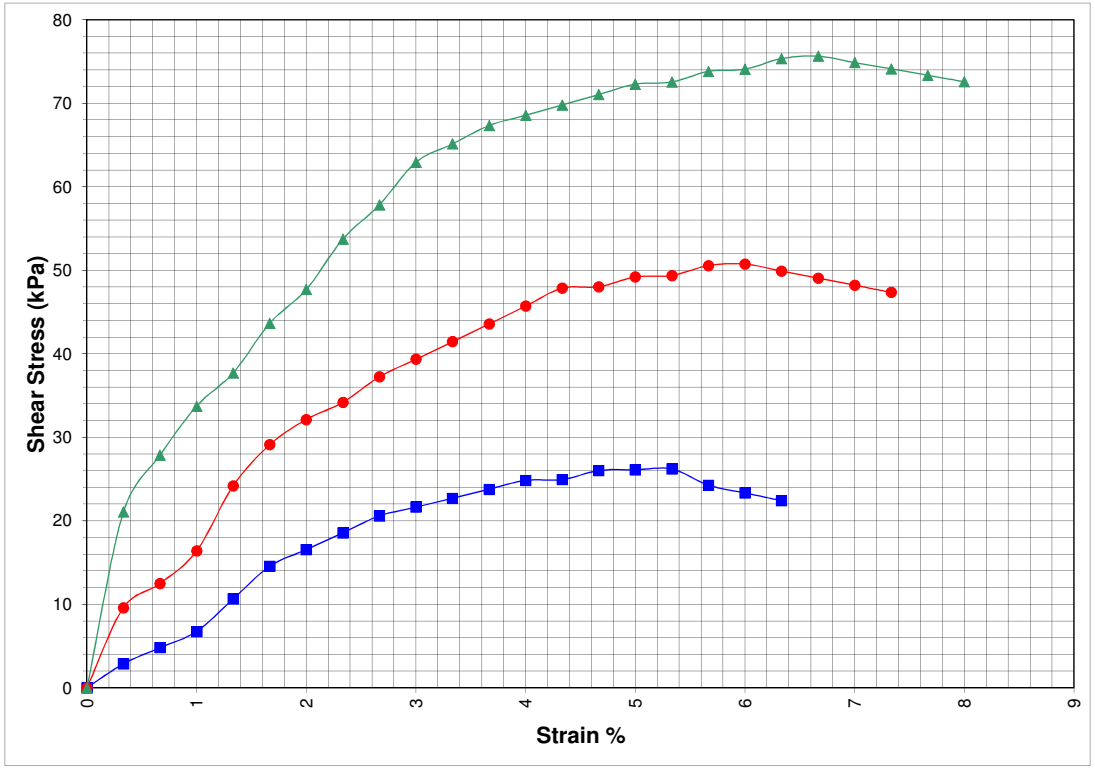
**Borehole: MBH-12**

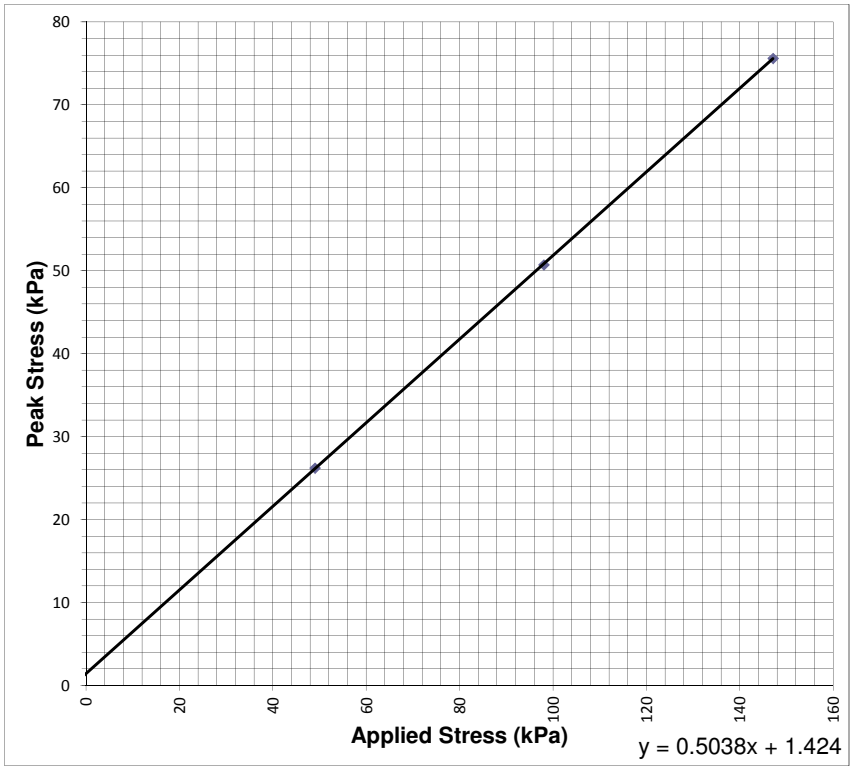
**Sample Type: SPT-19**

**Depth: 27.00-27.25 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 51 |
| | Stage 3 | 147 | 76 |

| | | |
|---|---|---|
| Angle of Friction | **26.74** | ° |
| Apparent Cohesion | **1.42** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: MBH-12**

**Sample Type: SPT-22**

**Depth: 31.50-31.70 m**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | | Chemical tests | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-1 | 0.00-0.20 | | | | | 22.8 | 20.29 | 10.23 | 16.52 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-2 | 1.50-1.65 | SM / SC | | | | 22.7 | 19.36 | 9.30 | 15.77 | 2.58 | 3 | 80 | <--> | <--> | 17 | | | | | | | | | | | | | | | | | | | | | |
| SPT-3 | 3.00-3.22 | | | | | 23.3 | 19.89 | 9.83 | 16.20 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-4 | 4.60-4.90 | SM / SC | | | | 18.2 | 20.31 | 10.25 | 17.18 | 2.60 | 0 | 79 | <--> | <--> | 21 | DST | | | 1.49 | 30.7 | | | | | | | | | | | | | | | | |
| SPT-5 | 6.30-6.45 | | | | | 21.2 | 18.56 | 8.50 | 15.32 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-6 | 7.65-7.95 | SM / SC | | | | 23.3 | 19.61 | 9.55 | 15.91 | 2.52 | 0 | 57 | <--> | <--> | 43 | | | | | | | | | | | | | | | | | | | | | |
| SPT-7 | 9.00-9.15 | | | | | 31.8 | 19.78 | 9.72 | 15.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| UDS-1 | 10.80-11.00 | SC | 43.9 | 17.3 | 26.6 | 26.4 | 19.33 | 9.27 | 15.30 | | 0 | 77 | <--> | <--> | 23 | | | | | | | | | | 40.0 | | | | | 8.35 | 3.77 | 2.00 | 2100 | 8850 |
| | 10.80-11.00 | | | | | | | | | 2.55 | 0 | 42 | 32 | 26 | 58 | | | | | | | | | | | | | | | | | | | |
| UDS-2 | 12.30-12.50 | | | | | 14.5 | 21.80 | 11.74 | 19.04 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-8 | 13.50-13.95 | SC | 30.4 | 13.7 | 16.7 | 16.4 | 21.51 | 11.45 | 18.48 | | 1 | 65 | <--> | <--> | 34 | | | | | | | | | | 57.9 | | | | | | | | | |
| | 13.50-13.95 | | | | | | | | | 2.54 | 0 | 66 | 11 | 23 | 34 | | | | | | | | | | | | | | | | | | | |
| SPT-9 | 15.00-15.45 | | | | | 15.6 | 19.30 | 9.24 | 16.69 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-10 | 16.50-16.65 | | | | | 20.7 | 19.66 | 9.60 | 16.29 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-11 | 18.00-18.18 | SC | | | | 22.3 | 19.33 | 9.27 | 15.81 | 2.58 | 0 | 61 | <--> | <--> | 39 | DST | | | 7.22 | 25.6 | | | | | | | | | | | | | | | | |
| SPT-14 | 22.50-22.95 | SM / SC | | | | 16.3 | 20.71 | 10.65 | 17.81 | | 0 | 85 | <--> | <--> | 15 | DST | | | 2.19 | 27.8 | | | | | | | | | | | | | | | | |
| SPT-15 | 24.10-24.45 | CI | 37.4 | 19.3 | 18.1 | 18.8 | 21.24 | 11.18 | 17.88 | | 0 | 24 | <--> | <--> | 76 | | | | | | | | | | 80.0 | | | | | | | | | |
| | 24.10-24.45 | | | | | | | | | 2.52 | 0 | 30 | 40 | 30 | 70 | | | | | | | | | | | | | | | | | | | | |
| SPT-16 | 25.50-25.95 | | | | | 18.2 | 21.31 | 11.25 | 18.04 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-17 | 26.65-26.95 | SM / SC | | | | 18.6 | 19.71 | 9.65 | 16.62 | 2.54 | 0 | 63 | <--> | <--> | 37 | DST | | | 1.78 | 28.1 | | | | | | | | | | | | | | | | |
| **END OF BOREHOLE** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

\# : Decayed Wood

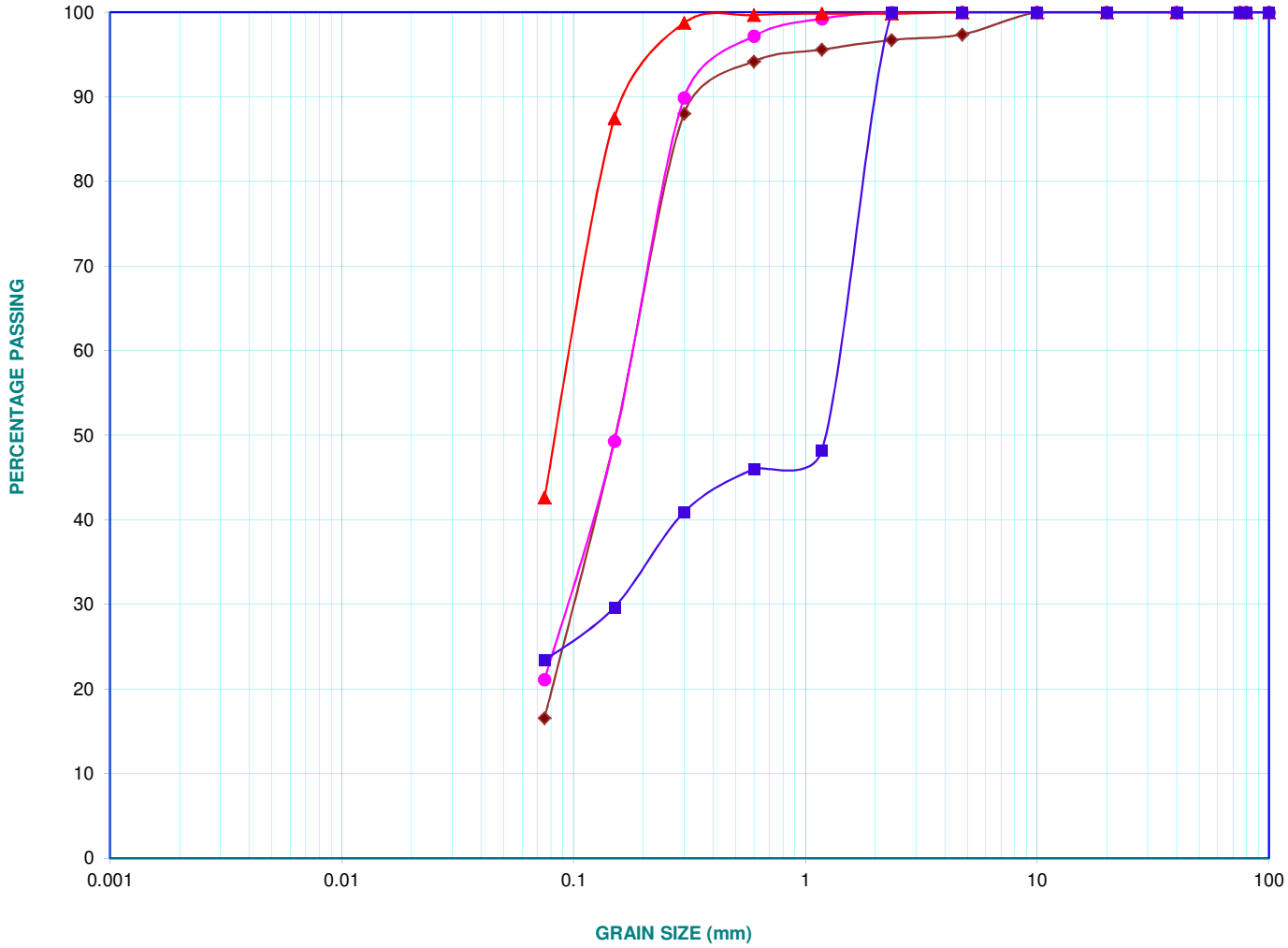
**Failure Type**
A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-13**

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-13** |
| **Date :** | **8-Apr-19** |

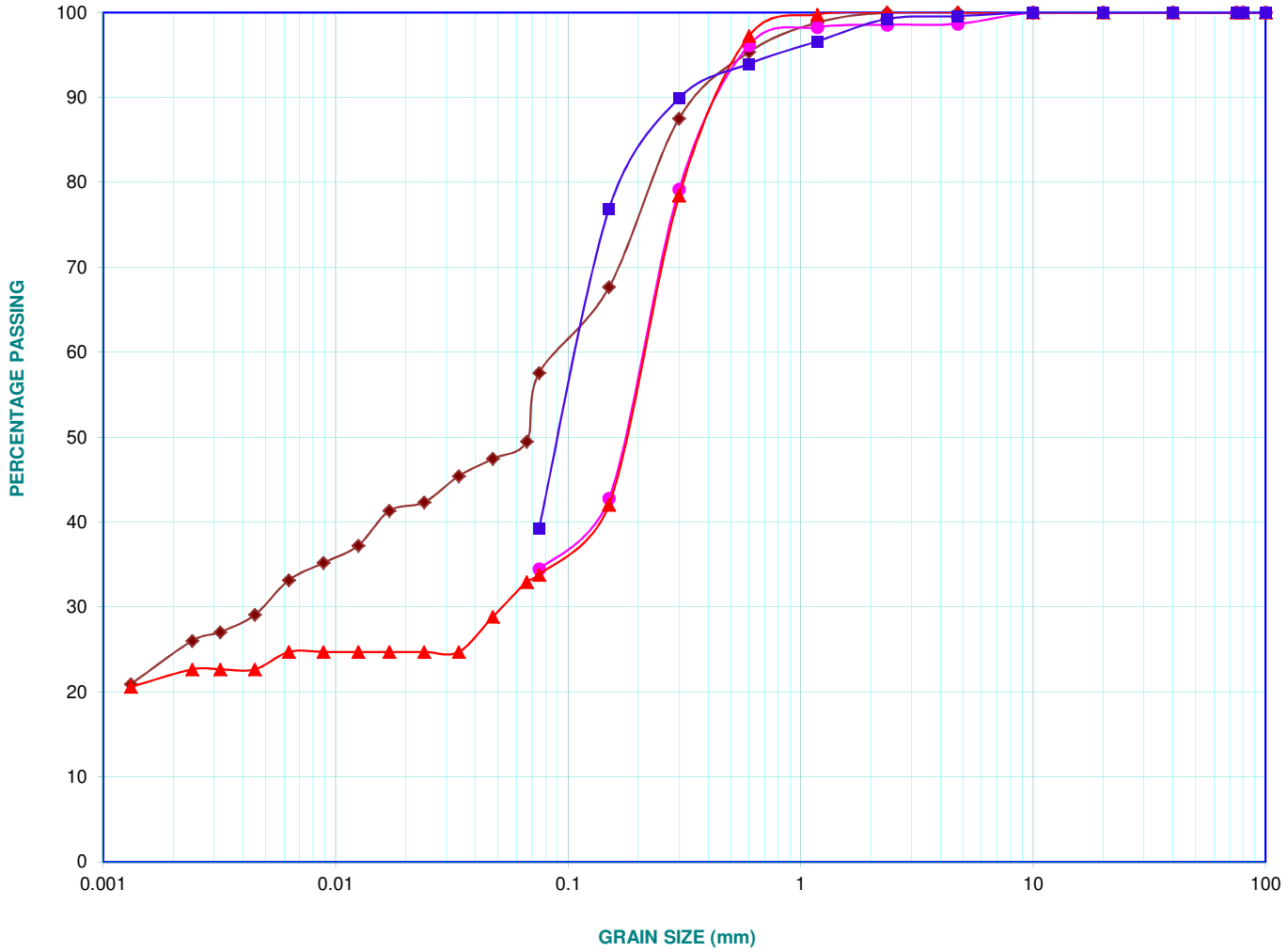
| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| Bore Hole . | MBH-13 | MBH-13 | MBH-13 | MBH-13 | | | | | | | | |
| Depth (m) | 1.50-1.65 | 4.60-4.90 | 7.65-7.95 | 10.80-11.00 | | | | | | | | |
| Sample Type | SPT-1 | SPT-4 | SPT-6 | UDS-1 | | | | | | | | |
| Classification | SM / SC | SM / SC | SM / SC | SC | | | | | | | | |
| Gravel % | 3 | 0 | 0 | 0 | | | | | | | | |
| Sand % | 80 | 79 | 57 | 77 | | | | | | | | |
| Silt % | <----> | <----> | <----> | <----> | | | | | | | | |
| Clay % | <----> | <----> | <----> | <----> | | | | | | | | |
| Fines % (Silt+Clay) | 17 | 21 | 43 | 23 | | | | | | | | |
| D60 mm | | | | | | | | | | | | |
| D30 mm | | | | | | | | | | | | |
| D10 mm | | | | | | | | | | | | |
| Cu | | | | | | | | | | | | |
| Cc | | | | | | | | | | | | |
| Liquid Limit % | --- | --- | --- | 43.9 | | | | | | | | |
| Plastic Limit % | --- | --- | --- | 17.3 | | | | | | | | |
| Plasticity Index | --- | --- | --- | 26.6 | | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | **Borehole No.** | **: MBH-13** | | | | | **Date :** | **8-Apr-19** | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-13 | MBH-13 | MBH-13 | MBH-13 | | | | | | | | |
| **Depth (m)** | 10.80-11.00 | 13.50-13.95 | 13.50-13.95 | 18.00-18.18 | | | | | | | | |
| **Sample Type** | UDS-1 | SPT-8 | SPT-8 | SPT-11 | | | | | | | | |
| **Classification** | SC | SC | SC | SC | | | | | | | | |
| **Gravel %** | 0 | 1 | 0 | 0 | | | | | | | | |
| **Sand %** | 42 | 65 | 66 | 61 | | | | | | | | |
| **Silt %** | 32 | <----> | 11 | <----> | | | | | | | | |
| **Clay %** | 26 | <----> | 23 | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 58 | 34 | 34 | 39 | | | | | | | | |
| **D60 mm** | | | | | | | | | | | | |
| **D30 mm** | | | | | | | | | | | | |
| **D10 mm** | | | | | | | | | | | | |
| **Cu** | | | | | | | | | | | | |
| **Cc** | | | | | | | | | | | | |
| **Liquid Limit %** | --- | 30.4 | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | 13.7 | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | 16.7 | --- | --- | | | | | | | | |

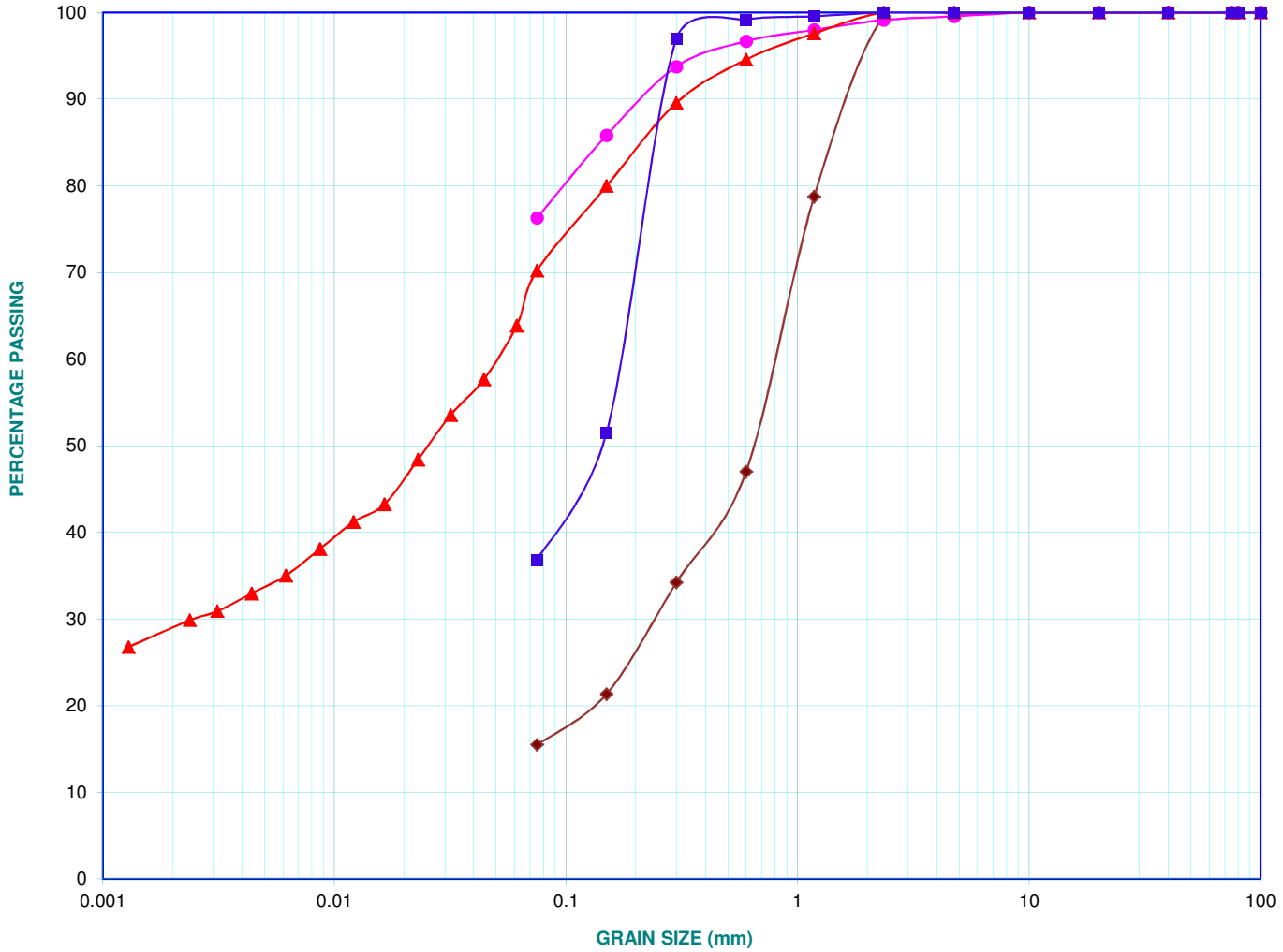



Checked By :

# GRAIN SIZE ANALYSIS

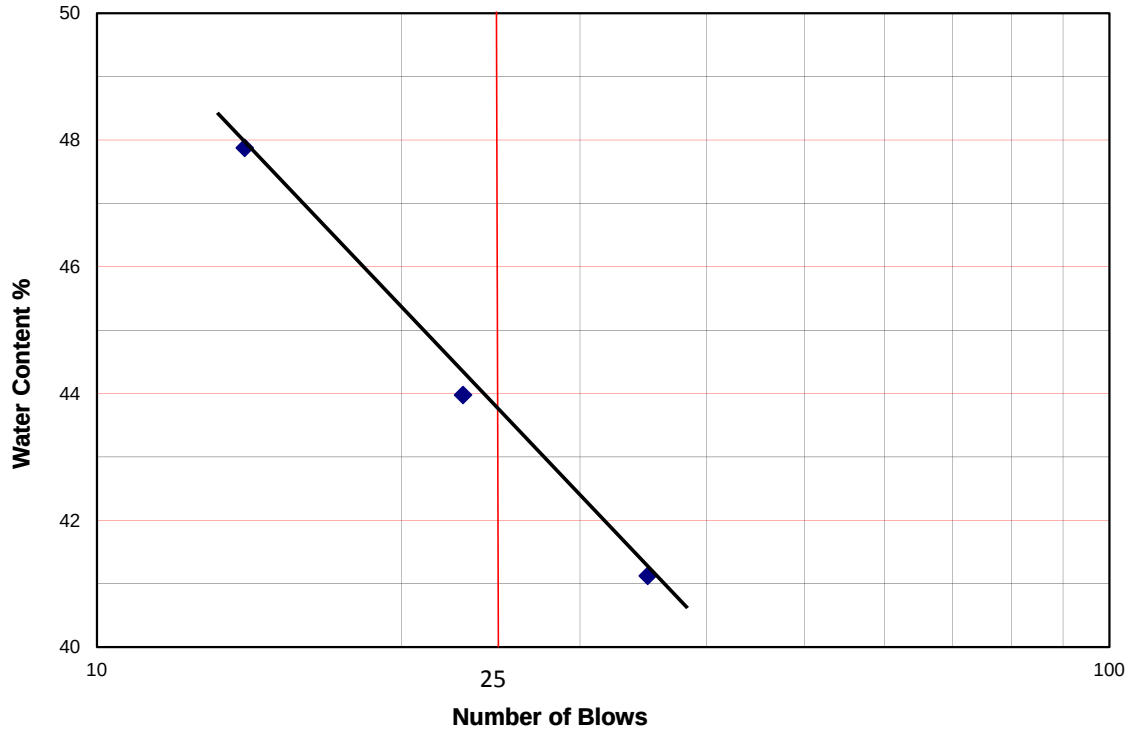
| | |
|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-13** |
| **Date :** | **8-Apr-19** |

| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-13 | MBH-13 | MBH-13 | MBH-13 | | | | | | | | |
| **Depth (m)** | 22.50-22.95 | 24.10-24.45 | 24.10-24.45 | 26.65-26.95 | | | | | | | | |
| **Sample Type** | SPT-14 | SPT-15 | SPT-15 | SPT-17 | | | | | | | | |
| **Classification** | SM / SC | CI | CI | SM / SC | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 85 | 24 | 30 | 63 | | | | | | | | |
| **Silt %** | <----> | <----> | 40 | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | 30 | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 15 | 76 | 70 | 37 | | | | | | | | |
| **D60 mm** | | | | | | | | | | | | |
| **D30 mm** | | | | | | | | | | | | |
| **D10 mm** | | | | | | | | | | | | |
| **Cu** | | | | | | | | | | | | |
| **Cc** | | | | | | | | | | | | |
| **Liquid Limit %** | --- | 37.4 | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | 19.3 | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | 18.1 | --- | --- | | | | | | | | |




Checked By :

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 29.35 | 29.05 | 27.70 | | |
| Dry Weight + Can (g) | 24.88 | 23.10 | 21.73 | | |
| Can Weight (g) | 14.01 | 9.57 | 9.26 | | |
| Water Content, % | 41.1 | 44.0 | 47.9 | | |
| Number of Blows | 35 | 23 | 14 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 16.32 | 17.63 | 16.71 |
| Dry Weight + Can (g) | 15.21 | 17.00 | 15.55 |
| Can Weight (g) | 8.87 | 13.33 | 8.84 |
| Water Content, % | 17.5 | 17.2 | 17.3 |

Liquid Limit % 43.9

Plastic Limit % 17.3

Plasticity Index % 26.6

Preparation of Sample :
Dry State

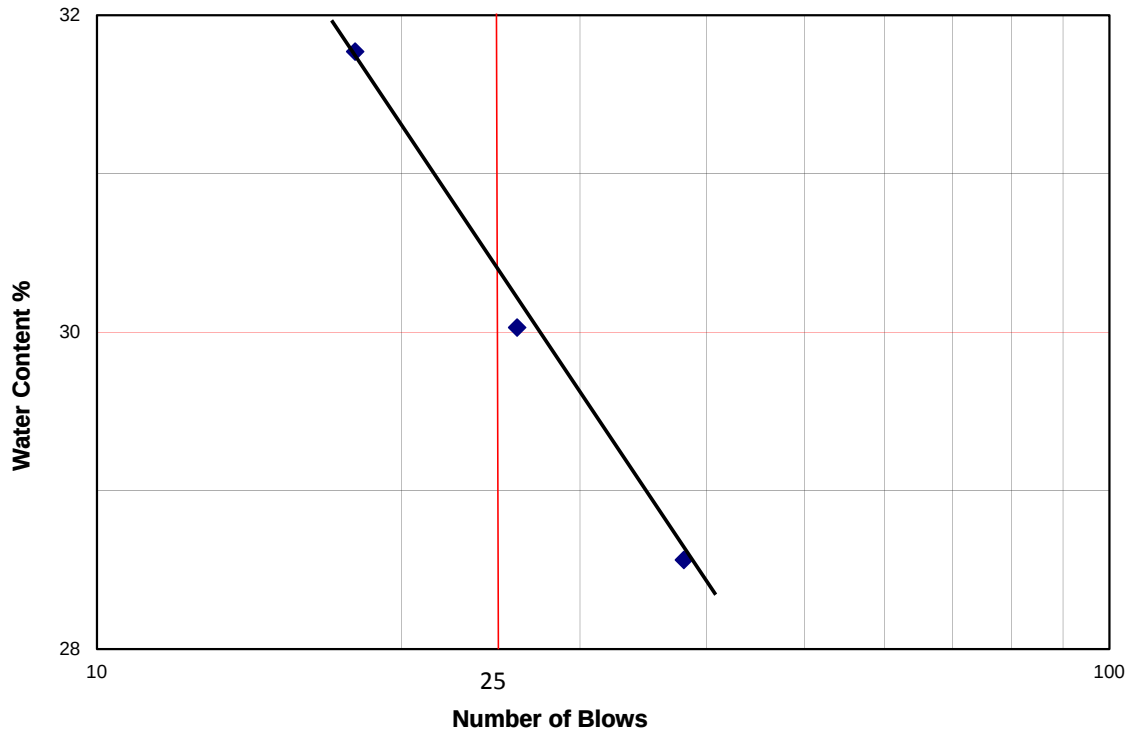
Sample Type: UDS-01

Borehole no.: MBH-13

Depth :10.80-11.00

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 35.73 | 30.64 | 28.89 | | |
| Dry Weight + Can (g) | 30.84 | 26.55 | 24.15 | | |
| Can Weight (g) | 13.72 | 12.93 | 9.23 | | |
| Water Content, % | 28.6 | 30.0 | 31.8 | | |
| Number of Blows | 38 | 26 | 18 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 17.47 | 17.48 | 18.22 |
| Dry Weight + Can (g) | 16.95 | 16.46 | 17.63 |
| Can Weight (g) | 13.17 | 8.93 | 13.33 |
| Water Content, % | 13.8 | 13.5 | 13.7 |

Liquid Limit % 30.4

Plastic Limit % 13.7

Plasticity Index % 16.7

Preparation of Sample :
Dry State

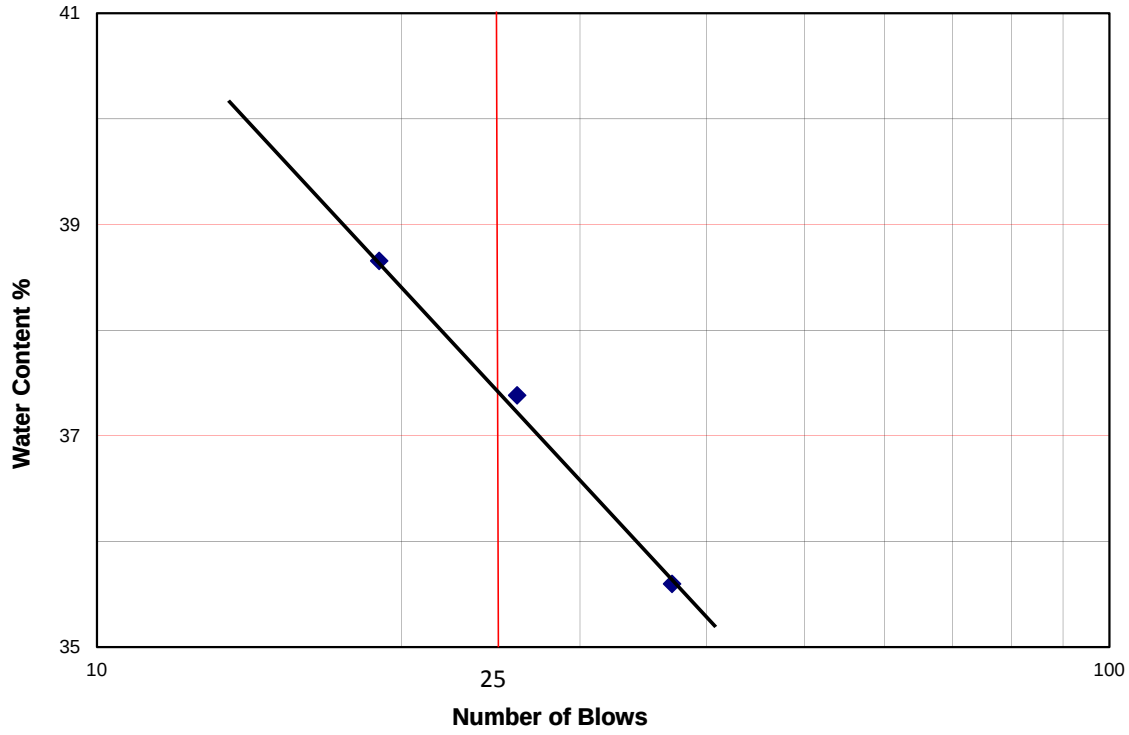
Sample Type: SPT-08

Borehole no.: MBH-13

Depth :10.80-11.00

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 32.06 | 30.52 | 27.82 | | |
| Dry Weight + Can (g) | 27.03 | 24.55 | 22.71 | | |
| Can Weight (g) | 12.90 | 8.58 | 9.49 | | |
| Water Content, % | 35.6 | 37.4 | 38.7 | | |
| Number of Blows | 37 | 26 | 19 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 18.52 | 17.25 | 16.50 |
| Dry Weight + Can (g) | 17.76 | 16.46 | 15.34 |
| Can Weight (g) | 13.85 | 12.40 | 9.24 |
| Water Content, % | 19.4 | 19.5 | 19.0 |

Liquid Limit % 37.4

Plastic Limit % 19.3

Plasticity Index % 18.1

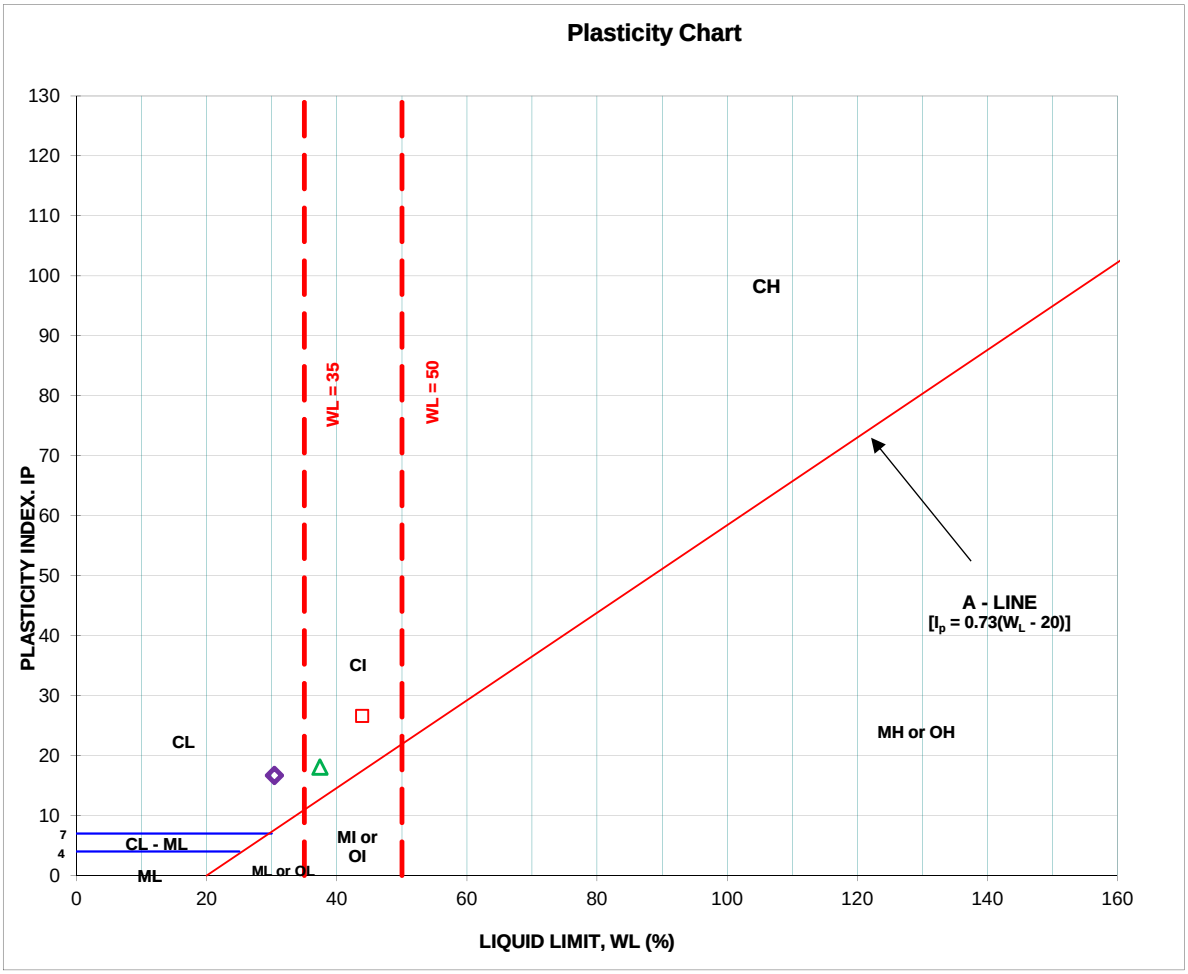
Preparation of Sample :
Dry State

Sample Type: SPT-15

Borehole no.: MBH-13

Depth :10.80-11.00

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.




| | Sample Type | Depth (m) | $W_L$ | $W_P$ | $I_P$ | Remarks |
|---|---|---|---|---|---|---|
| □ | UDS-01 | 10.80-11.00 | 43.9 | 17.3 | 26.6 | CI: Clays with Intermediate plasticity |
| ◇ | SPT-08 | 13.50-13.95 | 30.4 | 13.7 | 16.7 | CL: Inorganic clays of low to medium plasticity. |
| △ | SPT-15 | 24.10-24.45 | 37.4 | 19.3 | 18.1 | CI: Clays with Intermediate plasticity |
| ● | | | | | | |
| + | | | | | | |
| ■ | | | | | | |
| ○ | | | | | | |
| | | | | | | |

| | | | |
|---|---|---|---|
| ML | Inorganic silts, very fine sands, rock flour, silty or clayey fine sands | MH | Inorganic silts, or diatomaceous fine sands or silts, elastic silts |
| CL | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays | CH | Inorganic clays of high plasticity, fat clays |
| OL | Organic silts and organic silty clays of low plasticity | OH | Organic silts and organic clays of medium t high plasticity |
| CI | Clays with Intermediate plasticity | MI | Silt with intermediate plasticity |

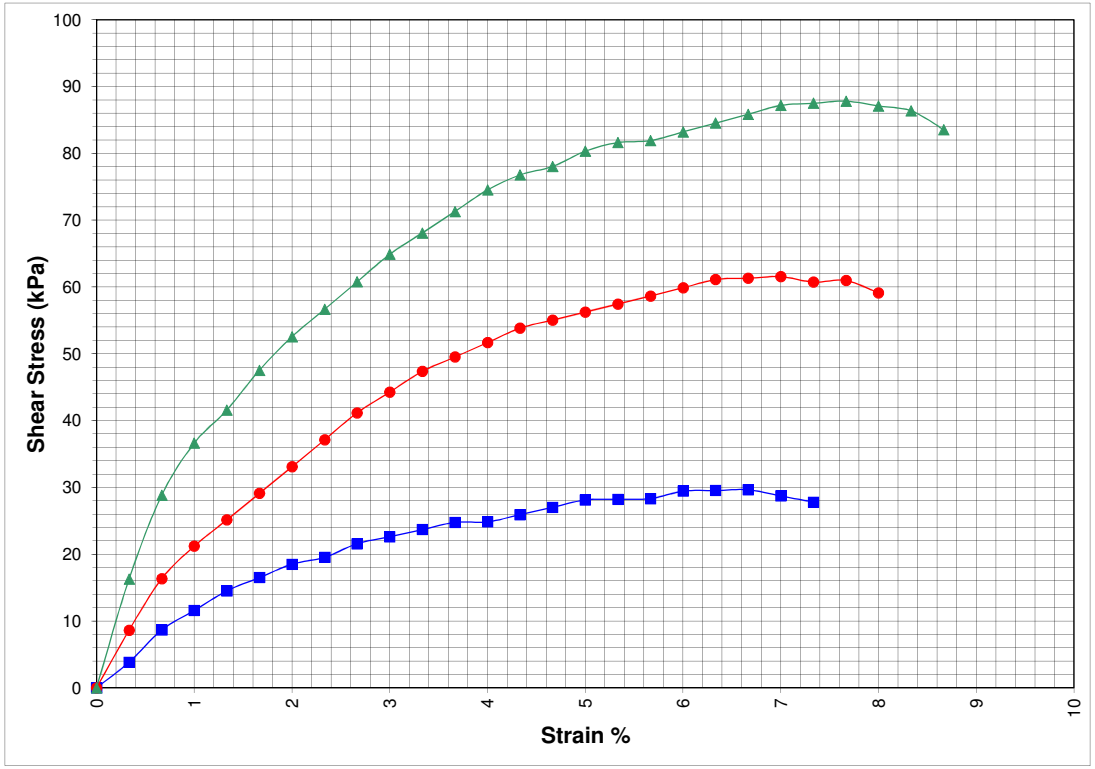
## PLASTICITY CHART (IS : 1498 - 1987)

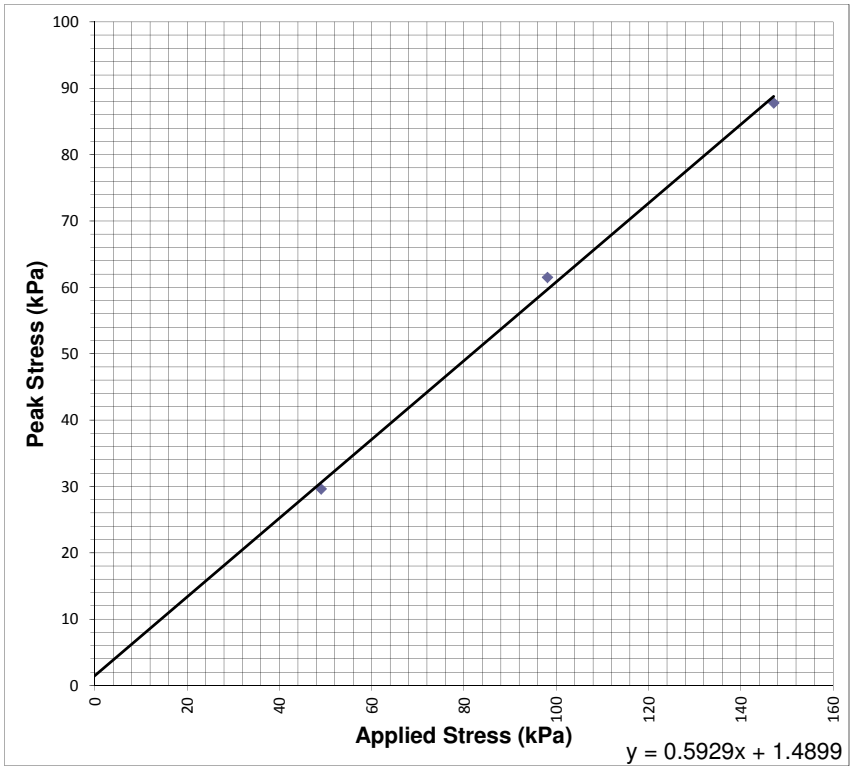
BOREHOLE NAME : MBH-13

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 30 |
| | Stage 2 | 98 | 62 |
| | Stage 3 | 147 | 88 |

| | | |
|---|---|---|
| Angle of Friction | **30.7** | ° |
| Apparent Cohesion | **1.49** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

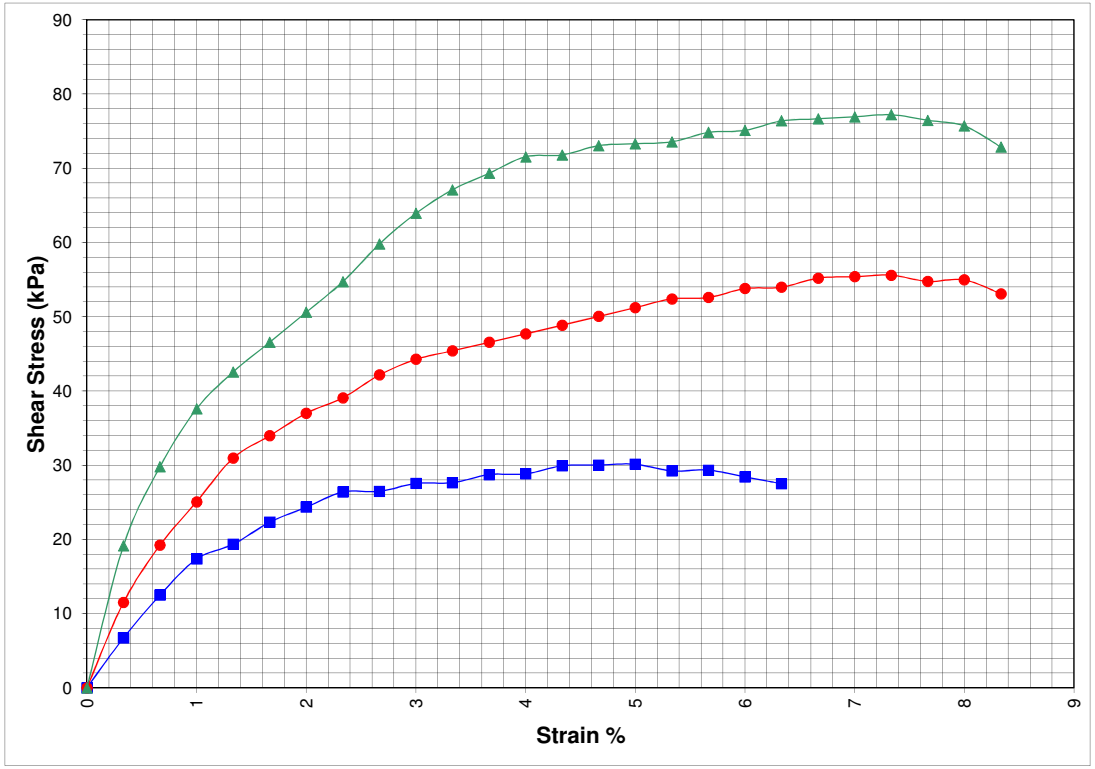
**Borehole: MBH-13**

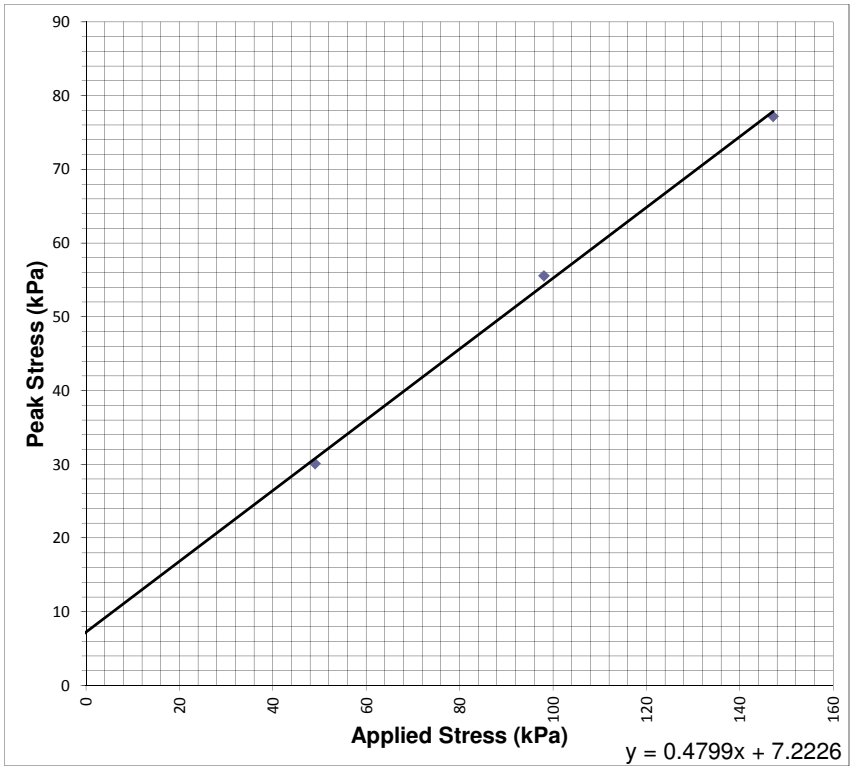
**Sample Type: SPT-4**

**Depth: 4.60-4.90 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 30 |
| | Stage 2 | 98 | 56 |
| | Stage 3 | 147 | 77 |

| | | |
|---|---|---|
| Angle of Friction | **25.6** | ° |
| Apparent Cohesion | **7.22** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

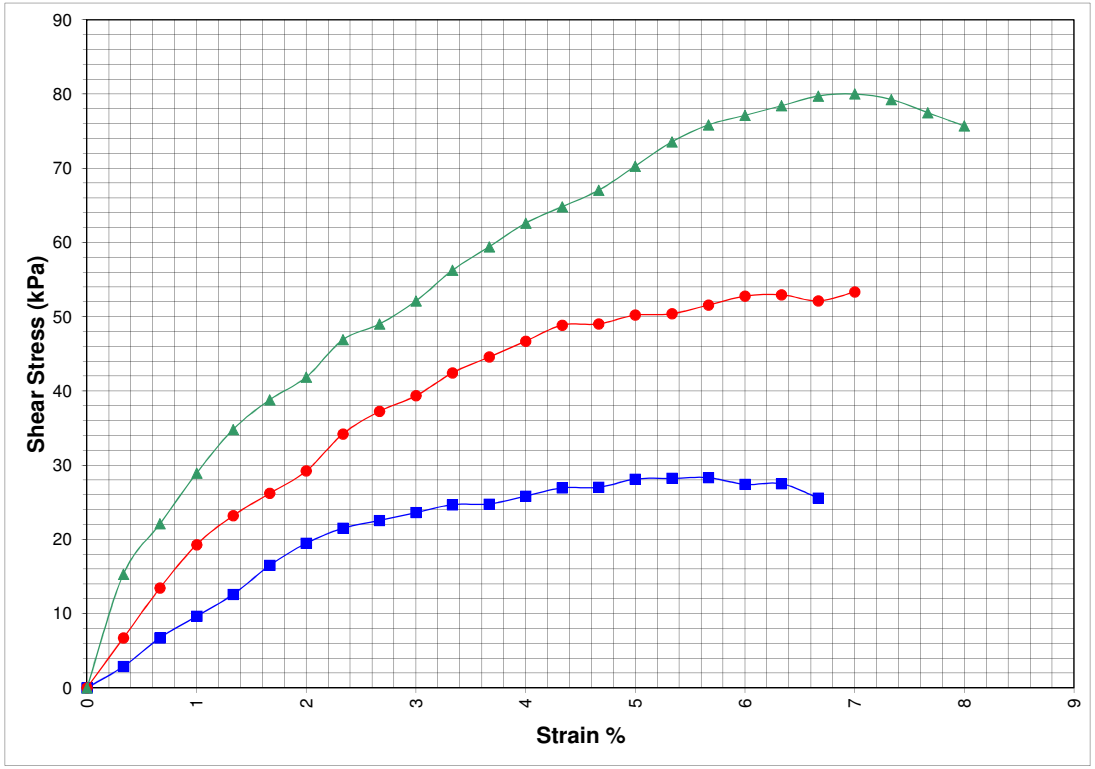
**Borehole: MBH-13**

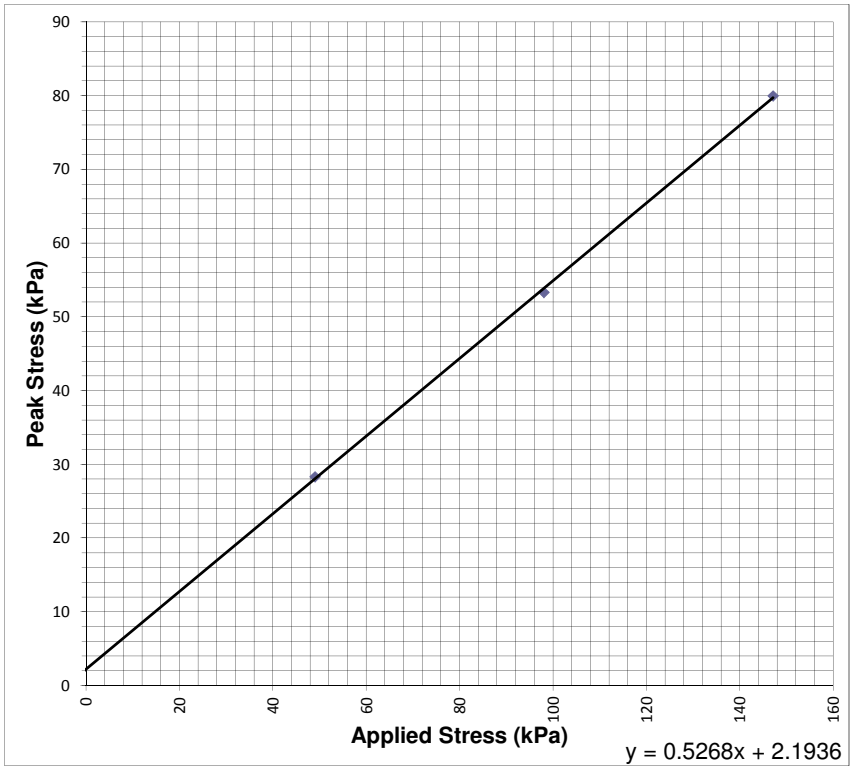
**Sample Type: SPT-11**

**Depth: 18.00-18.18 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 53 |
| | Stage 3 | 147 | 80 |

| | | |
|---|---|---|
| Angle of Friction | **27.8** | ° |
| Apparent Cohesion | **2.19** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

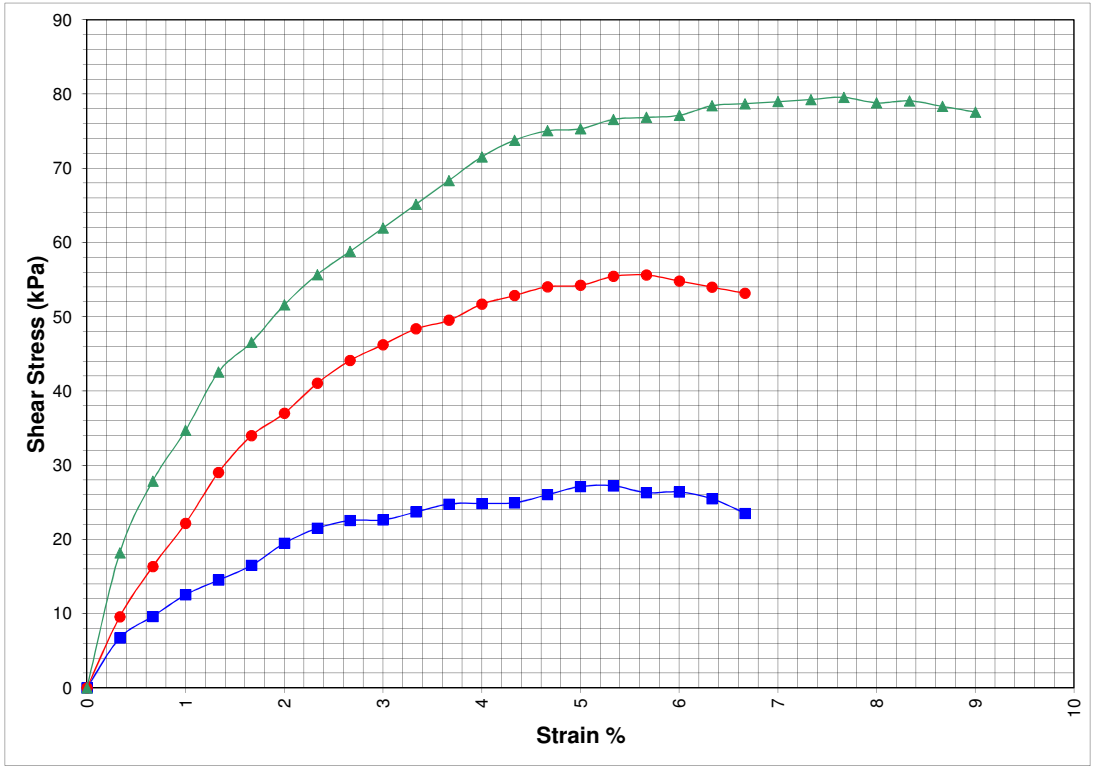
**Borehole: MBH-13**

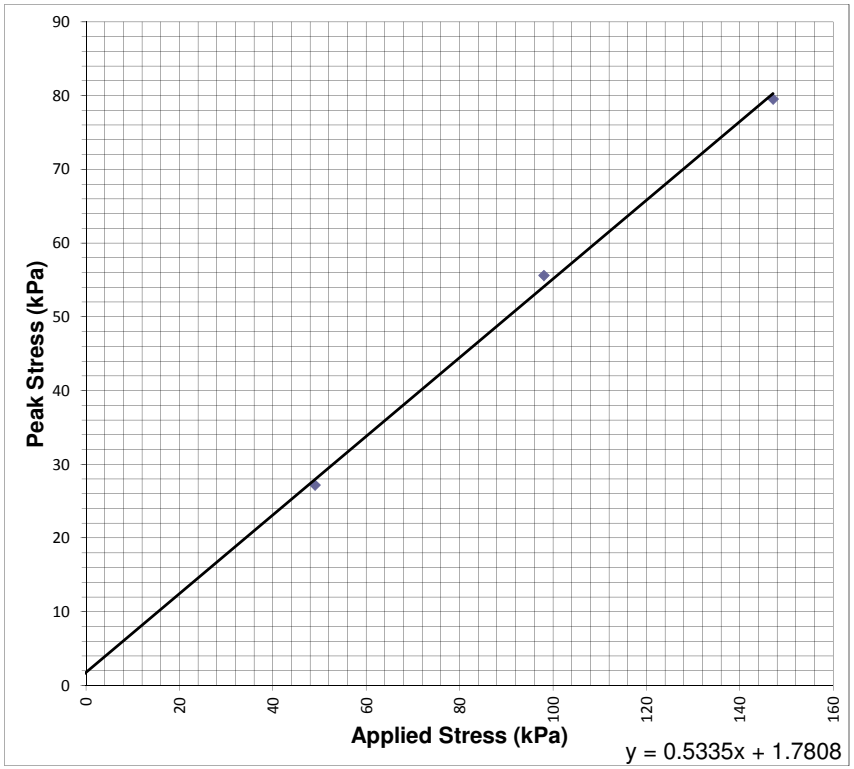
**Sample Type: SPT-16**

**Depth: 22.50-22.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 56 |
| | Stage 3 | 147 | 80 |

| | | |
|---|---|---|
| Angle of Friction | **28.1** | ° |
| Apparent Cohesion | **1.78** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: MBH-13**

**Sample Type: SPT-17**

**Depth: 26.65-26.95 m**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| DS | 0.00-0.50 | SP | | | | 13.33 | 13.76 | 3.70 | 12.14 | 2.61 | 0 | 99 | <--> | <--> | 1 | | | | | | | | | | | | | | | | | | |
| SPT-1 | 1.50-1.95 | | | | | 21.08 | 13.90 | 3.84 | 11.48 | 2.60 | | | | | | DST | | | 1.09 | 25.1 | | | | | | | | | | | | | |
| SPT-2 | 3.00-3.45 | SP | | | | 20.62 | 14.96 | 4.90 | 12.40 | 2.67 | 0 | 97 | <--> | <--> | 3 | | | | | | | | | | | | | | | | | | |
| SPT-3 | 4.50-4.95 | | | | | 5.89 | 15.06 | 5.00 | 14.22 | 2.66 | | | | | | DST | | | 1.04 | 26.6 | | | | | | | | | | | | | |
| SPT-4 | 6.00-6.45 | SP | | | | 16.27 | 15.71 | 5.65 | 13.51 | 2.64 | 0 | 99 | <--> | <--> | 1 | | | | | | | | | | | | | | | | | | |
| SPT-5 | 7.50-7.95 | | | | | 10.26 | 13.73 | 3.67 | 12.46 | 2.62 | | | | | | DST | | | 0.66 | 26.6 | | | | | | | | | | | | | |
| SPT-6 | 9.00-9.45 | | | | | 10.37 | 13.86 | 3.80 | 12.55 | 2.64 | | | | | | DST | | | 0.86 | 25.1 | | | | | | | | | | | | | |
| SPT-7 | 10.50-10.95 | SP | | | | 14.79 | 14.63 | 4.57 | 12.74 | 2.66 | 0 | 99 | <--> | <--> | 1 | | | | | | | | | | | | | | | | | | |
| SPT-8 | 12.00-12.45 | | | | | 17.90 | 14.84 | 4.78 | 12.58 | 2.61 | | | | | | DST | | | 1.04 | 26.5 | | | | | | | | | | | | | |
| SPT-9 | 13.50-13.95 | | | | | 5.14 | 14.50 | 4.44 | 13.79 | 2.64 | | | | | | | | | | | | | | | | | | | 7.80 | 0.40 | 1.00 | 500 | 12390 |
| SPT-10 | 15.00-15.45 | SP | | | | 6.64 | 14.53 | 4.47 | 13.63 | 2.67 | 0 | 98 | <--> | <--> | 2 | | | | | | | | | | | | | | | | | | |
| SPT-11 | 16.50-16.95 | | | | | 11.24 | 15.48 | 5.42 | 13.91 | 2.61 | | | | | | DST | | | 0.74 | 33.4 | | | | | | | | | | | | | |
| SPT-12 | 18.00-18.45 | | | | | 18.04 | 17.64 | 7.58 | 14.94 | 2.60 | | | | | | DST | | | 0.70 | 27.9 | | | | | | | | | | | | | |
| SPT-13 | 19.50-19.95 | SP-SM | | | | 17.49 | 17.54 | 7.48 | 14.93 | 2.61 | 0 | 94 | <--> | <--> | 6 | | | | | | | | | | | | | | | | | | |
| SPT-14 | 21.00-21.45 | SP | | | | 16.36 | 17.69 | 7.63 | 15.20 | 2.59 | 0 | 96 | <--> | <--> | 4 | | | | | | | | | | | | | | | | | | |
| SPT-15 | 22.50-22.95 | | | | | 13.93 | 17.32 | 7.26 | 15.20 | 2.62 | | | | | | DST | | | 1.36 | 27.3 | | | | | | | | | | | | | |
| SPT-16 | 24.00-24.45 | | | | | 11.66 | 14.43 | 4.37 | 12.92 | 2.65 | | | | | | DST | | | 1.08 | 26.7 | | | | | | | | | | | | | |
| SPT-17 | 25.50-25.95 | SP | | | | 14.69 | 14.50 | 4.44 | 12.64 | 2.62 | 0 | 99 | <--> | <--> | 1 | | | | | | | | | | | | | | | | | | |
| SPT-18 | 27.00-27.45 | | | | | 16.31 | 14.57 | 4.51 | 12.53 | 2.61 | | | | | | DST | | | 0.89 | 26.4 | | | | | | | | | | | | | |
| SPT-19 | 28.50-28.95 | SP | | | | 21.40 | 14.62 | 4.56 | 12.04 | 2.61 | 0 | 99 | <--> | <--> | 1 | | | | | | | | | | | | | | | | | | |
| SPT-20 | 30.00-30.45 | | | | | 20.93 | 16.53 | 6.47 | 13.67 | 2.64 | | | | | | DST | | | 0.94 | 27.1 | | | | | | | | | | | | | |
| **END OF BOREHOLE** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

\# : Decayed Wood

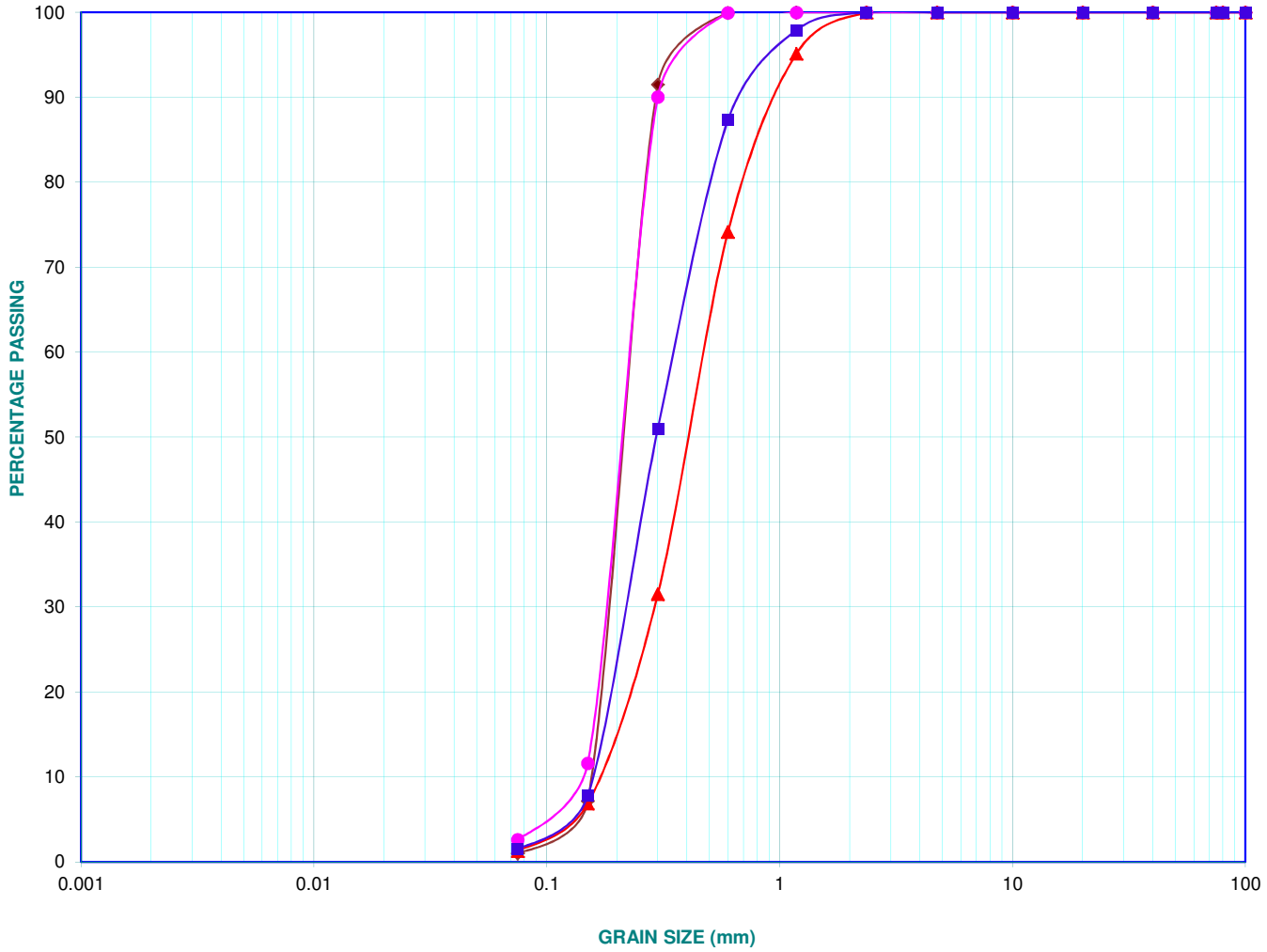
**Failure Type**
A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha**
Project Code : **CM 19 01 03**
Borehole No. : **LBH-14**

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: LBH-14** |
| **Date :** | **31-May-19** |

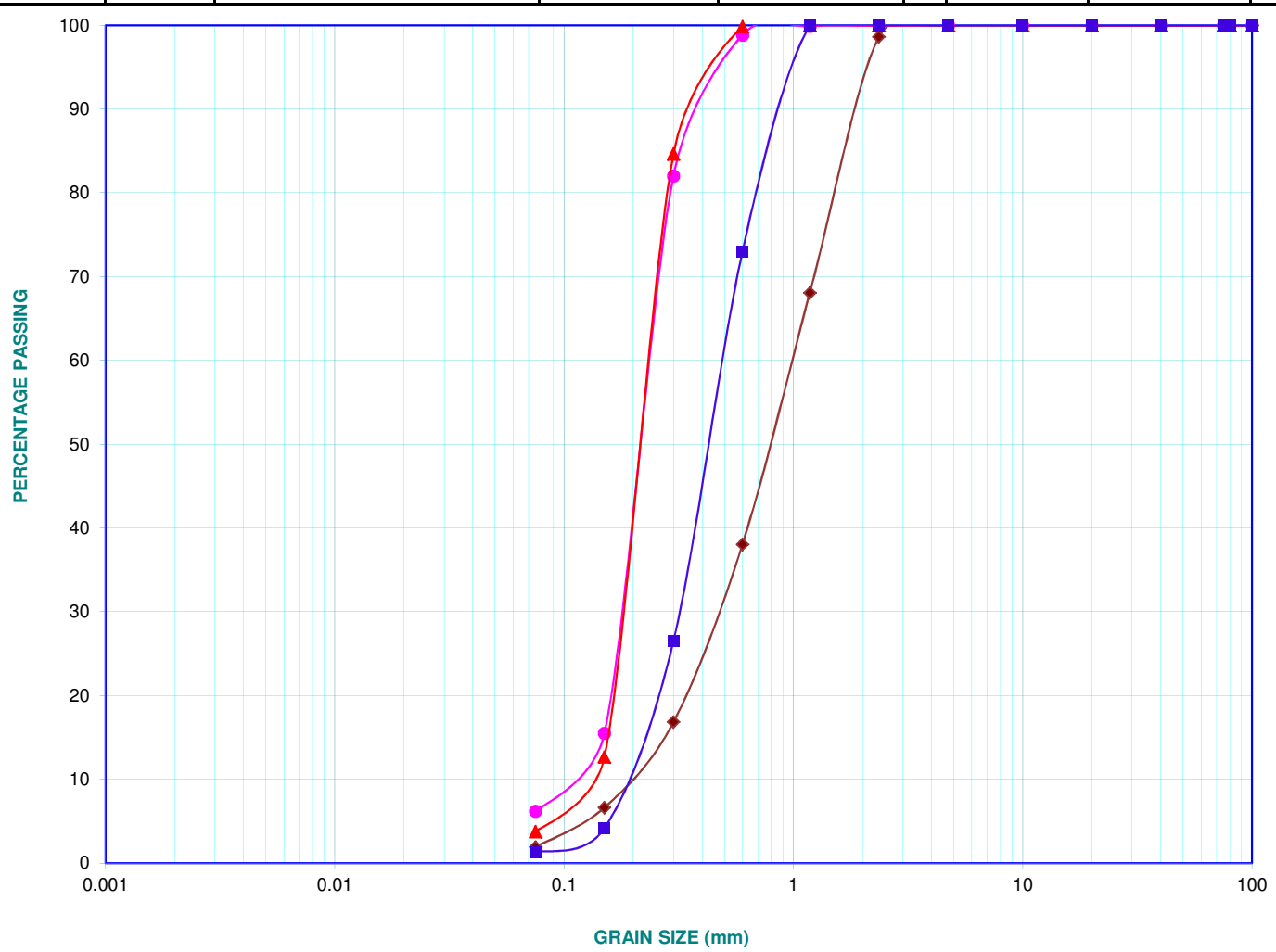
| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | LBH-14 | LBH-14 | LBH-14 | LBH-14 | | | | | | | | |
| **Depth (m)** | 0.00-0.50 | 3.00-3.45 | 6.00-6.45 | 10.50-10.95 | | | | | | | | |
| **Sample Type** | DS | SPT-2 | SPT-4 | SPT-7 | | | | | | | | |
| **Classification** | SP | SP | SP | SP | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 99 | 97 | 99 | 99 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 1 | 3 | 1 | 1 | | | | | | | | |
| **D60 mm** | 0.220 | 0.220 | 0.480 | 0.350 | | | | | | | | |
| **D30 mm** | 0.190 | 0.180 | 0.300 | 0.220 | | | | | | | | |
| **D10 mm** | 0.160 | 0.150 | 0.170 | 0.160 | | | | | | | | |
| **Cu** | 1.38 | 1.47 | 2.82 | 2.19 | | | | | | | | |
| **Cc** | 1.03 | 0.98 | 1.10 | 0.86 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | : Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha | | | | | | | | | | |
| **Job No.** | : CM 19 01 03 | | | **Borehole No.** | : LBH-14 | | | **Date :** | 31-May-19 | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND F | SAND M | SAND C | GRAVEL F / GRAVEL C |
| **Bore Hole .** | LBH-14 | LBH-14 | LBH-14 | LBH-14 | | | | | | | |
| **Depth (m)** | 15.00-15.45 | 19.50-19.95 | 21.00-21.45 | 25.50-25.95 | | | | | | | |
| **Sample Type** | SPT-10 | SPT-13 | SPT-14 | SPT-17 | | | | | | | |
| **Classification** | SP | SP-SM | SP | SP | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | |
| **Sand %** | 98 | 94 | 96 | 99 | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | |
| **Fines % (Silt+Clay)** | 2 | 6 | 4 | 1 | | | | | | | |
| **D60 mm** | 1.000 | 0.230 | 0.230 | 0.560 | | | | | | | |
| **D30 mm** | 0.480 | 0.180 | 0.180 | 0.310 | | | | | | | |
| **D10 mm** | 0.200 | 0.120 | 0.140 | 0.190 | | | | | | | |
| **Cu** | 5.00 | 1.92 | 1.64 | 2.95 | | | | | | | |
| **Cc** | 1.15 | 1.17 | 1.01 | 0.90 | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | |

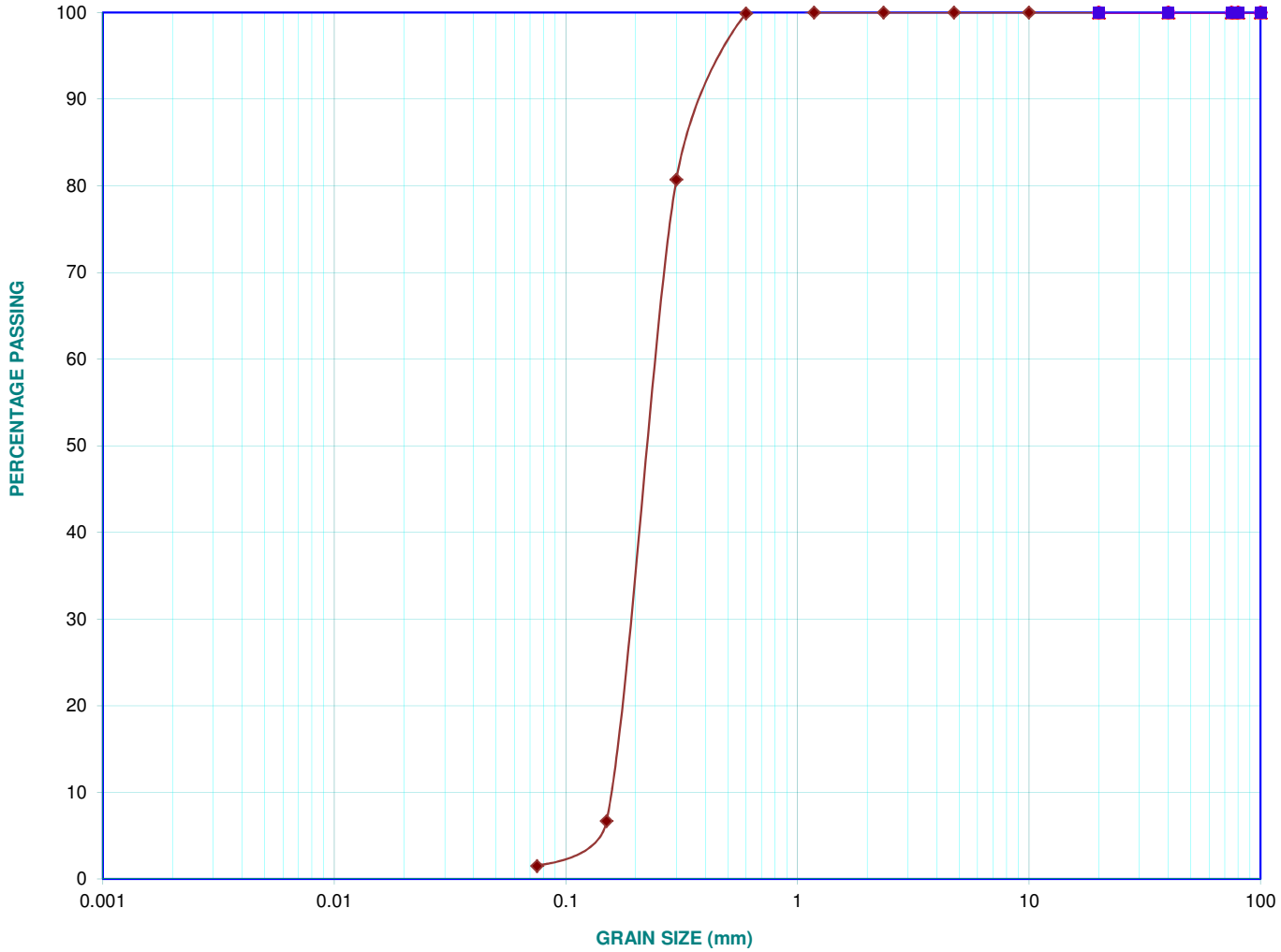



Checked By :

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: LBH-14** |
| **Date :** | **31-May-19** |

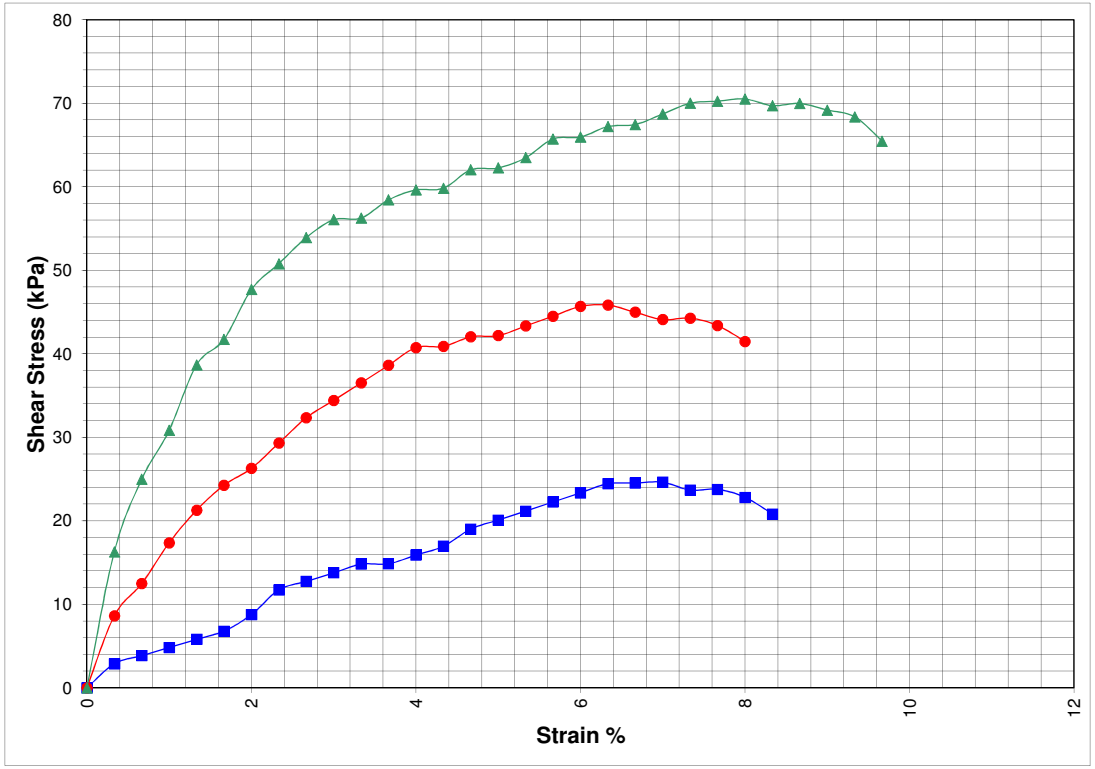
| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| Bore Hole . | LBH-14 | | | | | | | | | | | |
| Depth (m) | 28.50-28.95 | | | | | | | | | | | |
| Sample Type | SPT-19 | | | | | | | | | | | |
| Classification | SP | | | | | | | | | | | |
| Gravel % | 0 | | | | | | | | | | | |
| Sand % | 99 | | | | | | | | | | | |
| Silt % | <----> | | | | | | | | | | | |
| Clay % | <----> | | | | | | | | | | | |
| Fines % (Silt+Clay) | 1 | | | | | | | | | | | |
| D60 mm | 0.240 | | | | | | | | | | | |
| D30 mm | 0.190 | | | | | | | | | | | |
| D10 mm | 0.160 | | | | | | | | | | | |
| Cu | 1.50 | | | | | | | | | | | |
| Cc | 0.94 | | | | | | | | | | | |
| Liquid Limit % | --- | | | | | | | | | | | |
| Plastic Limit % | --- | | | | | | | | | | | |
| Plasticity Index | --- | | | | | | | | | | | |

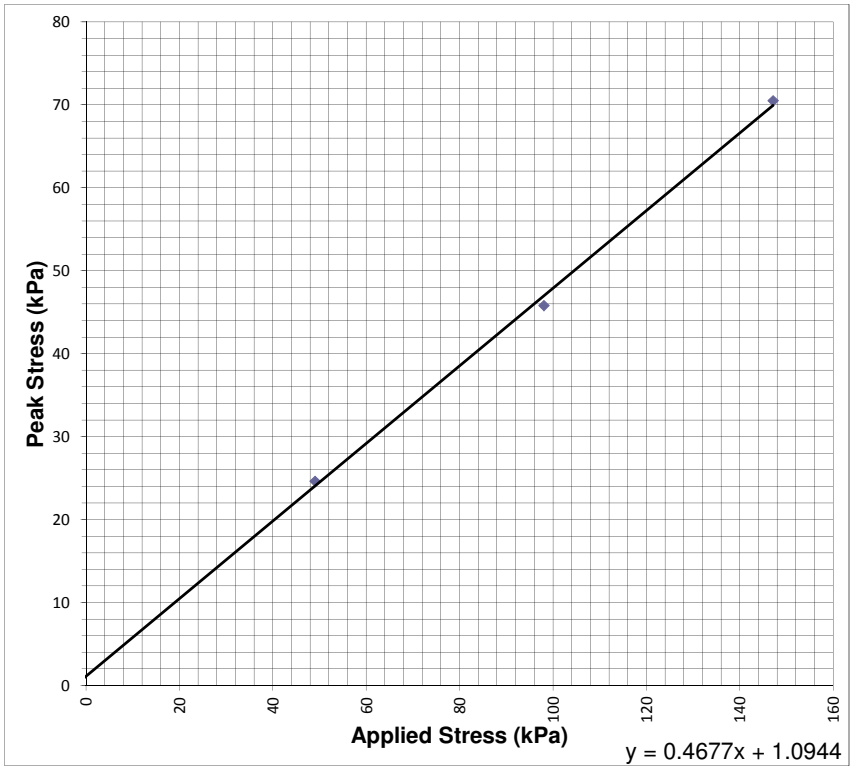



Checked By :

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 25 |
| | Stage 2 | 98 | 46 |
| | Stage 3 | 147 | 70 |

| | | |
|---|---|---|
| Angle of Friction | **25.07** | ° |
| Apparent Cohesion | **1.09** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

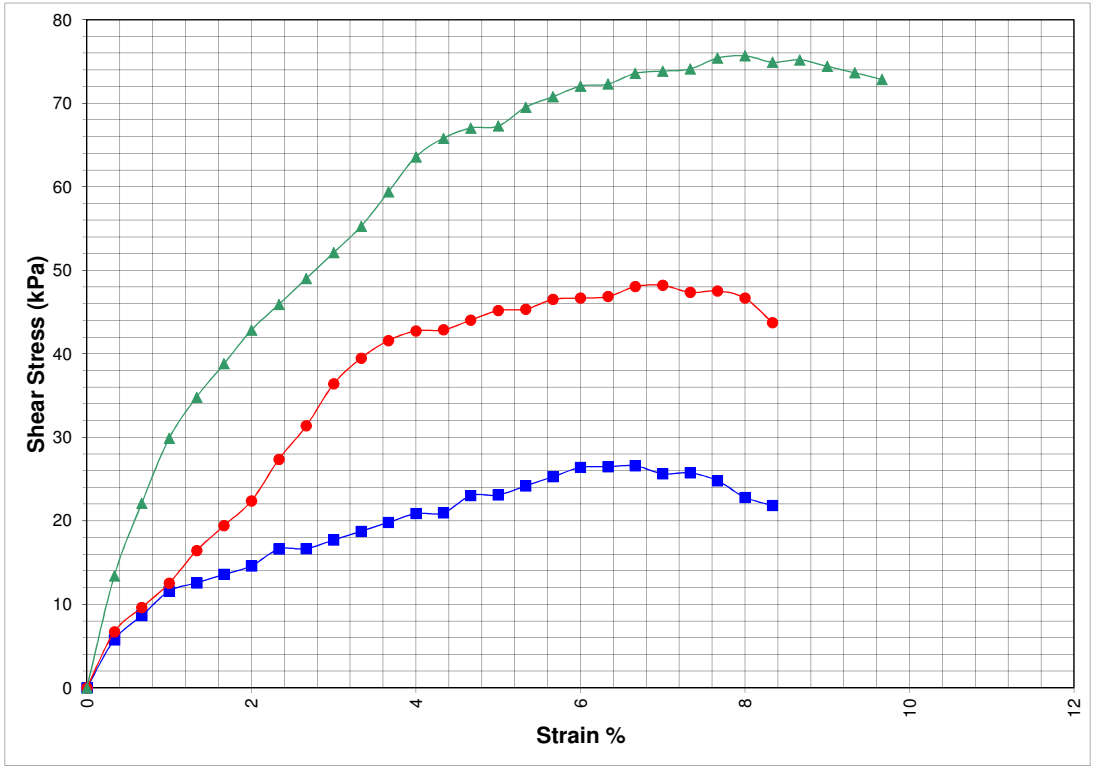
**Borehole: LBH-14**

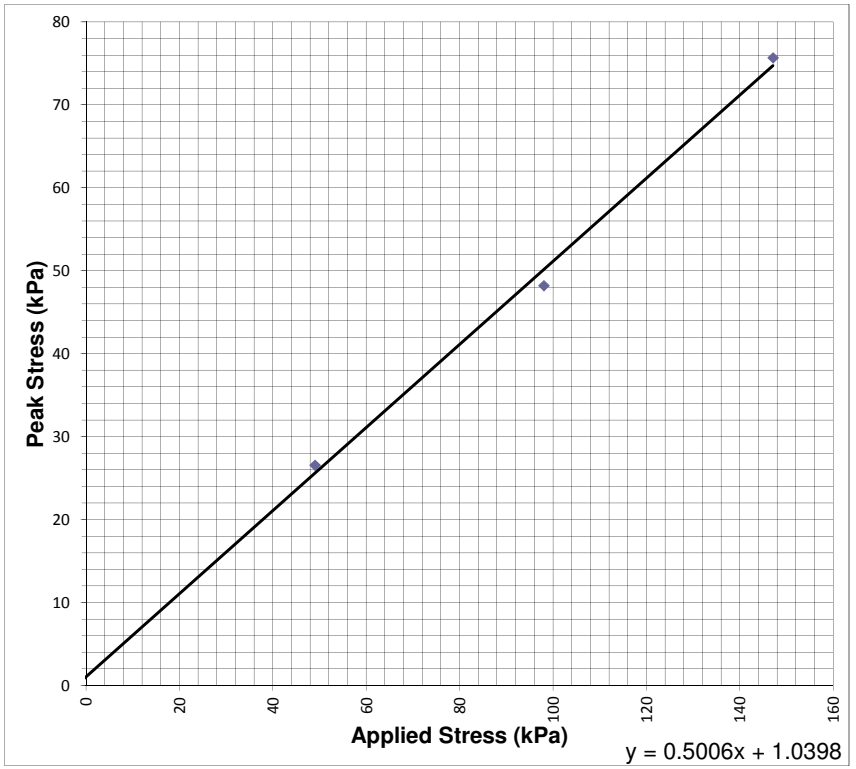
**Sample Type: SPT-01**

**Depth: 1.50-1.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 48 |
| | Stage 3 | 147 | 76 |

| | | |
|---|---|---|
| Angle of Friction | **26.59** | ° |
| Apparent Cohesion | **1.04** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

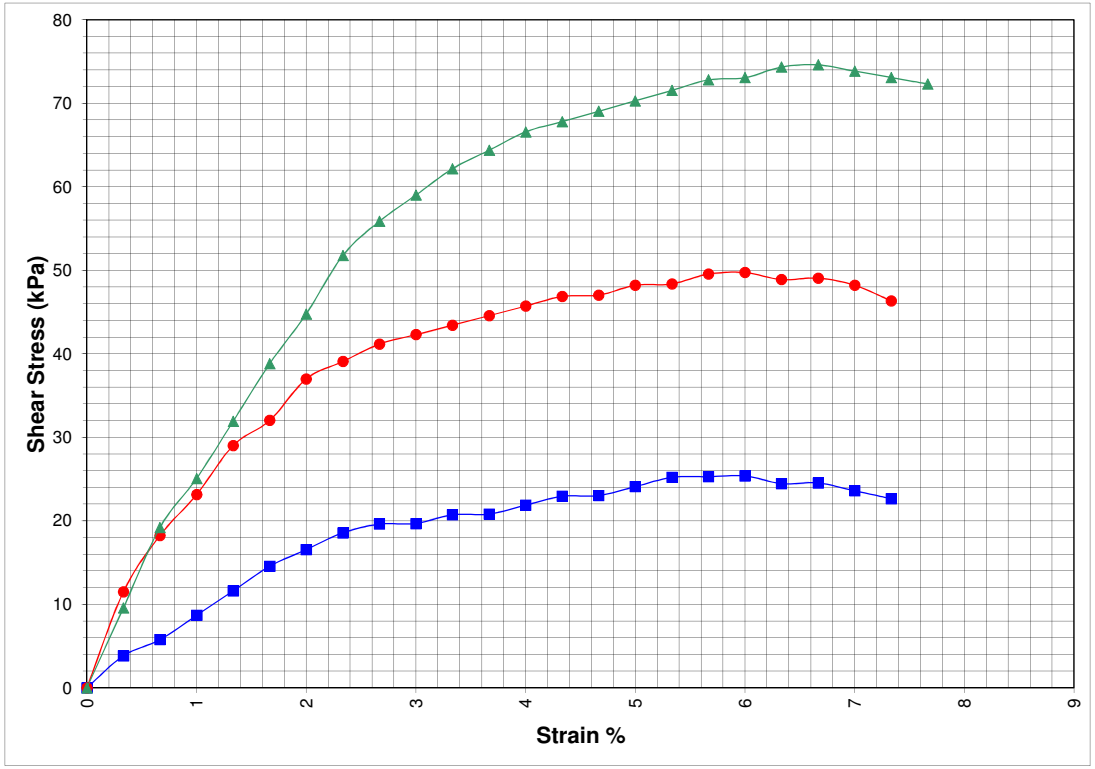
**Borehole: LBH-14**

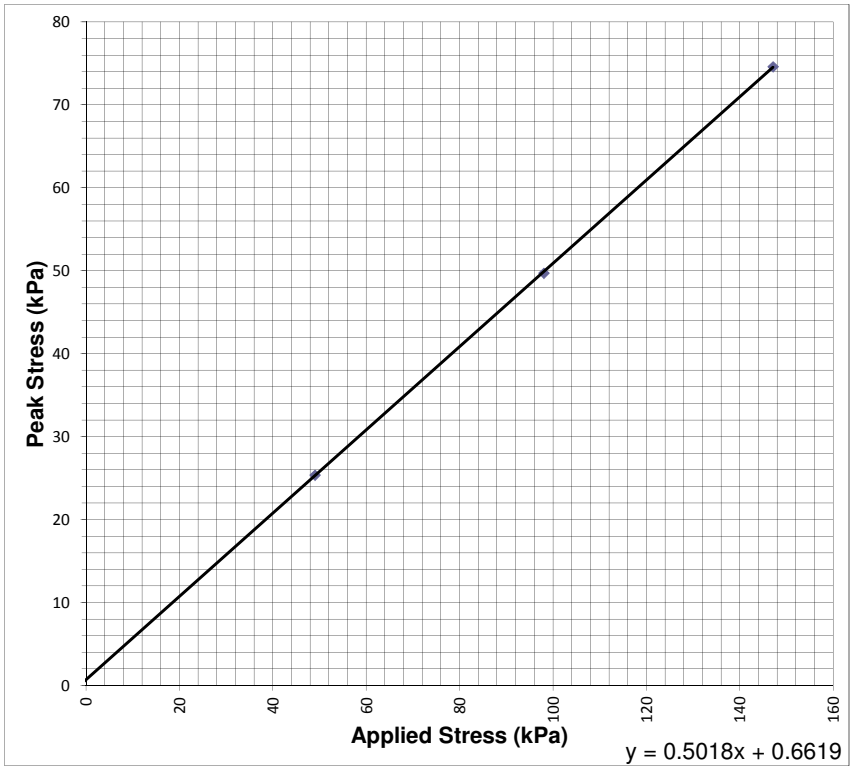
**Sample Type: SPT-03**

**Depth: 4.50-4.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 25 |
| | Stage 2 | 98 | 50 |
| | Stage 3 | 147 | 75 |

| | | |
|---|---|---|
| Angle of Friction | **26.6** | ° |
| Apparent Cohesion | **0.66** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

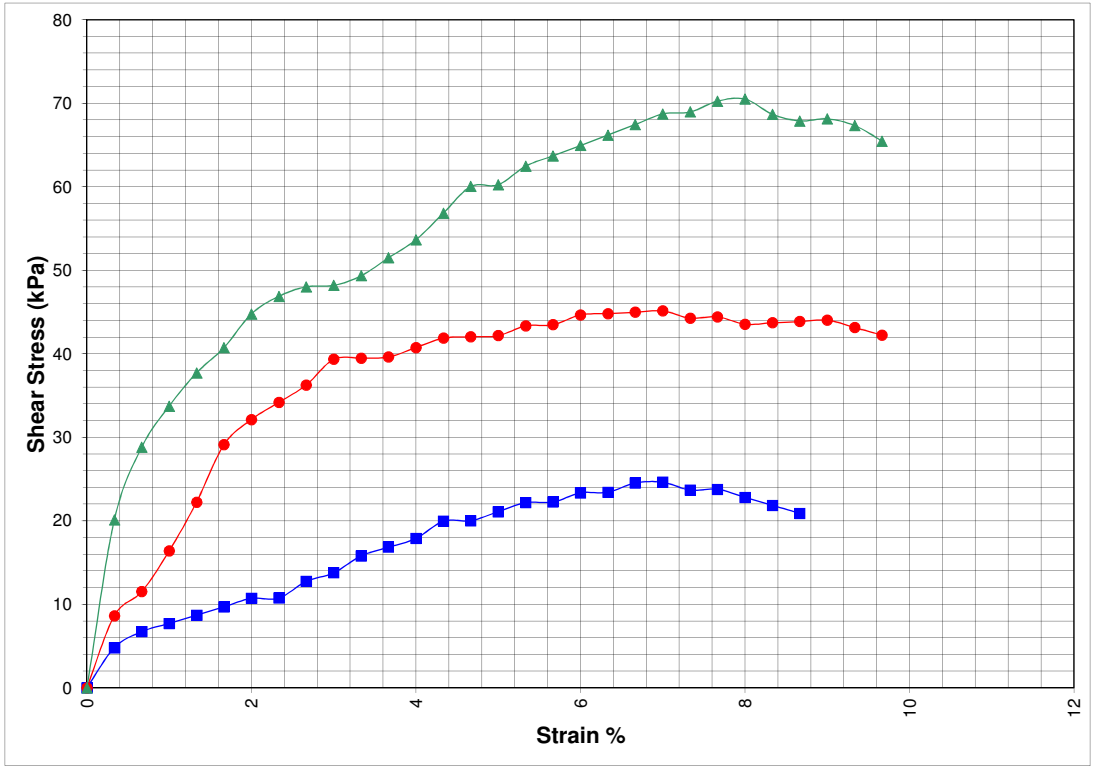
**Borehole: LBH-14**

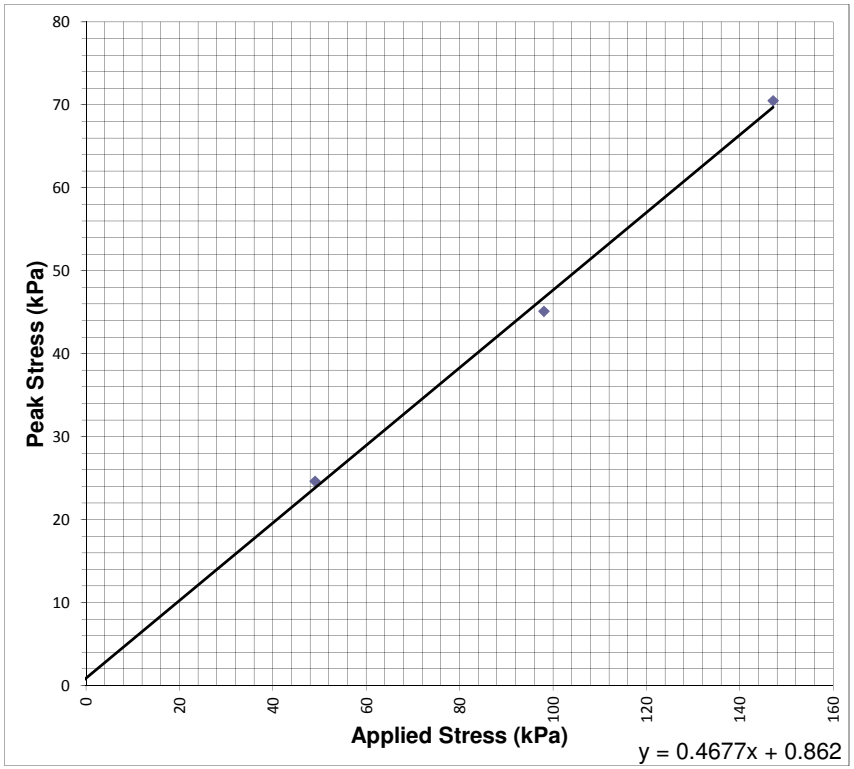
**Sample Type: SPT-05**

**Depth: 7.50-7.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 25 |
| | Stage 2 | 98 | 45 |
| | Stage 3 | 147 | 70 |

| | | |
|---|---|---|
| Angle of Friction | **25.07** | ° |
| Apparent Cohesion | **0.86** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

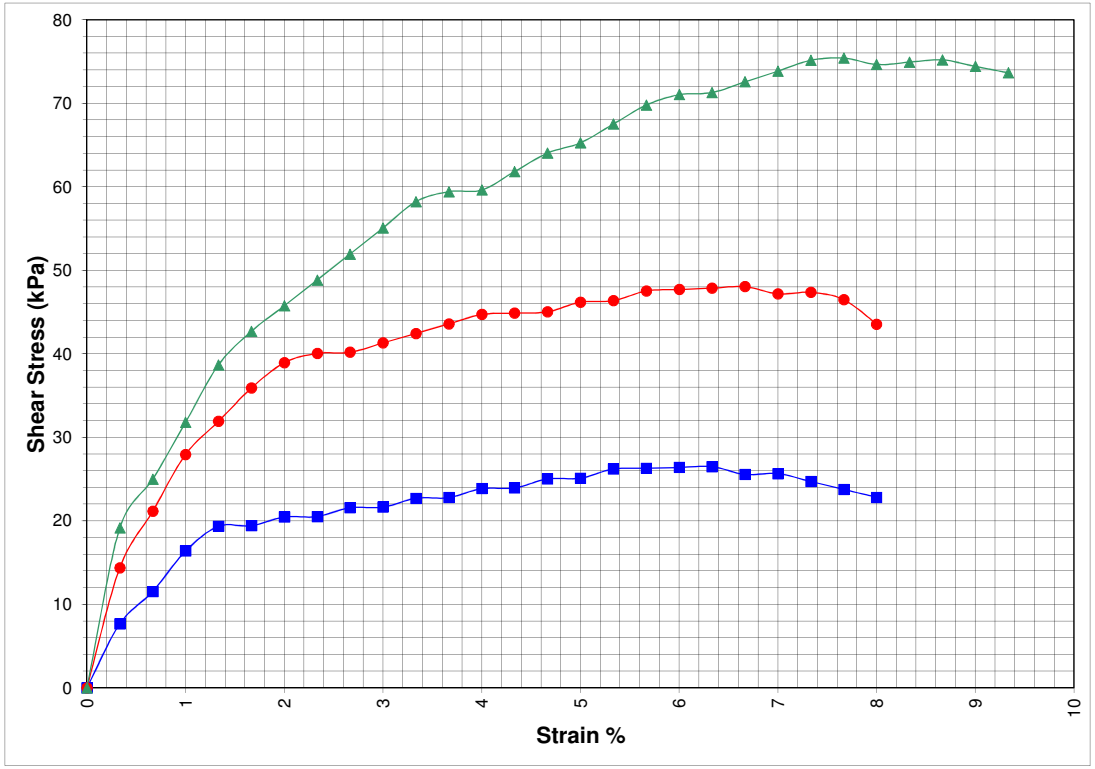
**Borehole: LBH-14**

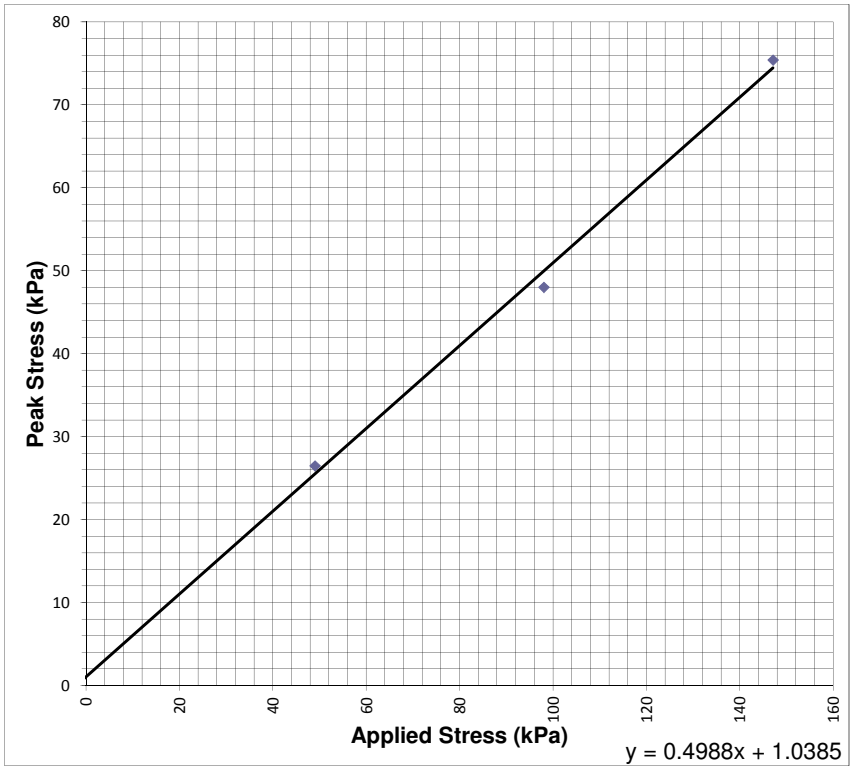
**Sample Type: SPT-06**

**Depth: 9.00-9.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 48 |
| | Stage 3 | 147 | 75 |

| | | |
|---|---|---|
| Angle of Friction | **26.51** | ° |
| Apparent Cohesion | **1.04** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

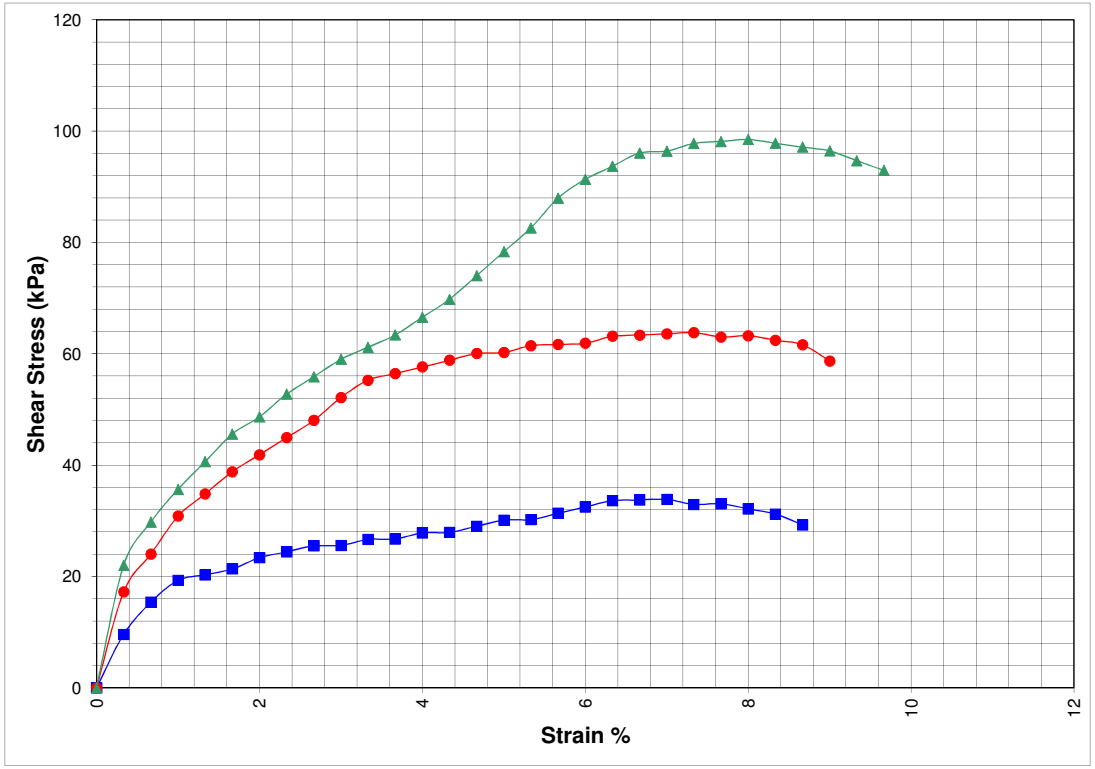
**Borehole: LBH-14**

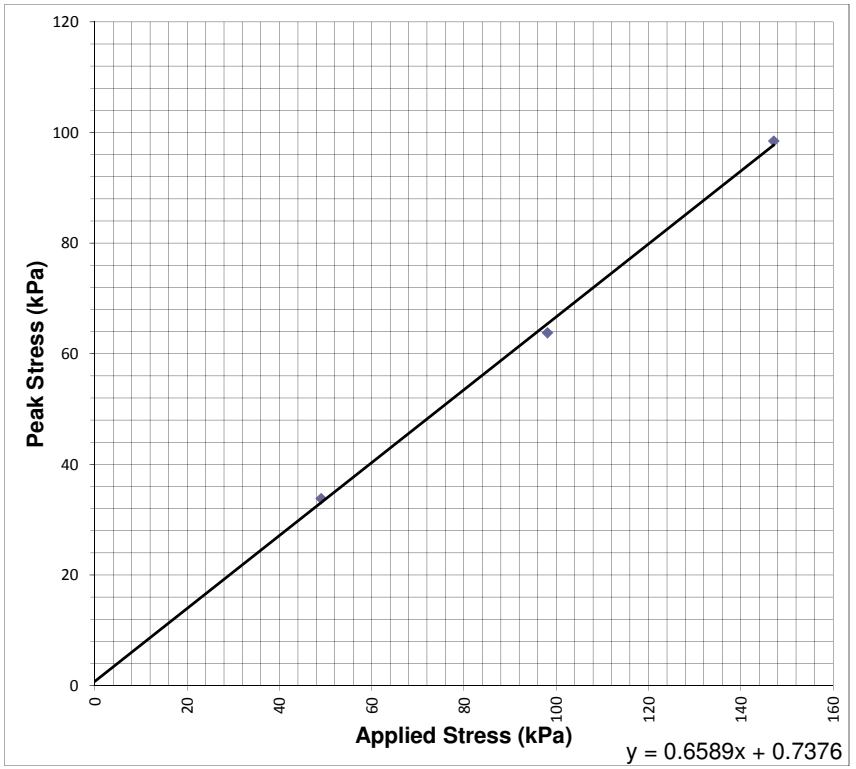
**Sample Type: SPT-08**

**Depth: 12.00-12.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 34 |
| | Stage 2 | 98 | 64 |
| | Stage 3 | 147 | 98 |

| | | |
|---|---|---|
| Angle of Friction | **33.38** | ° |
| Apparent Cohesion | **0.74** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

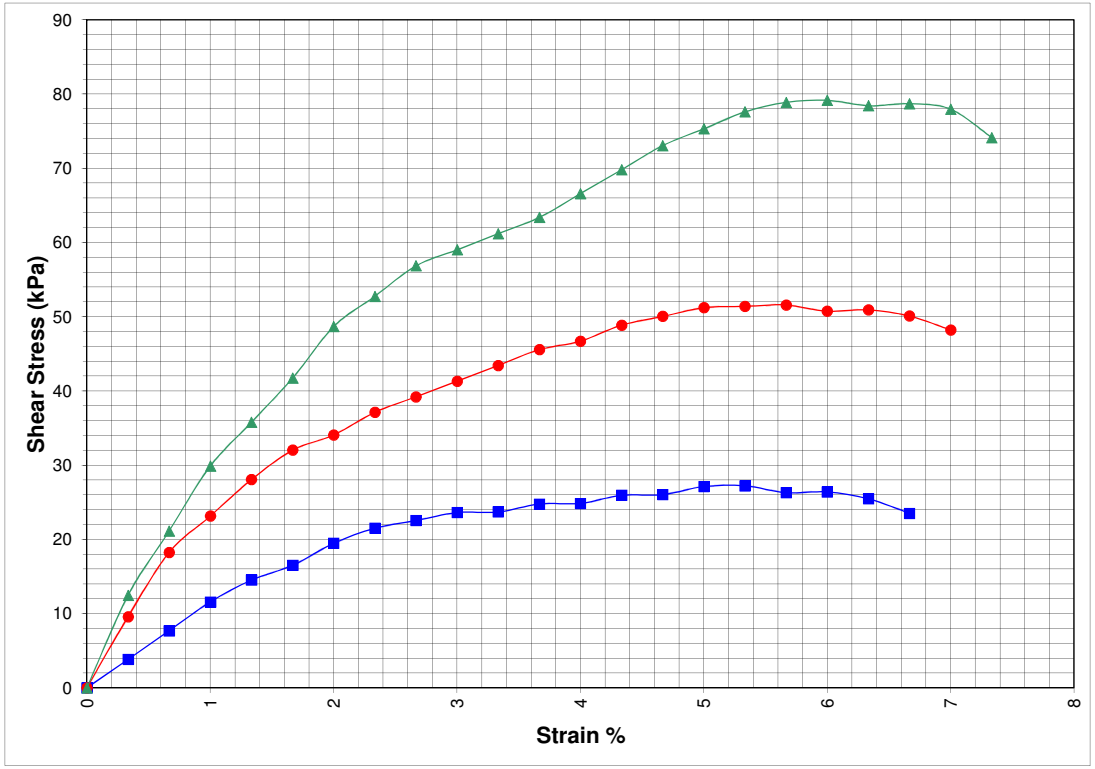
**Borehole: LBH-14**

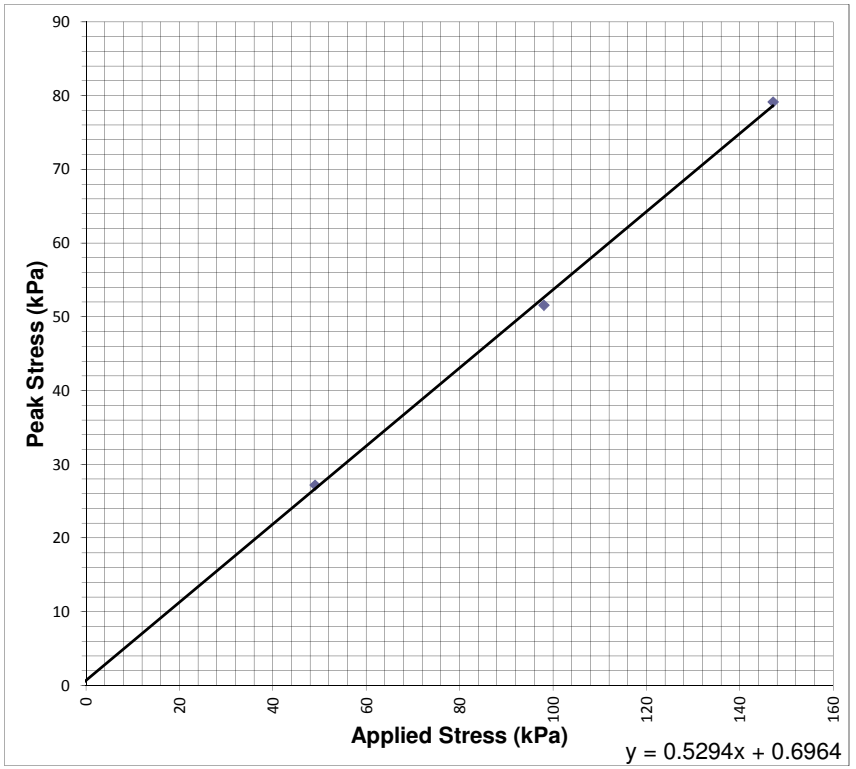
**Sample Type: SPT-11**

**Depth: 16.50-16.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 52 |
| | Stage 3 | 147 | 79 |

| | | |
|---|---|---|
| Angle of Friction | **27.90** | ° |
| Apparent Cohesion | **0.70** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

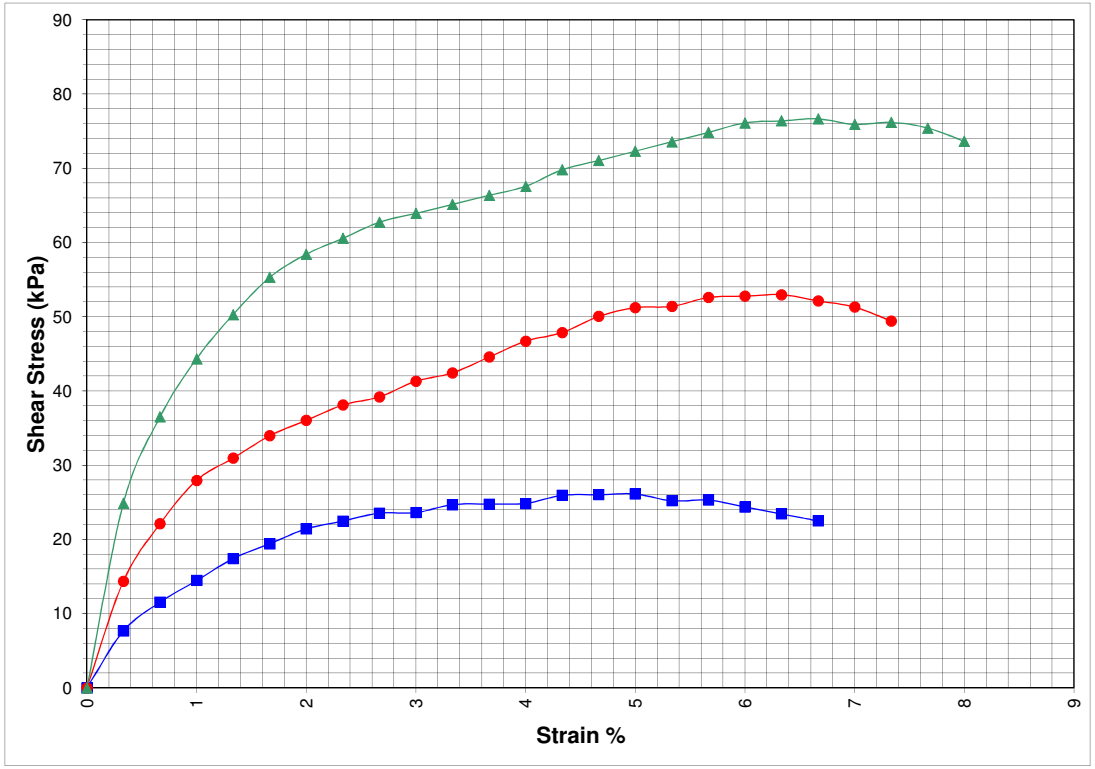
**Borehole: LBH-14**

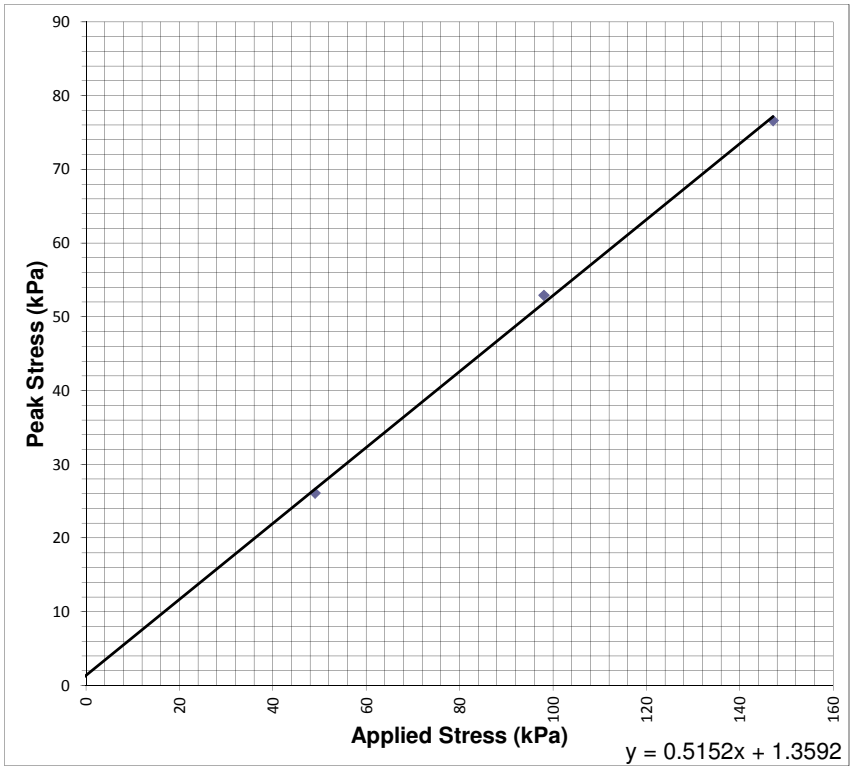
**Sample Type: SPT-12**

**Depth: 18.00-18.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 53 |
| | Stage 3 | 147 | 77 |

| | | |
|---|---|---|
| Angle of Friction | **27.26** | ° |
| Apparent Cohesion | **1.36** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

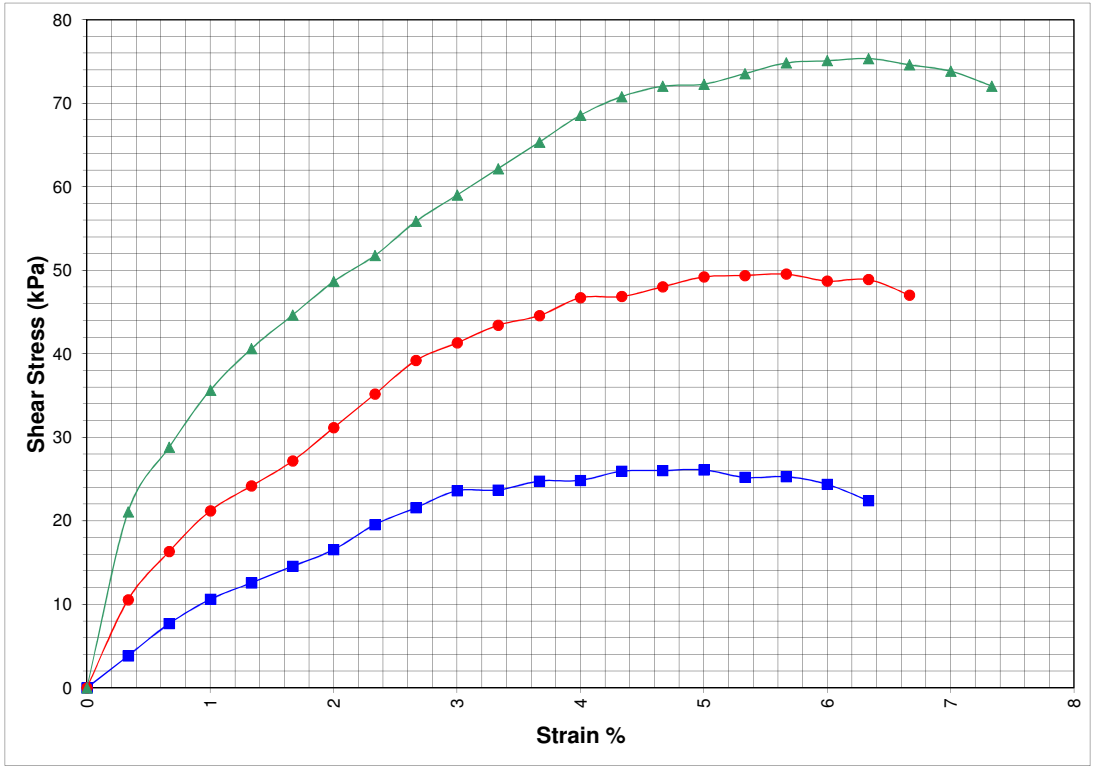
**Borehole: LBH-14**

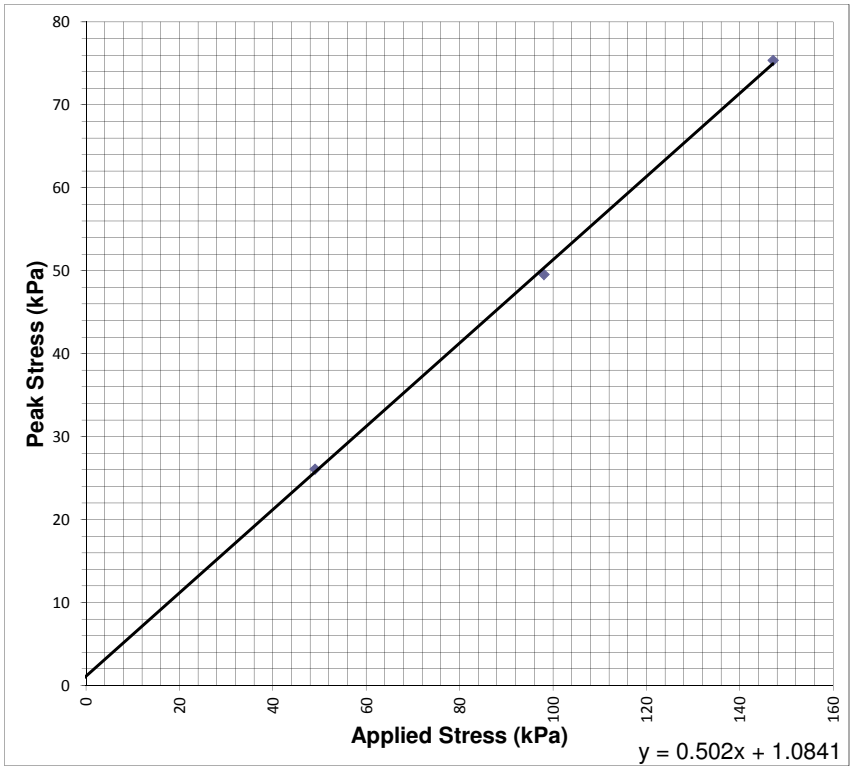
**Sample Type: SPT-15**

**Depth: 22.50-22.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 50 |
| | Stage 3 | 147 | 75 |

| | | |
|---|---|---|
| Angle of Friction | **26.66** | ° |
| Apparent Cohesion | **1.08** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

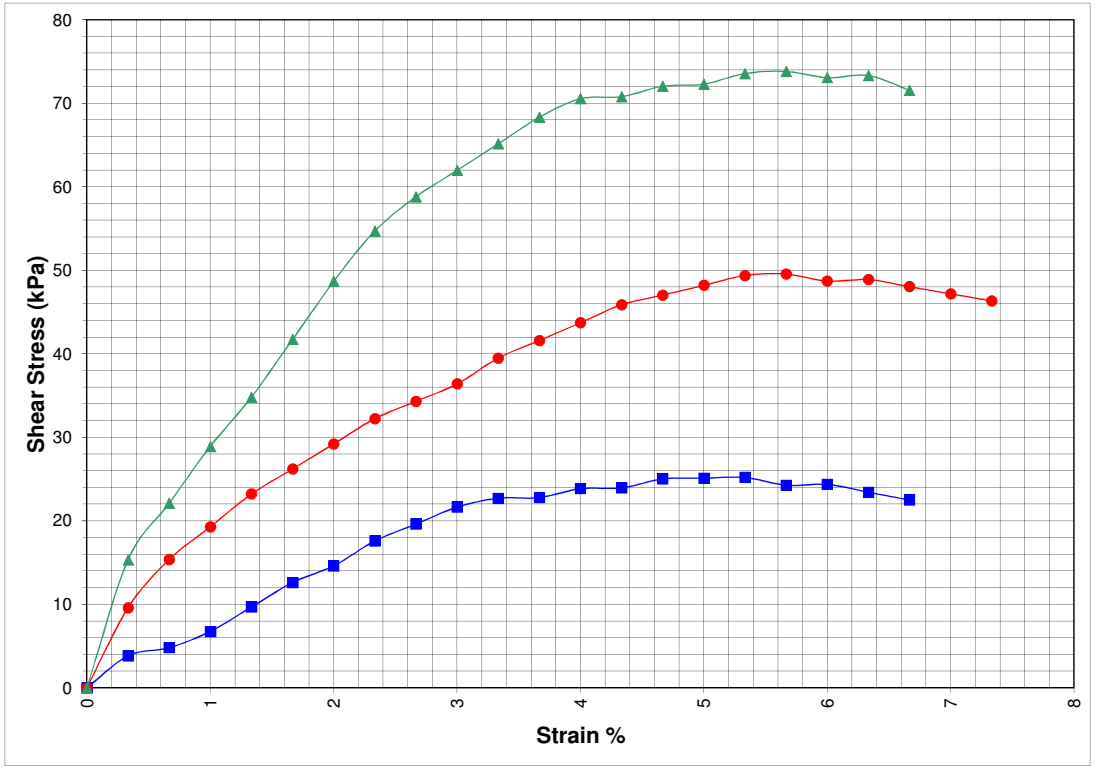
**Borehole: LBH-14**

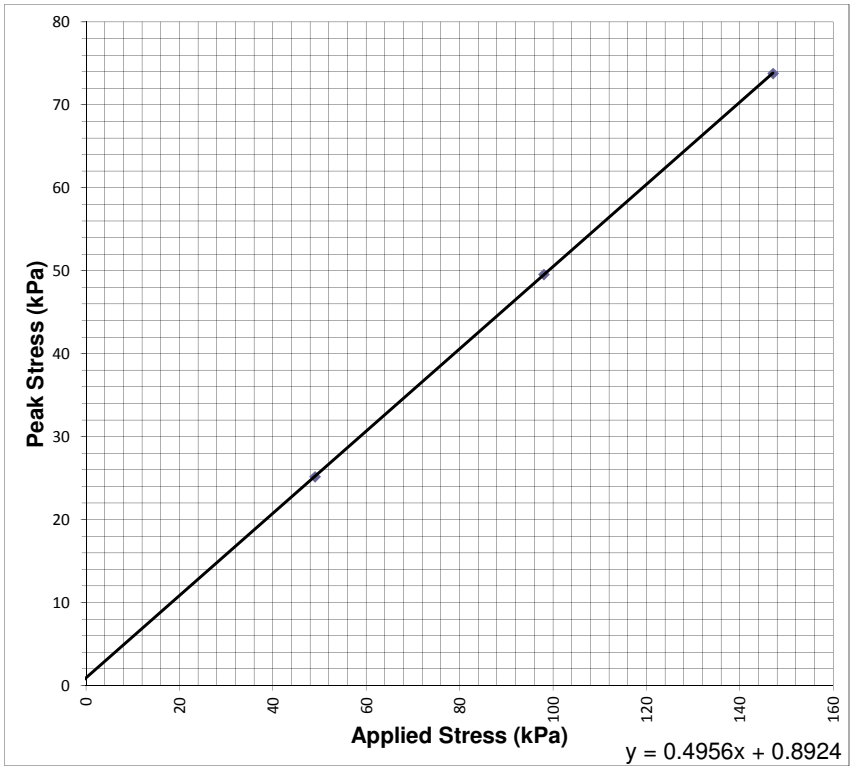
**Sample Type: SPT-16**

**Depth: 24.00-24.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 25 |
| | Stage 2 | 98 | 50 |
| | Stage 3 | 147 | 74 |

| | | |
|---|---|---|
| Angle of Friction | **26.36** | ° |
| Apparent Cohesion | **0.89** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

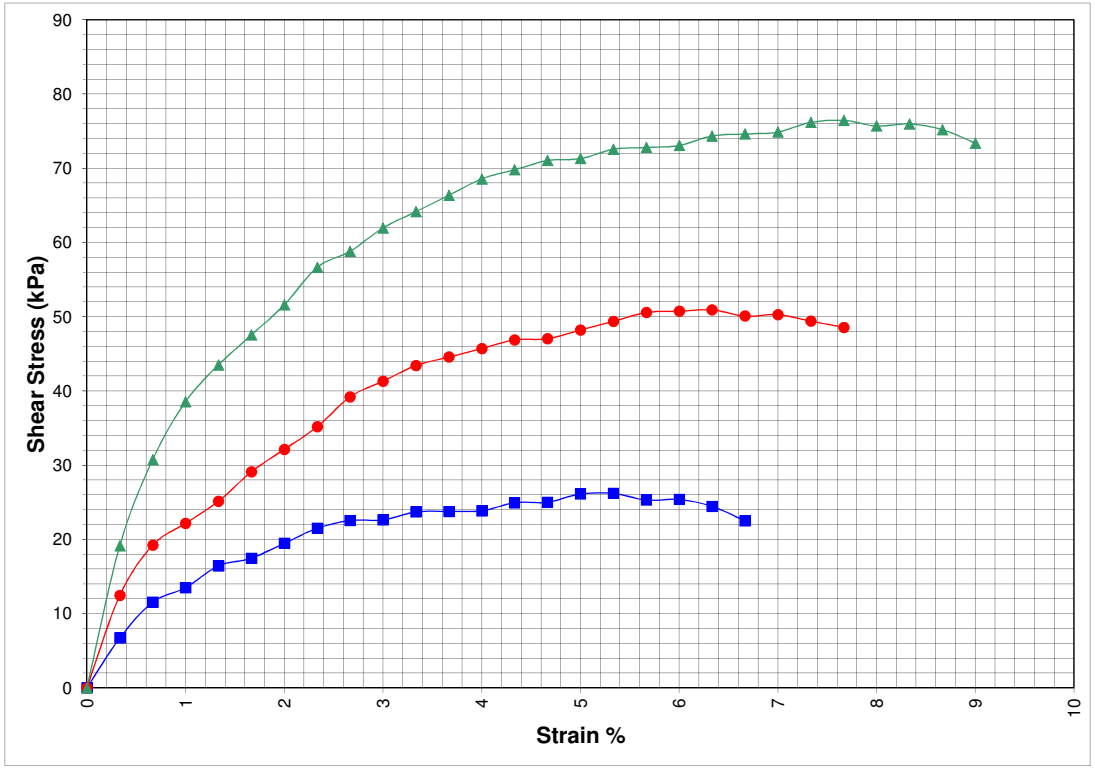
**Borehole: LBH-14**

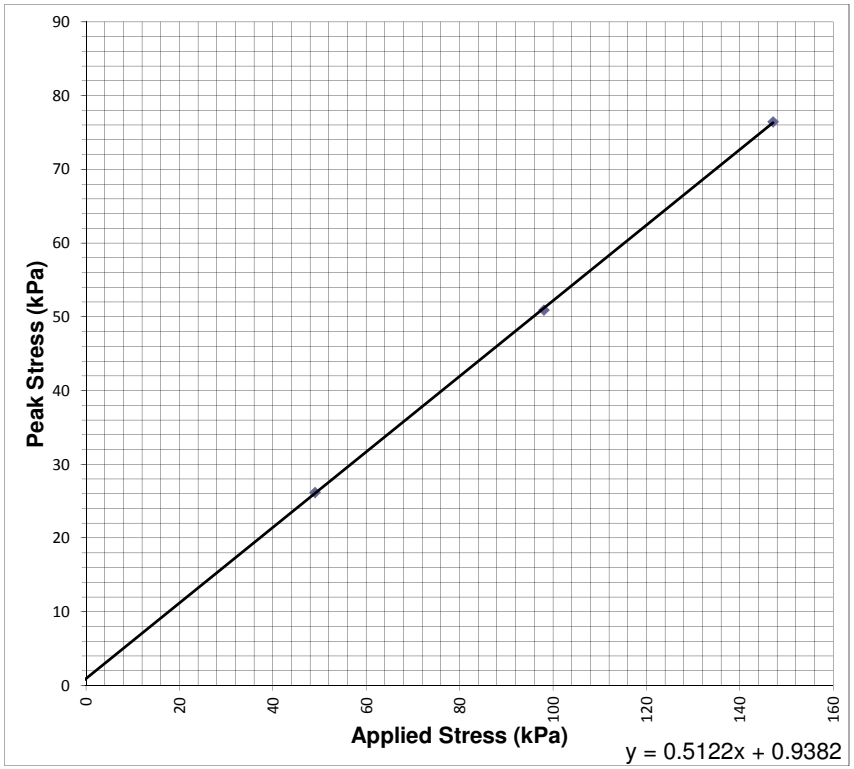
**Sample Type: SPT-18**

**Depth: 27.00-27.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 51 |
| | Stage 3 | 147 | 76 |

| | | |
|---|---|---|
| Angle of Friction | **27.12** | ° |
| Apparent Cohesion | **0.94** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: LBH-14**

**Sample Type: SPT-20**

**Depth: 30.00-30.45 m**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-1 | 0.00-0.20 | SM / SC | | | | 22.2 | 19.22 | 9.16 | 15.73 | | 0 | 85 | <--> | <--> | 15 | | | | | | | | | | | | | | | | | | | | |
| SPT-2 | 1.50-1.65 | | | | | 20.2 | 19.51 | 9.45 | 15.97 | 2.60 | 3 | 86 | <--> | <--> | 11 | DST | | | 0.54 | 31.3 | | | | | | | | | | | | | | | |
| SPT-3 | 3.00-3.22 | | | | | 18.0 | 19.18 | 9.12 | 15.70 | | 2 | 85 | <--> | <--> | 13 | | | | | | | | | | | | | | | | | | | | |
| SPT-4 | 4.50-4.68 | | | | | 21.9 | 19.22 | 9.16 | 15.76 | | 0 | 86 | <--> | <--> | 14 | DST | | | 0.16 | 32.8 | | | | | | | | | | | | | | | |
| SPT-5 | 6.00-6.16 | SM / SC | | | | 24.5 | 18.78 | 8.72 | 15.08 | | 0 | 61 | <--> | <--> | 39 | | | | | | | | | | | | | | | | | | | | |
| SPT-6 | 7.50-7.70 | | | | | 25.2 | 18.78 | 8.72 | 15.00 | 2.63 | 0 | 60 | <--> | <--> | 40 | | | | | | | | | | | | | | | | | | | | |
| SPT-7 | 9.00-9.15 | | | | | 25.6 | 19.10 | 9.04 | 15.21 | | 0 | 67 | <--> | <--> | 33 | | | | | | | | | | | | | | | | | | | | |
| SPT-8 | 10.50-10.95 | CI | 42.8 | 15.5 | 27.3 | 19.3 | 19.65 | 9.59 | 16.48 | 2.57 | 0 | 47 | 22 | 31 | 53 | | | | | | | | | 50.0 | | | | | 8.76 | 3.57 | 1.00 | 1500 | 10620 |
| SPT-9 | 12.00-12.45 | | | | | 17.4 | 19.66 | 9.60 | 16.75 | 2.55 | 0 | 49 | 22 | 29 | 51 | | | | | | | | | | | | | | | | | | | | |
| SPT-10 | 13.50-13.60 | SC | 32.1 | 14.9 | 17.2 | 20.4 | 19.19 | 9.13 | 15.94 | 2.58 | 0 | 75 | 9 | 16 | 25 | | | | | | | | | | | | | | | | | | | |
| SPT-11 | 15.30-15.45 | | | | | 16.1 | 19.52 | 9.46 | 16.82 | | 0 | 87 | <--> | <--> | 13 | DST | | | 0.99 | 27.6 | | | | | | | | | | | | | | | |
| SPT-12 | 16.65-16.85 | | | | | 17.2 | 19.68 | 9.62 | 16.78 | 2.64 | 0 | 77 | <--> | <--> | 23 | DST | | | 1.85 | 30.7 | | | | | | | | | | | | | | | |
| SPT-13 | 18.15-18.30 | SM / SC | | | | 20.3 | 19.22 | 9.16 | 15.98 | | 0 | 59 | <--> | <--> | 41 | | | | | | | | | | | | | | | | | | | | |
| SPT-14 | 19.65-19.95 | | | | | 22.3 | 19.25 | 9.19 | 15.74 | 2.61 | 0 | 74 | <--> | <--> | 26 | DST | | | 1.11 | 31.4 | | | | | | | | | | | | | | | |
| SPT-15 | 21.20-21.45 | | | | | 18.6 | 19.37 | 9.31 | 16.33 | 2.54 | 0 | 44 | 27 | 29 | 56 | | | | | | | | | | | | | | | | | | | | |
| SPT-16 | 22.50-22.95 | SM / SC | | | | 18.2 | 20.31 | 10.25 | 17.18 | 2.56 | 0 | 79 | 15 | 6 | 21 | | | | | | | | | | | | | | | | | | | | |
| SPT-17 | 24.00-24.45 | CI | 45.0 | 18.2 | 26.8 | 24.2 | 19.65 | 9.59 | 15.83 | 2.55 | 0 | 28 | 43 | 29 | 72 | | | | | | | | | 50.0 | | | | | | | | | | |
| SPT-18 | 25.50-25.95 | | | | | 21.6 | 19.66 | 9.60 | 16.17 | 2.54 | 0 | 17 | 51 | 32 | 83 | | | | | | | | | | | | | | | | | | | | |
| SPT-19 | 27.20-27.38 | | | | | 26.7 | 19.65 | 9.59 | 15.51 | 2.61 | 0 | 18 | <--> | <--> | 82 | | | | | | | | | | | | | | | | | | | | |
| END OF BOREHOLE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

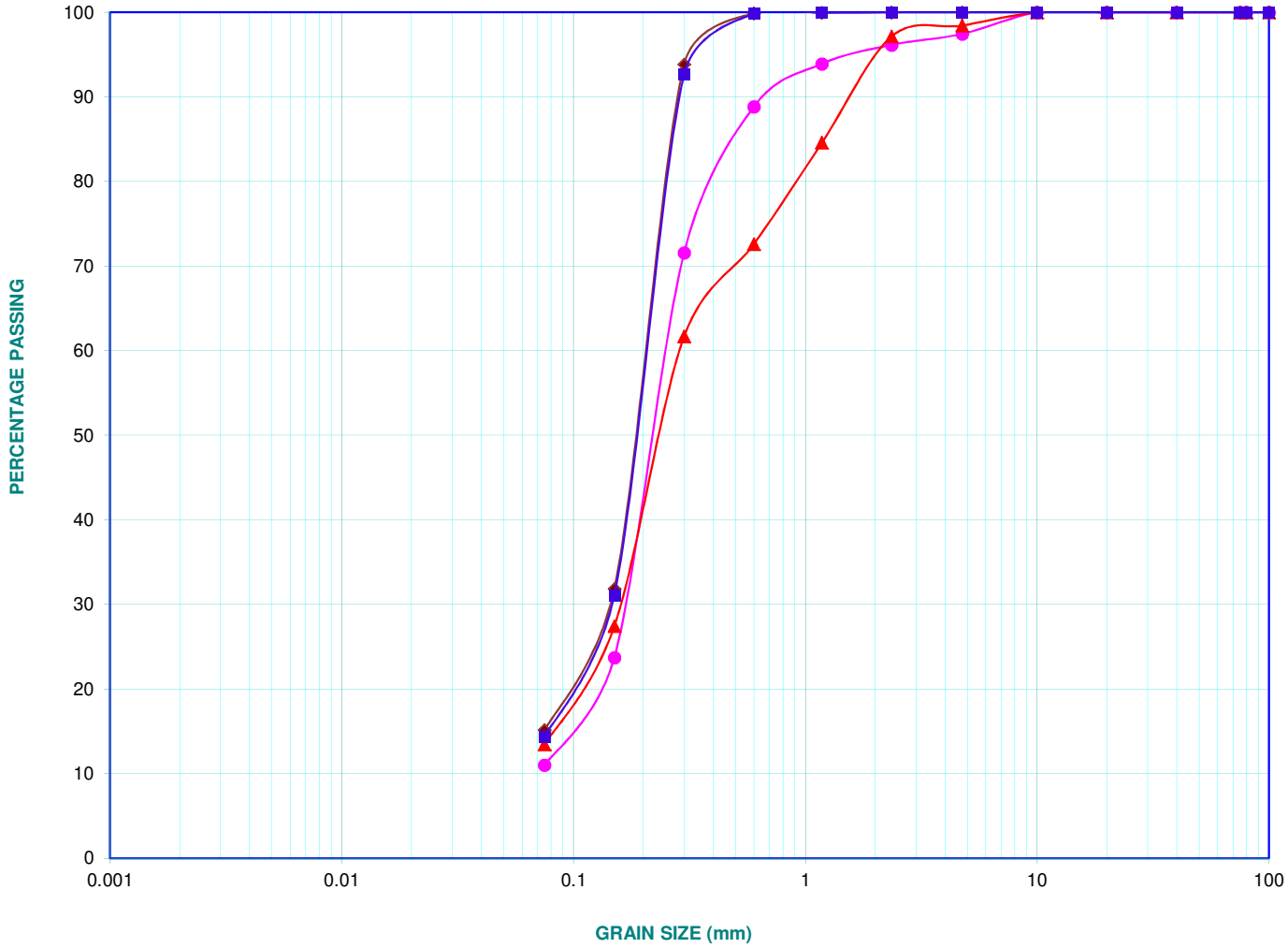
\# : Decayed Wood

**Failure Type**
A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-15**

# GRAIN SIZE ANALYSIS

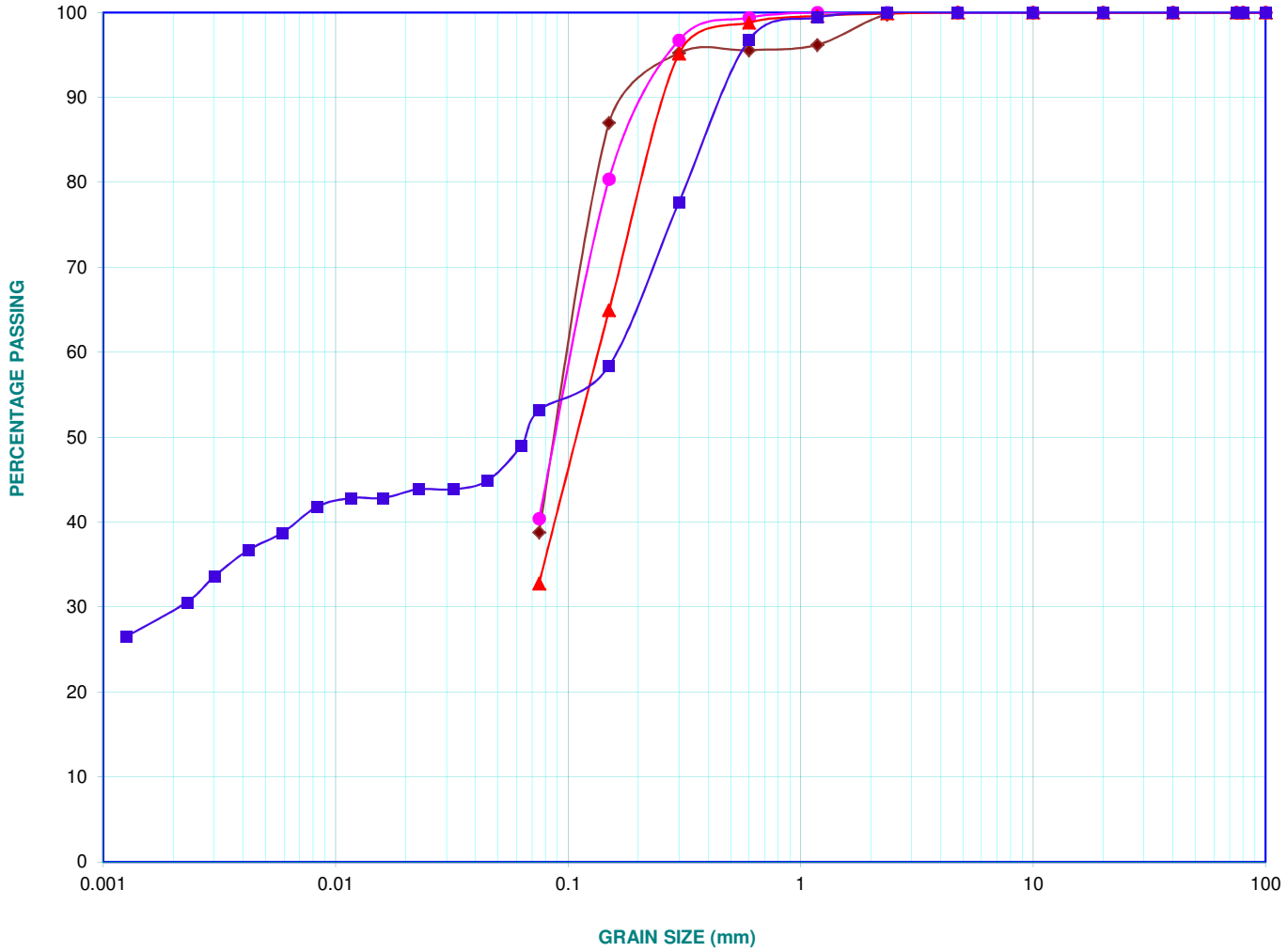
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | **Borehole No.** | **: MBH-15** | | | | **Date :** | **8-Apr-19** | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-15 | MBH-15 | MBH-15 | MBH-15 | | | | | | | | |
| **Depth (m)** | 0.00-0.20 | 1.50-1.65 | 3.00-3.22 | 4.50-4.68 | | | | | | | | |
| **Sample Type** | SPT-1 | SPT-2 | SPT-3 | SPT-4 | | | | | | | | |
| **Classification** | SM / SC | SM / SC | SM / SC | SM / SC | | | | | | | | |
| **Gravel %** | 0 | 3 | 2 | 0 | | | | | | | | |
| **Sand %** | 85 | 86 | 85 | 86 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 15 | 11 | 13 | 14 | | | | | | | | |
| **D60 mm** | | | | | | | | | | | | |
| **D30 mm** | | | | | | | | | | | | |
| **D10 mm** | | | | | | | | | | | | |
| **Cu** | | | | | | | | | | | | |
| **Cc** | | | | | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

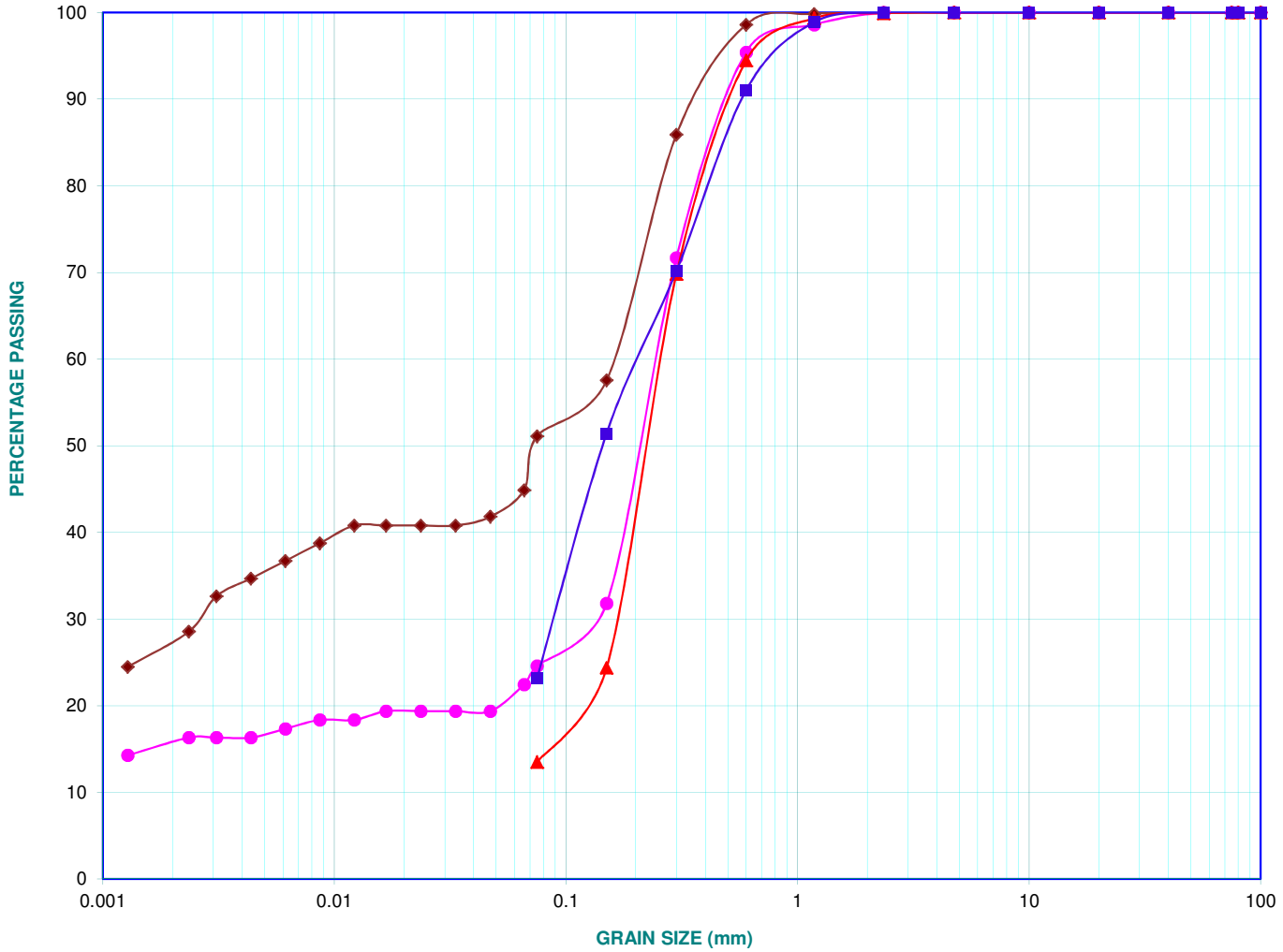
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | **Borehole No.** | **: MBH-15** | | | | **Date :** | **8-Apr-19** | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-15 | MBH-15 | MBH-15 | MBH-15 | | | | | | | | |
| **Depth (m)** | 6.00-6.16 | 7.50-7.70 | 9.00-9.15 | 10.50-10.95 | | | | | | | | |
| **Sample Type** | SPT-5 | SPT-6 | SPT-7 | SPT-8 | | | | | | | | |
| **Classification** | SM / SC | SM / SC | SM / SC | CI | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 61 | 60 | 67 | 47 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | 22 | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | 31 | | | | | | | | |
| **Fines % (Silt+Clay)** | 39 | 40 | 33 | 53 | | | | | | | | |
| **D60 mm** | | | | | | | | | | | | |
| **D30 mm** | | | | | | | | | | | | |
| **D10 mm** | | | | | | | | | | | | |
| **Cu** | | | | | | | | | | | | |
| **Cc** | | | | | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | 42.8 | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | 15.5 | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | 27.3 | | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

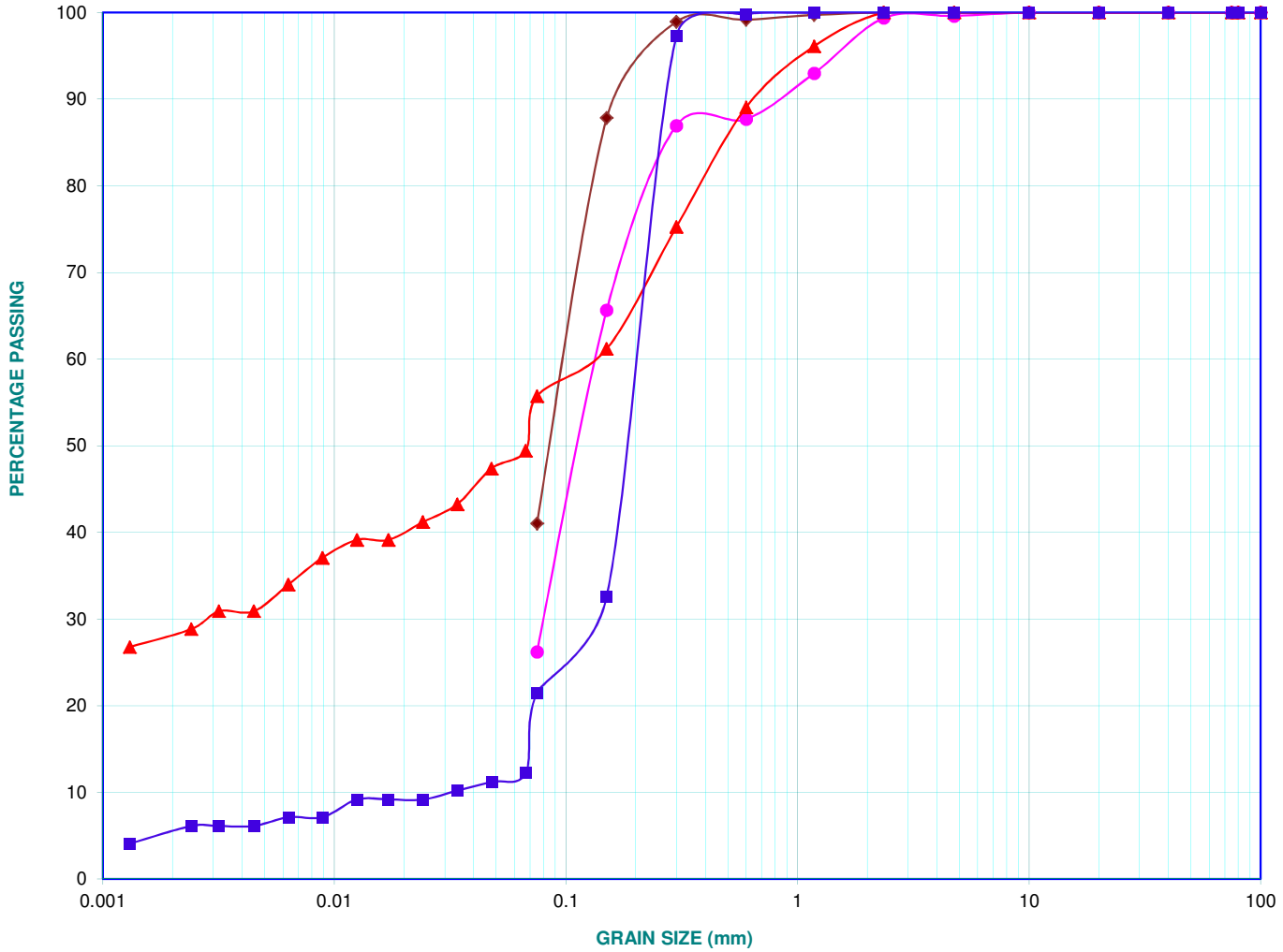
| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | **Borehole No.** | **: MBH-15** | | | | | **Date :** | **8-Apr-19** | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND F | SAND M | SAND C | GRAVEL F / GRAVEL C |
| **Bore Hole .** | MBH-15 | MBH-15 | MBH-15 | MBH-15 | | | | | | | |
| **Depth (m)** | 12.00-12.45 | 13.50-13.60 | 15.30-15.45 | 16.65-16.85 | | | | | | | |
| **Sample Type** | SPT-9 | SPT-10 | SPT-11 | SPT-12 | | | | | | | |
| **Classification** | | SC | SC | SC | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | |
| **Sand %** | 49 | 75 | 87 | 77 | | | | | | | |
| **Silt %** | 22 | 9 | <----> | <----> | | | | | | | |
| **Clay %** | 29 | 16 | <----> | <----> | | | | | | | |
| **Fines % (Silt+Clay)** | 51 | 25 | 13 | 23 | | | | | | | |
| **D60 mm** | | | | | | | | | | | |
| **D30 mm** | | | | | | | | | | | |
| **D10 mm** | | | | | | | | | | | |
| **Cu** | | | | | | | | | | | |
| **Cc** | | | | | | | | | | | |
| **Liquid Limit %** | --- | 32.1 | --- | --- | | | | | | | |
| **Plastic Limit %** | --- | 14.9 | --- | --- | | | | | | | |
| **Plasticity Index** | --- | 17.2 | --- | --- | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

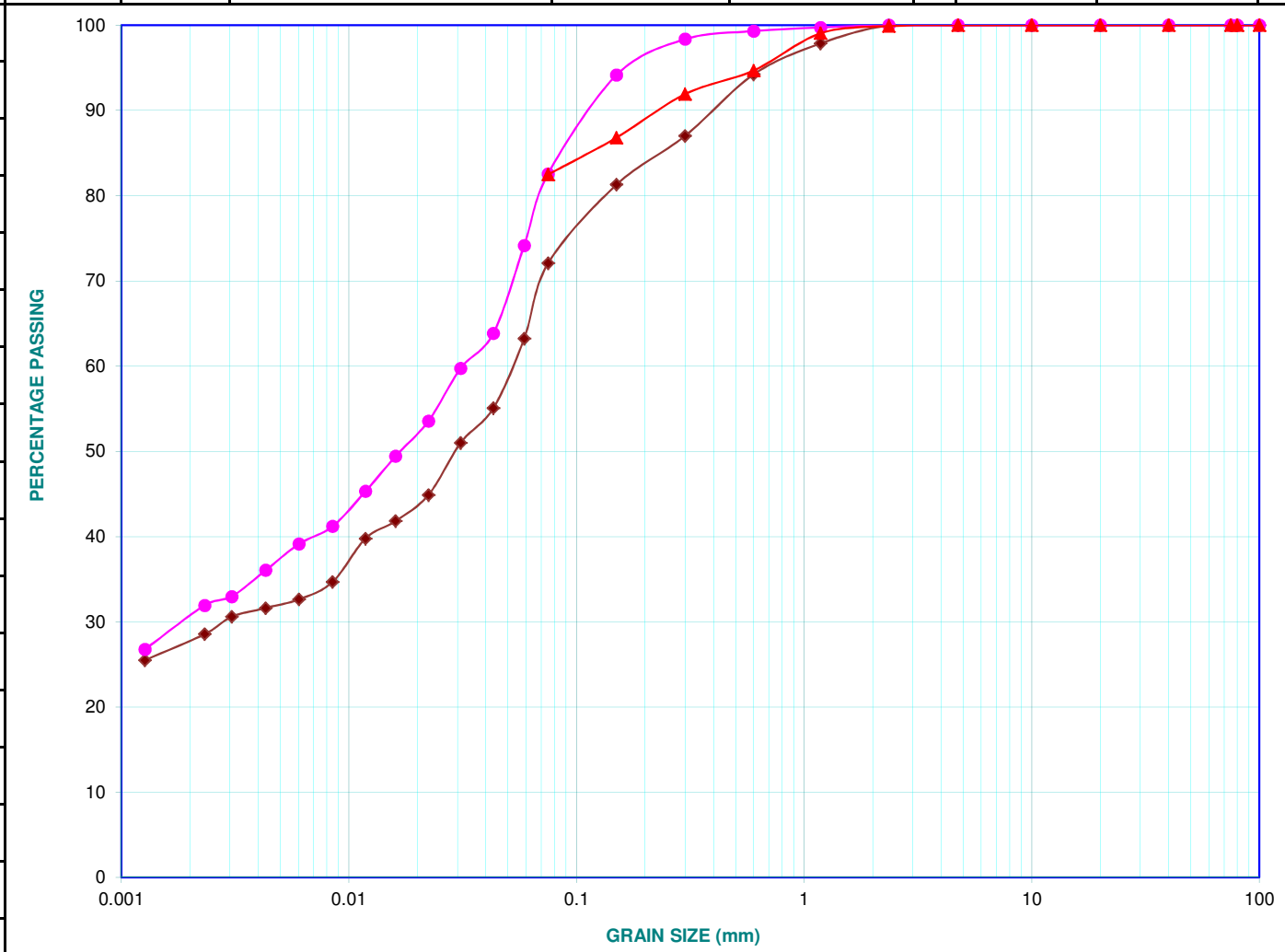
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | **Borehole No.** | **: MBH-15** | | | | **Date :** | **8-Apr-19** | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-15 | MBH-15 | MBH-15 | MBH-15 | | | | | | | | |
| **Depth (m)** | 18.15-18.30 | 19.65-19.95 | 21.20-21.45 | 22.50-22.95 | | | | | | | | |
| **Sample Type** | SPT-13 | SPT-14 | SPT-15 | SPT-16 | | | | | | | | |
| **Classification** | SC | SM / SC | | SM / SC | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 59 | 74 | 44 | 79 | | | | | | | | |
| **Silt %** | <----> | <----> | 27 | 15 | | | | | | | | |
| **Clay %** | <----> | <----> | 29 | 6 | | | | | | | | |
| **Fines % (Silt+Clay)** | 41 | 26 | 56 | 21 | | | | | | | | |
| **D60 mm** | | | | | | | | | | | | |
| **D30 mm** | | | | | | | | | | | | |
| **D10 mm** | | | | | | | | | | | | |
| **Cu** | | | | | | | | | | | | |
| **Cc** | | | | | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |




Checked By :

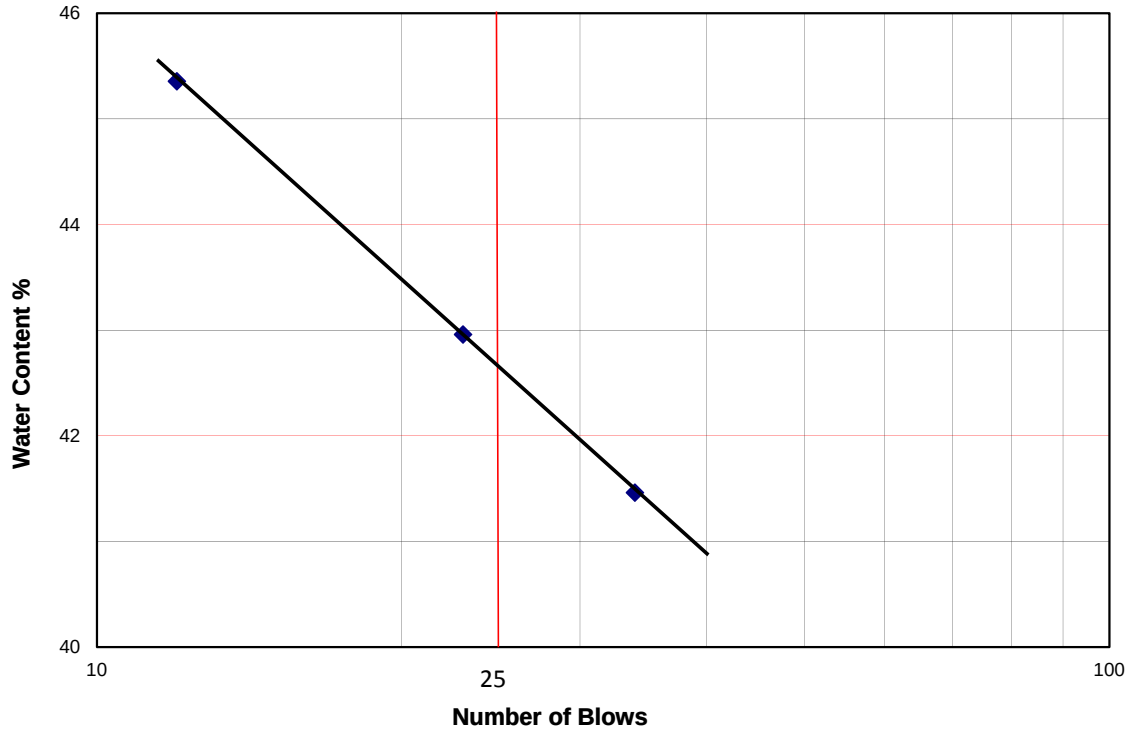
# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | **Borehole No.** | **: MBH-15** | | | **Date :** | **8-Apr-19** | | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-15 | MBH-15 | MBH-15 | | | | | | | | | |
| **Depth (m)** | 24.00-24.45 | 25.50-25.95 | 27.20-27.38 | | | | | | | | | |
| **Sample Type** | SPT-17 | SPT-18 | SPT-19 | | | | | | | | | |
| **Classification** | CI | CI | CI | | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | | | | | | | | | |
| **Sand %** | 28 | 17 | 18 | | | | | | | | | |
| **Silt %** | 43 | 51 | <----> | | | | | | | | | |
| **Clay %** | 29 | 32 | <----> | | | | | | | | | |
| **Fines % (Silt+Clay)** | 72 | 83 | 82 | | | | | | | | | |
| **D60 mm** | | | | | | | | | | | | |
| **D30 mm** | | | | | | | | | | | | |
| **D10 mm** | | | | | | | | | | | | |
| **Cu** | | | | | | | | | | | | |
| **Cc** | | | | | | | | | | | | |
| **Liquid Limit %** | 45.0 | --- | --- | | | | | | | | | |
| **Plastic Limit %** | 18.2 | --- | --- | | | | | | | | | |
| **Plasticity Index** | 26.8 | --- | --- | | | | | | | | | |




Checked By :

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 24.17 | 29.23 | 32.04 | | |
| Dry Weight + Can (g) | 19.58 | 24.38 | 25.89 | | |
| Can Weight (g) | 8.51 | 13.09 | 12.33 | | |
| Water Content, % | 41.5 | 43.0 | 45.4 | | |
| Number of Blows | 34 | 23 | 12 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 16.23 | 17.67 | 15.54 |
| Dry Weight + Can (g) | 15.18 | 16.51 | 15.21 |
| Can Weight (g) | 8.50 | 8.93 | 13.09 |
| Water Content, % | 15.7 | 15.3 | 15.6 |

Liquid Limit % 42.8

Plastic Limit % 15.5

Plasticity Index % 27.3

Preparation of Sample :
Dry State

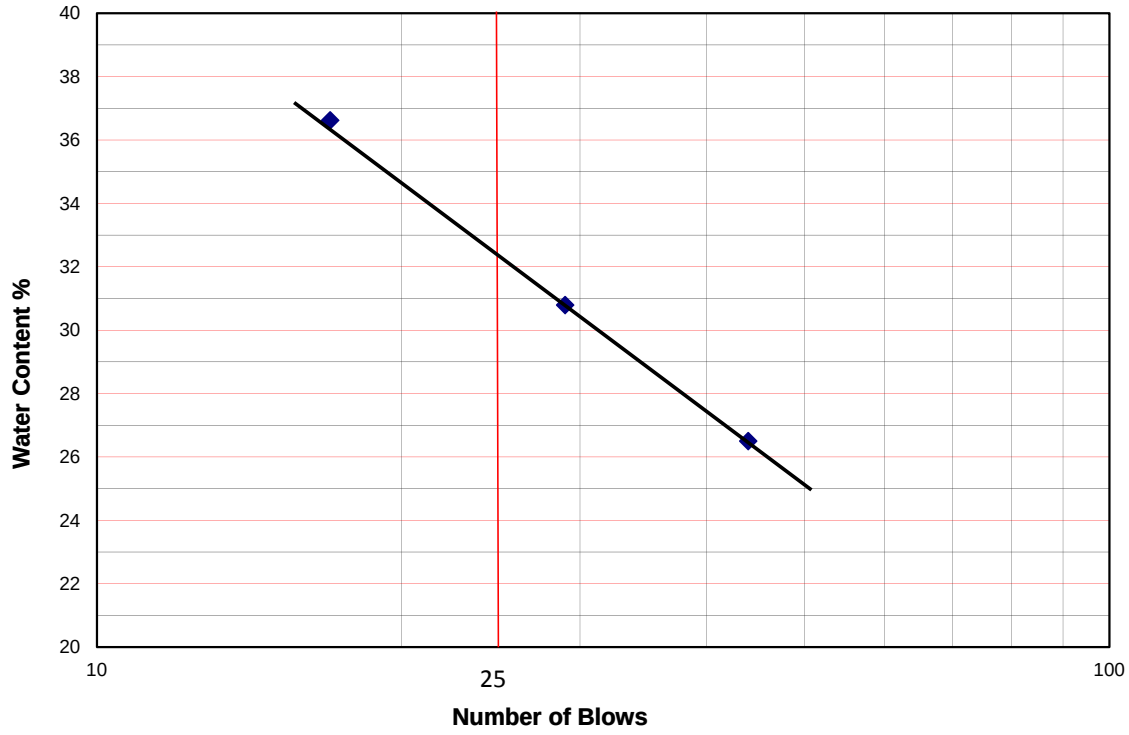
Sample Type: SPT-8

Borehole no.: MBH-15

Depth :10.50-10.95

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 25.28 | 27.38 | 30.91 | | |
| Dry Weight + Can (g) | 22.58 | 23.75 | 26.34 | | |
| Can Weight (g) | 12.39 | 11.96 | 13.86 | | |
| Water Content, % | 26.5 | 30.8 | 36.6 | | |
| Number of Blows | 44 | 29 | 17 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 15.57 | 16.32 | 16.77 |
| Dry Weight + Can (g) | 14.78 | 15.19 | 15.72 |
| Can Weight (g) | 9.51 | 7.60 | 8.63 |
| Water Content, % | 15.0 | 14.9 | 14.8 |

Liquid Limit % 32.1

Plastic Limit % 14.9

Plasticity Index % 17.2

Preparation of Sample :
Dry State

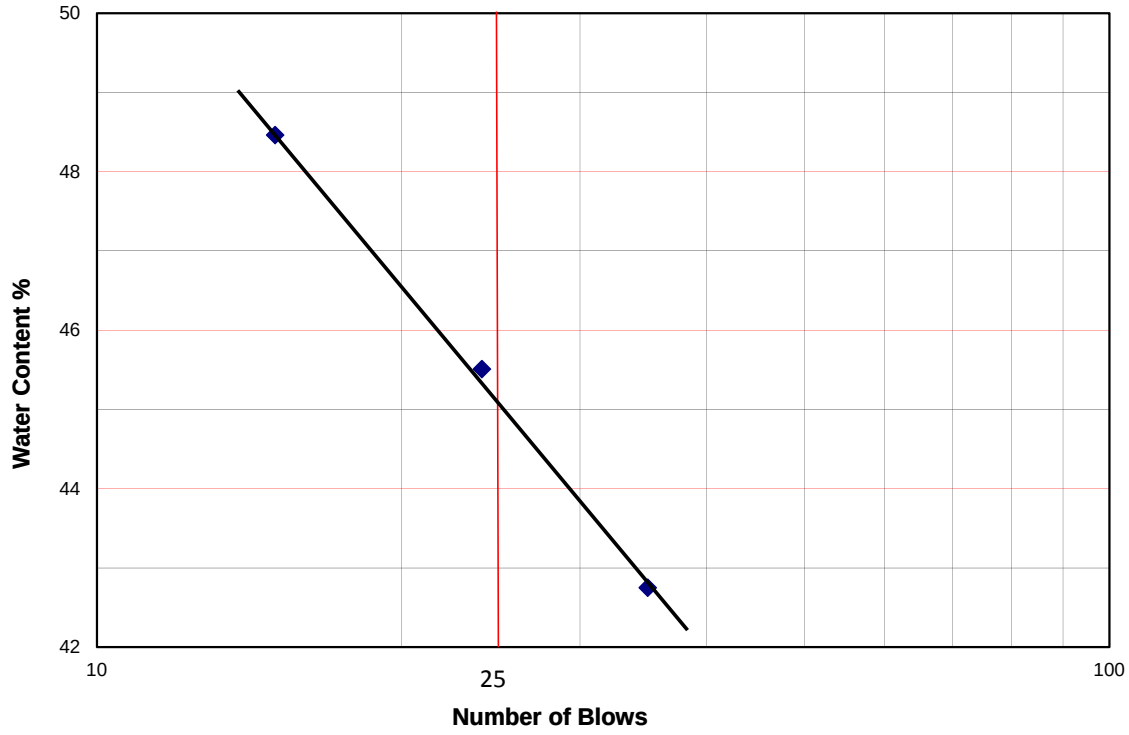
Sample Type: SPT-10

Borehole no.: MBH-15

Depth :13.50-13.60

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 25.95 | 30.10 | 34.09 | | |
| Dry Weight + Can (g) | 22.00 | 24.63 | 27.16 | | |
| Can Weight (g) | 12.76 | 12.61 | 12.86 | | |
| Water Content, % | 42.7 | 45.5 | 48.5 | | |
| Number of Blows | 35 | 24 | 15 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 17.75 | 16.83 | 15.22 |
| Dry Weight + Can (g) | 17.00 | 15.73 | 14.32 |
| Can Weight (g) | 12.93 | 9.47 | 9.52 |
| Water Content, % | 18.4 | 17.6 | 18.8 |

Liquid Limit % 45.0

Plastic Limit % 18.2

Plasticity Index % 26.8

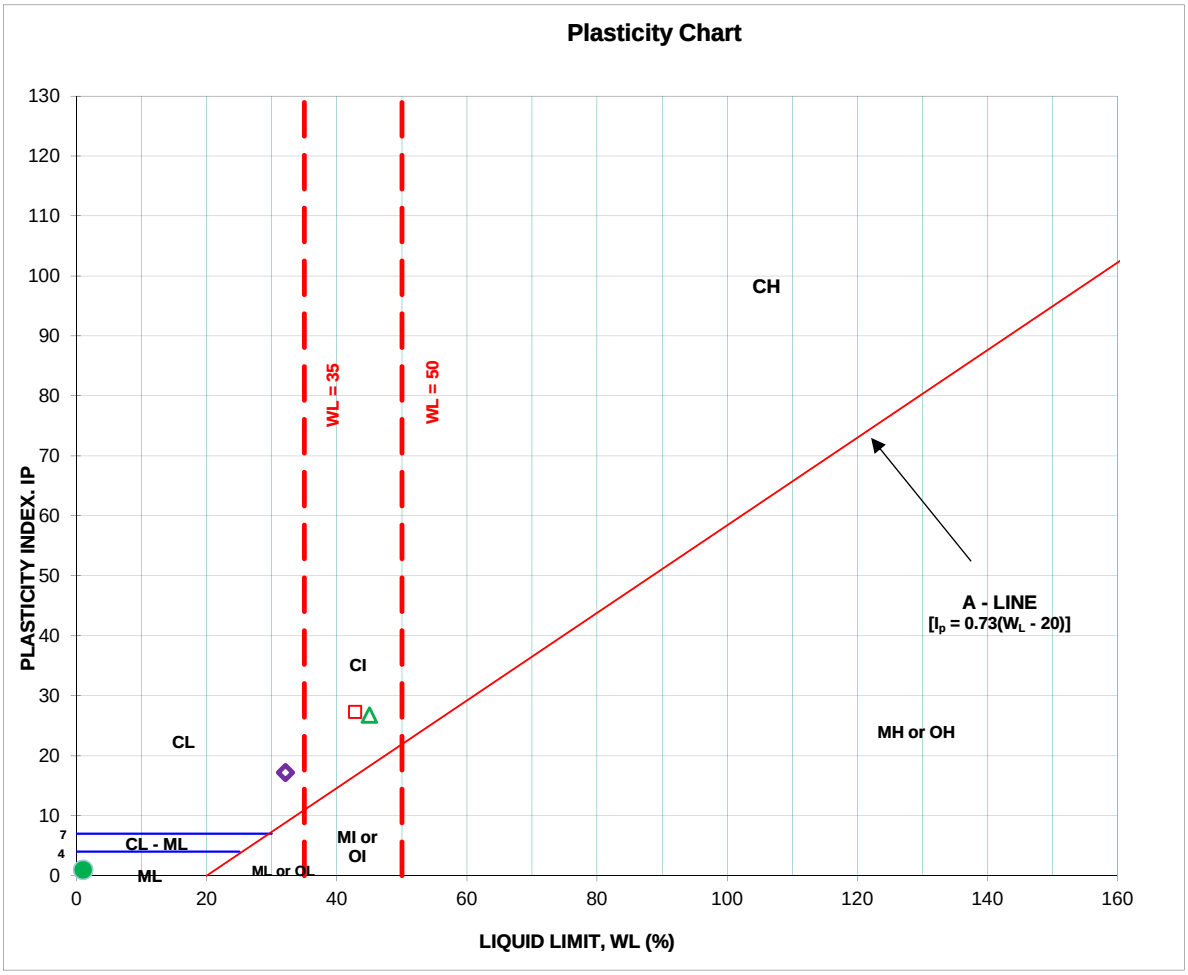
Preparation of Sample :
Dry State

Sample Type: SPT-17

Borehole no.: MBH-15

Depth :24.00-24.45

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.




| | Sample Type | Depth (m) | $W_L$ | $W_P$ | $I_P$ | Remarks |
|---|---|---|---|---|---|---|
| □ | SPT-08 | 10.50-10.95 | 42.8 | 15.5 | 27.3 | CI: Clays with Intermediate plasticity |
| ◇ | SPT-10 | 13.50-13.60 | 32.1 | 14.9 | 17.2 | CL: Inorganic clays of low to medium plasticity. |
| △ | SPT-15 | 24.00-24.45 | 45.0 | 18.2 | 26.8 | CI: Clays with Intermediate plasticity |
| ● | | | | | | |
| + | | | | | | |
| ■ | | | | | | |

| | | | |
|---|---|---|---|
| ML | Inorganic silts, very fine sands, rock flour, silty or clayey fine sands | MH | Inorganic silts, or diatomaceous fine sands or silts, elastic silts |
| CL | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays | CH | Inorganic clays of high plasticity, fat clays |
| OL | Organic silts and organic silty clays of low plasticity | OH | Organic silts and organic clays of medium t high plasticity |
| CI | Clays with Intermediate plasticity | MI | Silt with intermediate plasticity |

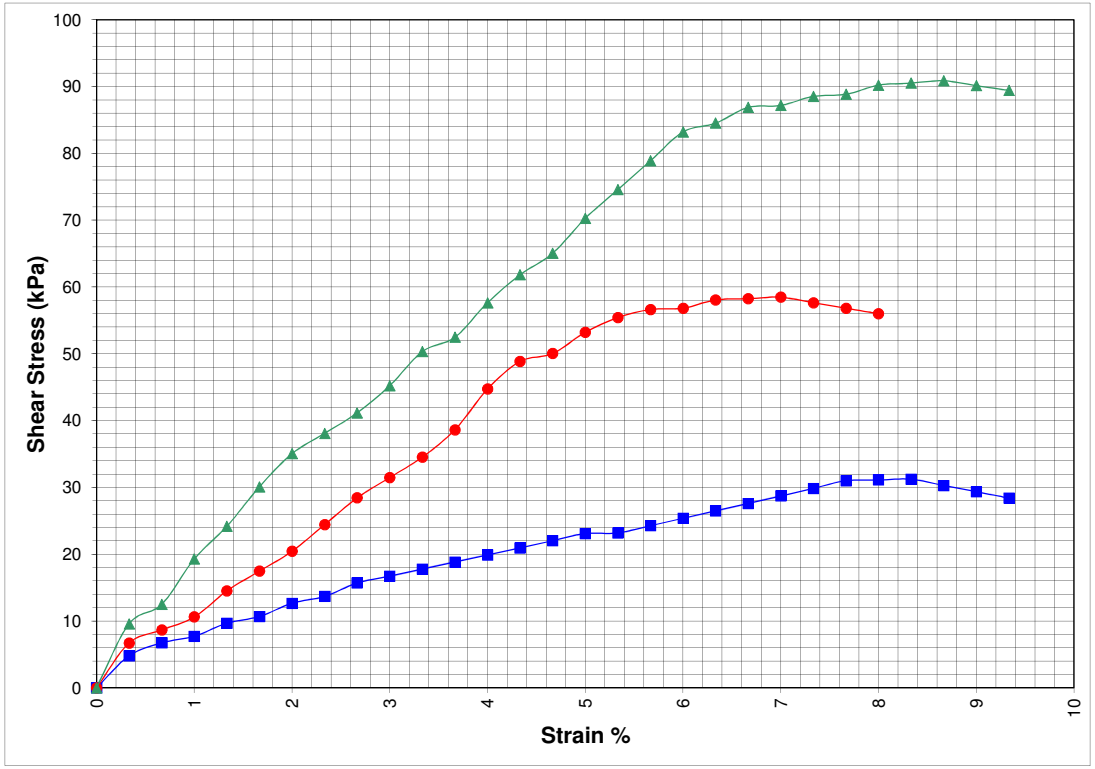
## PLASTICITY CHART (IS : 1498 - 1987)

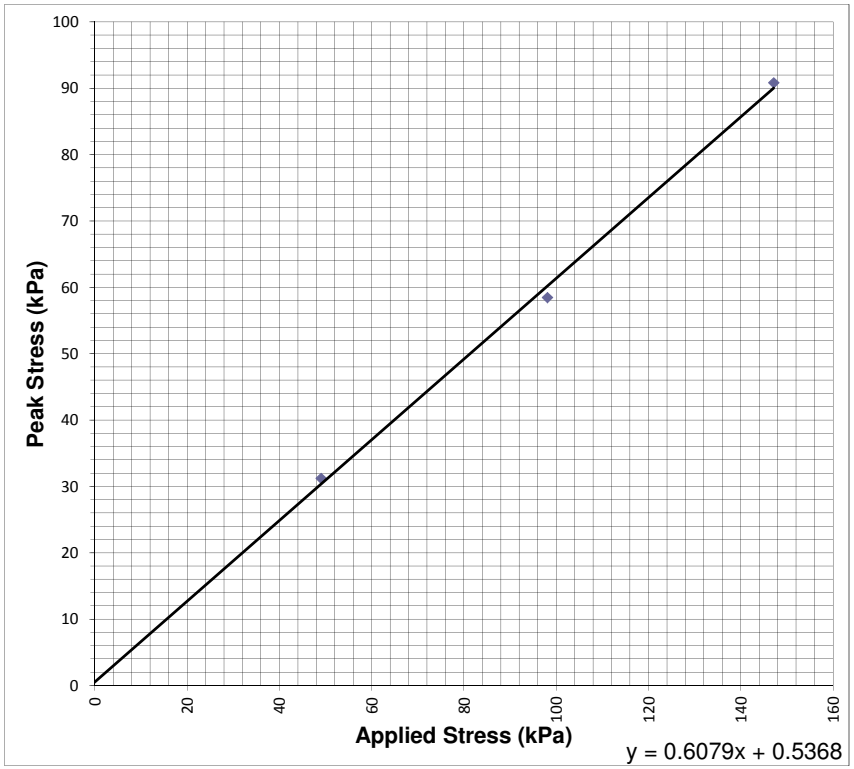
BOREHOLE NAME : MBH-15

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 31 |
| | Stage 2 | 98 | 58 |
| | Stage 3 | 147 | 91 |

| | | |
|---|---|---|
| Angle of Friction | **31.3** | ° |
| Apparent Cohesion | **0.54** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

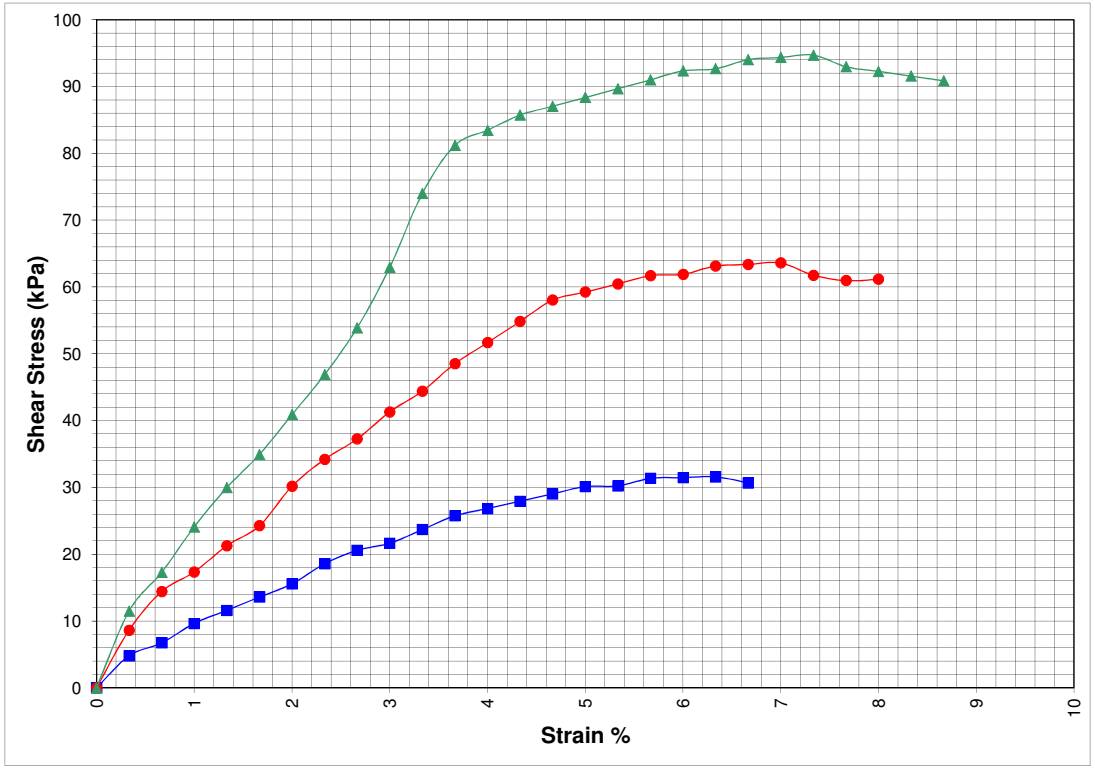
**Borehole: MBH-15**

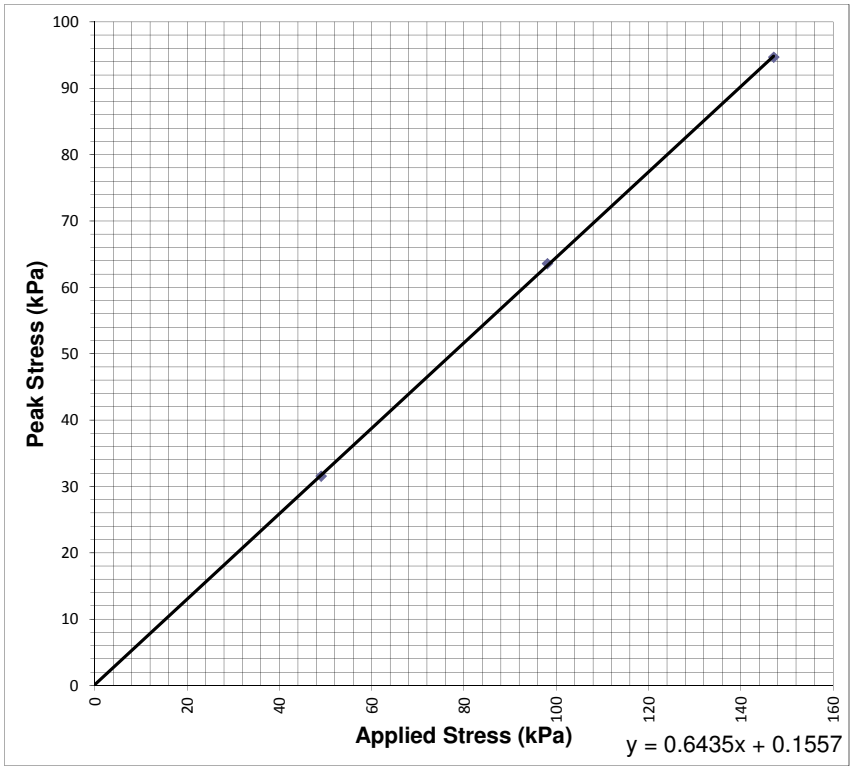
**Sample Type: SPT-02**

**Depth: 1.50-1.65 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 32 |
| | Stage 2 | 98 | 64 |
| | Stage 3 | 147 | 95 |

| | | |
|---|---|---|
| Angle of Friction | **32.8** | ° |
| Apparent Cohesion | **0.16** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

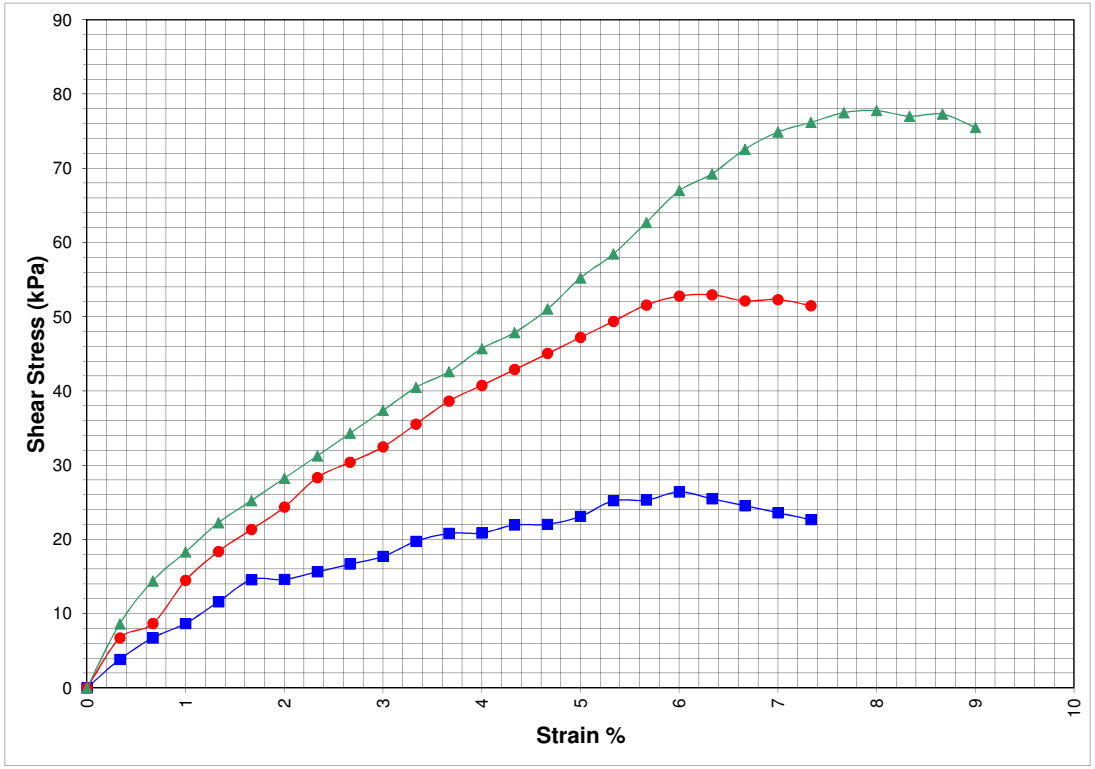
**Borehole: MBH-15**

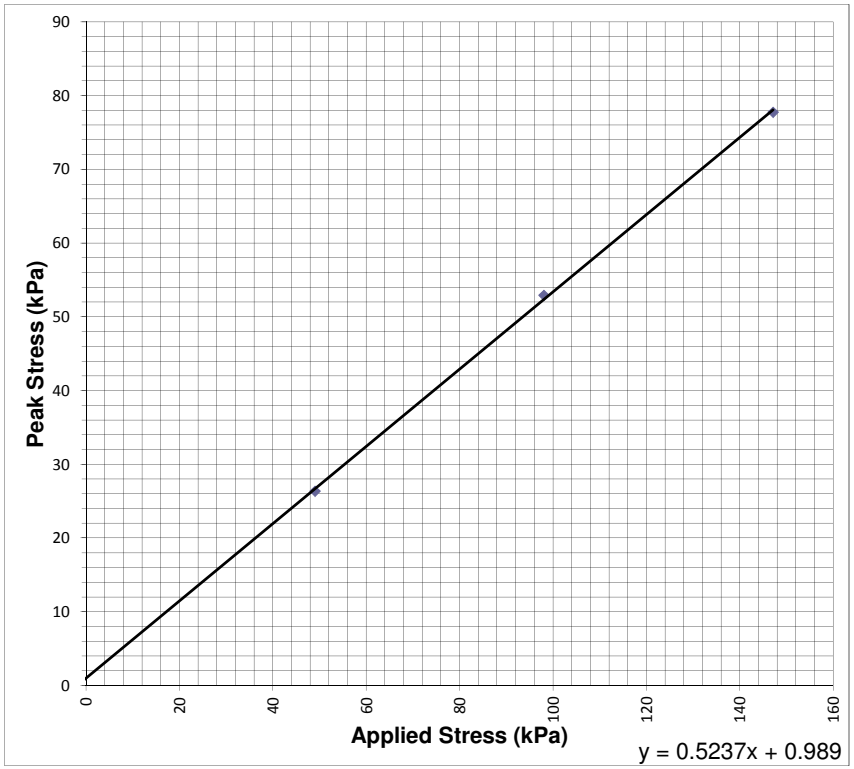
**Sample Type: SPT-04**

**Depth: 4.50-4.68 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 53 |
| | Stage 3 | 147 | 78 |

| | | |
|---|---|---|
| Angle of Friction | **27.6** | ° |
| Apparent Cohesion | **0.99** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

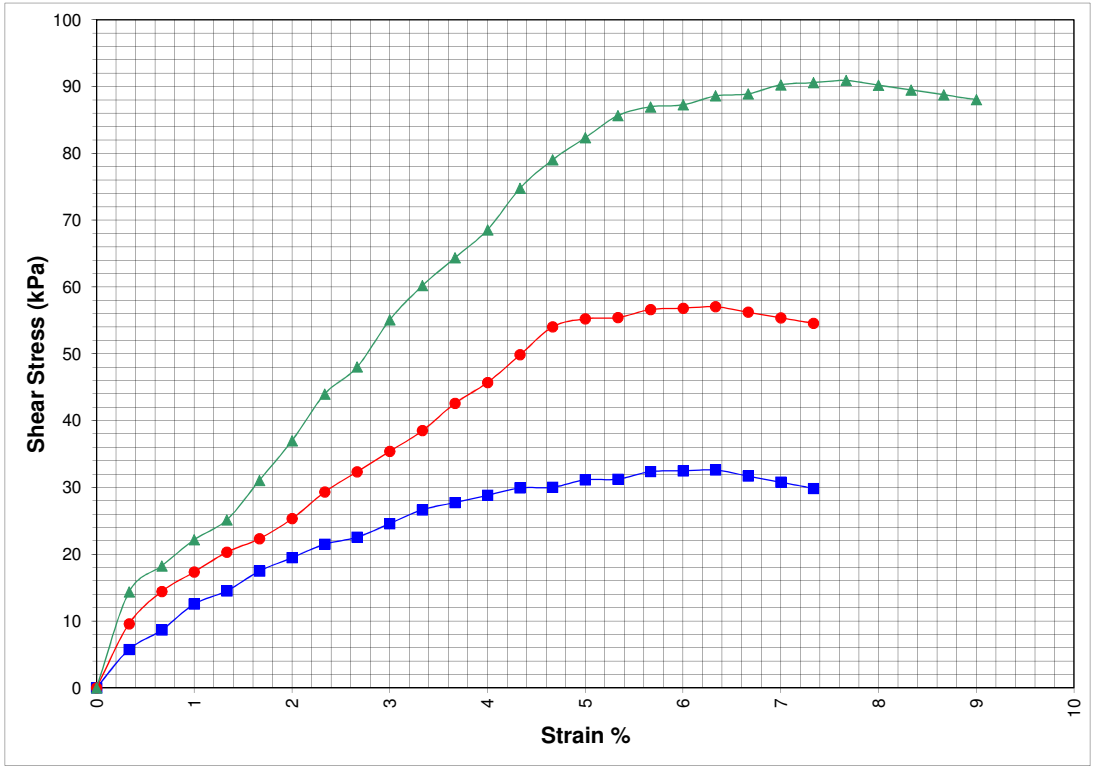
**Borehole: MBH-15**

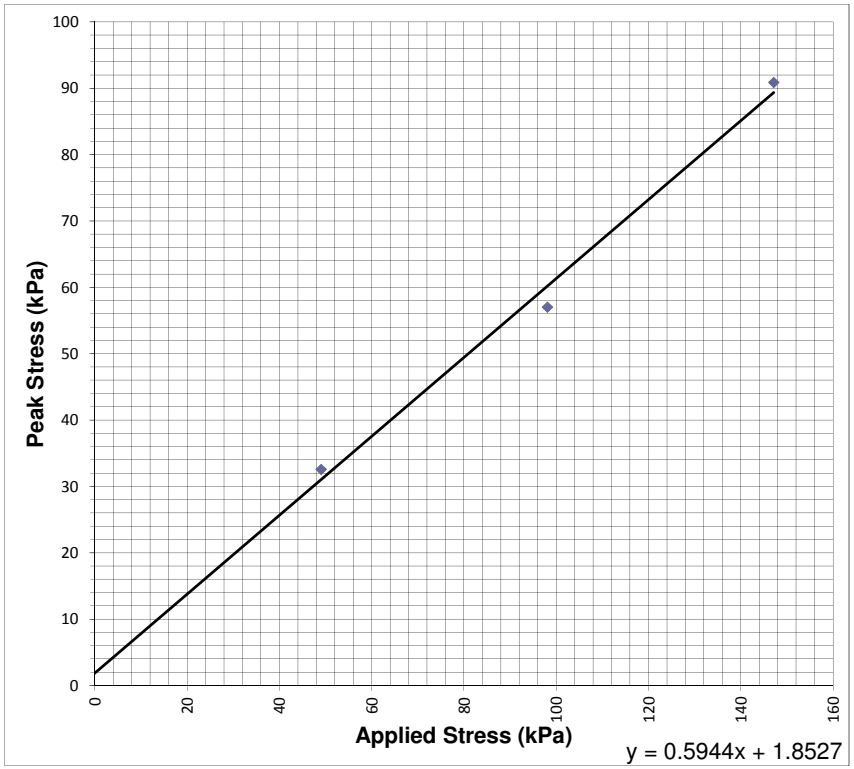
**Sample Type: SPT-11**

**Depth: 15.30-15.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 33 |
| | Stage 2 | 98 | 57 |
| | Stage 3 | 147 | 91 |

| | | |
|---|---|---|
| Angle of Friction | **30.7** | ° |
| Apparent Cohesion | **1.85** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

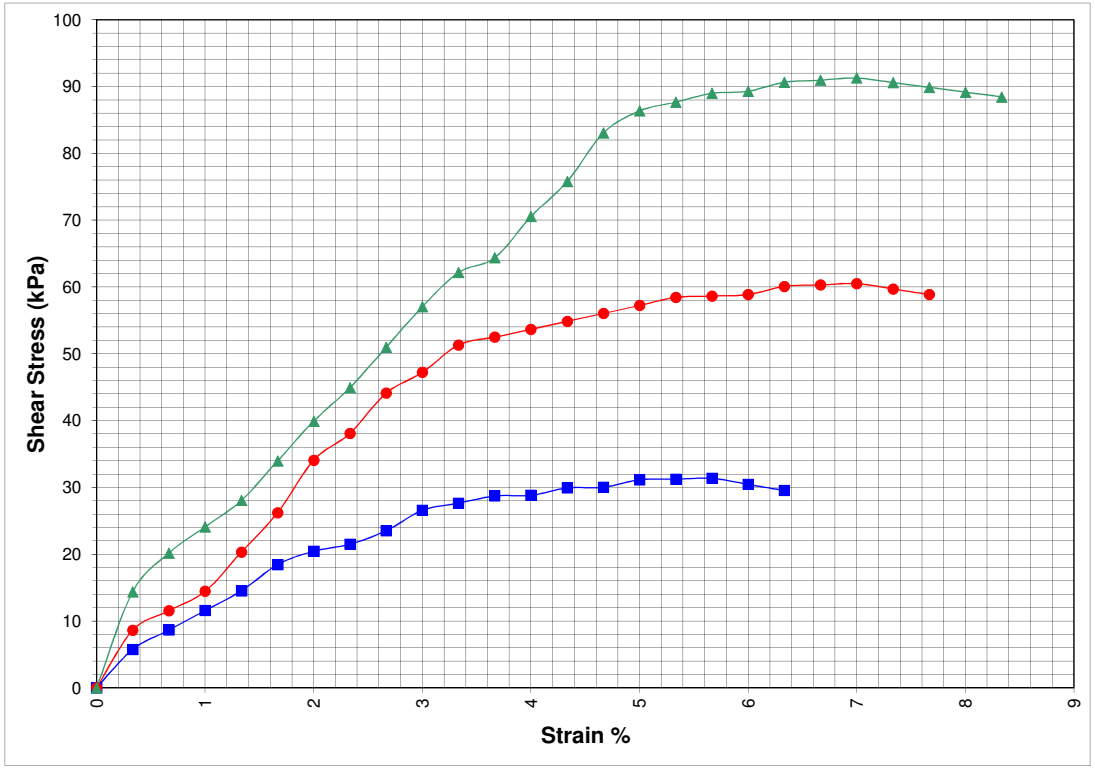
**Borehole: MBH-15**

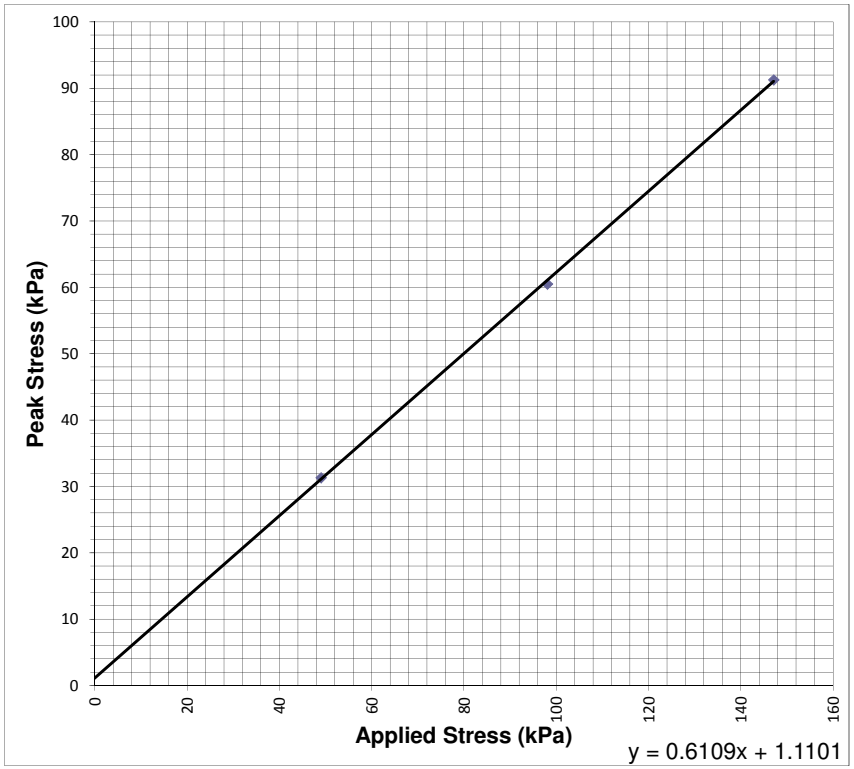
**Sample Type: SPT-12**

**Depth: 16.65-16.85 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 31 |
| | Stage 2 | 98 | 61 |
| | Stage 3 | 147 | 91 |

| | | |
|---|---|---|
| Angle of Friction | **31.42** | ° |
| Apparent Cohesion | **1.11** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: MBH-15**

**Sample Type: SPT-14**

**Depth: 19.65-19.95 m**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-1 | 0.00-0.45 | | | | | 16.1 | 18.96 | 8.90 | 16.34 | 2.58 | | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-2 | 1.50-1.95 | | | | | 20.7 | 18.85 | 8.79 | 16.24 | | 1 | 85 | <--> | <--> | 14 | | | | | | | | | | | | | | | | | | | |
| SPT-3 | 3.00-3.45 | SM \ SC | | | | 25.2 | 18.49 | 8.43 | 15.93 | | 0 | 64 | <--> | <--> | 36 | | | | | | | | | | | | | | | | | | | |
| SPT-4 | 4.50-4.95 | | | | | 20.6 | 19.77 | 9.71 | 16.39 | | 0 | 54 | <--> | <--> | 46 | DST | | | 3.18 | 29.6 | | | | | | | | | | | | | | |
| SPT-5 | 6.00-6.45 | | | | | 18.8 | 20.44 | 10.38 | 17.20 | | 5 | 64 | <--> | <--> | 31 | | | | | | | | | | | | | | | | | | | |
| SPT-6 | 7.57-7.95 | | 30.6 | 13.3 | 17.3 | 18.2 | 20.52 | 10.46 | 17.36 | 2.56 | 0 | 57 | 19 | 24 | 43 | | | | | | | | | 77.8 | | | | | 8.33 | 2.59 | 1.00 | 1800 | 7080 |
| SPT-7 | 9.00-9.45 | SC | 30.1 | 13.3 | 16.8 | 16.1 | 20.53 | 10.47 | 17.68 | 2.57 | 0 | 63 | 15 | 22 | 37 | | | | | | | | | | | | | | | | | | | |
| SPT-8 | 10.50-10.70 | | | | | 20.3 | 20.34 | 10.28 | 16.91 | | 2 | 59 | <--> | <--> | 39 | | | | | | | | | | | | | | | | | | | |
| SPT-8 | 10.70-10.95 | | | | | 17.3 | 19.03 | 8.97 | 16.23 | | 1 | 80 | <--> | <--> | 19 | | | | | | | | | | | | | | | | | | | |
| SPT-9 | 12.20-12.45 | | | | | 15.0 | 19.95 | 9.89 | 17.36 | 2.60 | 0 | 81 | <--> | <--> | 19 | DST | | | 1.11 | 28.6 | | | | | | | | | | | | | | |
| SPT-10 | 13.65-13.95 | | | | | 19.7 | 19.97 | 9.91 | 16.69 | | 0 | 64 | <--> | <--> | 36 | | | | | | | | | | | | | | | | | | | |
| SPT-11 | 15.20-15.45 | SM \ SC | | | | 22.3 | 19.95 | 9.89 | 16.32 | | 0 | 58 | <--> | <--> | 42 | | | | | | | | | | | | | | | | | | | |
| SPT-12 | 16.75-16.95 | | | | | 23.9 | 19.50 | 9.44 | 15.74 | 2.58 | 0 | 68 | 30 | 2 | 32 | | | | | | | | | | | | | | | | | | | |
| SPT-13 | 18.00-18.20 | | | | | 17.8 | 19.42 | 9.36 | 16.48 | | 0 | 89 | <--> | <--> | 11 | | | | | | | | | | | | | | | | | | | |
| SPT-13 | 18.20-18.45 | | | | | 24.5 | 19.50 | 9.44 | 15.66 | | 0 | 25 | <--> | <--> | 75 | | | | | | | | | | | | | | | | | | | |
| SPT-14 | 19.50-19.95 | SM \ SC | | | | 16.2 | 20.26 | 10.20 | 17.44 | 2.57 | 0 | 54 | 34 | 12 | 46 | | | | | | | | | | | | | | | | | | | |
| SPT-15 | 21.00-21.45 | SM \ SC | | | | 14.4 | 19.95 | 9.89 | 17.44 | 2.54 | 0 | 70 | 16 | 14 | 30 | | | | | | | | | | | | | | | | | | | |
| **END OF BOREHOLE** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

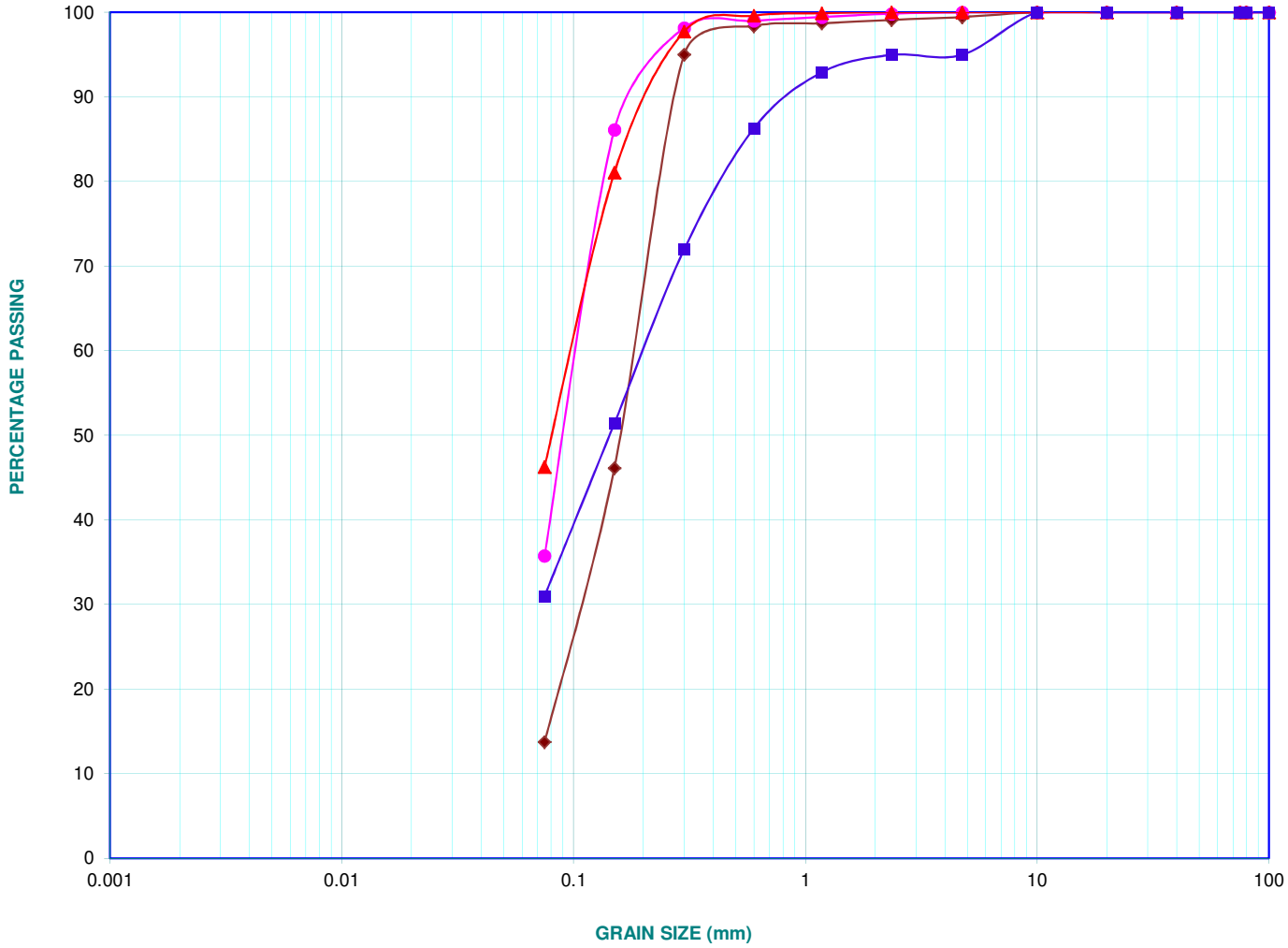
\# : Decayed Wood

**Failure Type**
A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-13**

# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | | **Borehole No.** | **: MBH-16** | | | **Date :** | **9-Apr-19** | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-16 | MBH-16 | MBH-16 | MBH-16 | | | | | | | | |
| **Depth (m)** | 1.50-1.95 | 3.00-3.45 | 4.50-4.95 | 6.00-6.45 | | | | | | | | |
| **Sample Type** | SPT-2 | SPT-3 | SPT-4 | SPT-5 | | | | | | | | |
| **Classification** | SM \ SC | SM \ SC | SM \ SC | SM \ SC | | | | | | | | |
| **Gravel %** | 1 | 0 | 0 | 5 | | | | | | | | |
| **Sand %** | 85 | 64 | 54 | 64 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 14 | 36 | 46 | 31 | | | | | | | | |
| **D60 mm** | | | | | | | | | | | | |
| **D30 mm** | | | | | | | | | | | | |
| **D10 mm** | | | | | | | | | | | | |
| **Cu** | | | | | | | | | | | | |
| **Cc** | | | | | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |

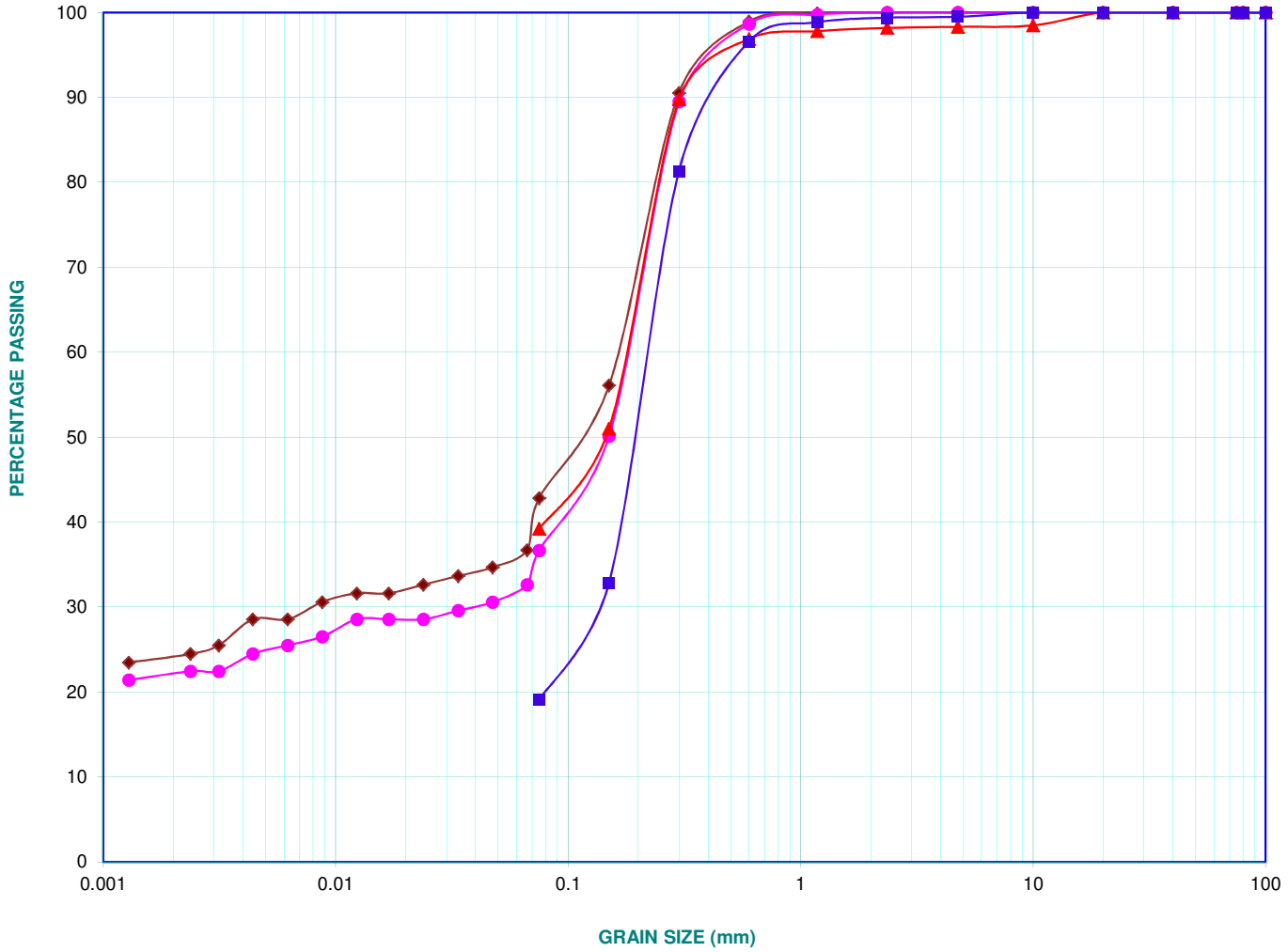



Checked By :

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-16** |
| **Date :** | **9-Apr-19** |

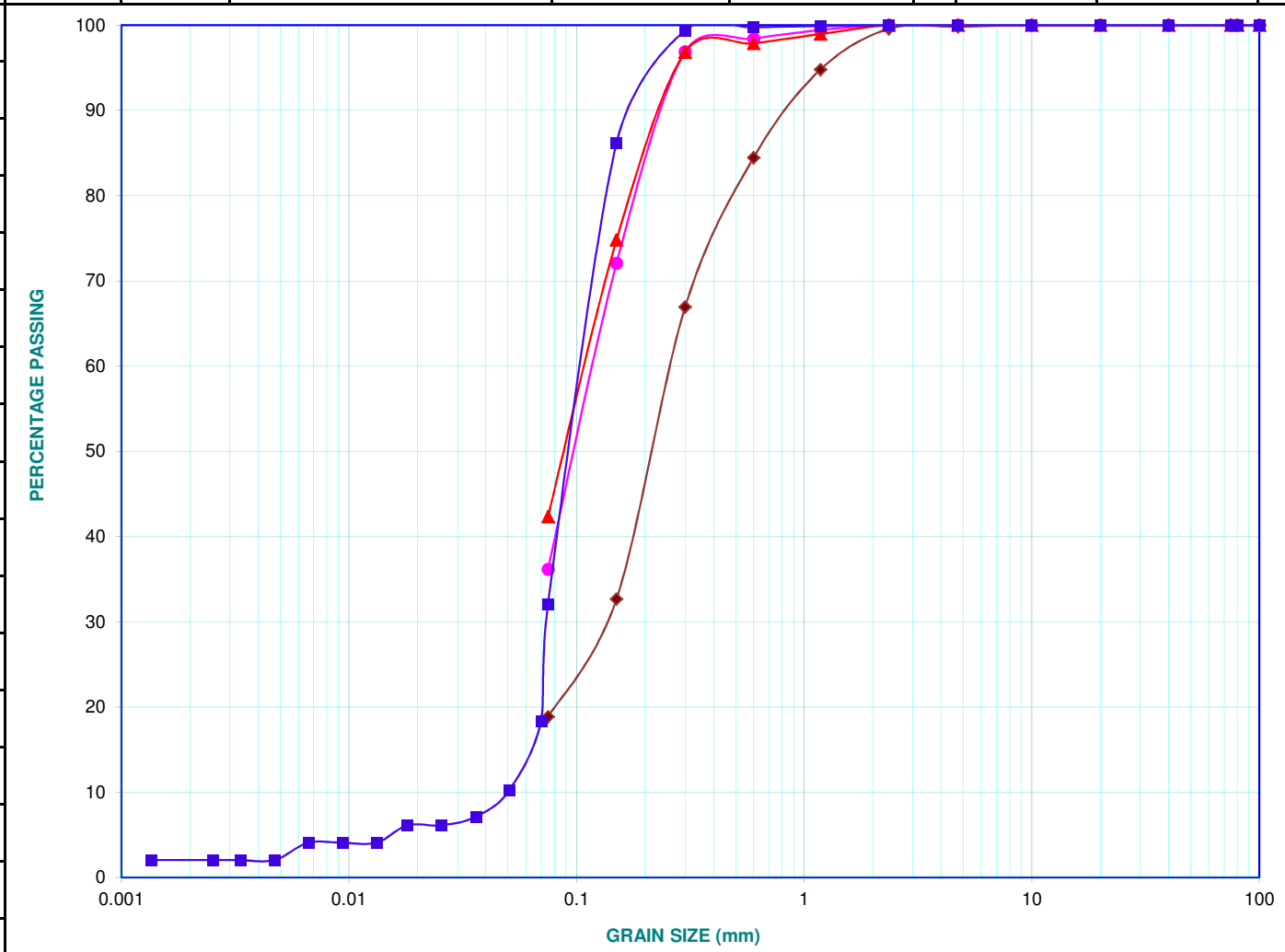
| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| Bore Hole . | MBH-16 | MBH-16 | MBH-16 | MBH-16 | | | | | | | | |
| Depth (m) | 7.50-7.95 | 9.00-9.45 | 10.50-10.70 | 10.70-10.95 | | | | | | | | |
| Sample Type | SPT-6 | SPT-7 | SPT-8 | SPT-8 | | | | | | | | |
| Classification | SC | SC | SC | SM \ SC | | | | | | | | |
| Gravel % | 0 | 0 | 2 | 1 | | | | | | | | |
| Sand % | 57 | 63 | 59 | 80 | | | | | | | | |
| Silt % | 19 | 15 | <----> | <----> | | | | | | | | |
| Clay % | 24 | 22 | <----> | <----> | | | | | | | | |
| Fines % (Silt+Clay) | 43 | 37 | 39 | 19 | | | | | | | | |
| D60 mm | | | | | | | | | | | | |
| D30 mm | | | | | | | | | | | | |
| D10 mm | | | | | | | | | | | | |
| Cu | | | | | | | | | | | | |
| Cc | | | | | | | | | | | | |
| Liquid Limit % | 30.6 | 30.1 | --- | --- | | | | | | | | |
| Plastic Limit % | 13.3 | 13.3 | --- | --- | | | | | | | | |
| Plasticity Index | 17.3 | 16.8 | --- | --- | | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

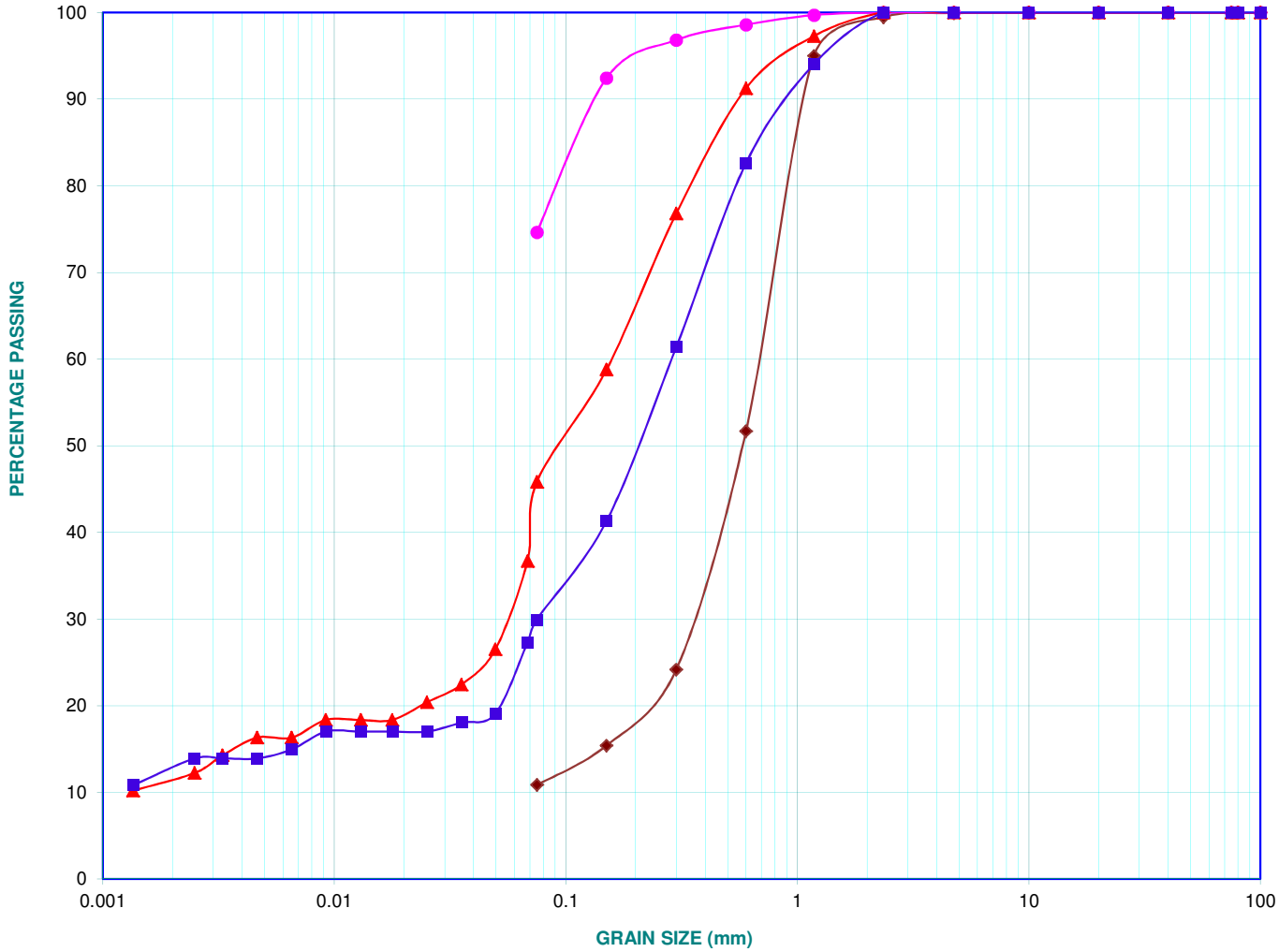
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | | **Borehole No.** | **: MBH-16** | | | | **Date :** | **9-Apr-19** | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-16 | MBH-16 | MBH-16 | MBH-16 | | | | | | | | |
| **Depth (m)** | 12.20-12.45 | 13.65-13.95 | 15.20-15.45 | 16.75-16.95 | | | | | | | | |
| **Sample Type** | SPT-9 | SPT-10 | SPT-11 | SPT-12 | | | | | | | | |
| **Classification** | SM \ SC | SM \ SC | SM \ SC | SM \ SC | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 81 | 64 | 58 | 68 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | 30 | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | 2 | | | | | | | | |
| **Fines % (Silt+Clay)** | 19 | 36 | 42 | 32 | | | | | | | | |
| **D60 mm** | | | | | | | | | | | | |
| **D30 mm** | | | | | | | | | | | | |
| **D10 mm** | | | | | | | | | | | | |
| **Cu** | | | | | | | | | | | | |
| **Cc** | | | | | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |




Checked By :

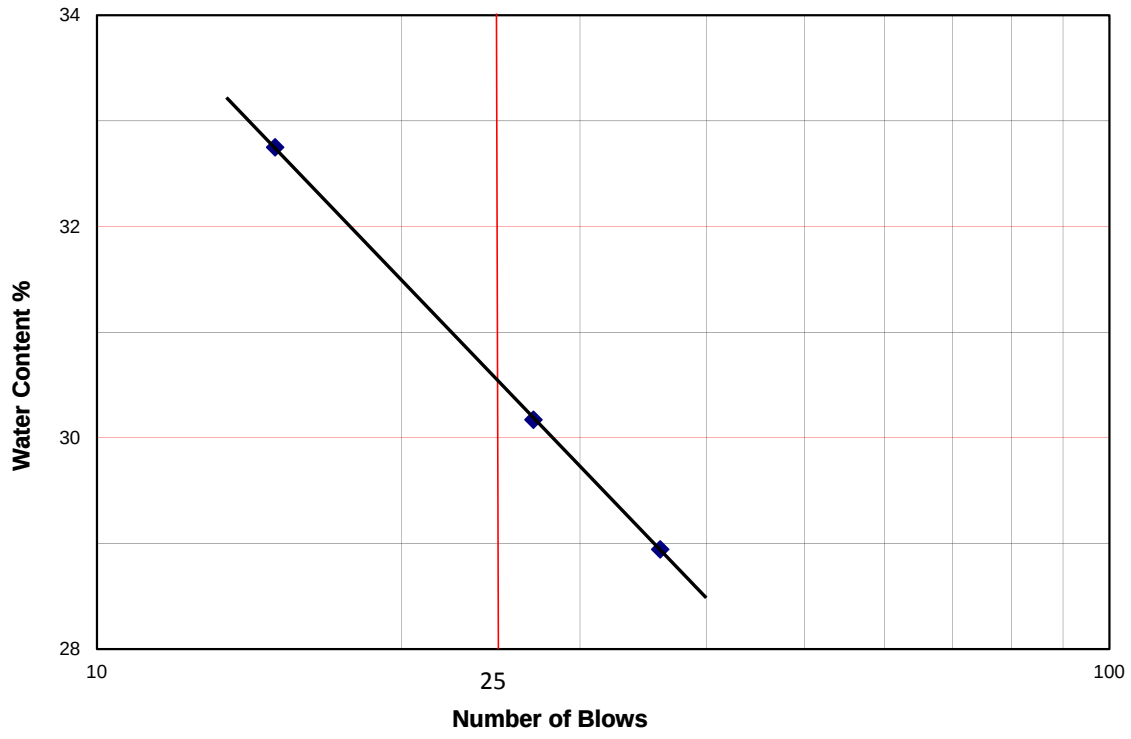
# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | **Borehole No.** | **: MBH-16** | | | | **Date :** | **9-Apr-19** | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-16 | MBH-16 | MBH-16 | MBH-16 | | | | | | | | |
| **Depth (m)** | 18.00-18.20 | 18.20-18.45 | 19.50-19.95 | 21.00-21.45 | | | | | | | | |
| **Sample Type** | SPT-13 | SPT-13 | SPT-14 | SPT-15 | | | | | | | | |
| **Classification** | SM \ SC | | SM \ SC | SM \ SC | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 89 | 25 | 54 | 70 | | | | | | | | |
| **Silt %** | <----> | <----> | 34 | 16 | | | | | | | | |
| **Clay %** | <----> | <----> | 12 | 14 | | | | | | | | |
| **Fines % (Silt+Clay)** | 11 | 75 | 46 | 30 | | | | | | | | |
| **D60 mm** | | | | | | | | | | | | |
| **D30 mm** | | | | | | | | | | | | |
| **D10 mm** | | | | | | | | | | | | |
| **Cu** | | | | | | | | | | | | |
| **Cc** | | | | | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |




Checked By :

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 32.12 | 33.14 | 31.21 | | |
| Dry Weight + Can (g) | 27.81 | 28.37 | 25.79 | | |
| Can Weight (g) | 12.92 | 12.56 | 9.24 | | |
| Water Content, % | 28.9 | 30.2 | 32.7 | | |
| Number of Blows | 36 | 27 | 15 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 17.85 | 18.56 | 17.84 |
| Dry Weight + Can (g) | 17.19 | 17.46 | 16.94 |
| Can Weight (g) | 12.25 | 9.07 | 10.25 |
| Water Content, % | 13.4 | 13.1 | 13.5 |

| | |
|---|---|
| Liquid Limit % | 30.6 |
| Plastic Limit % | 13.3 |
| Plasticity Index % | 17.3 |

Preparation of Sample :
Dry State

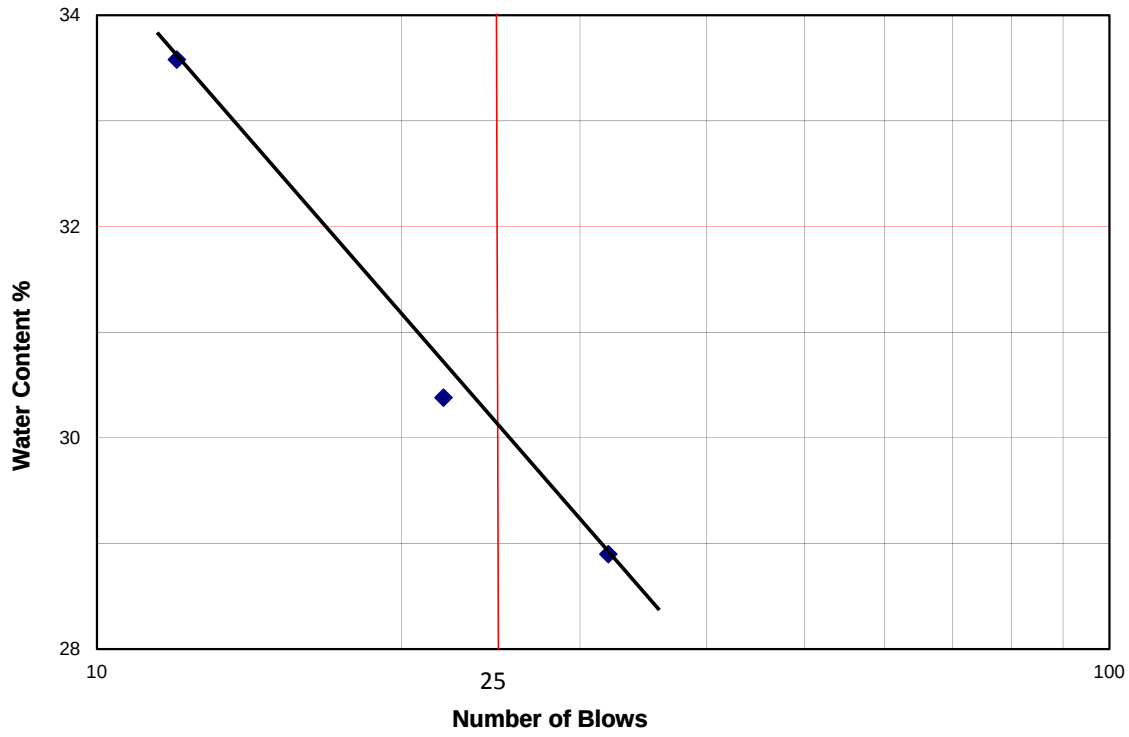
Sample Type: SPT-06

Borehole no.: MBH-16

Depth :7.50-7.95

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 33.41 | 38.05 | 29.60 | | |
| Dry Weight + Can (g) | 29.00 | 32.53 | 24.55 | | |
| Can Weight (g) | 13.74 | 14.36 | 9.51 | | |
| Water Content, % | 28.9 | 30.4 | 33.6 | | |
| Number of Blows | 32 | 22 | 12 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 18.54 | 16.89 | 18.78 |
| Dry Weight + Can (g) | 17.82 | 16.08 | 18.03 |
| Can Weight (g) | 12.45 | 9.87 | 12.45 |
| Water Content, % | 13.4 | 13.0 | 13.4 |

| | |
|---|---|
| Liquid Limit % | 30.1 |
| Plastic Limit % | 13.3 |
| Plasticity Index % | 16.8 |

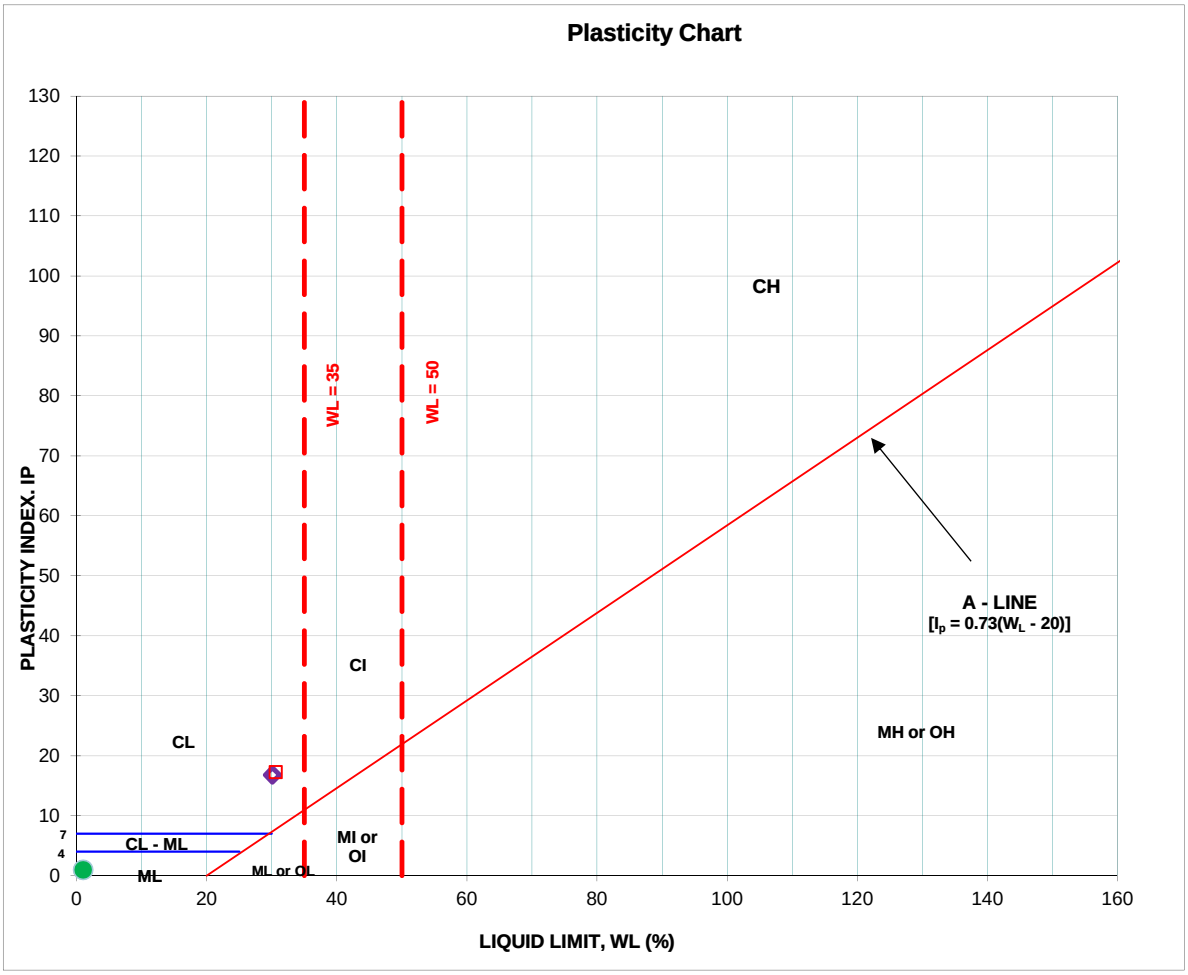
Preparation of Sample :
Dry State

Sample Type: SPT-07

Borehole no.: MBH-16

Depth :9.00-9.45

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.




| | Sample Type | Depth (m) | $W_L$ | $W_P$ | $I_P$ | Remarks |
|---|---|---|---|---|---|---|
| □ | SPT-06 | 7.50-7.95 | 30.6 | 13.3 | 17.3 | CL: Inorganic clays of low to medium plasticity. |
| ◇ | SPT-07 | 9.00-9.45 | 30.1 | 13.3 | 16.8 | CL: Inorganic clays of low to medium plasticity. |
| △ | | | | | | |
| ● | | | | | | |
| + | | | | | | |
| ■ | | | | | | |

| | | | |
|---|---|---|---|
| ML | Inorganic silts, very fine sands, rock flour, silty or clayey fine sands | MH | Inorganic silts, or diatomaceous fine sands or silts, elastic silts |
| CL | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays | CH | Inorganic clays of high plasticity, fat clays |
| OL | Organic silts and organic silty clays of low plasticity | OH | Organic silts and organic clays of medium t high plasticity |
| CI | Clays with Intermediate plasticity | MI | Silt with intermediate plasticity |

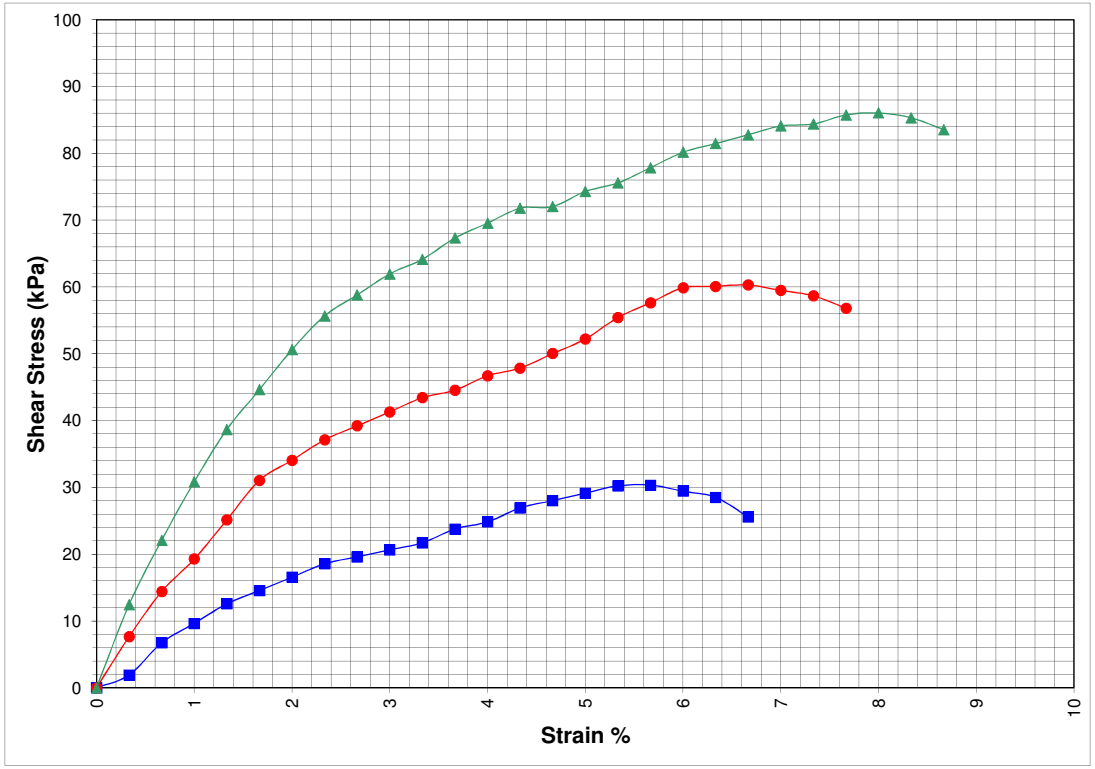
## PLASTICITY CHART (IS : 1498 - 1987)

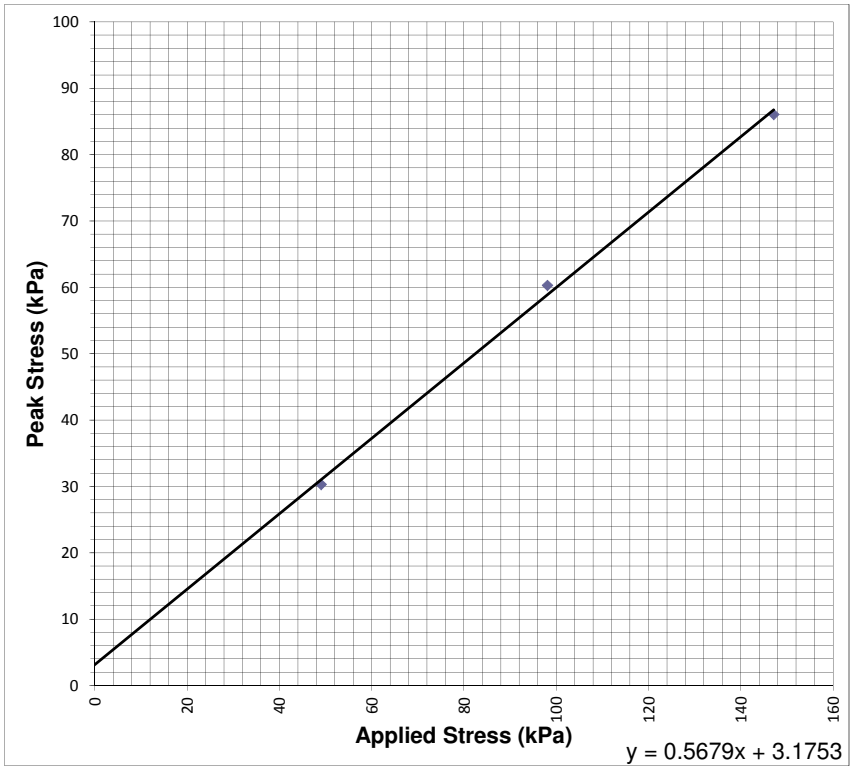
BOREHOLE NAME : MBH-16

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 30 |
| | Stage 2 | 98 | 60 |
| | Stage 3 | 147 | 86 |

| | | |
|---|---|---|
| Angle of Friction | **29.6** | ° |
| Apparent Cohesion | **3.18** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

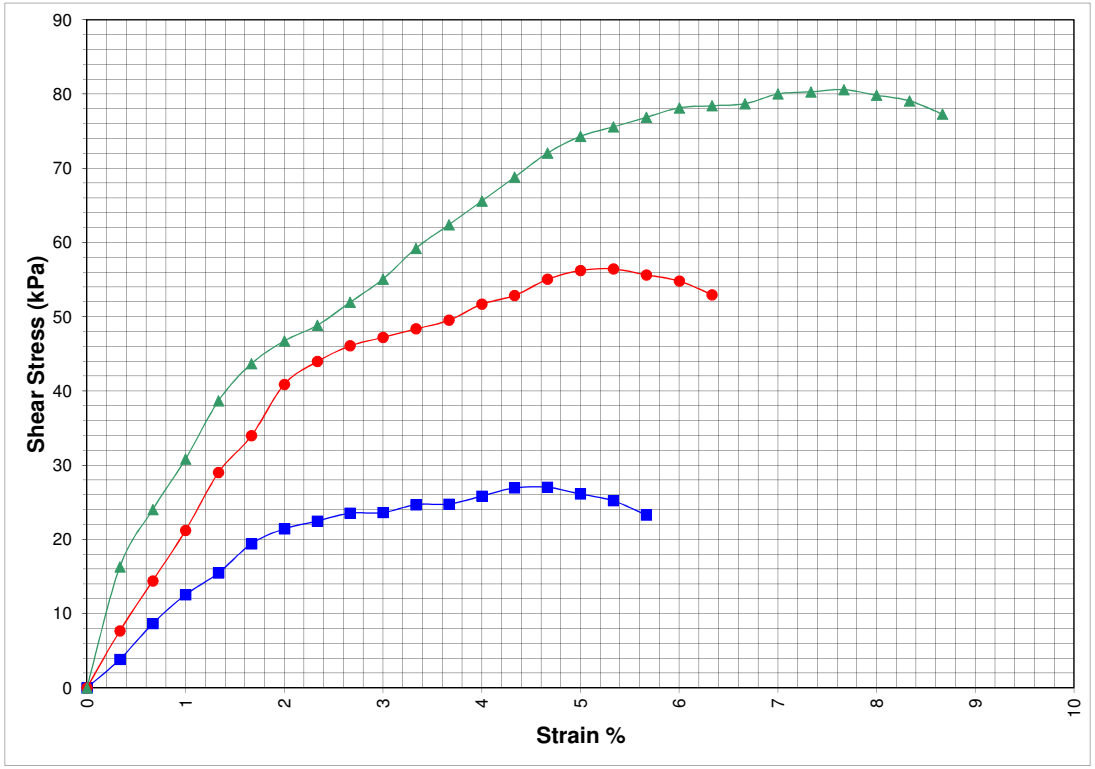
**Borehole: MBH-16**

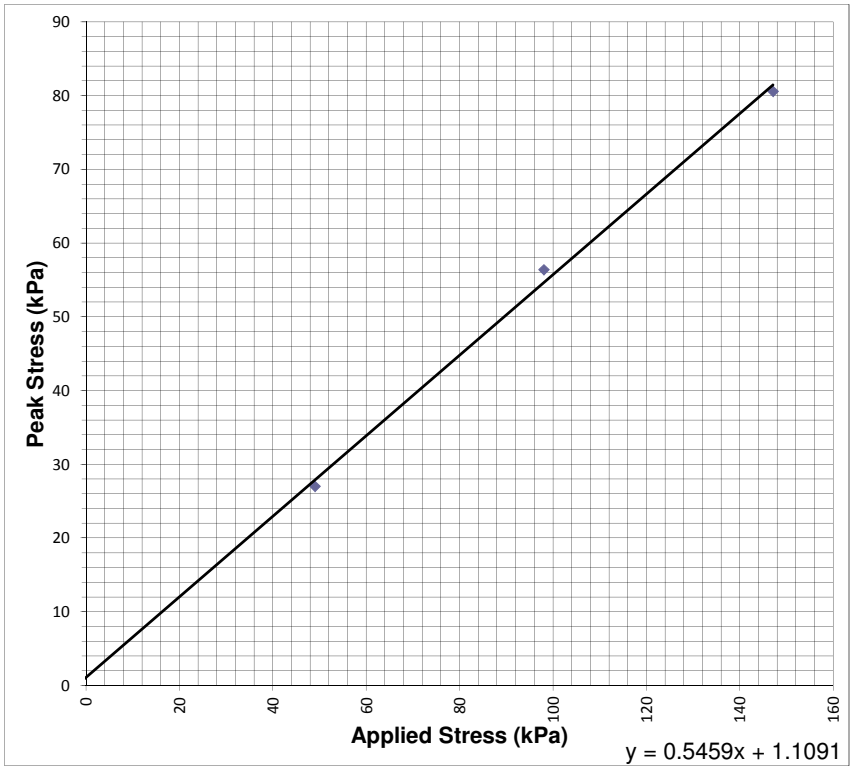
**Sample Type: SPT-4**

**Depth: 4.50-4.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 56 |
| | Stage 3 | 147 | 81 |

| | | |
|---|---|---|
| Angle of Friction | **28.6** | ° |
| Apparent Cohesion | **1.11** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: MBH-16**

**Sample Type: SPT-9**

**Depth: 12.20-12.45 m**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-1 | 0.00-0.27 | SM \SC | | | | 22.0 | 19.46 | 9.40 | 15.95 | | 0 | 81 | <--> | <--> | 19 | | | | | | | | | | | | | | | | | | | |
| SPT-2 | 1.60-1.95 | | | | | 20.5 | 19.47 | 9.41 | 15.96 | 2.60 | 0 | 55 | <--> | <--> | 45 | DST | | | 1.03 | 29.1 | | | | | | | | | | | | | | |
| SPT-3 | 3.00-3.40 | | | | | 28.6 | 17.67 | 7.61 | 14.48 | 2.57 | 0 | 35 | 49 | 16 | 65 | | | | | | | | | | | | | | | | | | | |
| SPT-4 | 4.50-4.95 | SC | 30.9 | 16.0 | 14.9 | 16.5 | 21.38 | 11.32 | 18.36 | 2.54 | 0 | 60 | 13 | 27 | 40 | | | | | | | | | 50.0 | | | | | 7.94 | 2.67 | 2.00 | 1900 | 3540 |
| SPT-5 | 6.00-6.30 | | | | | 18.2 | 21.37 | 11.31 | 18.08 | | 0 | 65 | <--> | <--> | 35 | | | | | | | | | | | | | | | | | | |
| SPT-5 | 6.30-6.45 | SM \SC | | | | 16.8 | 17.68 | 7.62 | 15.13 | | 24 | 54 | <--> | <--> | 22 | DST | | | 2.90 | 28.0 | | | | | | | | | | | | | |
| SPT-6 | 7.50-7.95 | | | | | 16.7 | 19.55 | 9.49 | 16.75 | | 0 | 84 | <--> | <--> | 16 | | | | | | | | | | | | | | | | | | |
| SPT-7 | 9.16-9.45 | | | | | 15.8 | 19.93 | 9.87 | 17.20 | 2.58 | 0 | 88 | <--> | <--> | 12 | DST | | | 0.82 | 29.8 | | | | | | | | | | | | | |
| SPT-8 | 10.50-10.95 | | | | | 21.8 | 19.85 | 9.79 | 16.30 | | 0 | 72 | <--> | <--> | 28 | | | | | | | | | | | | | | | | | | |
| SPT-9 | 12.00-12.45 | SP-SM \ SP-SC | | | | 16.3 | 19.10 | 9.04 | 16.43 | | 0 | 94 | <--> | <--> | 6 | | | | | | | | | | | | | | | | | | |
| SPT-10 | 13.50-13.95 | | | | | 24.2 | 19.38 | 9.32 | 15.60 | 2.55 | 0 | 47 | 47 | 6 | 53 | | | | | | | | | | | | | | | | | | |
| SPT-11 | 15.00-15.45 | SM \SC | | | | 16.3 | 19.88 | 9.82 | 17.10 | | 0 | 70 | <--> | <--> | 30 | | | | | | | | | | | | | | | | | | |
| SPT-12 | 16.60-16.83 | | | | | 15.2 | 19.43 | 9.37 | 16.86 | 2.58 | 0 | 58 | <--> | <--> | 42 | DST | | | 2.45 | 28.4 | | | | | | | | | | | | | |
| **END OF BOREHOLE** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

\# : Decayed Wood

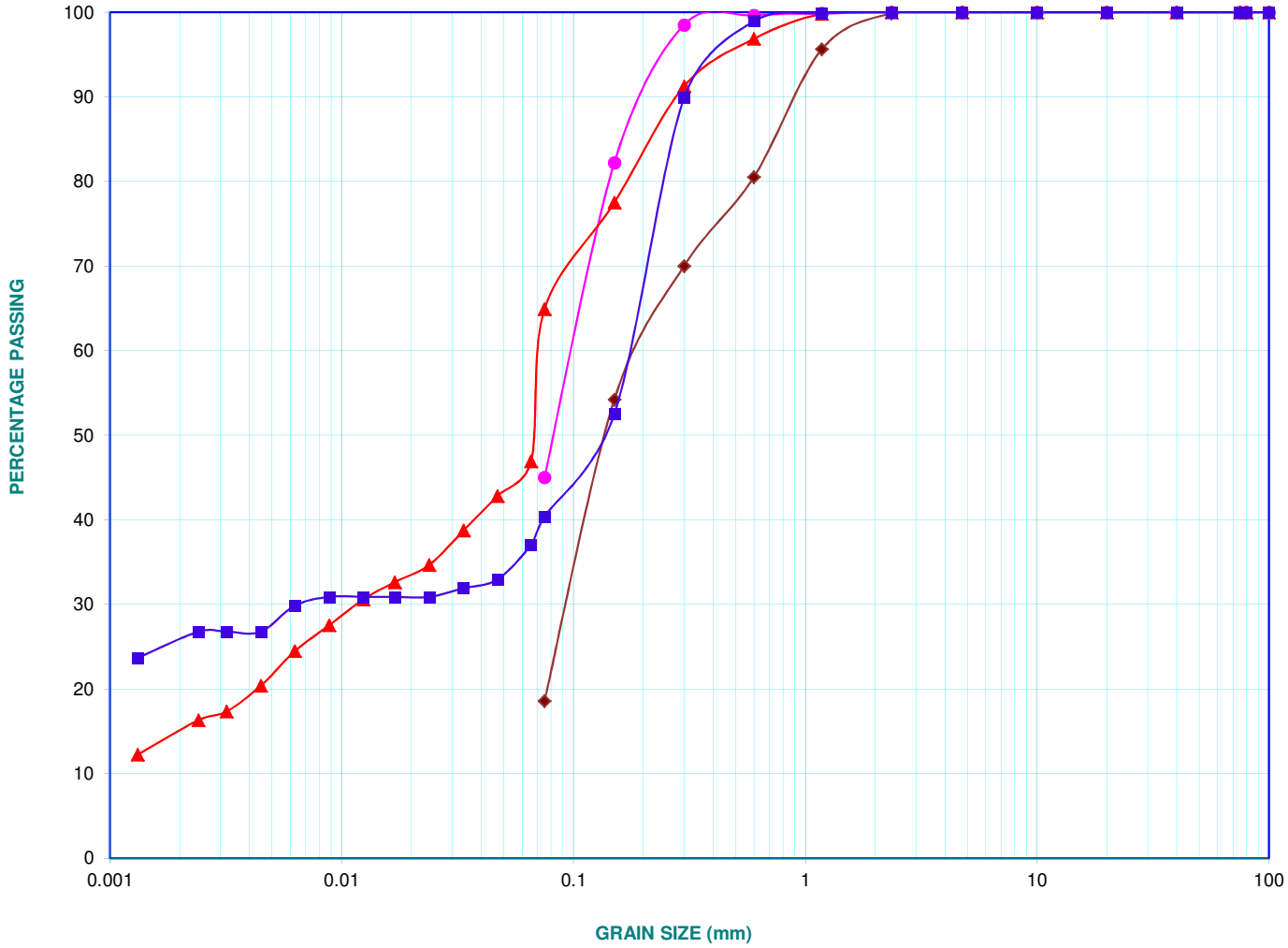
**Failure Type**

A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-17**

# GRAIN SIZE ANALYSIS

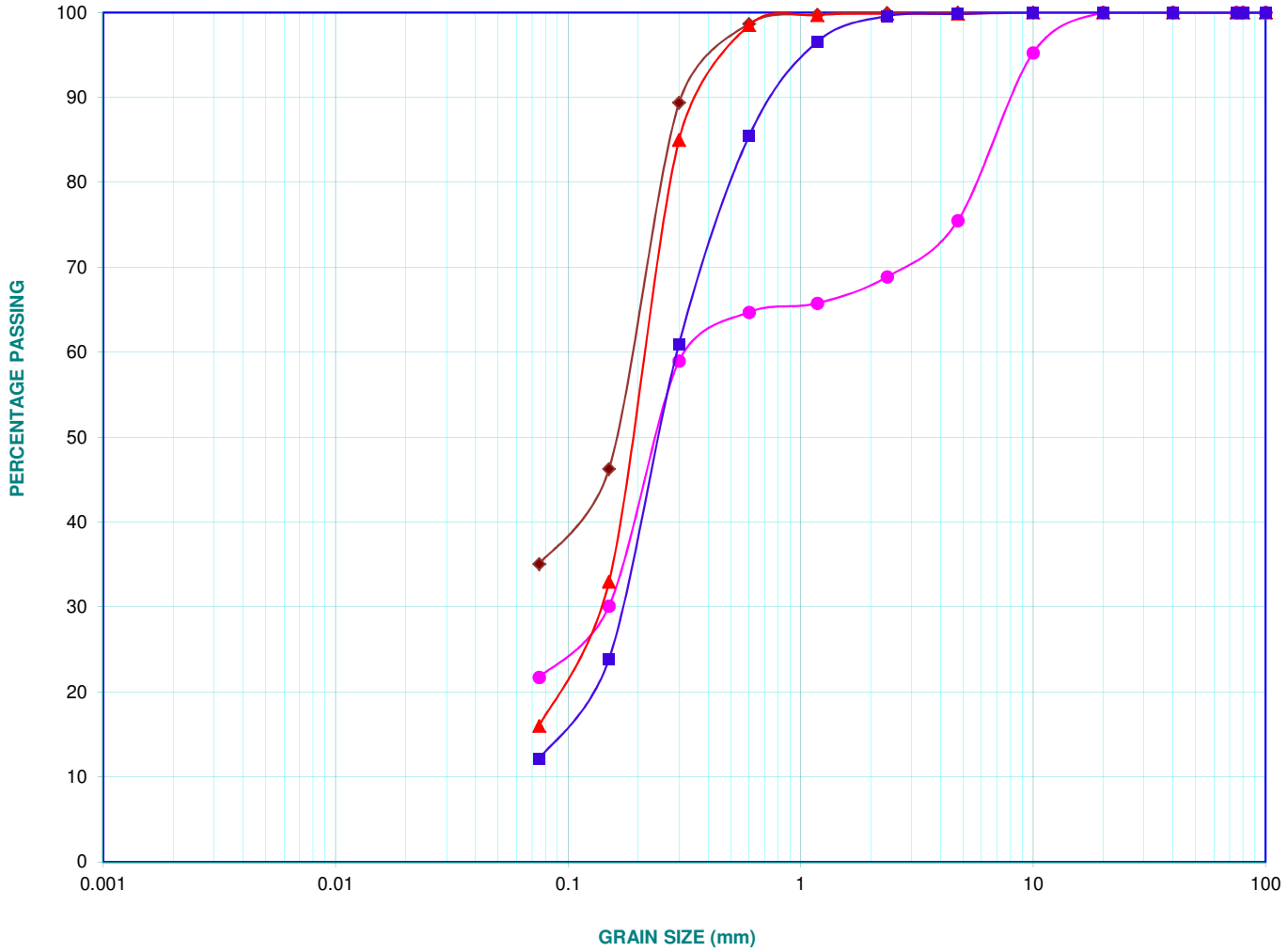
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | **Borehole No.** | **: MBH-17** | | | **Date :** | **9-Apr-19** | | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-17 | MBH-17 | MBH-17 | MBH-17 | | | | | | | | |
| **Depth (m)** | 0.00-0.27 | 1.60-1.95 | 3.00-3.40 | 4.50-4.95 | | | | | | | | |
| **Sample Type** | SPT-1 | SPT-2 | SPT-3 | SPT-4 | | | | | | | | |
| **Classification** | SM \ SC | SM \ SC | | SC | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 81 | 55 | 35 | 60 | | | | | | | | |
| **Silt %** | <----> | <----> | 49 | 13 | | | | | | | | |
| **Clay %** | <----> | <----> | 16 | 27 | | | | | | | | |
| **Fines % (Silt+Clay)** | 19 | 45 | 65 | 40 | | | | | | | | |
| **D60 mm** | | | | | | | | | | | | |
| **D30 mm** | | | | | | | | | | | | |
| **D10 mm** | | | | | | | | | | | | |
| **Cu** | | | | | | | | | | | | |
| **Cc** | | | | | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | 30.9 | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | 16.0 | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | 14.9 | | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

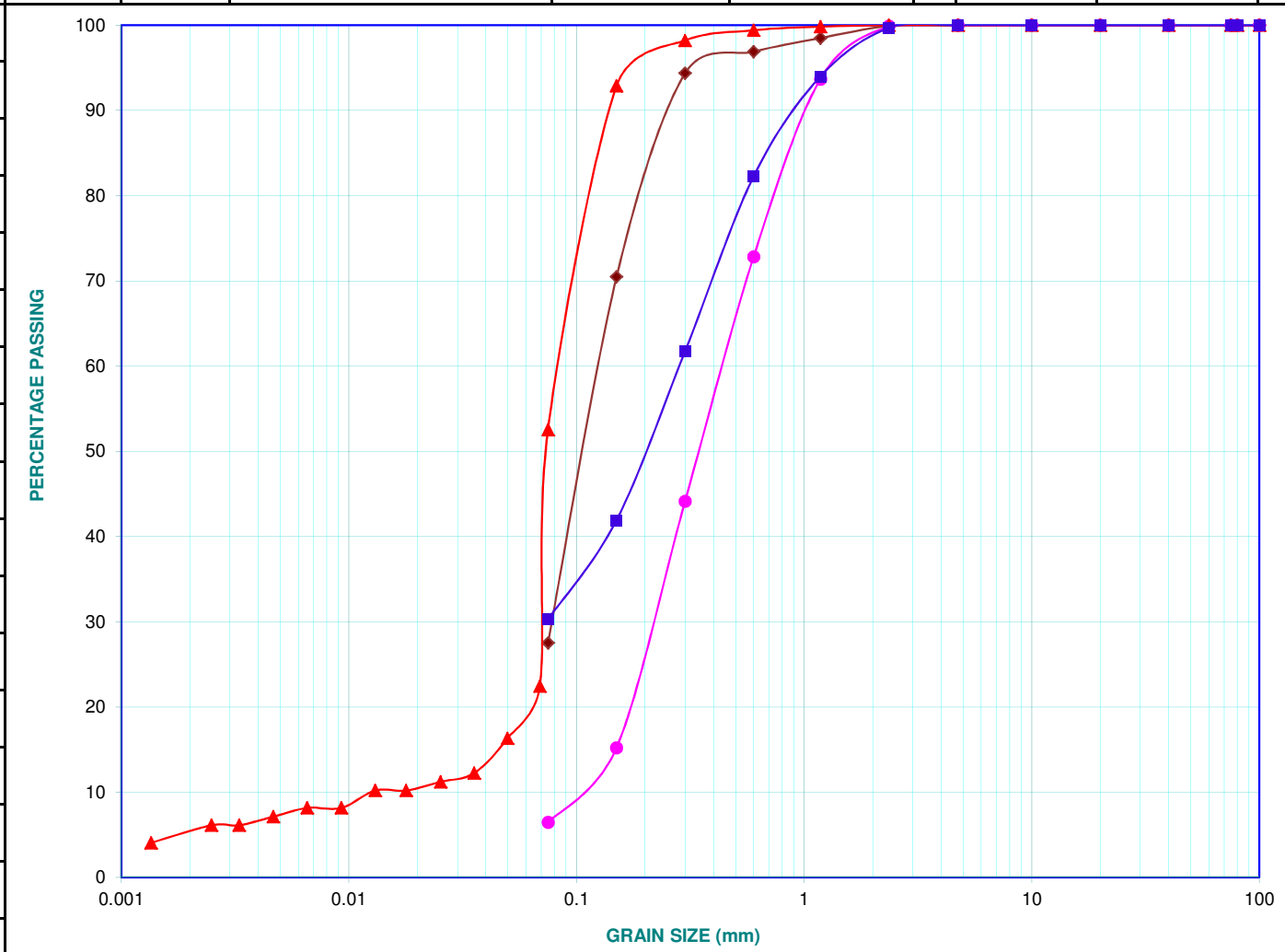
| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | : Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha | | | | | | | | | | |
| **Job No.** | : CM 19 01 03 | | | | **Borehole No.** | : MBH-17 | | | **Date :** | 9-Apr-19 | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND F | SAND M | SAND C | GRAVEL F / GRAVEL C |
| **Bore Hole .** | MBH-17 | MBH-17 | MBH-17 | MBH-17 | | | | | | | |
| **Depth (m)** | 6.00-6.30 | 6.30-6.45 | 7.50-7.95 | 9.16-9.45 | | | | | | | |
| **Sample Type** | SPT-5 | SPT-5 | SPT-6 | SPT-7 | | | | | | | |
| **Classification** | SC | SM \ SC | SM \ SC | SM \ SC | | | | | | | |
| **Gravel %** | 0 | 24 | 0 | 0 | | | | | | | |
| **Sand %** | 65 | 54 | 84 | 88 | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | |
| **Fines % (Silt+Clay)** | 35 | 22 | 16 | 12 | | | | | | | |
| **D60 mm** | | | | | | | | | | | |
| **D30 mm** | | | | | | | | | | | |
| **D10 mm** | | | | | | | | | | | |
| **Cu** | | | | | | | | | | | |
| **Cc** | | | | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | **Borehole No.** | **: MBH-17** | | | | | **Date :** | **9-Apr-19** | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-17 | MBH-17 | MBH-17 | MBH-17 | | | | | | | | |
| **Depth (m)** | 10.50-10.95 | 12.00-12.45 | 13.50-13.95 | 15.00-15.45 | | | | | | | | |
| **Sample Type** | SPT-8 | SPT-9 | SPT-10 | SPT-11 | | | | | | | | |
| **Classification** | SM \ SC | SP-SM \ SP-SC | | SM \ SC | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 72 | 94 | 47 | 70 | | | | | | | | |
| **Silt %** | <----> | <----> | 47 | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | 6 | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 28 | 6 | 53 | 30 | | | | | | | | |
| **D60 mm** | | 0.430 | | | | | | | | | | |
| **D30 mm** | | 0.220 | | | | | | | | | | |
| **D10 mm** | | 0.120 | | | | | | | | | | |
| **Cu** | | 3.58 | | | | | | | | | | |
| **Cc** | | 0.94 | | | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |

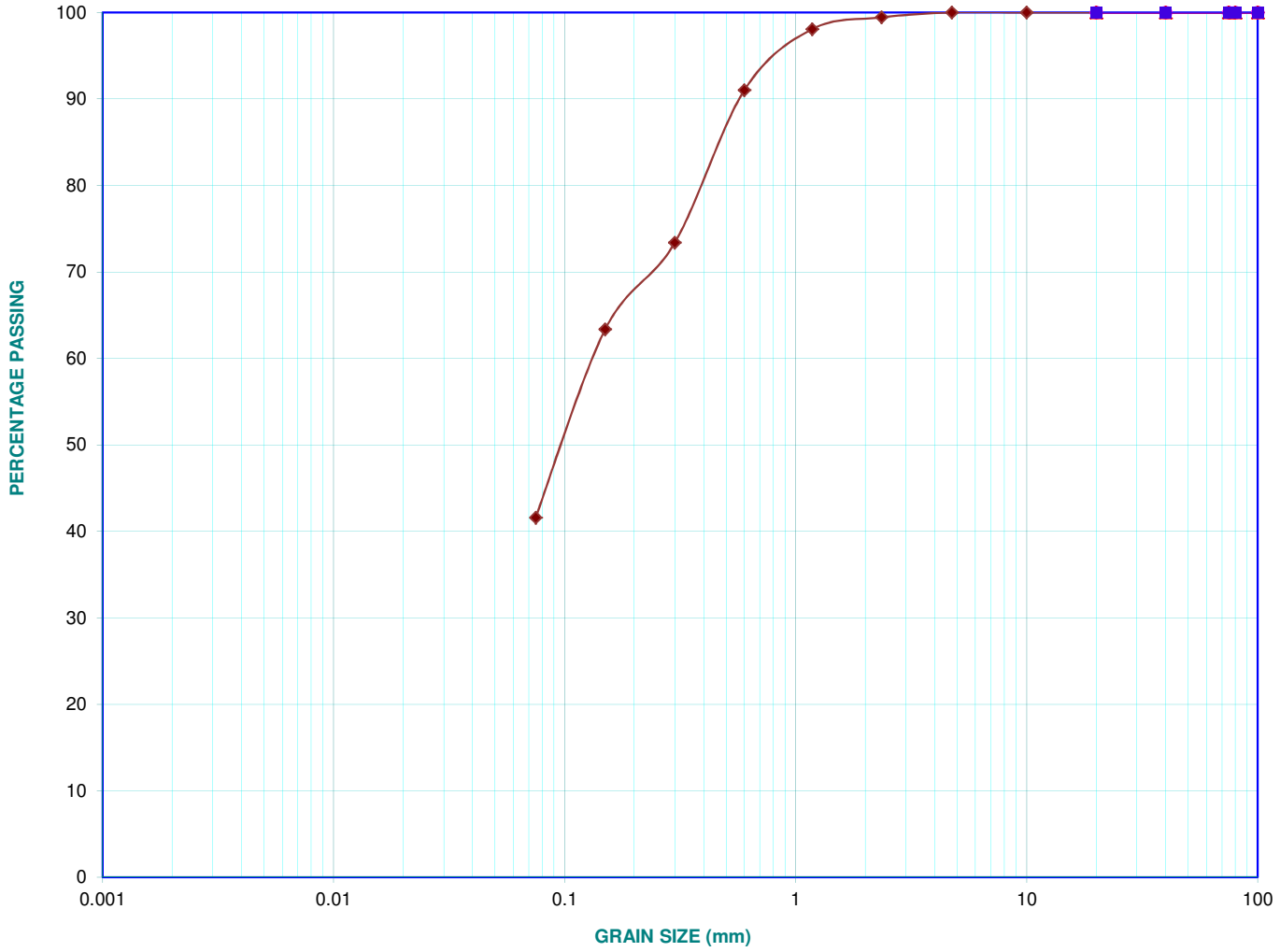



Checked By :

# GRAIN SIZE ANALYSIS

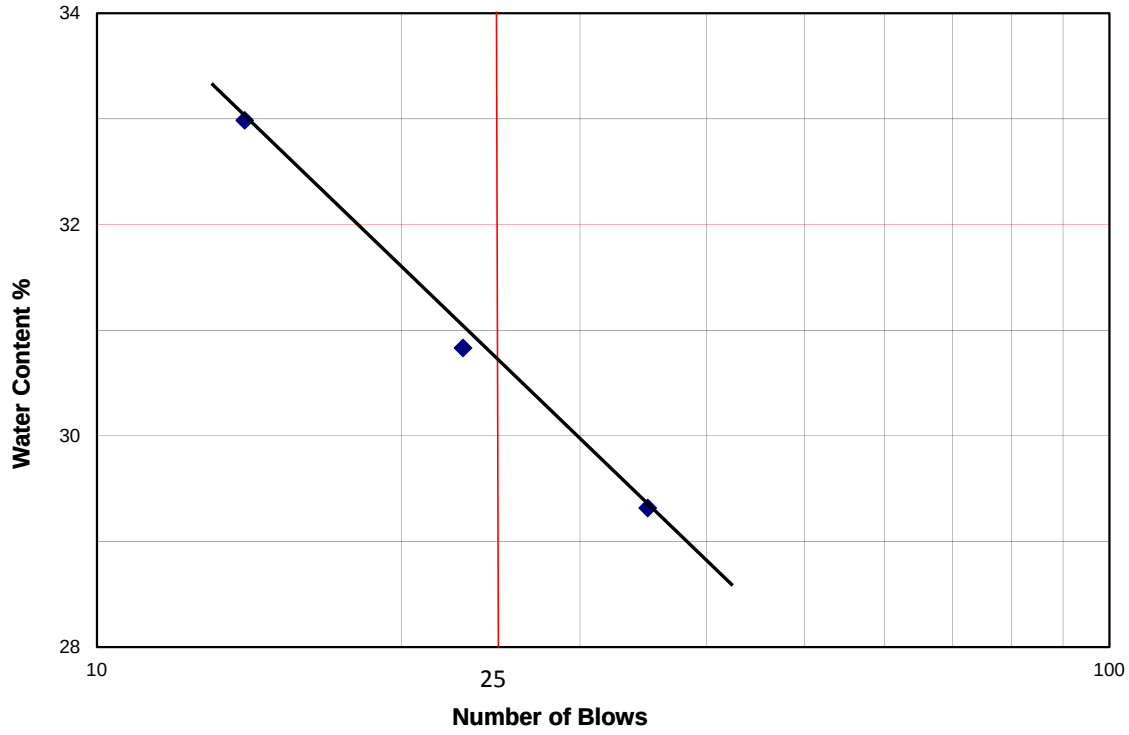
| | |
|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-17** |
| **Date :** | **9-Apr-19** |

| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| Bore Hole . | MBH-17 | | | | | | | | | | | |
| Depth (m) | 16.60-16.83 | | | | | | | | | | | |
| Sample Type | SPT-12 | | | | | | | | | | | |
| Classification | SM \ SC | | | | | | | | | | | |
| Gravel % | 0 | | | | | | | | | | | |
| Sand % | 58 | | | | | | | | | | | |
| Silt % | <----> | | | | | | | | | | | |
| Clay % | <----> | | | | | | | | | | | |
| Fines % (Silt+Clay) | 42 | | | | | | | | | | | |
| D60 mm | | | | | | | | | | | | |
| D30 mm | | | | | | | | | | | | |
| D10 mm | | | | | | | | | | | | |
| Cu | | | | | | | | | | | | |
| Cc | | | | | | | | | | | | |
| Liquid Limit % | --- | | | | | | | | | | | |
| Plastic Limit % | --- | | | | | | | | | | | |
| Plasticity Index | --- | | | | | | | | | | | |




Checked By :

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 26.35 | 30.92 | 34.68 | | |
| Dry Weight + Can (g) | 22.41 | 26.61 | 28.36 | | |
| Can Weight (g) | 8.97 | 12.63 | 9.20 | | |
| Water Content, % | 29.3 | 30.8 | 33.0 | | |
| Number of Blows | 35 | 23 | 14 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 16.45 | 17.87 | 17.77 |
| Dry Weight + Can (g) | 15.49 | 17.15 | 16.48 |
| Can Weight (g) | 9.54 | 12.56 | 8.54 |
| Water Content, % | 16.1 | 15.7 | 16.2 |

Liquid Limit % 30.9

Plastic Limit % 16.0

Plasticity Index % 14.9

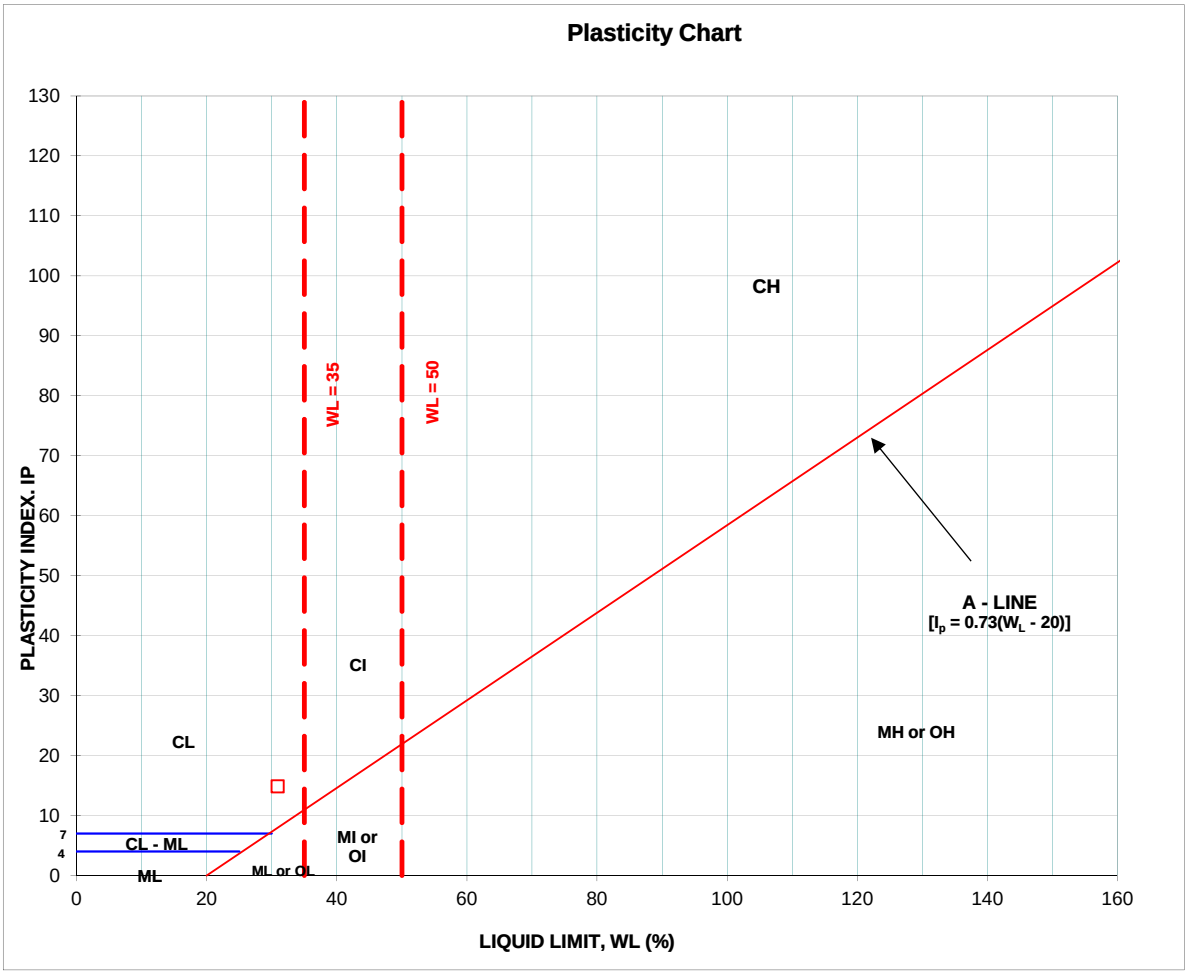
Preparation of Sample :
Dry State

Sample Type: SPT-04

Borehole no.: MBH-17

Depth :4.50-4.95

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.




| | Sample Type | Depth (m) | $W_L$ | $W_P$ | $I_P$ | Remarks |
|---|---|---|---|---|---|---|
| □ | SPT-04 | 4.50-4.95 | 30.9 | 16.0 | 14.9 | CL: Inorganic clays of low to medium plasticity. |
| ◇ | | | | | | |
| △ | | | | | | |
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| ○ | | | | | | |
| | | | | | | |

| | | | |
|---|---|---|---|
| ML | Inorganic silts, very fine sands, rock flour, silty or clayey fine sands | MH | Inorganic silts, or diatomaceous fine sands or silts, elastic silts |
| CL | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays | CH | Inorganic clays of high plasticity, fat clays |
| OL | Organic silts and organic silty clays of low plasticity | OH | Organic silts and organic clays of medium t high plasticity |
| CI | Clays with Intermediate plasticity | MI | Silt with intermediate plasticity |

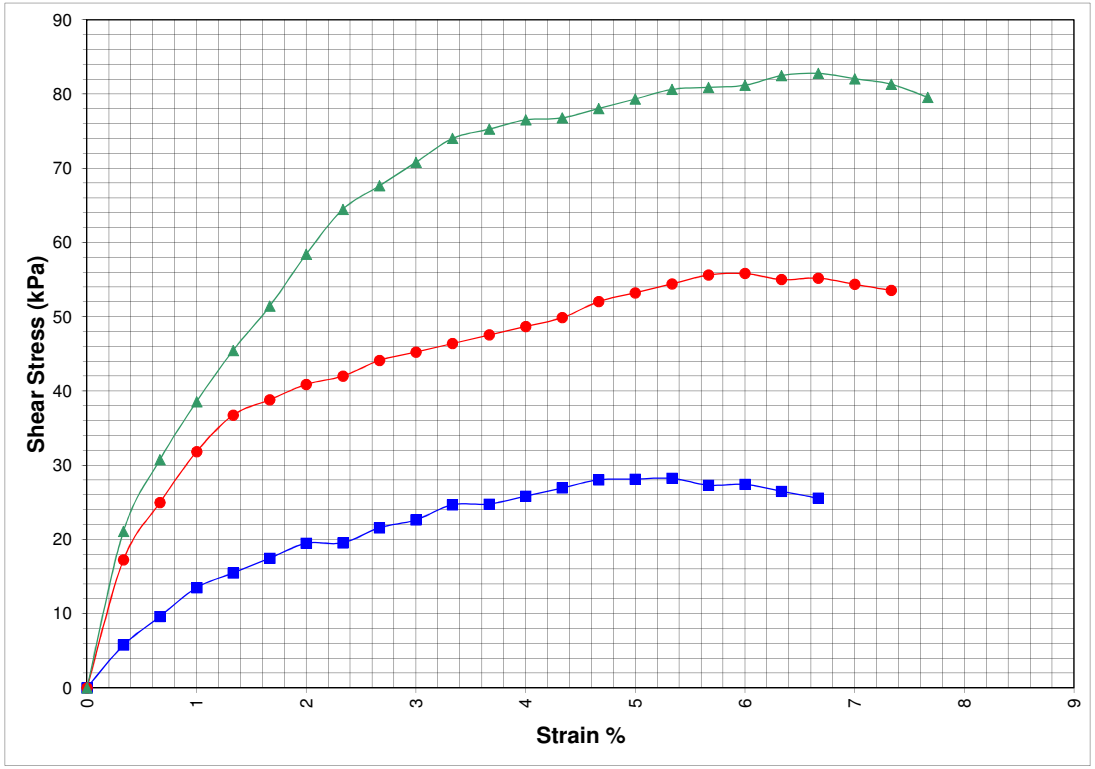
## PLASTICITY CHART (IS : 1498 - 1987)

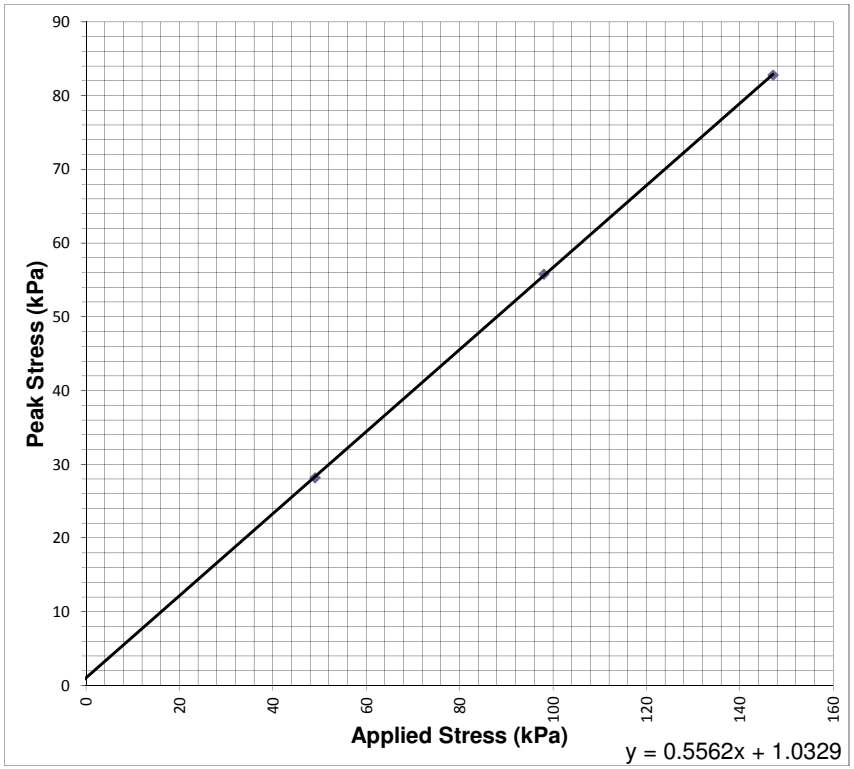
BOREHOLE NAME : MBH-17

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 56 |
| | Stage 3 | 147 | 83 |

| | | |
|---|---|---|
| Angle of Friction | **29.1** | ° |
| Apparent Cohesion | **1.03** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

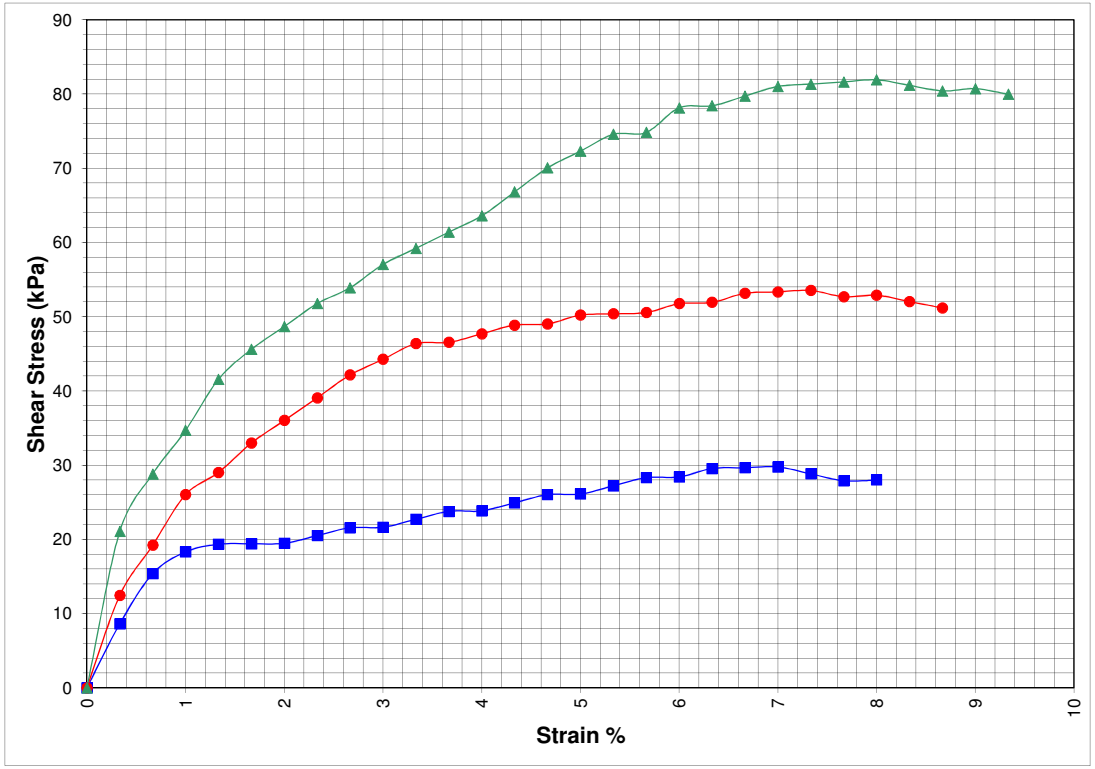
**Borehole: MBH-17**

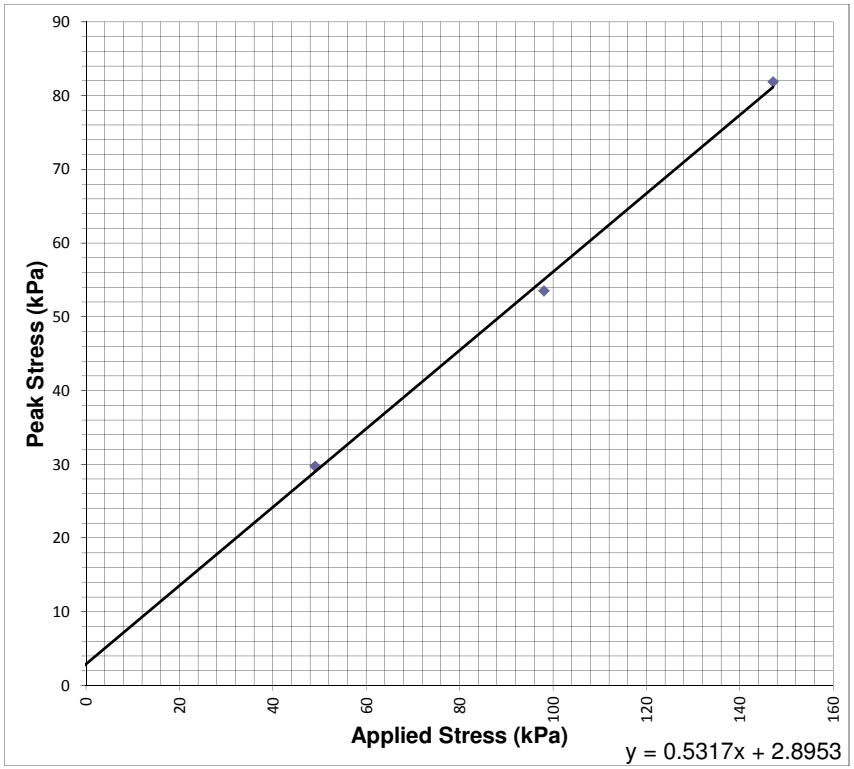
**Sample Type: SPT-02**

**Depth: 1.60-1.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 30 |
| | Stage 2 | 98 | 54 |
| | Stage 3 | 147 | 82 |

| | | |
|---|---|---|
| Angle of Friction | **28.0** | ° |
| Apparent Cohesion | **2.90** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

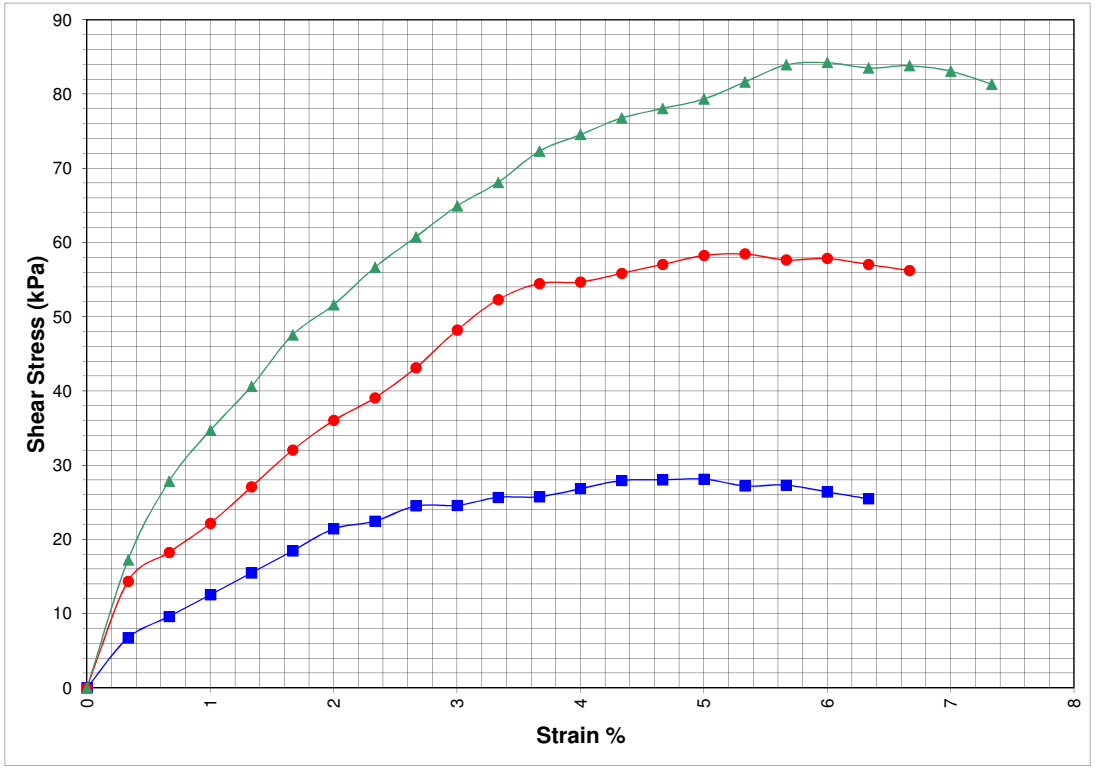
**Borehole: MBH-17**

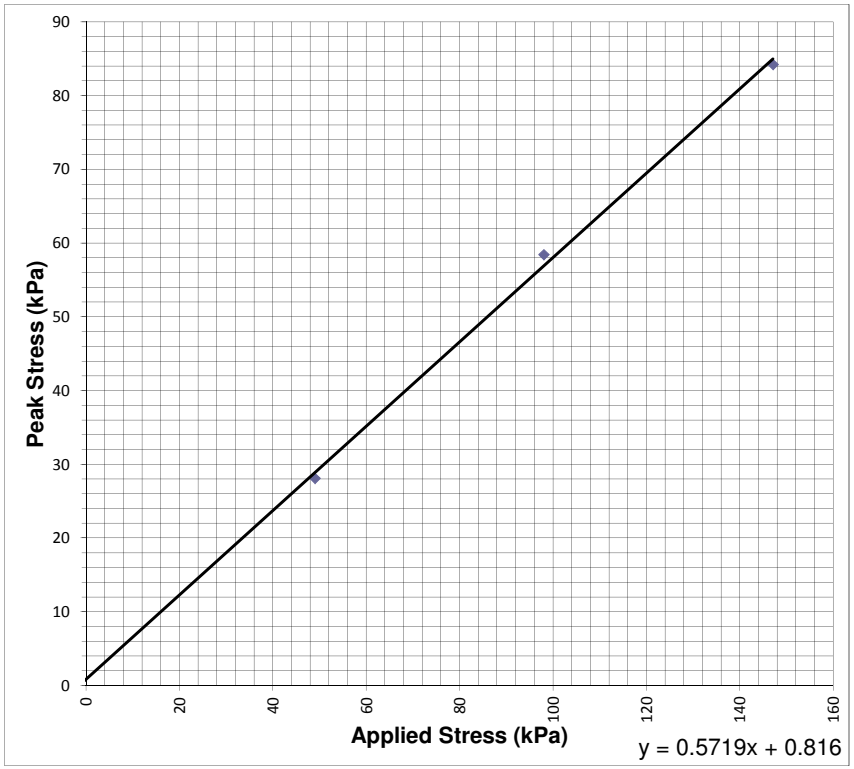
**Sample Type: SPT-5**

**Depth: 6.30-6.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 58 |
| | Stage 3 | 147 | 84 |

| | | |
|---|---|---|
| Angle of Friction | **29.8** | ° |
| Apparent Cohesion | **0.82** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

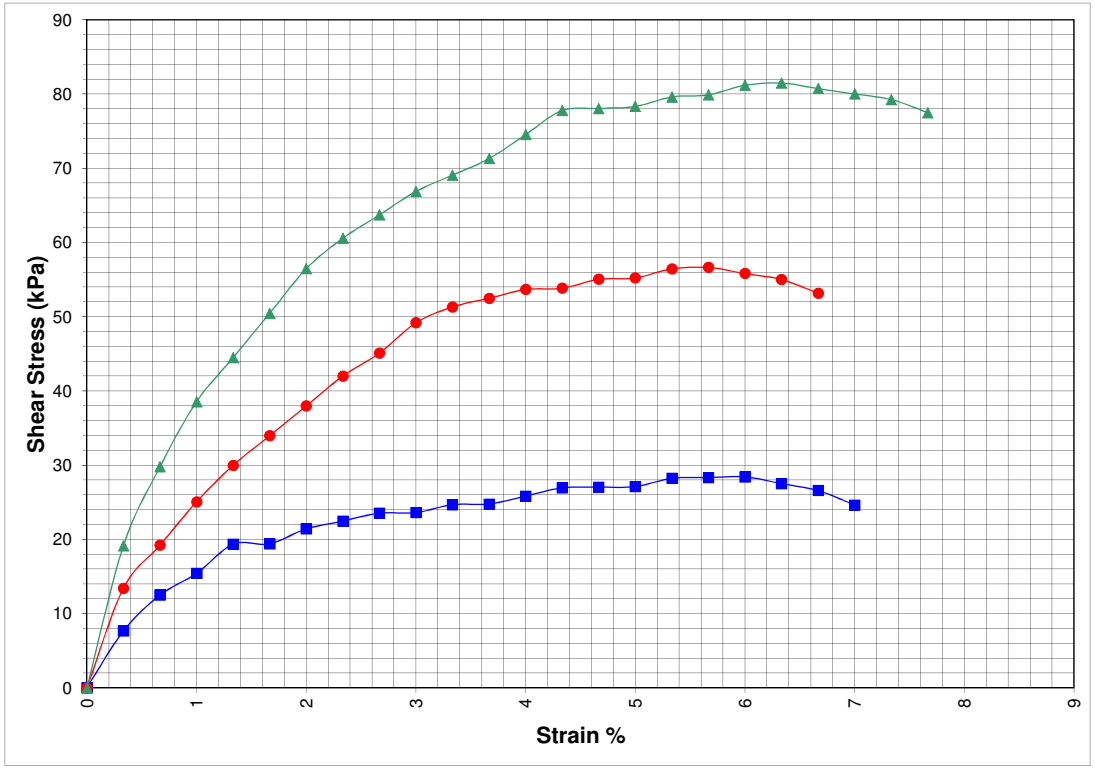
**Borehole: MBH-17**

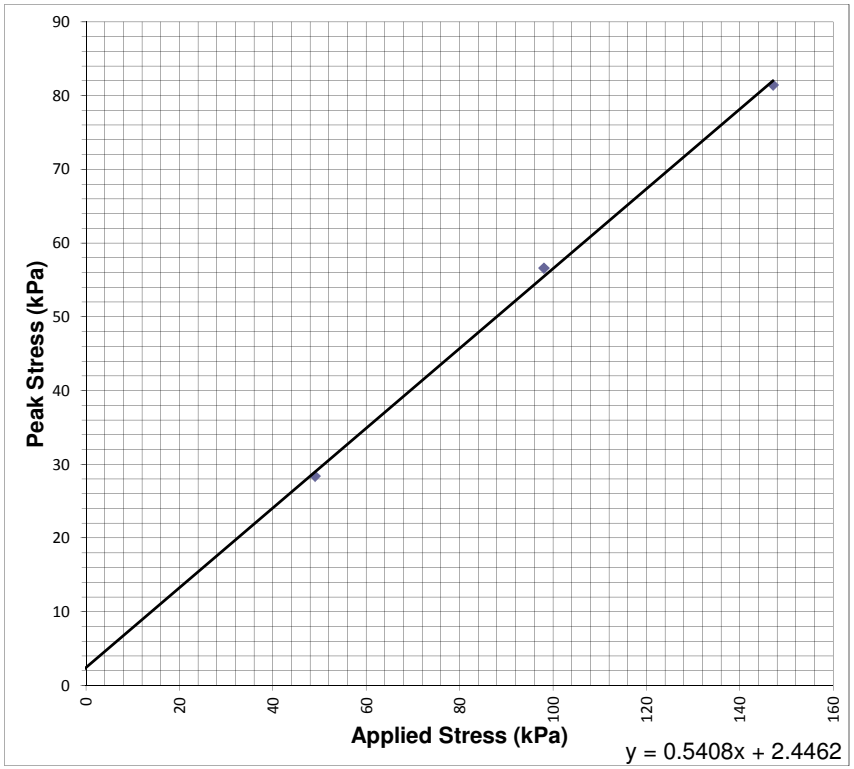
**Sample Type: SPT-7**

**Depth: 9.16-9.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 57 |
| | Stage 3 | 147 | 81 |

| | | |
|---|---|---|
| Angle of Friction | **28.4** | ° |
| Apparent Cohesion | **2.45** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: MBH-17**

**Sample Type: SPT-12**

**Depth: 16.60-16.83 m**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | | Chemical tests | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| UDS-1 | 0.80-1.00 | CL | 34.8 | 15.1 | 19.7 | 58.4 | 17.16 | 7.10 | 10.84 | 2.53 | 0 | 25 | 44 | 31 | 75 | | | | | | | | | 63.6 | | | | | 8.27 | 4.69 | 2.00 | 3500 | 8850 |
| SPT-1 | 1.00-1.45 | | 32.7 | 17.2 | 15.5 | 37.1 | 17.15 | 7.09 | 10.83 | 2.52 | 0 | 32 | 43 | 25 | 68 | | | | | | | | | 30.0 | | | | | | | | | |
| UDS-2 | 2.66-2.85 | SM \ SC | | | | 18.9 | 18.50 | 8.44 | 11.68 | 2.53 | 0 | 56 | 28 | 16 | 44 | | | | | | | | | | | | | | | | | | |
| SPT-2 | 3.00-3.45 | | | | | 17.6 | 19.10 | 9.04 | 16.24 | 2.55 | 0 | 62 | 16 | 22 | 38 | | | | | | | | | | | | | | | | | | |
| SPT-3 | 4.50-4.95 | | | | | 15.5 | 20.05 | 9.99 | 17.35 | 2.57 | 0 | 67 | 11 | 22 | 33 | | | | | | | | | | | | | | | | | | |
| SPT-4 | 6.15-6.45 | | | | | 16.7 | 21.04 | 10.98 | 18.03 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-5 | 7.65-7.95 | | | | | 17.9 | 20.62 | 10.56 | 17.48 | | | | | | | DST | | | 5.36 | 27.9 | | | | | | | | | | | | |
| SPT-6 | 9.00-9.45 | SM \ SC | | | | 16.6 | 20.28 | 10.22 | 17.40 | 2.59 | 0 | 84 | <--> | <--> | 16 | | | | | | | | | | | | | | | | | | |
| SPT-7 | 10.60-10.90 | | | | | 16.5 | 20.63 | 10.57 | 17.71 | 2.57 | 0 | 83 | <--> | <--> | 17 | | | | | | | | | | | | | | | | | | |
| SPT-8 | 12.00-12.45 | | | | | 21.6 | 18.31 | 8.25 | 15.06 | | 0 | 62 | <--> | <--> | 38 | | | | | | | | | | | | | | | | | | |
| SPT-9 | 13.65-13.95 | SC | | | | 24.9 | 20.86 | 10.80 | 16.70 | | 0 | 56 | <--> | <--> | 44 | DST | | | 2.08 | 30.4 | | | | | | | | | | | | |
| SPT-10 | 15.00-15.45 | | 30.0 | 16.5 | 13.5 | 22.5 | 19.23 | 9.17 | 15.69 | 2.56 | 0 | 54 | 26 | 20 | 46 | | | | | | | | | 27.8 | | | | | | | | | |
| SPT-11 | 16.50-16.95 | SM \ SC | | | | 14.3 | 19.80 | 9.74 | 17.32 | | 0 | 75 | <--> | <--> | 25 | DST | | | 1.57 | 31.0 | | | | | | | | | | | | | |
| END OF BOREHOLE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

\# : Decayed Wood

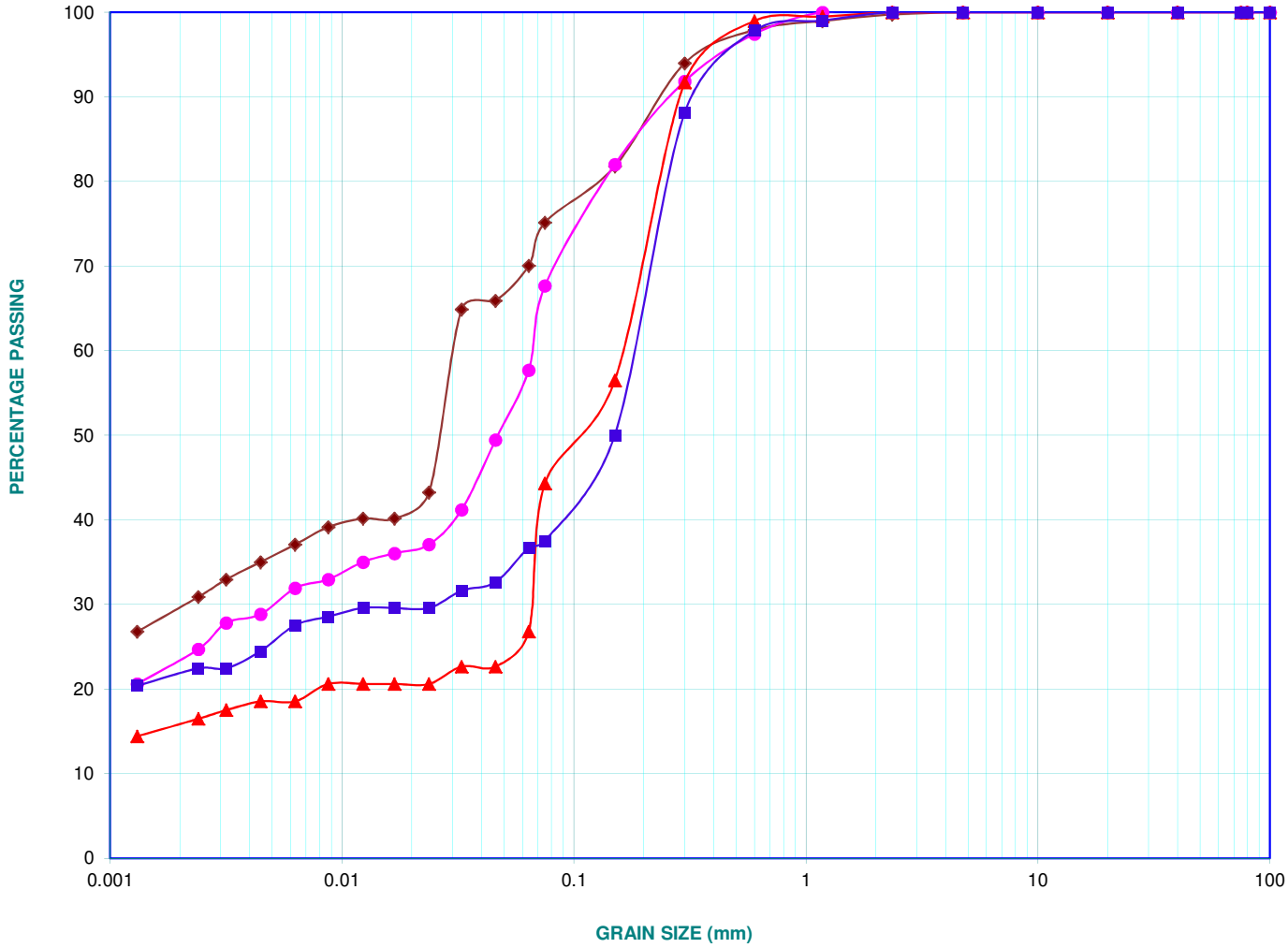
**Failure Type**
A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-18**

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-18** |
| **Date :** | **9-Apr-19** |

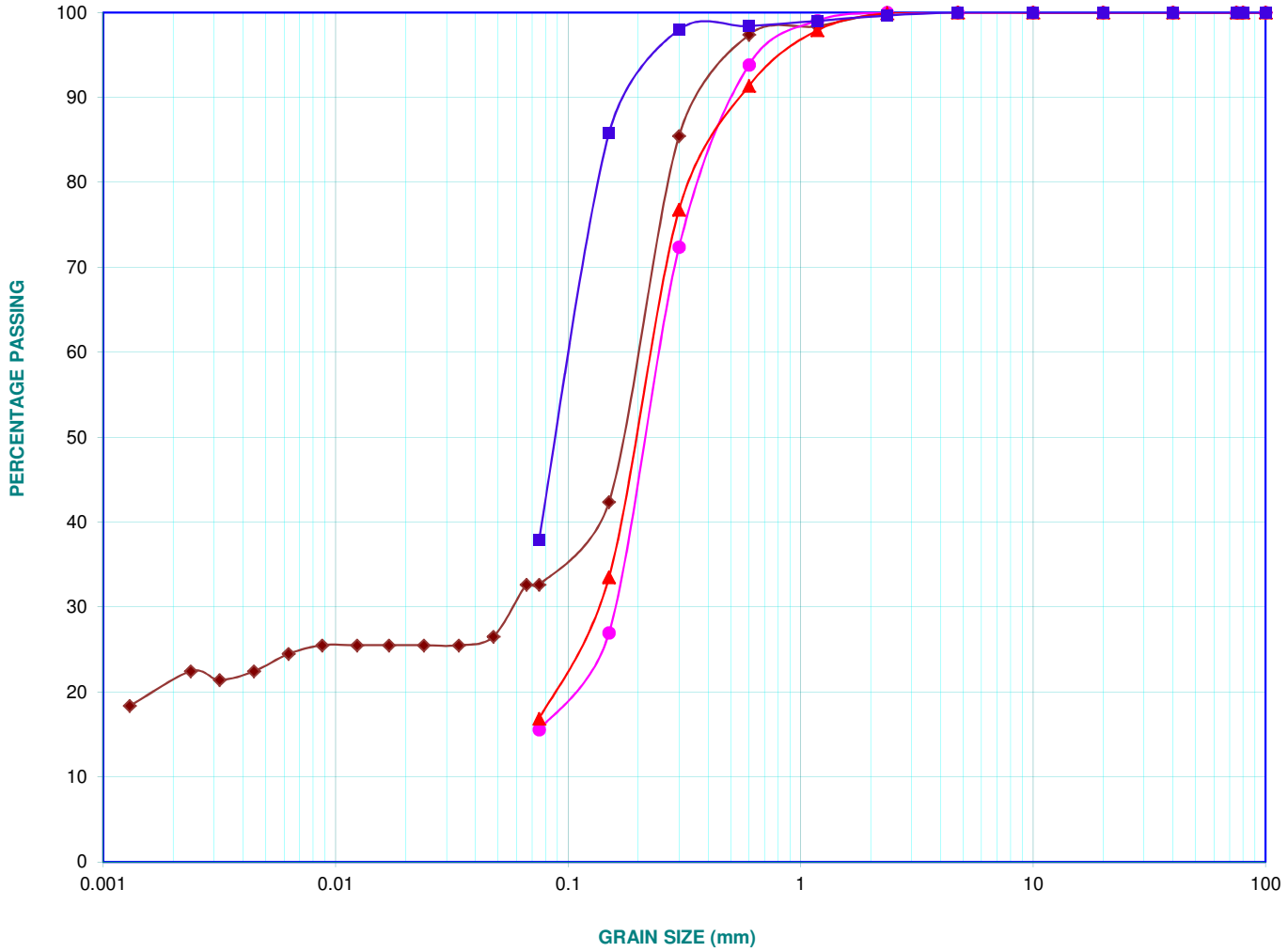
| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| Bore Hole . | MBH-18 | MBH-18 | MBH-18 | MBH-18 | | | | | | | | |
| Depth (m) | 0.80-1.00 | 1.00-1.45 | 2.66-2.85 | 3.00-3.45 | | | | | | | | |
| Sample Type | UDS-1 | SPT-1 | UDS-2 | SPT-2 | | | | | | | | |
| Classification | CL | CL | SM \ SC | SM \ SC | | | | | | | | |
| Gravel % | 0 | 0 | 0 | 0 | | | | | | | | |
| Sand % | 25 | 32 | 56 | 62 | | | | | | | | |
| Silt % | 44 | 43 | 28 | 16 | | | | | | | | |
| Clay % | 31 | 25 | 16 | 22 | | | | | | | | |
| Fines % (Silt+Clay) | 75 | 68 | 44 | 38 | | | | | | | | |
| D60 mm | | | | | | | | | | | | |
| D30 mm | | | | | | | | | | | | |
| D10 mm | | | | | | | | | | | | |
| Cu | | | | | | | | | | | | |
| Cc | | | | | | | | | | | | |
| Liquid Limit % | 34.8 | 32.7 | --- | --- | | | | | | | | |
| Plastic Limit % | 15.1 | 17.2 | --- | --- | | | | | | | | |
| Plasticity Index | 19.7 | 15.5 | --- | --- | | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | **Borehole No.** | **: MBH-18** | | | | **Date :** | **9-Apr-19** | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-18 | MBH-18 | MBH-18 | MBH-18 | | | | | | | | |
| **Depth (m)** | 4.50-4.95 | 9.00-9.45 | 10.60-10.90 | 12.00-12.45 | | | | | | | | |
| **Sample Type** | SPT-3 | SPT-6 | SPT-7 | SPT-8 | | | | | | | | |
| **Classification** | SM \ SC | SM \ SC | SM \ SC | SM \ SC | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 67 | 84 | 83 | 62 | | | | | | | | |
| **Silt %** | 11 | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | 22 | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 33 | 16 | 17 | 38 | | | | | | | | |
| **D60 mm** | | | | | | | | | | | | |
| **D30 mm** | | | | | | | | | | | | |
| **D10 mm** | | | | | | | | | | | | |
| **Cu** | | | | | | | | | | | | |
| **Cc** | | | | | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |

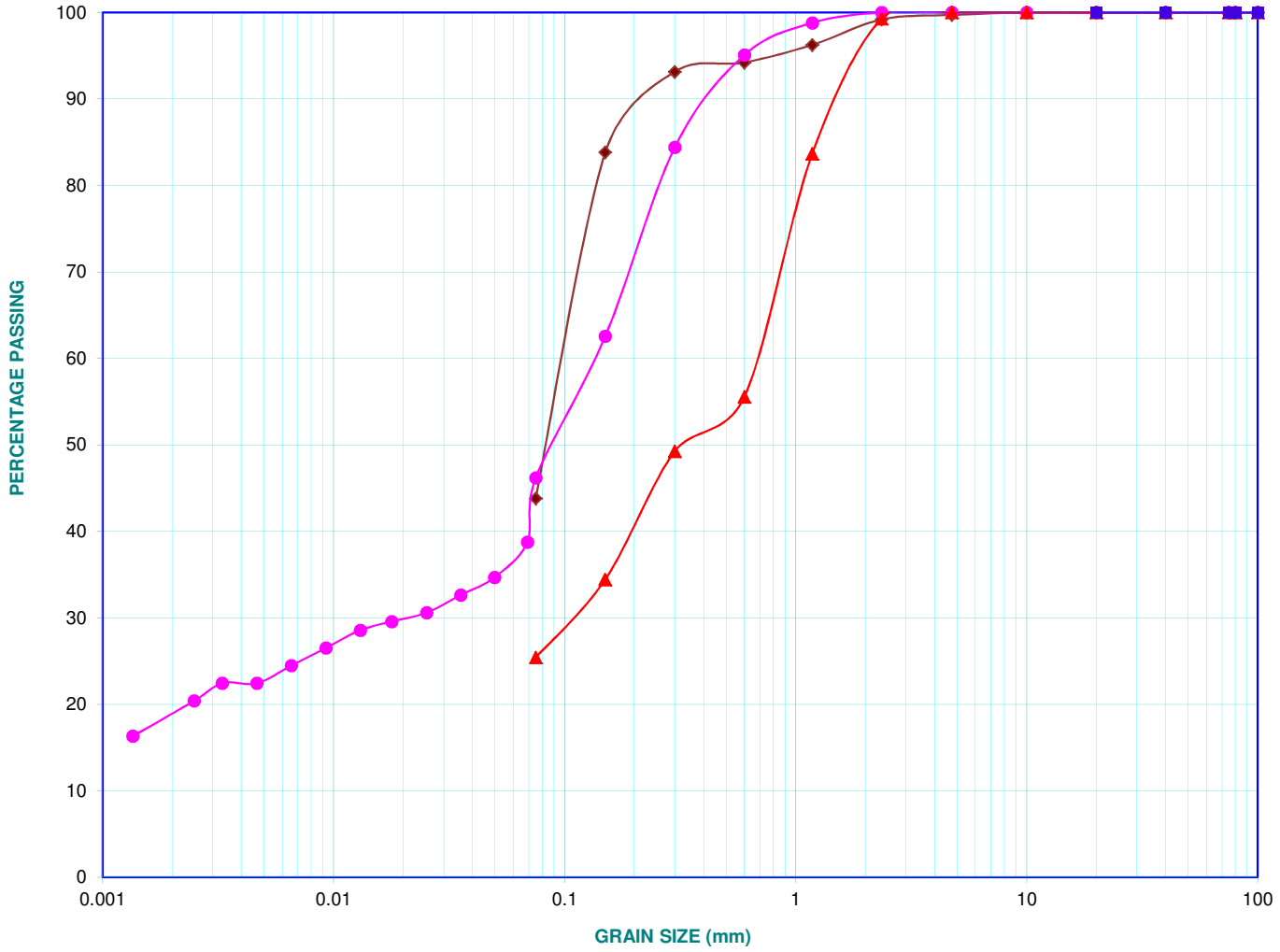



Checked By :

# GRAIN SIZE ANALYSIS

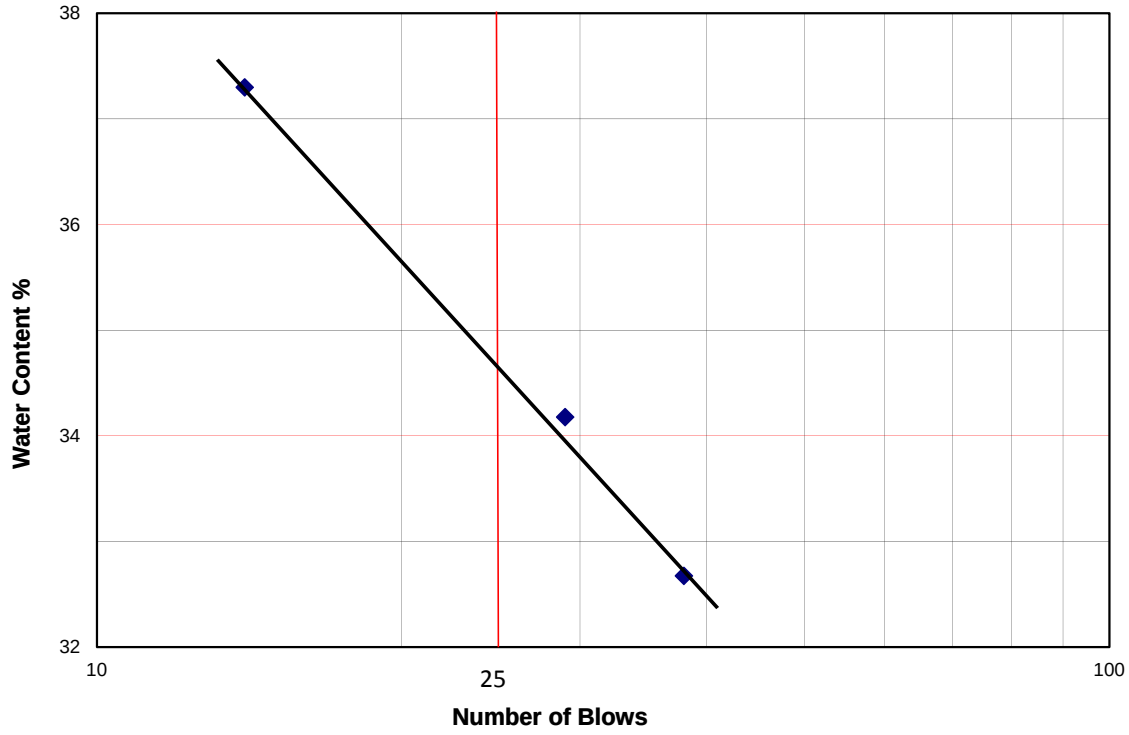
| | |
|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-18** |
| **Date :** | **9-Apr-19** |

| Symbol | | | | |
|---|---|---|---|---|
| Bore Hole . | MBH-18 | MBH-18 | MBH-18 | |
| Depth (m) | 13.65-13.95 | 15.00-15.45 | 16.50-16.95 | |
| Sample Type | SPT-9 | SPT-10 | SPT-11 | |
| Classification | SC | SC | SM \ SC | |
| Gravel % | 0 | 0 | 0 | |
| Sand % | 56 | 54 | 75 | |
| Silt % | <----> | 26 | <----> | |
| Clay % | <----> | 20 | <----> | |
| Fines % (Silt+Clay) | 44 | 46 | 25 | |
| D60 mm | | | | |
| D30 mm | | | | |
| D10 mm | | | | |
| Cu | | | | |
| Cc | | | | |
| Liquid Limit % | --- | 30.0 | --- | |
| Plastic Limit % | --- | 16.5 | --- | |
| Plasticity Index | --- | 13.5 | --- | |




Checked By :

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 30.59 | 31.71 | 25.61 | | |
| Dry Weight + Can (g) | 26.45 | 26.98 | 21.00 | | |
| Can Weight (g) | 13.78 | 13.14 | 8.64 | | |
| Water Content, % | 32.7 | 34.2 | 37.3 | | |
| Number of Blows | 38 | 29 | 14 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 17.22 | 18.67 | 20.25 |
| Dry Weight + Can (g) | 16.77 | 18.01 | 18.79 |
| Can Weight (g) | 13.80 | 13.63 | 9.20 |
| Water Content, % | 15.2 | 15.1 | 15.2 |

Liquid Limit % 34.8

Plastic Limit % 15.1

Plasticity Index % 19.7

Preparation of Sample :
Dry State

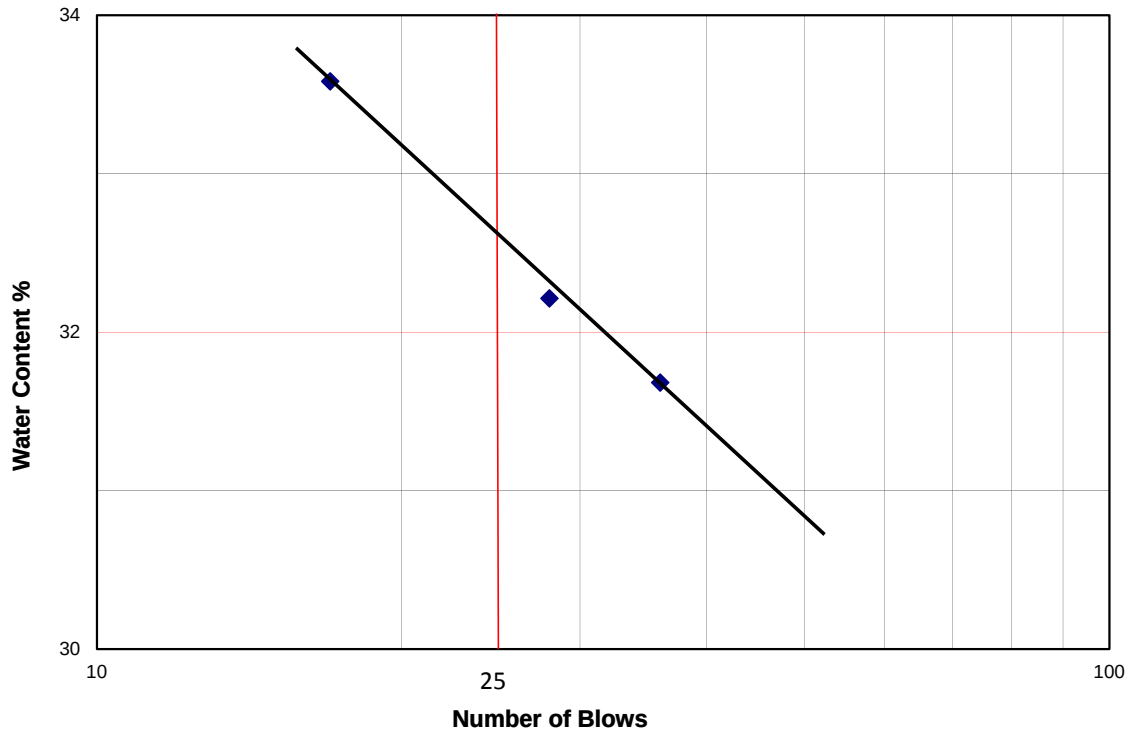
Sample Type: UDS-01

Borehole no.: MBH-18

Depth :0.80-1.00

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 32.58 | 30.89 | 28.97 | | |
| Dry Weight + Can (g) | 26.89 | 26.48 | 24.00 | | |
| Can Weight (g) | 8.93 | 12.79 | 9.20 | | |
| Water Content, % | 31.7 | 32.2 | 33.6 | | |
| Number of Blows | 36 | 28 | 17 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 20.58 | 19.57 | 20.29 |
| Dry Weight + Can (g) | 19.49 | 18.56 | 19.21 |
| Can Weight (g) | 13.09 | 12.72 | 12.93 |
| Water Content, % | 17.0 | 17.3 | 17.2 |

Liquid Limit % 32.7

Plastic Limit % 17.2

Plasticity Index % 15.5

Preparation of Sample :
Dry State

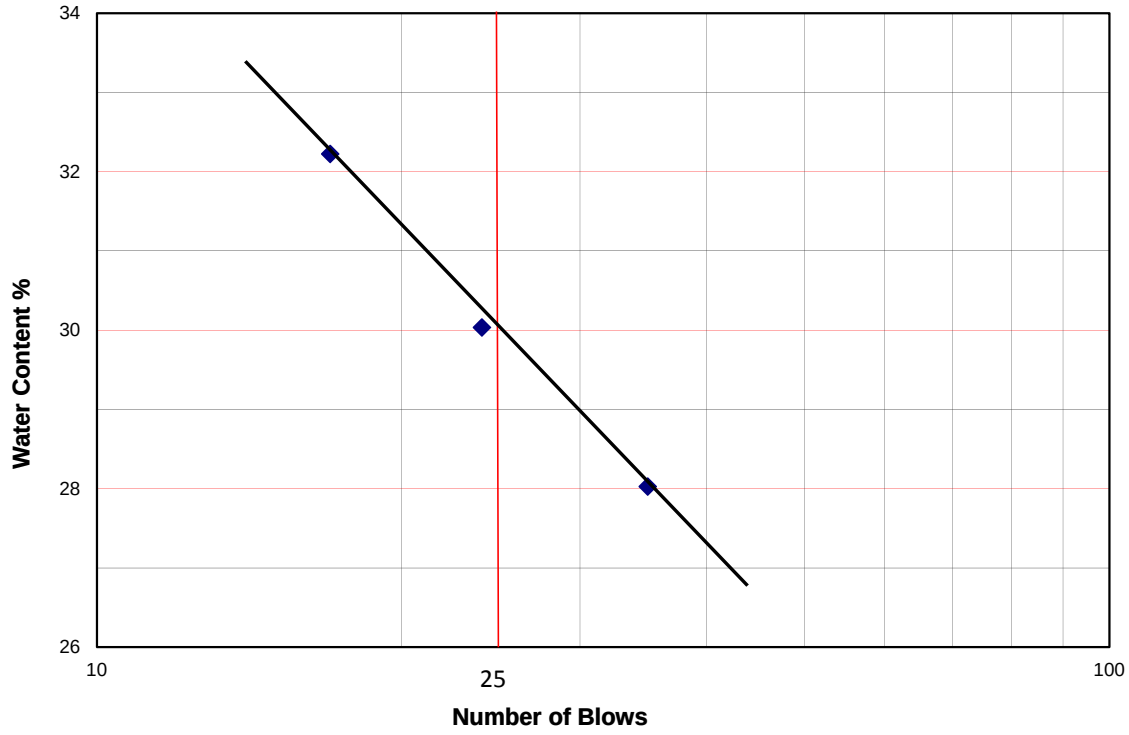
Sample Type: SPT-01

Borehole no.: MBH-18

Depth :1.00-1.45

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 31.58 | 28.32 | 29.59 | | |
| Dry Weight + Can (g) | 27.55 | 24.68 | 25.44 | | |
| Can Weight (g) | 13.17 | 12.56 | 12.56 | | |
| Water Content, % | 28.0 | 30.0 | 32.2 | | |
| Number of Blows | 35 | 24 | 17 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 17.26 | 16.99 | 17.78 |
| Dry Weight + Can (g) | 16.14 | 16.39 | 16.58 |
| Can Weight (g) | 9.52 | 12.76 | 9.14 |
| Water Content, % | 16.9 | 16.5 | 16.1 |

Liquid Limit % 30.0

Plastic Limit % 16.5

Plasticity Index % 13.5

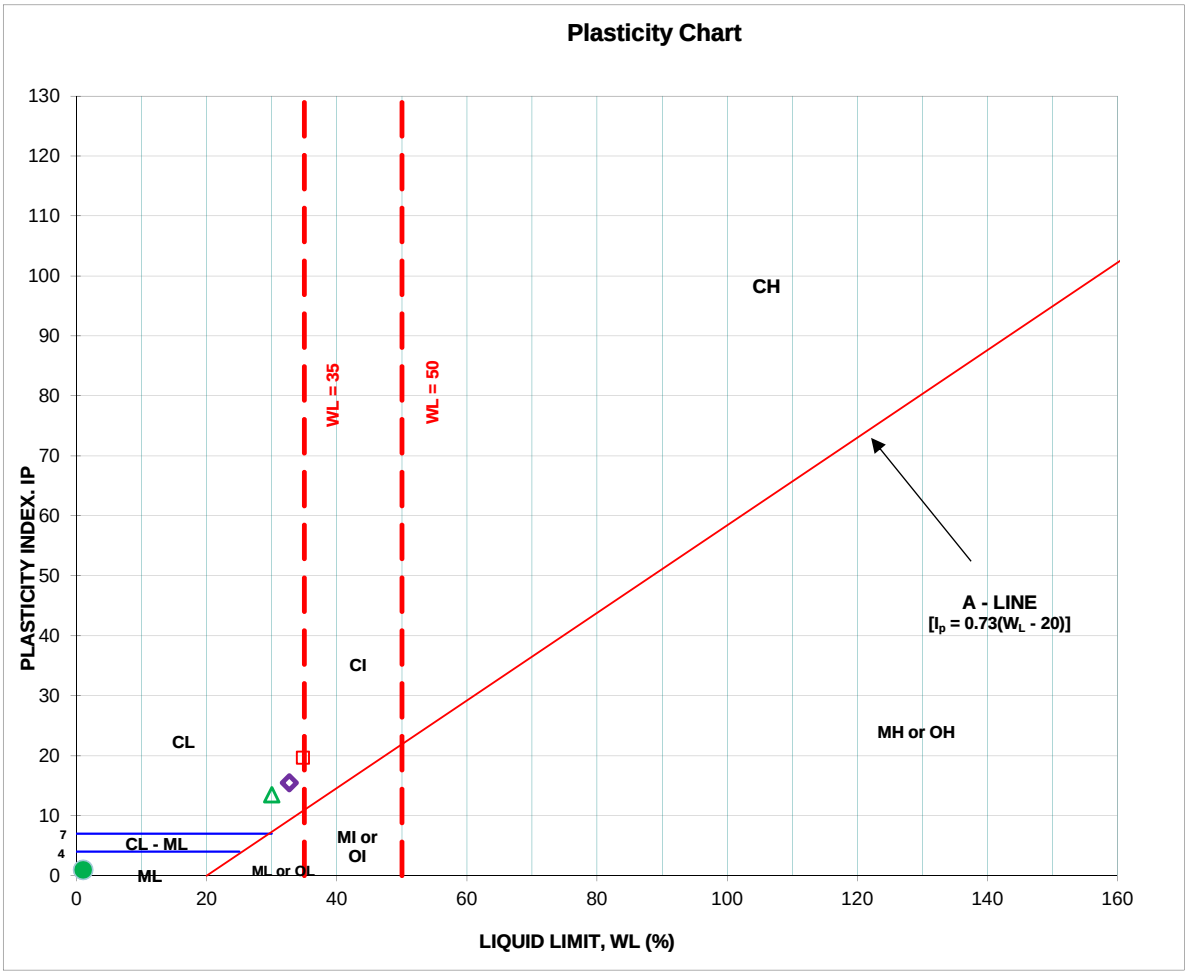
Preparation of Sample :
Dry State

Sample Type: SPT-10

Borehole no.: MBH-18

Depth :15.00-15.45

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.




| | Sample Type | Depth (m) | $W_L$ | $W_P$ | $I_P$ | Remarks |
|---|---|---|---|---|---|---|
| □ | UDS-01 | 0.80-1.00 | 34.8 | 15.1 | 19.7 | CL: Inorganic clays of low to medium plasticity. |
| ◇ | SPT-01 | 1.00-1.45 | 32.7 | 17.2 | 15.5 | CL: Inorganic clays of low to medium plasticity. |
| △ | SPT-10 | 15.00-15.45 | 30.0 | 16.5 | 13.5 | CL: Inorganic clays of low to medium plasticity. |
| ● | | | | | | |
| + | | | | | | |
| ■ | | | | | | |

| | | | |
|---|---|---|---|
| ML | Inorganic silts, very fine sands, rock flour, silty or clayey fine sands | MH | Inorganic silts, or diatomaceous fine sands or silts, elastic silts |
| CL | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays | CH | Inorganic clays of high plasticity, fat clays |
| OL | Organic silts and organic silty clays of low plasticity | OH | Organic silts and organic clays of medium t high plasticity |
| CI | Clays with Intermediate plasticity | MI | Silt with intermediate plasticity |

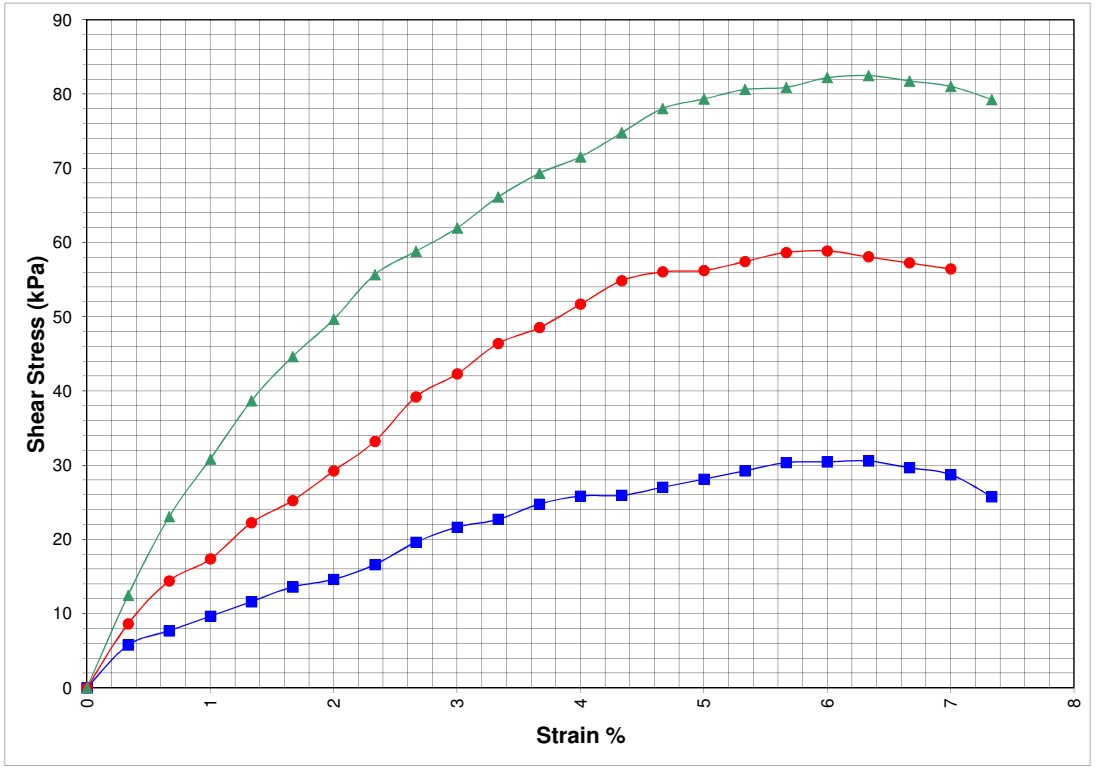
## PLASTICITY CHART (IS : 1498 - 1987)

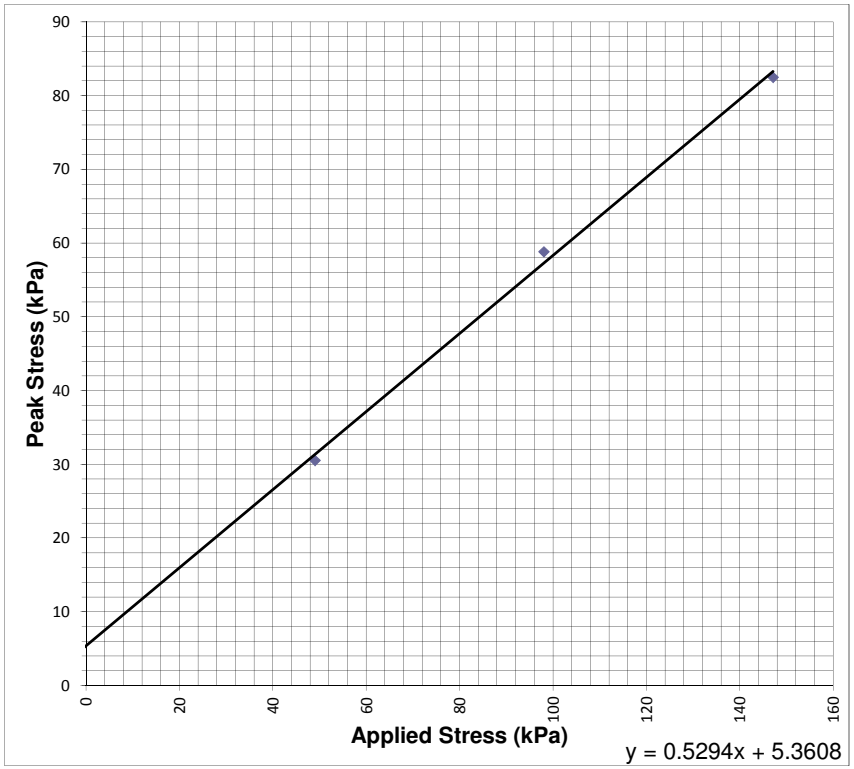
BOREHOLE NAME : MBH-18

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 31 |
| | Stage 2 | 98 | 59 |
| | Stage 3 | 147 | 82 |

| | | |
|---|---|---|
| Angle of Friction | **27.9** | ° |
| Apparent Cohesion | **5.36** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

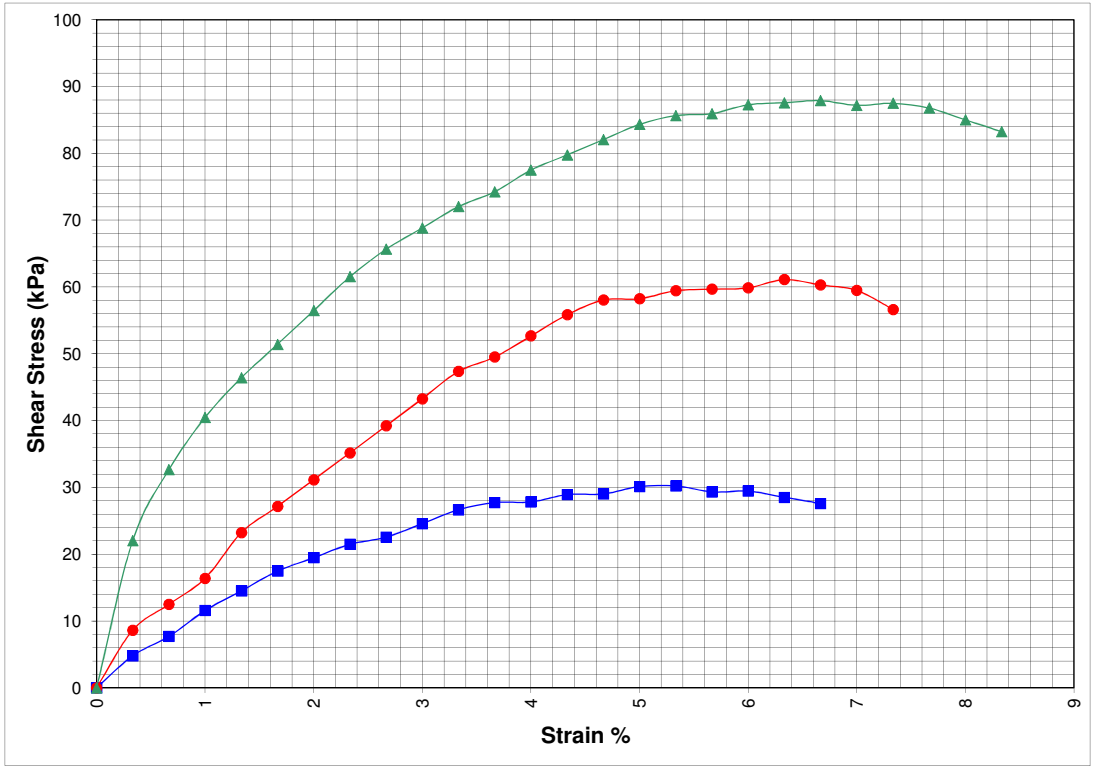
**Borehole: MBH-18**

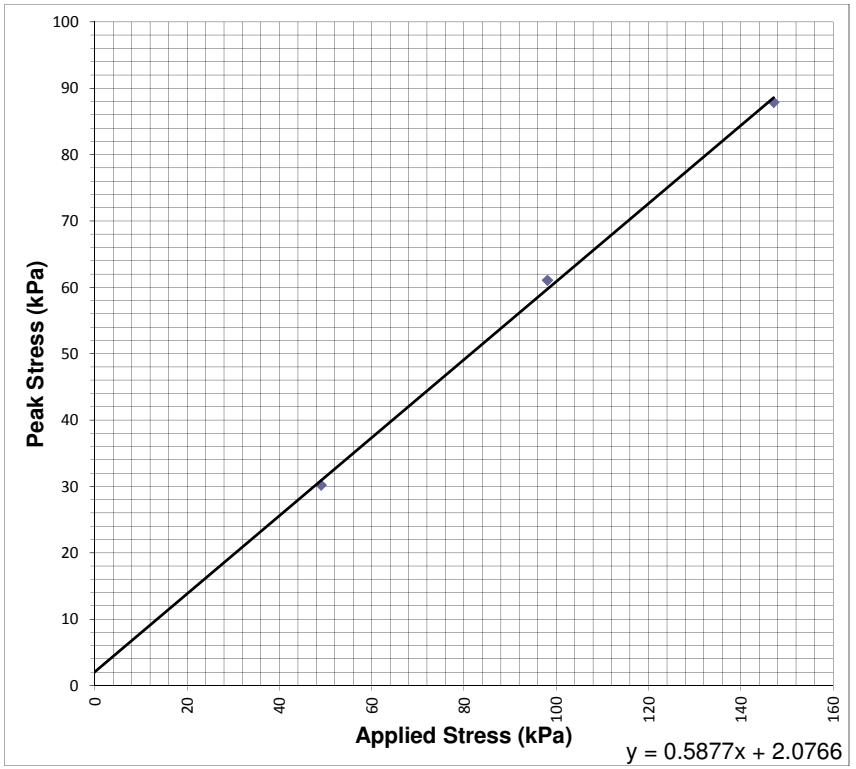
**Sample Type: SPT-05**

**Depth: 7.65-7.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 30 |
| | Stage 2 | 98 | 61 |
| | Stage 3 | 147 | 88 |

| | | |
|---|---|---|
| Angle of Friction | **30.4** | ° |
| Apparent Cohesion | **2.08** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

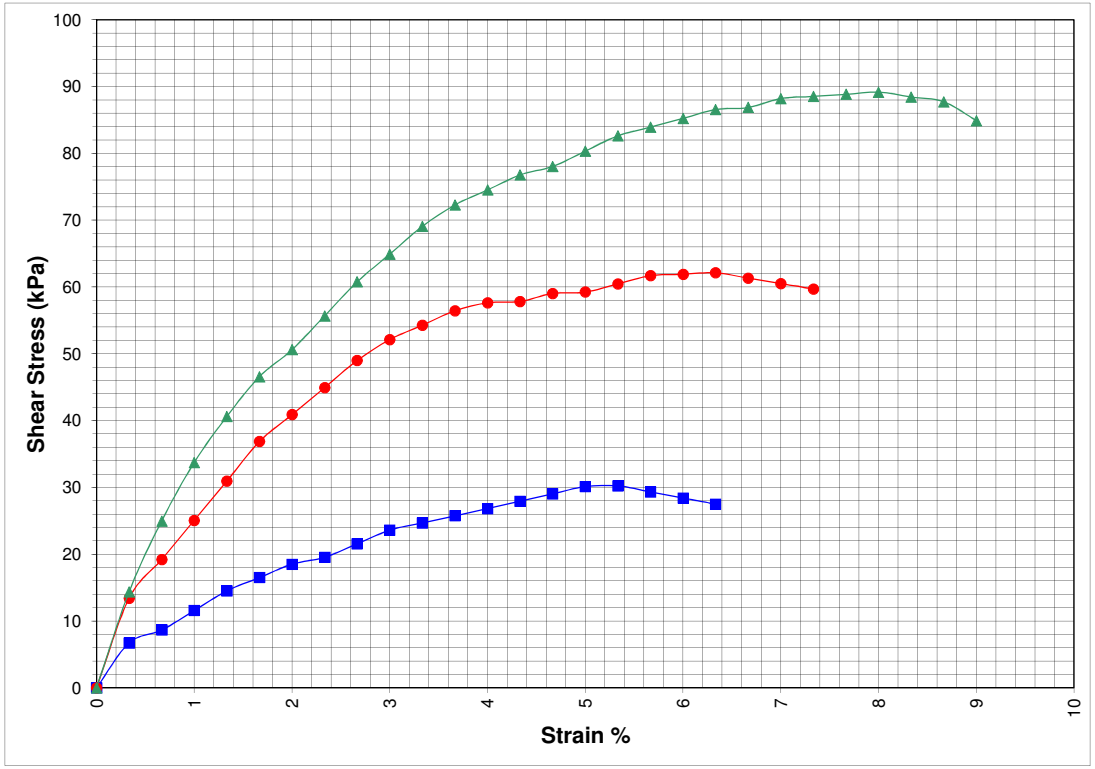
**Borehole: MBH-18**

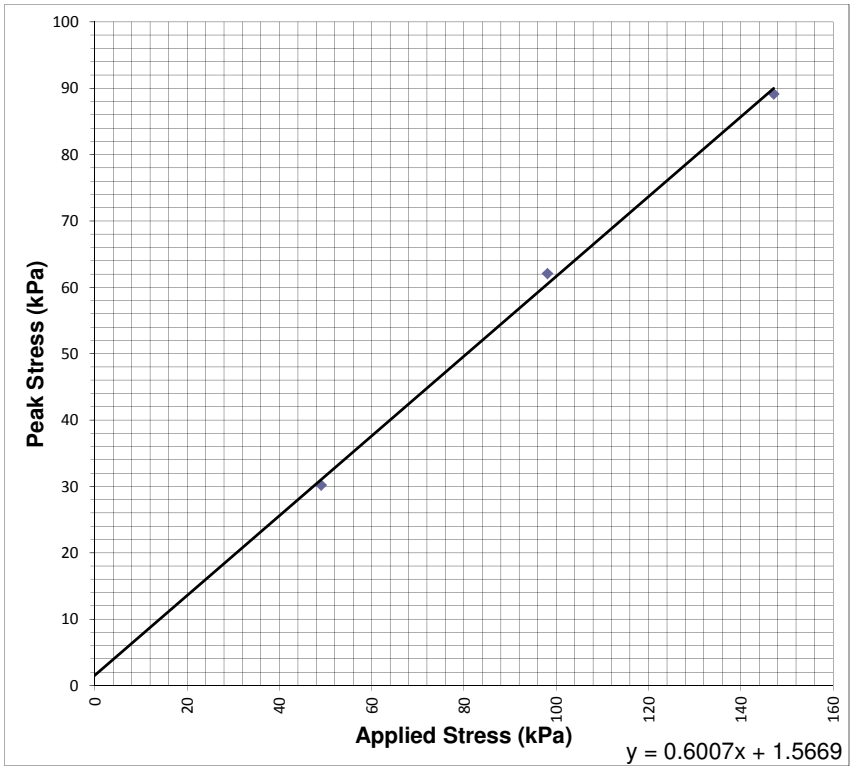
**Sample Type: SPT-09**

**Depth: 13.65-13.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 30 |
| | Stage 2 | 98 | 62 |
| | Stage 3 | 147 | 89 |

| | | |
|---|---|---|
| Angle of Friction | **31.0** | ° |
| Apparent Cohesion | **1.57** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: MBH-18**

**Sample Type: SPT-11**

**Depth: 16.50-16.95 m**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| UDS-1 | 0.00-0.30 | | | | | 23.0 | 19.63 | 9.57 | 15.95 | 2.53 | 0 | 40 | <--> | <--> | 60 | DST | | | 1.67 | 26.8 | | | | | | | | | | | | | |
| SPT-1 | 1.50-1.95 | | 31.2 | 14.6 | 16.6 | 20.3 | 21.65 | 11.59 | 17.60 | 2.52 | 0 | 60 | 14 | 26 | 40 | | | | | | | | | | | | | | | | | |
| SPT-2 | 3.00-3.45 | SC | 27.2 | 16.6 | 10.6 | 18.0 | 21.64 | 11.58 | 17.59 | 2.54 | 0 | 57 | 16 | 27 | 43 | | | | | | | | | 30.0 | | | | | 8.11 | 3.05 | 2.00 | 1800 | 10620 |
| SPT-3 | 4.50-4.95 | | 25.8 | 17.3 | 8.5 | 16.5 | 19.05 | 8.99 | 16.35 | 2.57 | 0 | 66 | 16 | 18 | 34 | | | | | | | | | | | | | | | | | |
| SPT-4 | 6.00-6.45 | | | | | 15.5 | 20.02 | 9.96 | 17.34 | 2.59 | 0 | 85 | <--> | <--> | 15 | DST | | | 1.59 | 27.2 | | | | | | | | | | | | | |
| SPT-5 | 7.50-7.95 | | | | | 17.0 | 20.12 | 10.06 | 17.20 | | 0 | 89 | <--> | <--> | 11 | | | | | | | | | | | | | | | | | | |
| SPT-6 | 9.00-9.45 | | | | | 16.0 | 19.81 | 9.75 | 17.07 | | 0 | 69 | <--> | <--> | 31 | DST | | | 1.17 | 28.4 | | | | | | | | | | | | | |
| SPT-7 | 10.50-10.95 | SM \ SC | | | | 22.5 | 19.13 | 9.07 | 15.62 | 2.62 | 0 | 87 | <--> | <--> | 13 | | | | | | | | | | | | | | | | | | |
| SPT-8 | 12.15-12.45 | | | | | 21.4 | 19.95 | 9.89 | 16.44 | | 1 | 87 | <--> | <--> | 12 | | | | | | | | | | | | | | | | | | |
| SPT-9 | 13.65-13.95 | | | | | 20.9 | 19.62 | 9.56 | 16.23 | | 0 | 88 | <--> | <--> | 12 | DST | | | 2.63 | 26.4 | | | | | | | | | | | | | |
| SPT-10 | 15.35-15.80 | CL | 30.7 | 16.4 | 14.3 | 20.4 | 20.63 | 10.57 | 17.14 | 2.54 | 0 | 46 | 41 | 13 | 54 | | | | | | | | | 15.0 | | | | | | | | | |
| **END OF BOREHOLE** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

\# : Decayed Wood

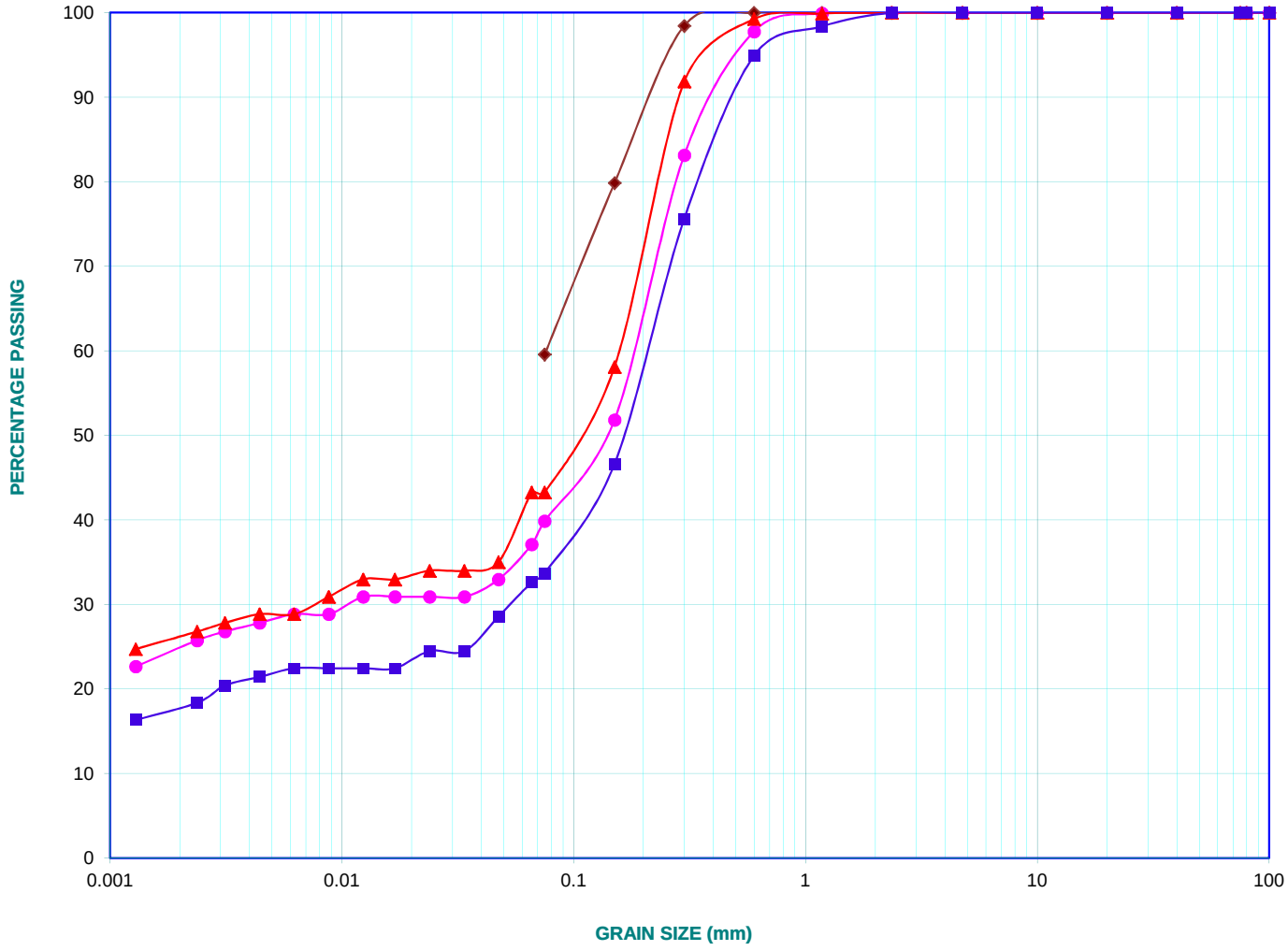
**Failure Type**
A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-19**

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-19** |
| **Date :** | **10-Apr-19** |

| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-19 | MBH-19 | MBH-19 | MBH-19 | | | | | | | | |
| **Depth (m)** | 0.00-0.30 | 1.50-1.95 | 3.00-3.45 | 4.50-4.95 | | | | | | | | |
| **Sample Type** | UDS-1 | SPT-1 | SPT-2 | SPT-3 | | | | | | | | |
| **Classification** | | SC | SC | SC | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 40 | 60 | 57 | 66 | | | | | | | | |
| **Silt %** | <----> | 14 | 16 | 16 | | | | | | | | |
| **Clay %** | <----> | 26 | 27 | 18 | | | | | | | | |
| **Fines % (Silt+Clay)** | 60 | 40 | 43 | 34 | | | | | | | | |
| **D60 mm** | | | | | | | | | | | | |
| **D30 mm** | | | | | | | | | | | | |
| **D10 mm** | | | | | | | | | | | | |
| **Cu** | | | | | | | | | | | | |
| **Cc** | | | | | | | | | | | | |
| **Liquid Limit %** | --- | 31.2 | 27.2 | 25.8 | | | | | | | | |
| **Plastic Limit %** | --- | 14.6 | 16.6 | 17.3 | | | | | | | | |
| **Plasticity Index** | --- | 16.6 | 10.6 | 8.5 | | | | | | | | |

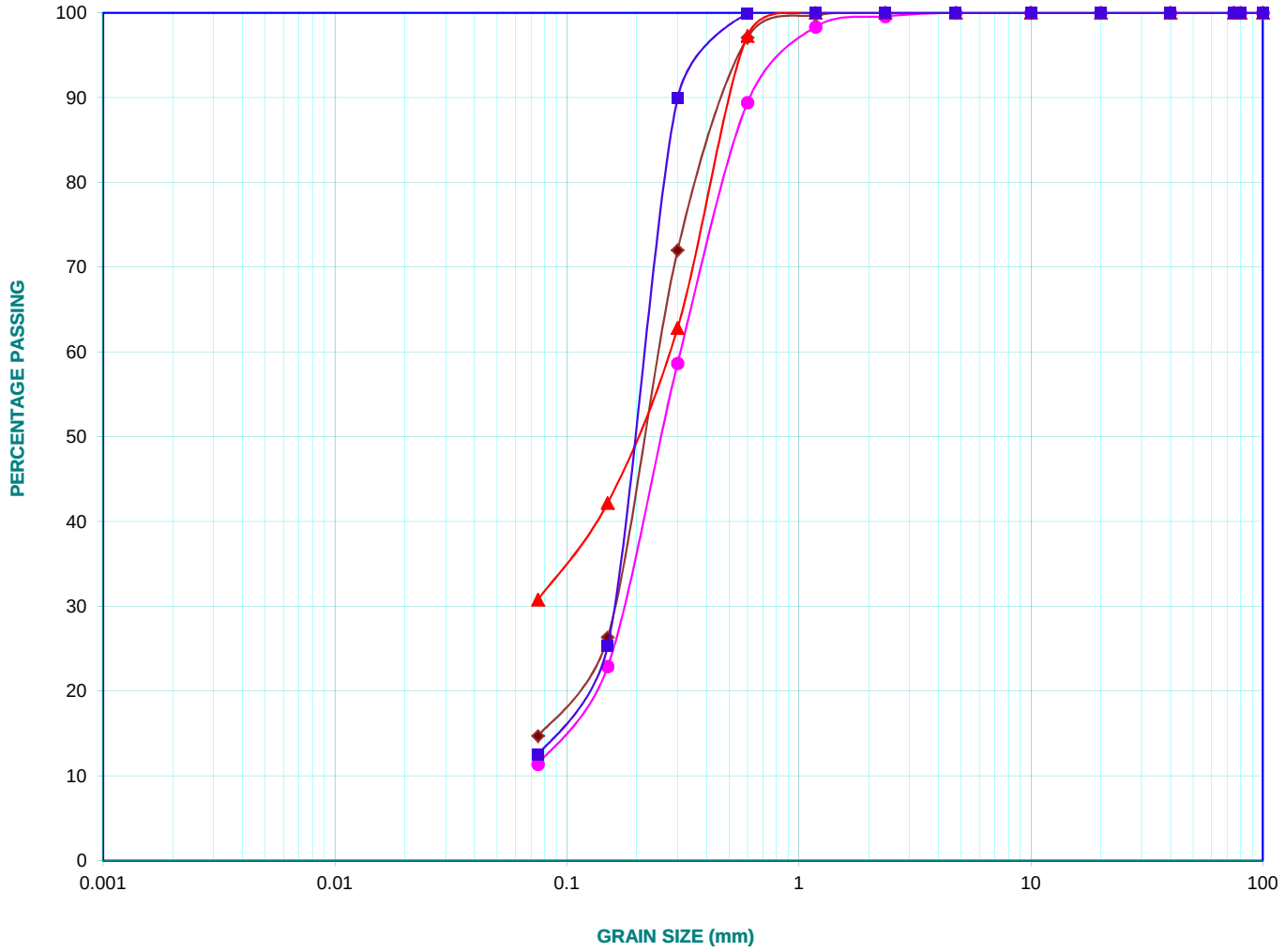



Checked By :

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-19** |
| **Date :** | **10-Apr-19** |

| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-19 | MBH-19 | MBH-19 | MBH-19 | | | | | | | | |
| **Depth (m)** | 6.00-6.45 | 7.50-7.95 | 9.00-9.45 | 10.50-10.95 | | | | | | | | |
| **Sample Type** | SPT-4 | SPT-5 | SPT-6 | SPT-7 | | | | | | | | |
| **Classification** | SM \ SC | SM \ SC | SM \ SC | SM \ SC | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 85 | 89 | 69 | 87 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 15 | 11 | 31 | 13 | | | | | | | | |
| **D60 mm** | | | | | | | | | | | | |
| **D30 mm** | | | | | | | | | | | | |
| **D10 mm** | | | | | | | | | | | | |
| **Cu** | | | | | | | | | | | | |
| **Cc** | | | | | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |

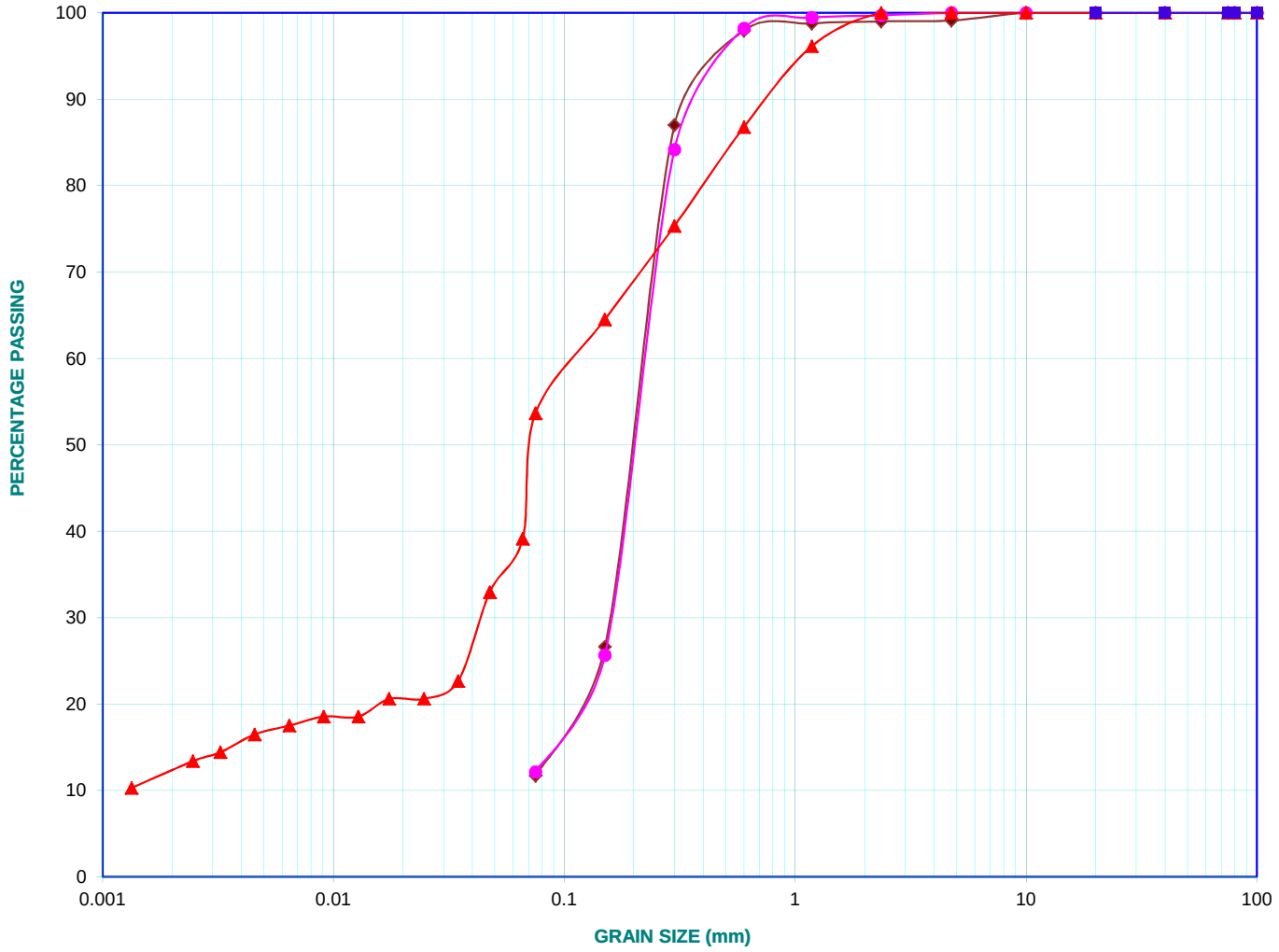



Checked By :

# GRAIN SIZE ANALYSIS

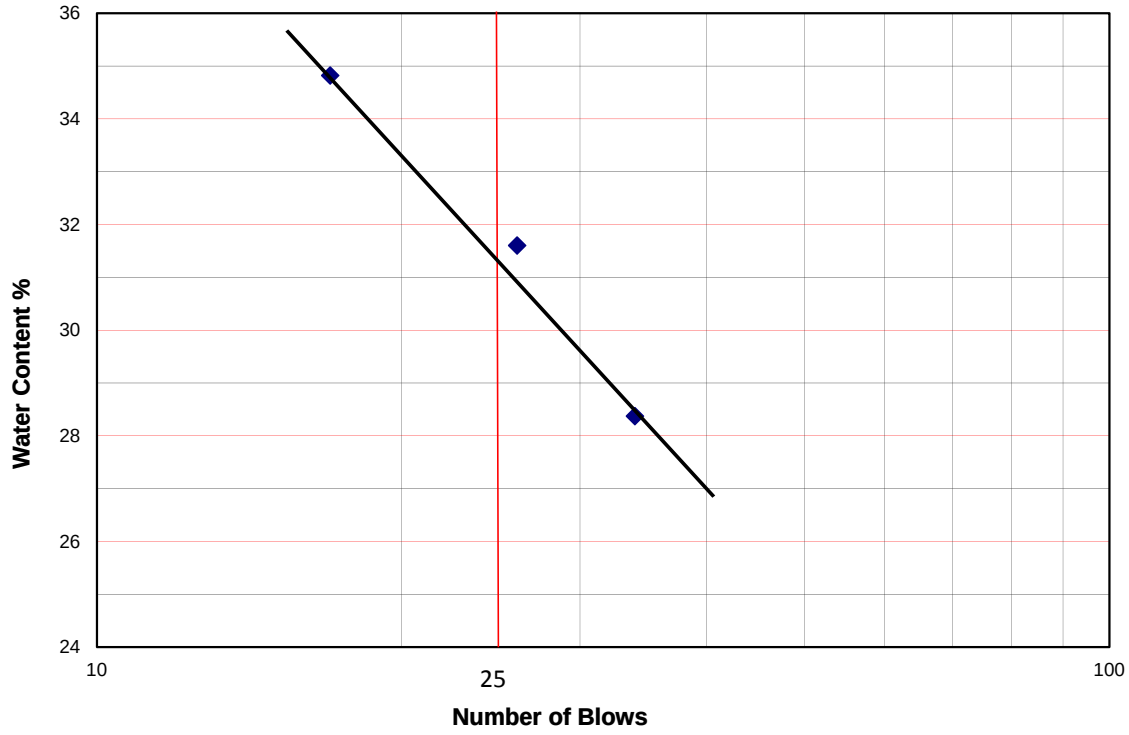
| | |
|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-19** |
| **Date :** | **10-Apr-19** |

| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-19 | MBH-19 | MBH-19 | | | | | | | | | |
| **Depth (m)** | 12.15-12.45 | 13.50-13.95 | 15.35-15.80 | | | | | | | | | |
| **Sample Type** | SPT-8 | SPT-9 | SPT-10 | | | | | | | | | |
| **Classification** | SM \ SC | SM \ SC | CL | | | | | | | | | |
| **Gravel %** | 1 | 0 | 0 | | | | | | | | | |
| **Sand %** | 87 | 88 | 46 | | | | | | | | | |
| **Silt %** | <----> | <----> | 41 | | | | | | | | | |
| **Clay %** | <----> | <----> | 13 | | | | | | | | | |
| **Fines % (Silt+Clay)** | 12 | 12 | 54 | | | | | | | | | |
| **D60 mm** | | | | | | | | | | | | |
| **D30 mm** | | | | | | | | | | | | |
| **D10 mm** | | | | | | | | | | | | |
| **Cu** | | | | | | | | | | | | |
| **Cc** | | | | | | | | | | | | |
| **Liquid Limit %** | --- | --- | 30.7 | | | | | | | | | |
| **Plastic Limit %** | --- | --- | 16.4 | | | | | | | | | |
| **Plasticity Index** | --- | --- | 14.3 | | | | | | | | | |




Checked By :

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 26.11 | 27.83 | 33.62 | | |
| Dry Weight + Can (g) | 22.45 | 23.27 | 28.38 | | |
| Can Weight (g) | 9.55 | 8.84 | 13.33 | | |
| Water Content, % | 28.4 | 31.6 | 34.8 | | |
| Number of Blows | 34 | 26 | 17 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 17.03 | 16.59 | 19.83 |
| Dry Weight + Can (g) | 16.04 | 16.08 | 19.07 |
| Can Weight (g) | 9.39 | 12.59 | 13.74 |
| Water Content, % | 14.9 | 14.6 | 14.3 |

Liquid Limit % 31.2

Plastic Limit % 14.6

Plasticity Index % 16.6

Preparation of Sample :
Dry State

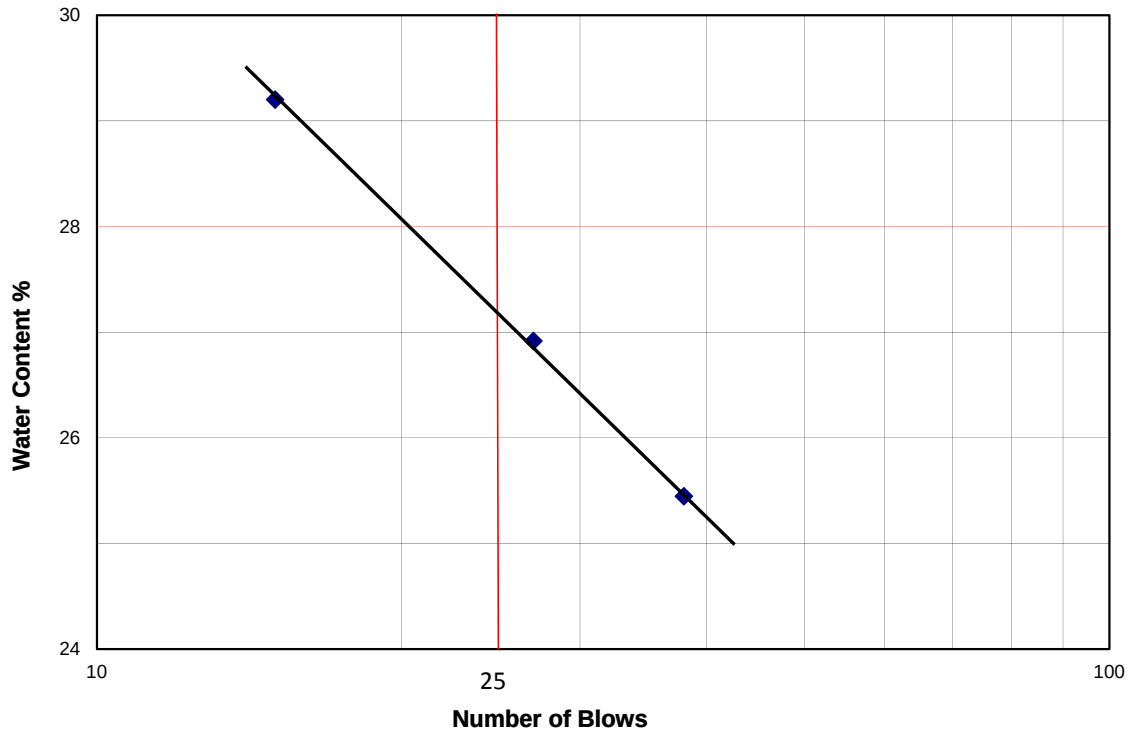
Sample Type: SPT-01

Borehole no.: MBH-19

Depth :1.50-1.95

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 30.56 | 29.47 | 32.59 | | |
| Dry Weight + Can (g) | 26.29 | 25.96 | 27.20 | | |
| Can Weight (g) | 9.51 | 12.92 | 8.74 | | |
| Water Content, % | 25.4 | 26.9 | 29.2 | | |
| Number of Blows | 38 | 27 | 15 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 17.33 | 17.88 | 17.63 |
| Dry Weight + Can (g) | 16.68 | 16.64 | 16.35 |
| Can Weight (g) | 12.76 | 9.25 | 8.52 |
| Water Content, % | 16.6 | 16.8 | 16.3 |

Liquid Limit % 27.2

Plastic Limit % 16.6

Plasticity Index % 10.6

Preparation of Sample :
Dry State

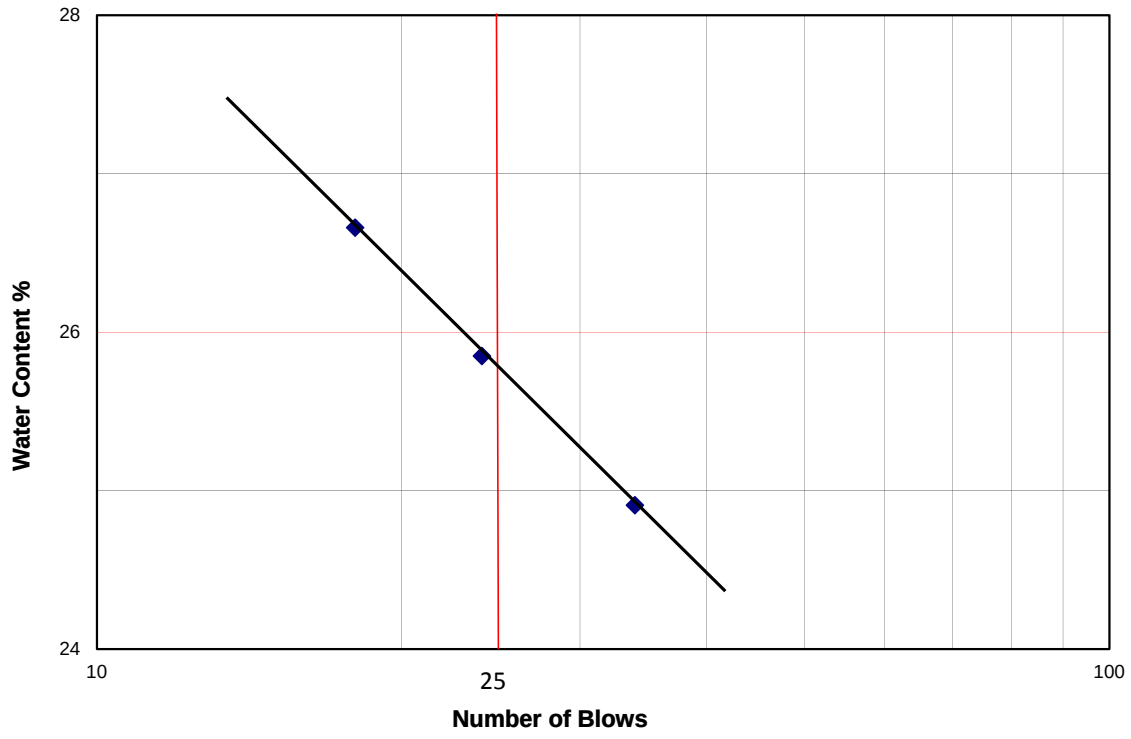
Sample Type: SPT-02

Borehole no.: MBH-19

Depth :3.00-3.45

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 34.82 | 30.87 | 26.63 | | |
| Dry Weight + Can (g) | 30.75 | 26.99 | 22.61 | | |
| Can Weight (g) | 14.41 | 11.98 | 7.53 | | |
| Water Content, % | 24.9 | 25.8 | 26.7 | | |
| Number of Blows | 34 | 24 | 18 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 19.67 | 18.84 | 17.57 |
| Dry Weight + Can (g) | 18.70 | 17.35 | 16.41 |
| Can Weight (g) | 13.06 | 8.65 | 9.83 |
| Water Content, % | 17.2 | 17.1 | 17.6 |

Liquid Limit % 25.8

Plastic Limit % 17.3

Plasticity Index % 8.5

Preparation of Sample :
Dry State

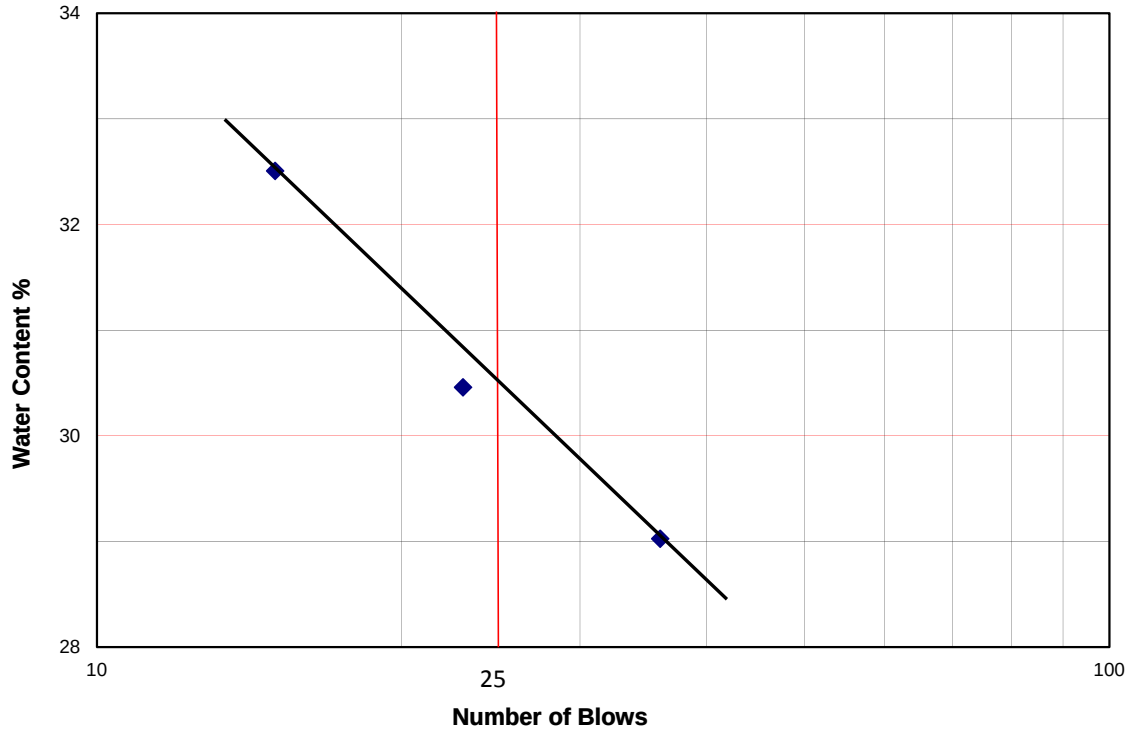
Sample Type: SPT-03

Borehole no.: MBH-19

Depth :4.50-4.95

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 26.95 | 35.35 | 30.36 | | |
| Dry Weight + Can (g) | 23.04 | 30.09 | 25.26 | | |
| Can Weight (g) | 9.57 | 12.82 | 9.57 | | |
| Water Content, % | 29.0 | 30.5 | 32.5 | | |
| Number of Blows | 36 | 23 | 15 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 16.56 | 17.39 | 18.73 |
| Dry Weight + Can (g) | 15.47 | 16.86 | 17.42 |
| Can Weight (g) | 8.75 | 13.74 | 9.27 |
| Water Content, % | 16.2 | 17.0 | 16.1 |

| | |
|---|---|
| Liquid Limit % | 30.7 |
| Plastic Limit % | 16.4 |
| Plasticity Index % | 14.3 |

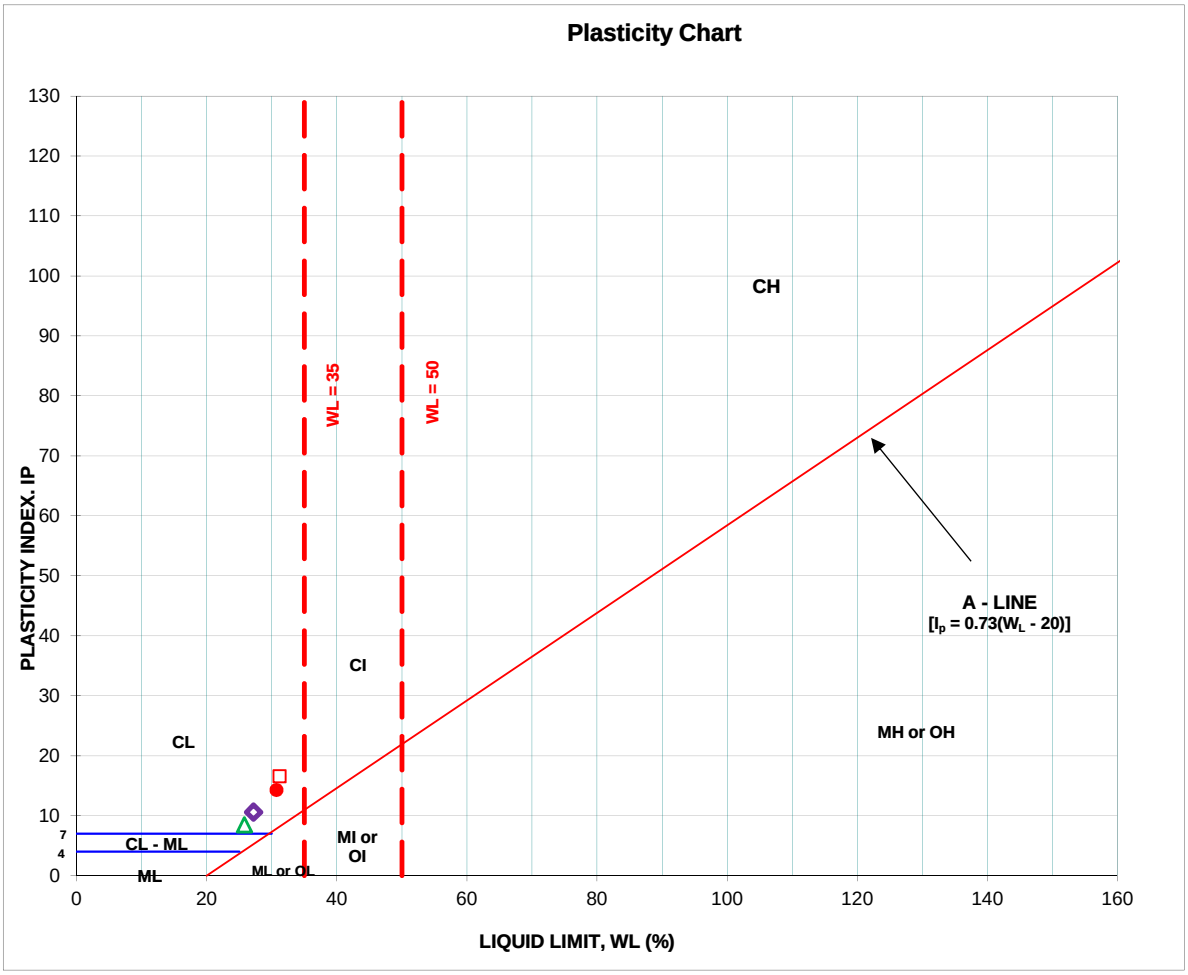
Preparation of Sample :
Dry State

Sample Type: SPT-10

Borehole no.: MBH-19

Depth :15.35-15.80

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.




| | Sample Type | Depth (m) | $W_L$ | $W_P$ | $I_P$ | Remarks |
|---|---|---|---|---|---|---|
| □ | SPT-01 | 1.50-1.95 | 31.2 | 14.6 | 16.6 | CL: Inorganic clays of low to medium plasticity. |
| ◇ | SPT-02 | 3.00-3.45 | 27.2 | 16.6 | 10.6 | CL: Inorganic clays of low to medium plasticity. |
| △ | SPT-03 | 4.50-4.95 | 25.8 | 17.3 | 8.5 | CL: Inorganic clays of low to medium plasticity. |
| ● | SPT-10 | 15.35-15.80 | 30.7 | 16.4 | 14.3 | CL: Inorganic clays of low to medium plasticity. |
| + | | | | | | |
| ■ | | | | | | |

| | | | |
|---|---|---|---|
| ML | Inorganic silts, very fine sands, rock flour, silty or clayey fine sands | MH | Inorganic silts, or diatomaceous fine sands or silts, elastic silts |
| CL | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays | CH | Inorganic clays of high plasticity, fat clays |
| OL | Organic silts and organic silty clays of low plasticity | OH | Organic silts and organic clays of medium t high plasticity |
| CI | Clays with Intermediate plasticity | MI | Silt with intermediate plasticity |

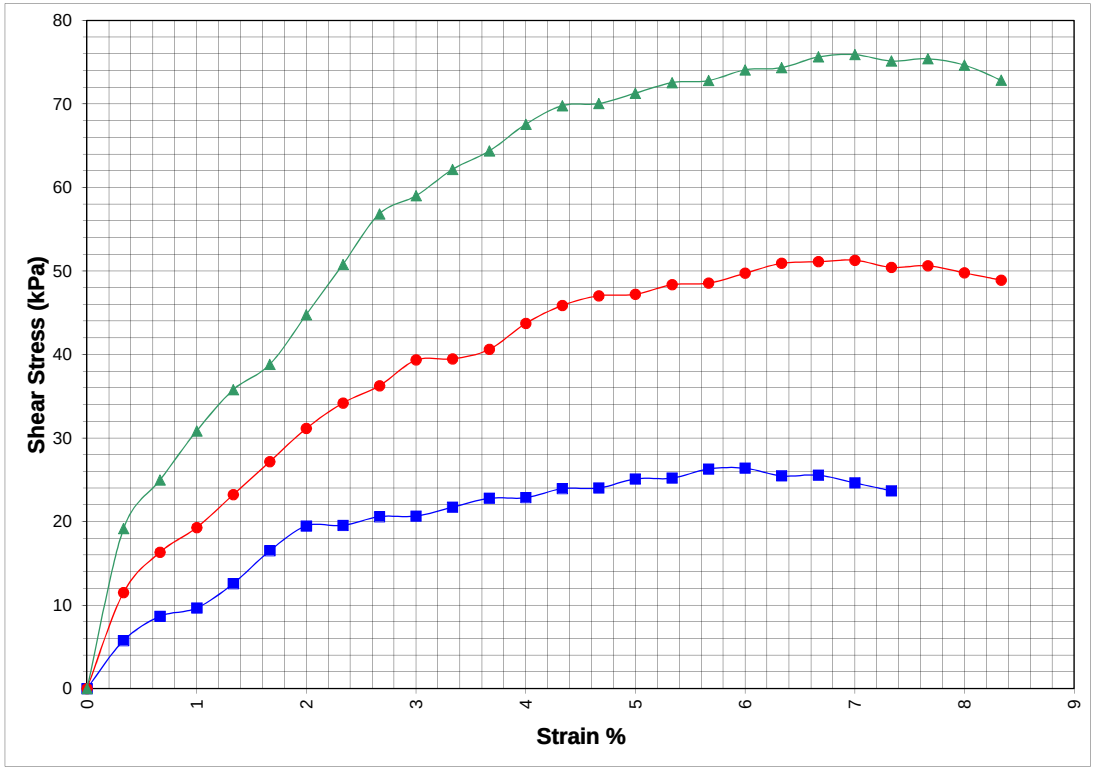
## PLASTICITY CHART (IS : 1498 - 1987)

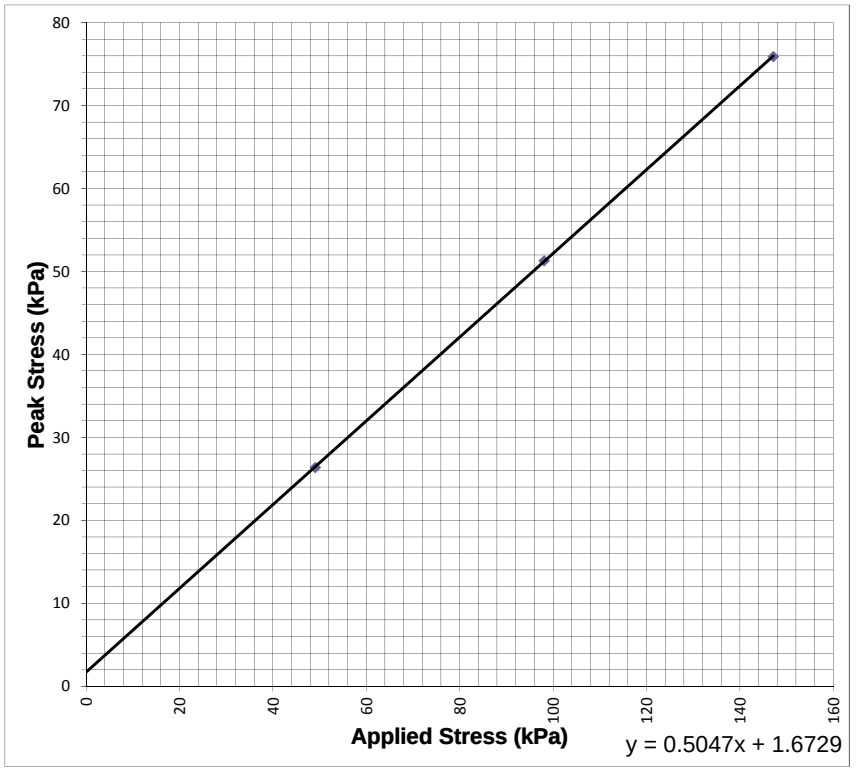
BOREHOLE NAME : MBH-19

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 51 |
| | Stage 3 | 147 | 76 |

| | | |
|---|---|---|
| Angle of Friction | **26.78** | ° |
| Apparent Cohesion | **1.67** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

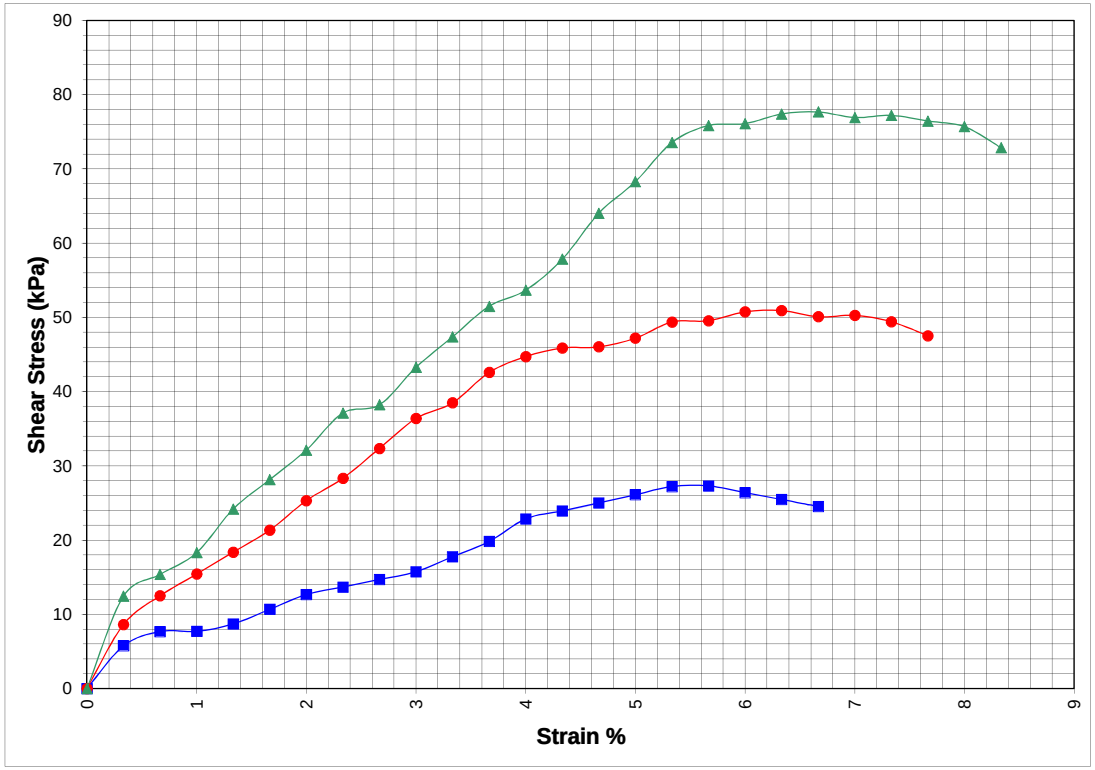
**Borehole: MBH-19**

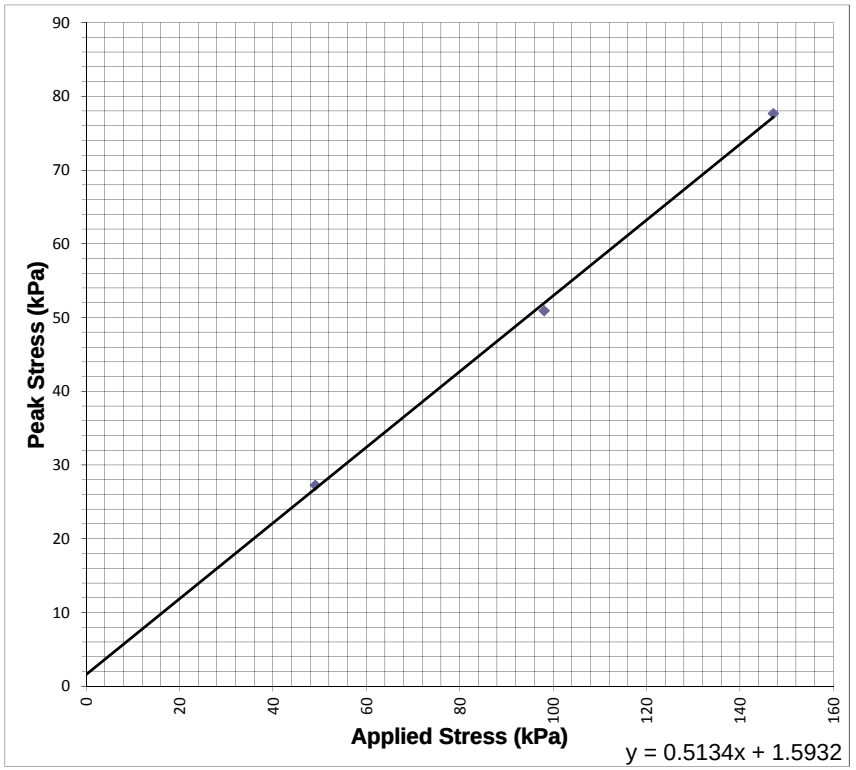
**Sample Type: UDS-01**

**Depth: 0.00-0.30 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 51 |
| | Stage 3 | 147 | 78 |

| | | |
|---|---|---|
| Angle of Friction | **27.18** | ° |
| Apparent Cohesion | **1.59** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

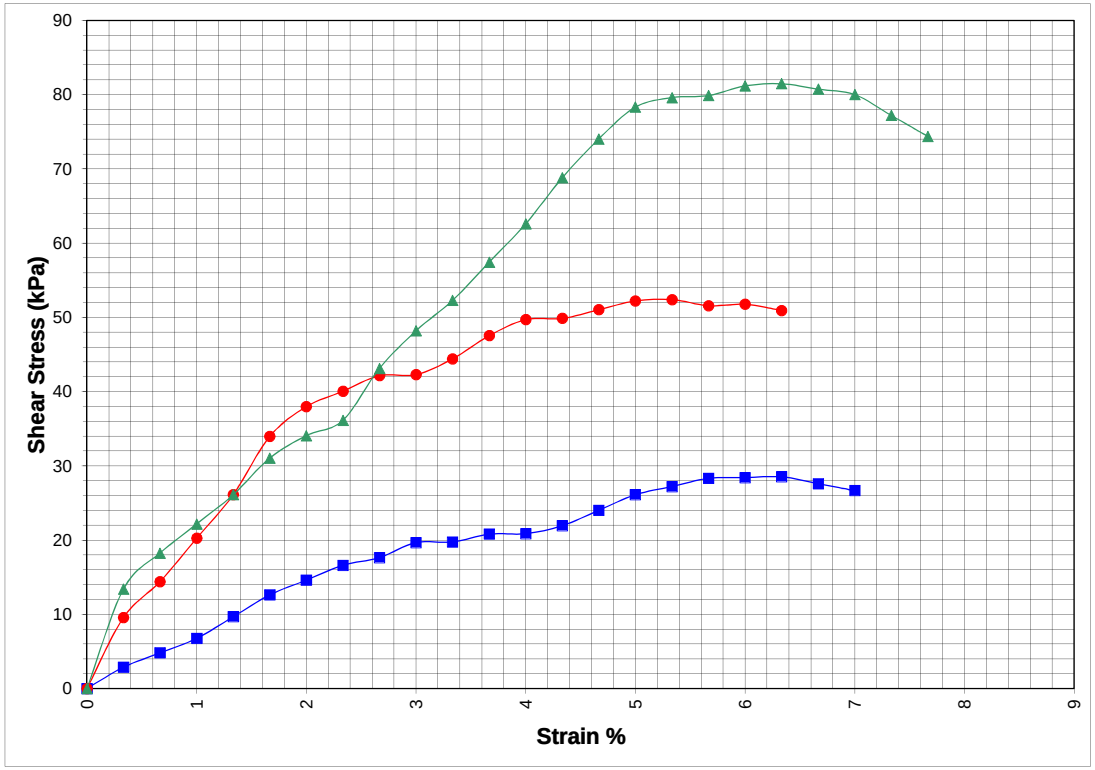
**Borehole: MBH-19**

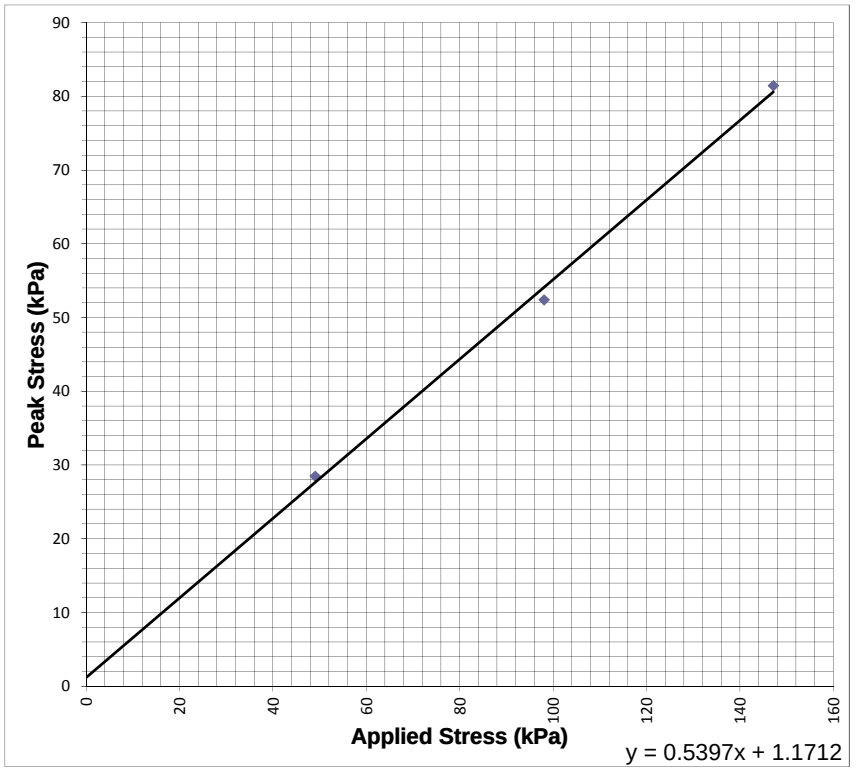
**Sample Type: SPT-04**

**Depth: 6.00-6.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 29 |
| | Stage 2 | 98 | 52 |
| | Stage 3 | 147 | 81 |

| | | |
|---|---|---|
| Angle of Friction | **28.36** | ° |
| Apparent Cohesion | **1.17** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

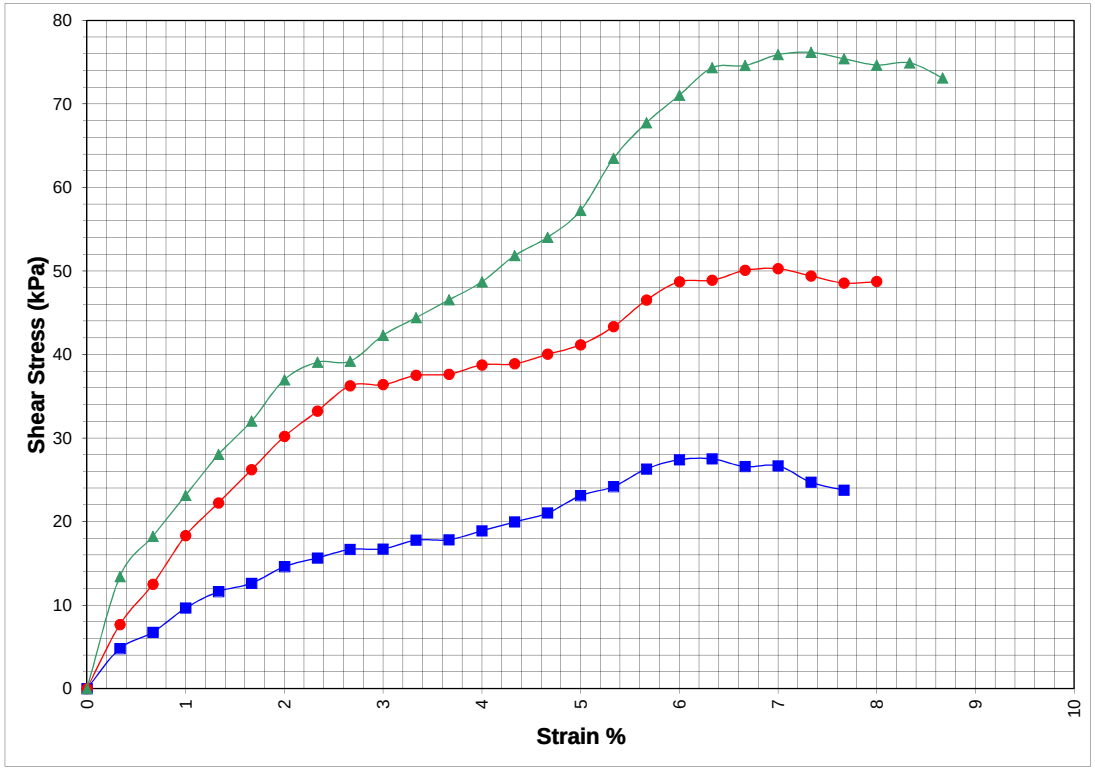
**Borehole: MBH-19**

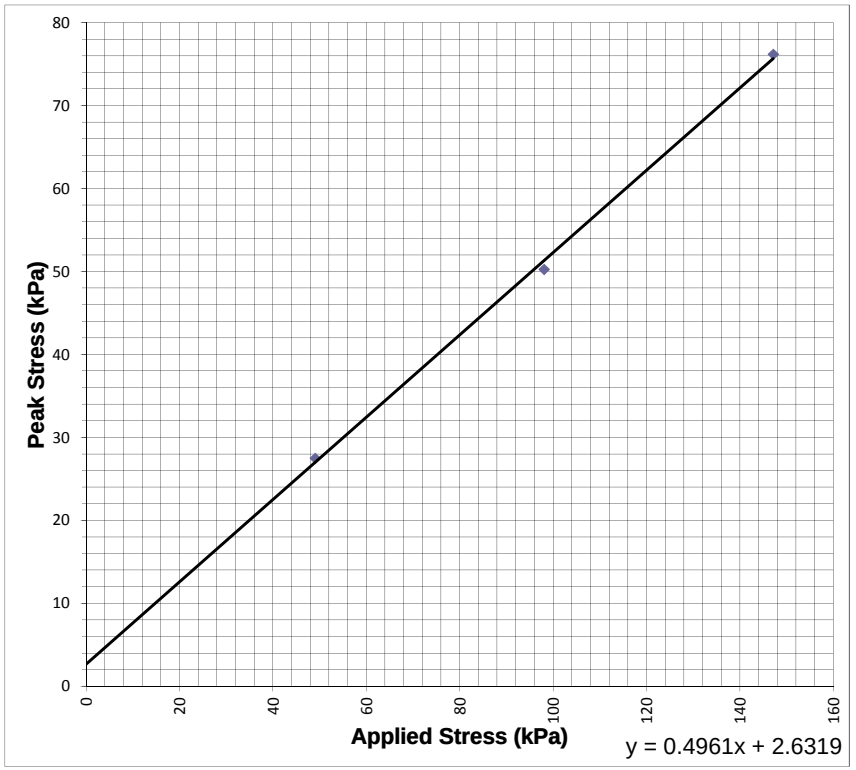
**Sample Type: SPT-06**

**Depth: 9.00-9.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 50 |
| | Stage 3 | 147 | 76 |

| | | |
|---|---|---|
| Angle of Friction | **26.4** | ° |
| Apparent Cohesion | **2.63** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: MBH-19**

**Sample Type: SPT-09**

**Depth: 13.50-13.95 m**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| UDS-1 | 0.00-0.30 | | | | | 24.5 | 19.37 | 9.31 | 15.56 | 2.55 | 0 | 29 | 67 | 4 | 71 | | | | | | | | | | | | | | | | | | | |
| SPT-1 | 1.00-1.10 | CL | | | | 24.2 | 19.37 | 9.31 | 15.55 | 2.53 | 0 | 44 | 48 | 8 | 56 | DST | | | 0.83 | 29.4 | | | | | | | | | | | | | |
| SPT-1 | 1.10-1.45 | | 29.3 | 17.5 | 11.8 | 32.7 | 20.91 | 10.85 | 16.79 | 2.56 | 0 | 28 | 52 | 20 | 72 | | | | | | | | | | | | | | | | | |
| SPT-2 | 4.00-4.45 | | 38.9 | 17.3 | 21.6 | 16.7 | 19.19 | 9.13 | 16.44 | 2.51 | 0 | 58 | 17 | 25 | 42 | | | | | | | | | 55.6 | | | | | | | | |
| SPT-3 | 5.50-5.65 | | | | | 17.0 | 19.10 | 9.04 | 16.33 | 2.58 | 0 | 57 | 15 | 28 | 43 | | | | | | | | | | | | | | | | | |
| SPT-3 | 5.65-5.95 | | | | | 21.4 | 20.47 | 10.41 | 16.86 | | 1 | 63 | <--> | <--> | 36 | DST | | | 1.22 | 29.6 | | | | | | | | | | | | |
| SPT-4 | 7.00-7.45 | | | | | 19.4 | 20.14 | 10.08 | 16.87 | 2.62 | 0 | 84 | <--> | <--> | 16 | DST | | | 2.23 | 28.2 | | | | | | | | | | | | |
| SPT-5 | 8.50-8.95 | SC | | | | 22.4 | 19.12 | 9.06 | 15.63 | | 1 | 73 | <--> | <--> | 26 | | | | | | | | | | | | | | | | | |
| SPT-6 | 10.00-10.45 | | | | | 21.5 | 19.36 | 9.30 | 15.93 | 2.58 | 0 | 88 | <--> | <--> | 12 | | | | | | | | | | | | | | | | | |
| SPT-7 | 11.50-11.95 | | | | | 22.2 | 18.89 | 8.83 | 15.46 | | 0 | 74 | <--> | <--> | 26 | DST | | | 0.87 | 30.6 | | | | | | | | | | | | |
| SPT-8 | 13.00-13.45 | | | | | 22.2 | 19.06 | 9.00 | 15.60 | | 0 | 64 | <--> | <--> | 36 | DST | | | 1.64 | 31.3 | | | | | | | | | | | | |
| SPT-9 | 14.50-14.95 | | | | | 20.3 | 20.59 | 10.53 | 17.12 | 2.56 | 0 | 41 | 35 | 24 | 59 | | | | | | | | | 50.0 | | | | | 7.23 | 2.72 | 1.00 | 1600 | 8850 |
| END OF BOREHOLE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

\# : Decayed Wood

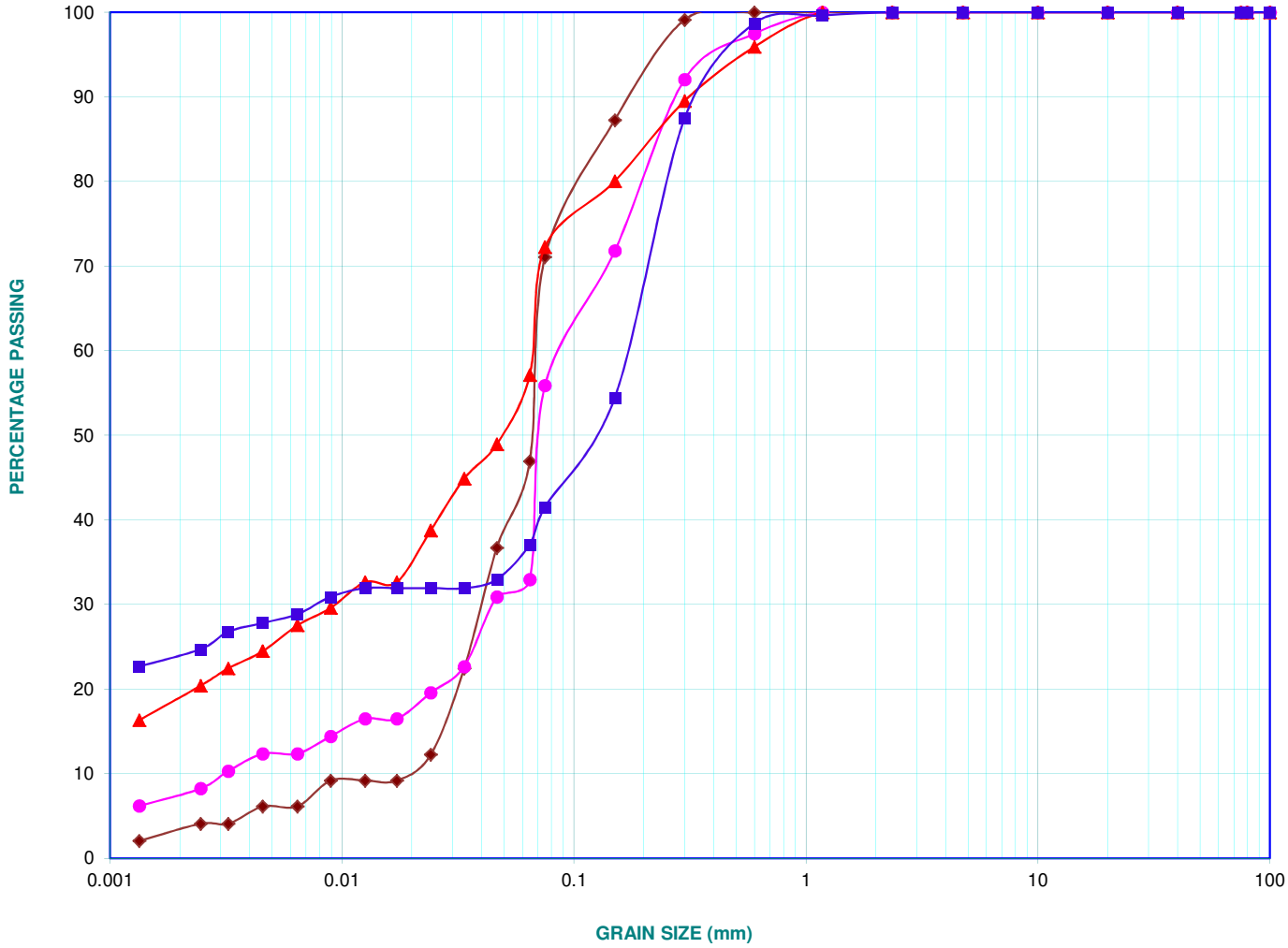
**Failure Type**
A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-20**

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-20** |
| **Date :** | **10-Apr-19** |

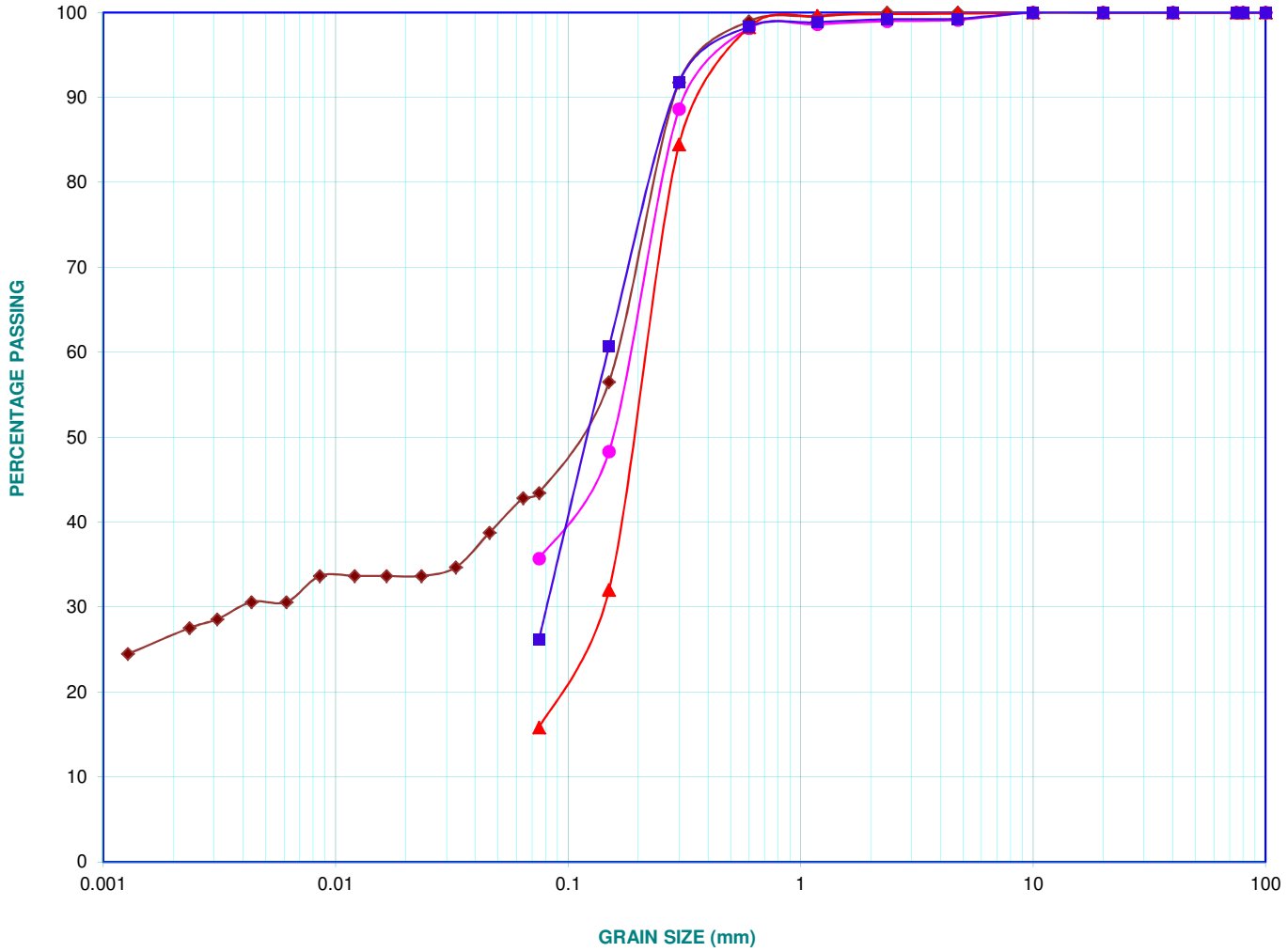
| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-20 | MBH-20 | MBH-20 | MBH-20 | | | | | | | | |
| **Depth (m)** | 0.00-0.30 | 1.00-1.10 | 1.10-1.45 | 4.00-4.45 | | | | | | | | |
| **Sample Type** | UDS-1 | SPT-1 | SPT-1 | SPT-2 | | | | | | | | |
| **Classification** | CL | CL | CL | SC | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 29 | 44 | 28 | 58 | | | | | | | | |
| **Silt %** | 67 | 48 | 52 | 17 | | | | | | | | |
| **Clay %** | 4 | 8 | 20 | 25 | | | | | | | | |
| **Fines % (Silt+Clay)** | 71 | 56 | 72 | 42 | | | | | | | | |
| **D60 mm** | | | | | | | | | | | | |
| **D30 mm** | | | | | | | | | | | | |
| **D10 mm** | | | | | | | | | | | | |
| **Cu** | | | | | | | | | | | | |
| **Cc** | | | | | | | | | | | | |
| **Liquid Limit %** | --- | --- | 29.3 | 38.9 | | | | | | | | |
| **Plastic Limit %** | --- | --- | 17.5 | 17.3 | | | | | | | | |
| **Plasticity Index** | --- | --- | 11.8 | 21.6 | | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

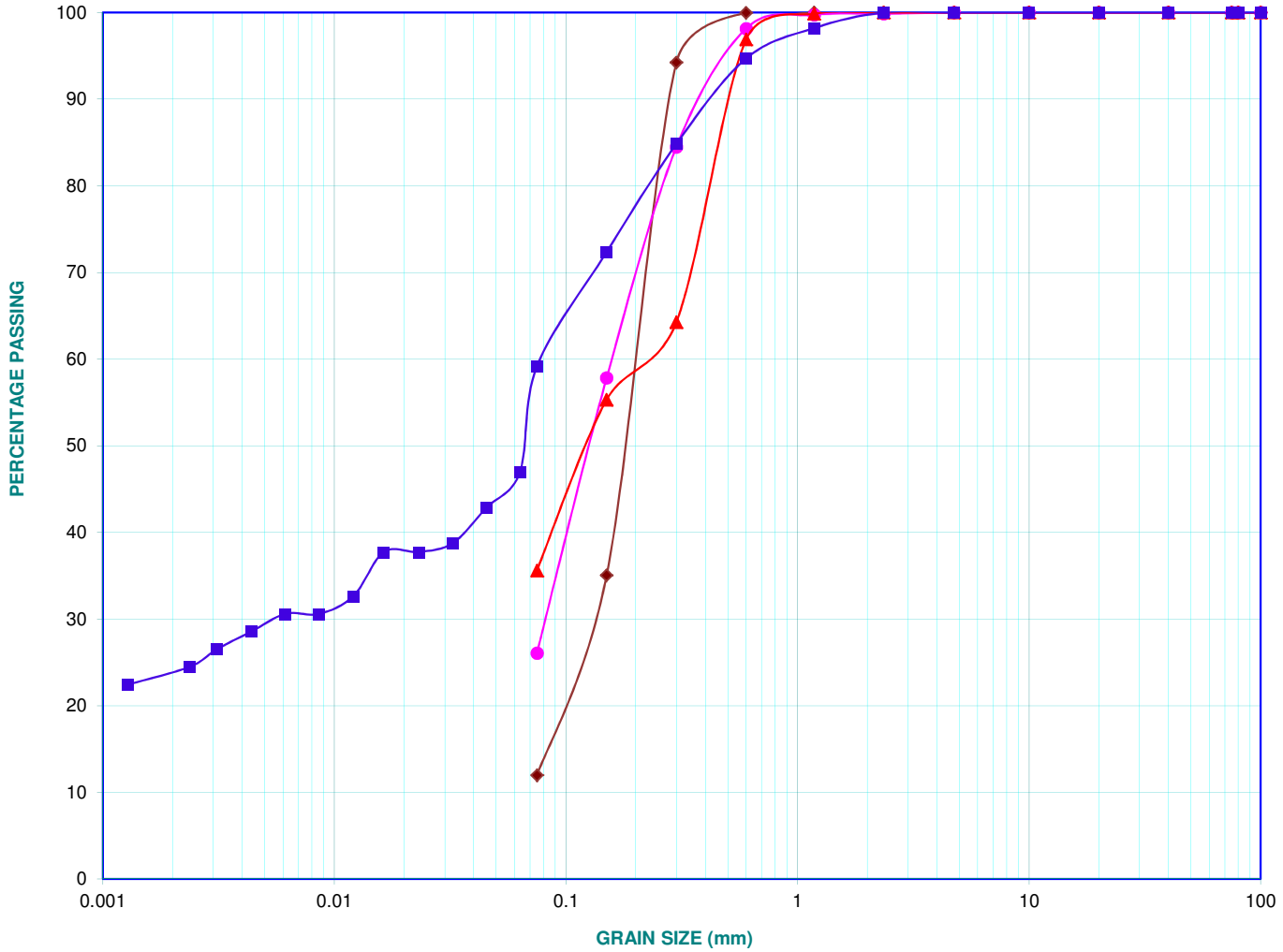
| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | **Borehole No.** | **: MBH-20** | | | | **Date :** | **10-Apr-19** | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND F | SAND M | SAND C | GRAVEL F / GRAVEL C |
| **Bore Hole .** | MBH-20 | MBH-20 | MBH-20 | MBH-20 | | | | | | | |
| **Depth (m)** | 5.50-5.65 | 5.65-5.95 | 7.00-7.45 | 8.50-8.95 | | | | | | | |
| **Sample Type** | SPT-3 | SPT-3 | SPT-4 | SPT-5 | | | | | | | |
| **Classification** | SC | SC | SC | SC | | | | | | | |
| **Gravel %** | 0 | 1 | 0 | 1 | | | | | | | |
| **Sand %** | 57 | 63 | 84 | 73 | | | | | | | |
| **Silt %** | 15 | <----> | <----> | <----> | | | | | | | |
| **Clay %** | 28 | <----> | <----> | <----> | | | | | | | |
| **Fines % (Silt+Clay)** | 43 | 36 | 16 | 26 | | | | | | | |
| **D60 mm** | | | | | | | | | | | |
| **D30 mm** | | | | | | | | | | | |
| **D10 mm** | | | | | | | | | | | |
| **Cu** | | | | | | | | | | | |
| **Cc** | | | | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | |




Checked By :

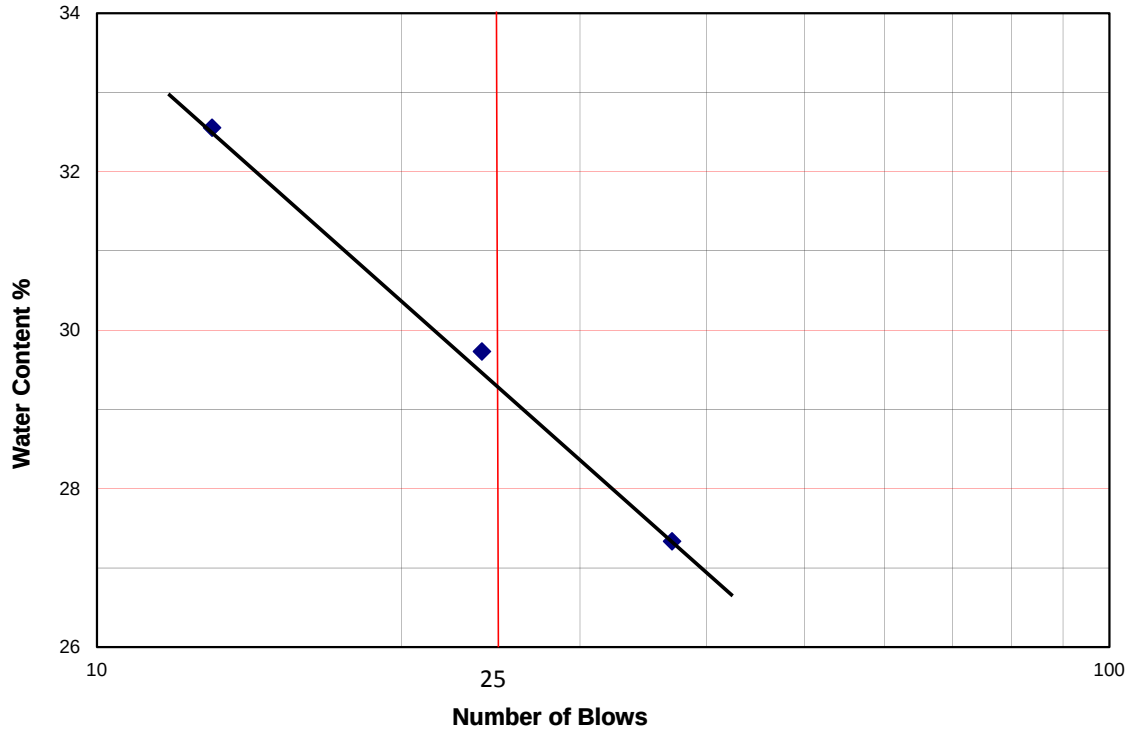
# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | : Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha | | | | | | | | | | | |
| **Job No.** | : CM 19 01 03 | | | | **Borehole No.** | : MBH-20 | | | **Date :** | 10-Apr-19 | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-20 | MBH-20 | MBH-20 | MBH-20 | | | | | | | | |
| **Depth (m)** | 10.00-10.45 | 11.50-11.95 | 13.00-13.45 | 14.50-14.95 | | | | | | | | |
| **Sample Type** | SPT-6 | SPT-7 | SPT-8 | SPT-9 | | | | | | | | |
| **Classification** | SC | SC | SC | | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 88 | 74 | 64 | 41 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | 35 | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | 24 | | | | | | | | |
| **Fines % (Silt+Clay)** | 12 | 26 | 36 | 59 | | | | | | | | |
| **D60 mm** | | | | | | | | | | | | |
| **D30 mm** | | | | | | | | | | | | |
| **D10 mm** | | | | | | | | | | | | |
| **Cu** | | | | | | | | | | | | |
| **Cc** | | | | | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |




Checked By :

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 28.78 | 24.47 | 31.82 | | |
| Dry Weight + Can (g) | 24.48 | 21.06 | 27.24 | | |
| Can Weight (g) | 8.75 | 9.59 | 13.17 | | |
| Water Content, % | 27.3 | 29.7 | 32.6 | | |
| Number of Blows | 37 | 24 | 13 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 21.99 | 20.52 | 19.44 |
| Dry Weight + Can (g) | 20.80 | 18.80 | 18.59 |
| Can Weight (g) | 14.02 | 8.87 | 13.73 |
| Water Content, % | 17.6 | 17.3 | 17.5 |

Liquid Limit % 29.3

Plastic Limit % 17.5

Plasticity Index % 11.8

Preparation of Sample :
Dry State

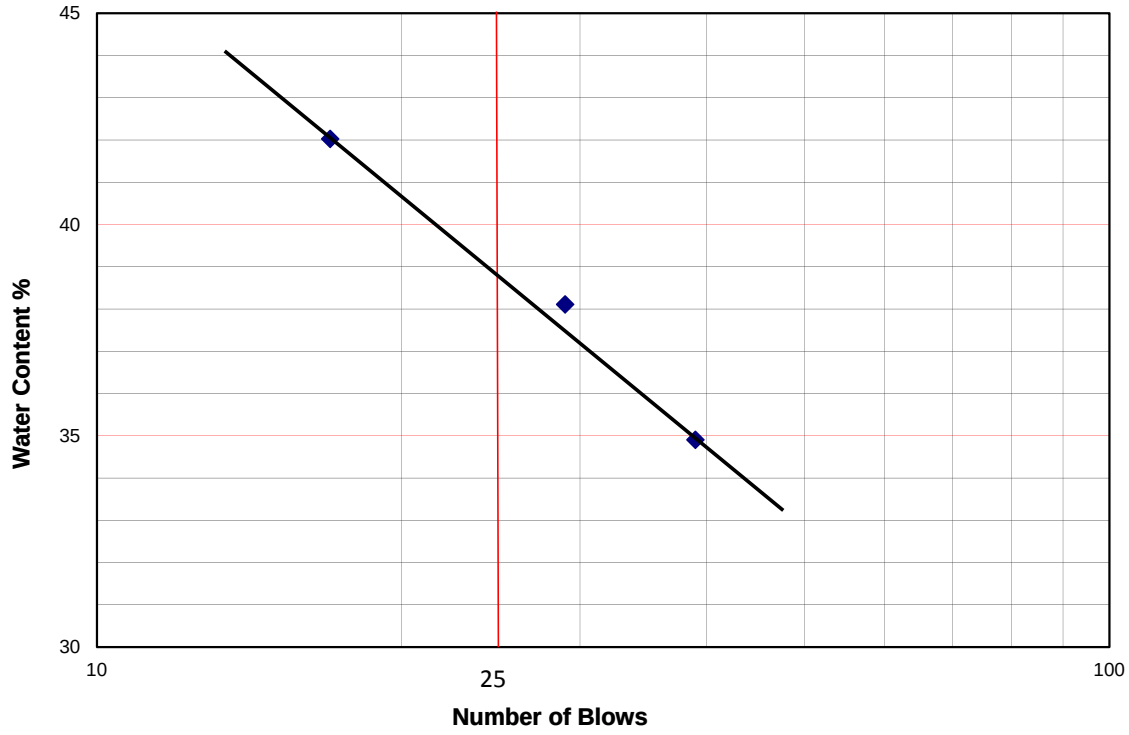
Sample Type: SPT-01

Borehole no.: MBH-20

Depth :1.10-1.45

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 27.01 | 31.55 | 35.37 | | |
| Dry Weight + Can (g) | 22.41 | 26.04 | 27.73 | | |
| Can Weight (g) | 9.23 | 11.58 | 9.55 | | |
| Water Content, % | 34.9 | 38.1 | 42.0 | | |
| Number of Blows | 39 | 29 | 17 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 19.25 | 17.93 | 14.97 |
| Dry Weight + Can (g) | 18.29 | 16.55 | 14.16 |
| Can Weight (g) | 12.76 | 8.51 | 9.52 |
| Water Content, % | 17.4 | 17.2 | 17.5 |

Liquid Limit % 38.9

Plastic Limit % 17.3

Plasticity Index % 21.6

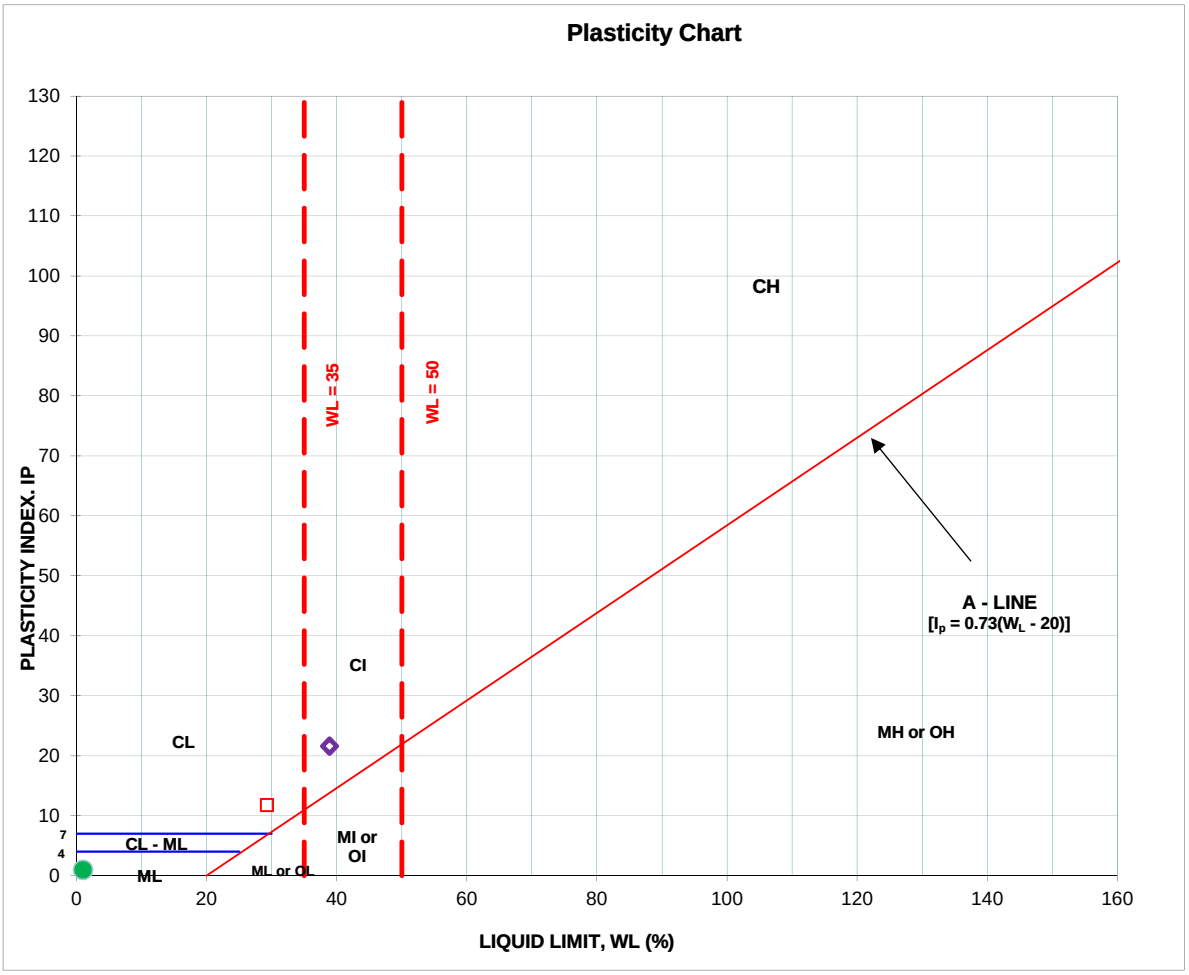
Preparation of Sample :
Dry State

Sample Type: SPT-02

Borehole no.: MBH-20

Depth :4.00-4.45

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.




| | Sample Type | Depth (m) | $W_L$ | $W_P$ | $I_P$ | Remarks |
|---|---|---|---|---|---|---|
| □ | SPT-01 | 1.10-1.45 | 29.3 | 17.5 | 11.8 | CL: Inorganic clays of low to medium plasticity. |
| ◇ | SPT-02 | 4.00-4.45 | 38.9 | 17.3 | 21.6 | CI: Clays with Intermediate plasticity |
| △ | | | | | | |
| ● | | | | | | |
| + | | | | | | |
| ■ | | | | | | |

| | | | |
|---|---|---|---|
| ML | Inorganic silts, very fine sands, rock flour, silty or clayey fine sands | MH | Inorganic silts, or diatomaceous fine sands or silts, elastic silts |
| CL | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays | CH | Inorganic clays of high plasticity, fat clays |
| OL | Organic silts and organic silty clays of low plasticity | OH | Organic silts and organic clays of medium t high plasticity |
| CI | Clays with Intermediate plasticity | MI | Silt with intermediate plasticity |

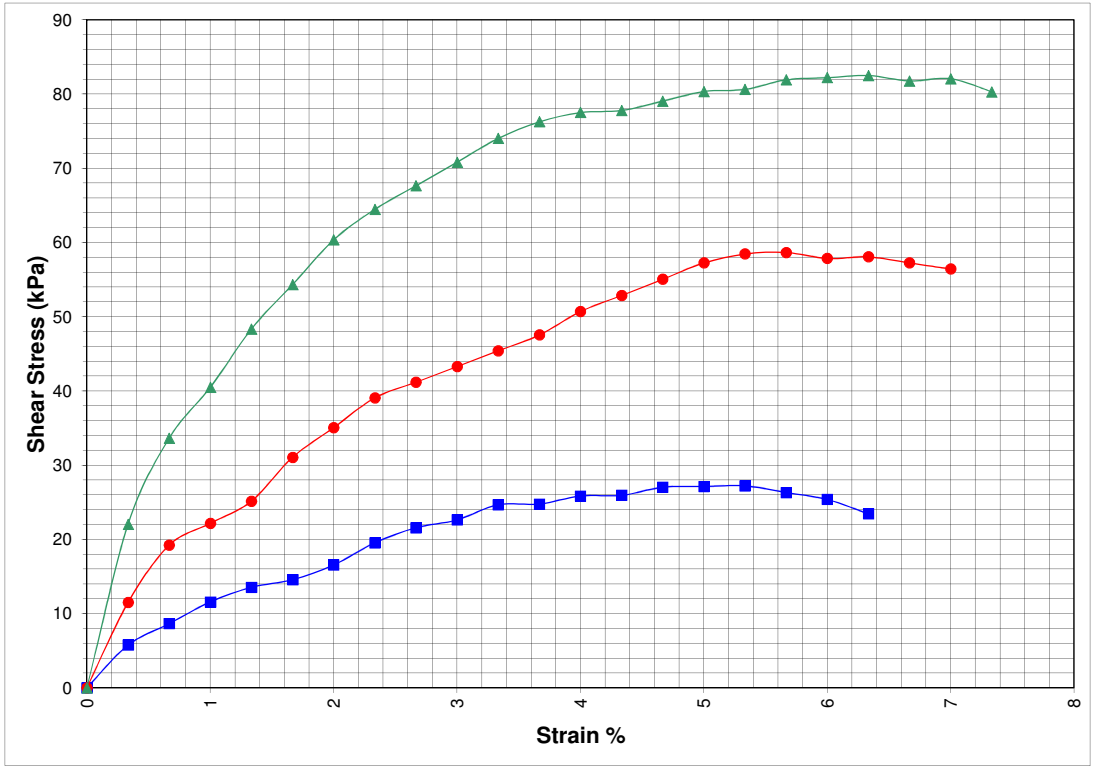
## PLASTICITY CHART (IS : 1498 - 1987)

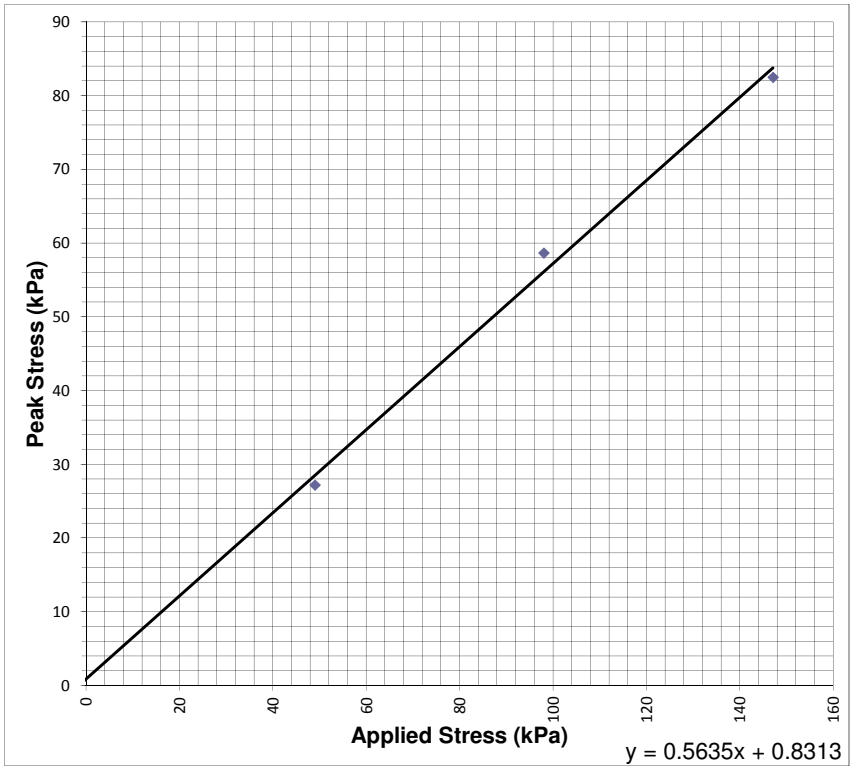
BOREHOLE NAME : MBH-20

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 59 |
| | Stage 3 | 147 | 82 |

| | | |
|---|---|---|
| Angle of Friction | **29.4** | ° |
| Apparent Cohesion | **0.83** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

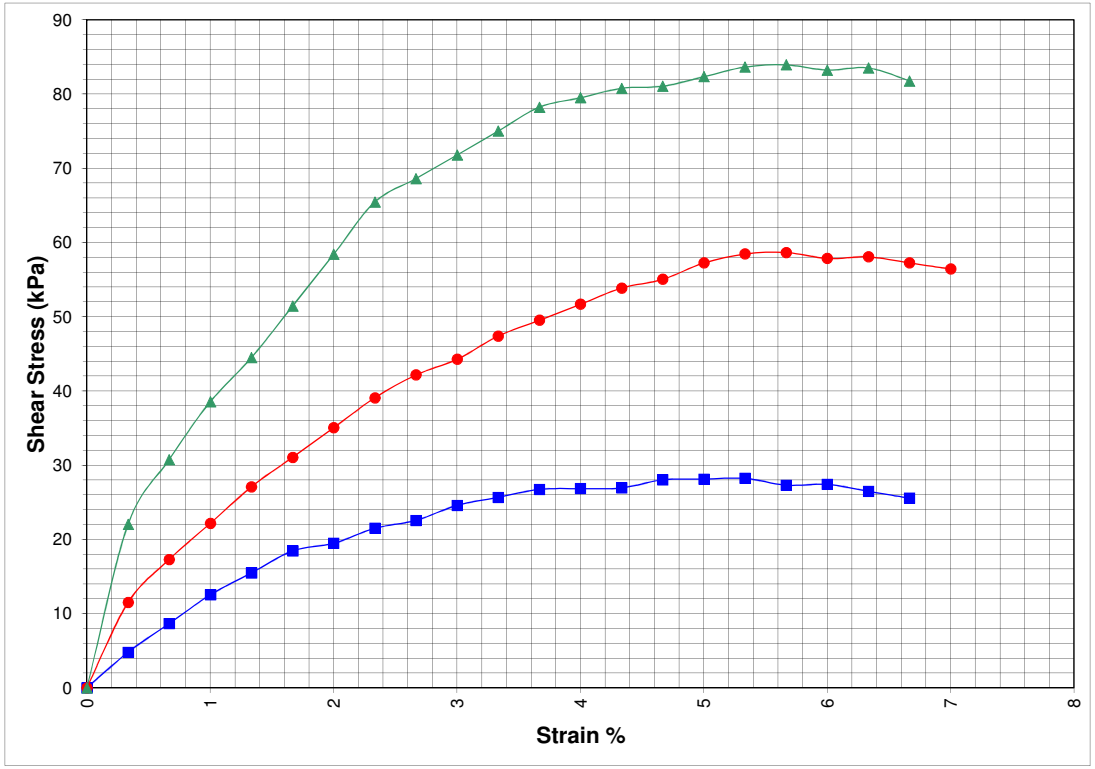
**Borehole: MBH-20**

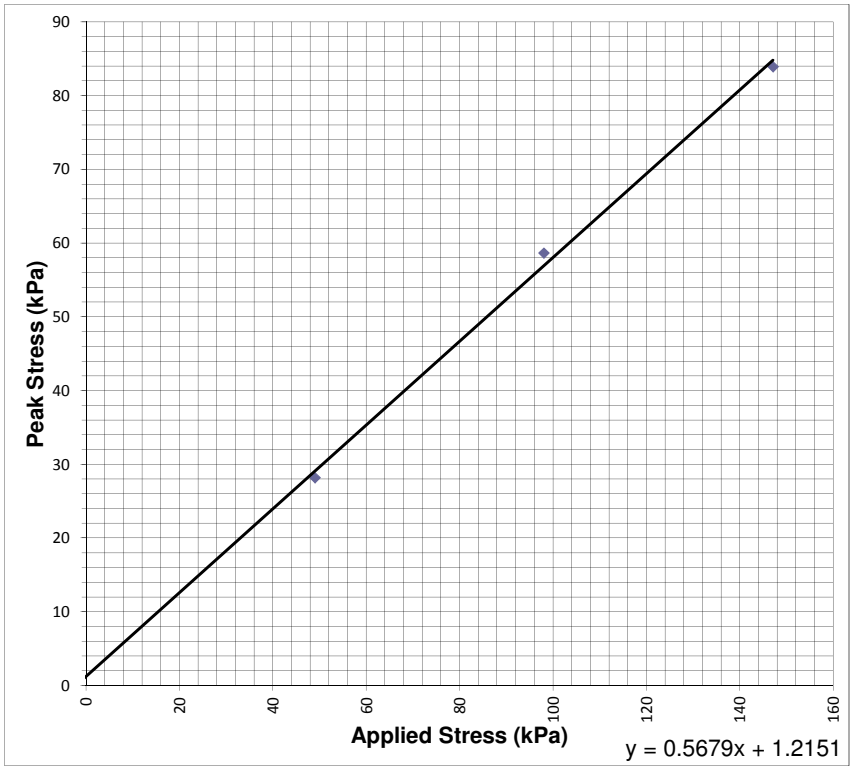
**Sample Type: SPT-01**

**Depth: 1.00-1.10 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 59 |
| | Stage 3 | 147 | 84 |

| | | |
|---|---|---|
| Angle of Friction | **29.6** | ° |
| Apparent Cohesion | **1.22** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

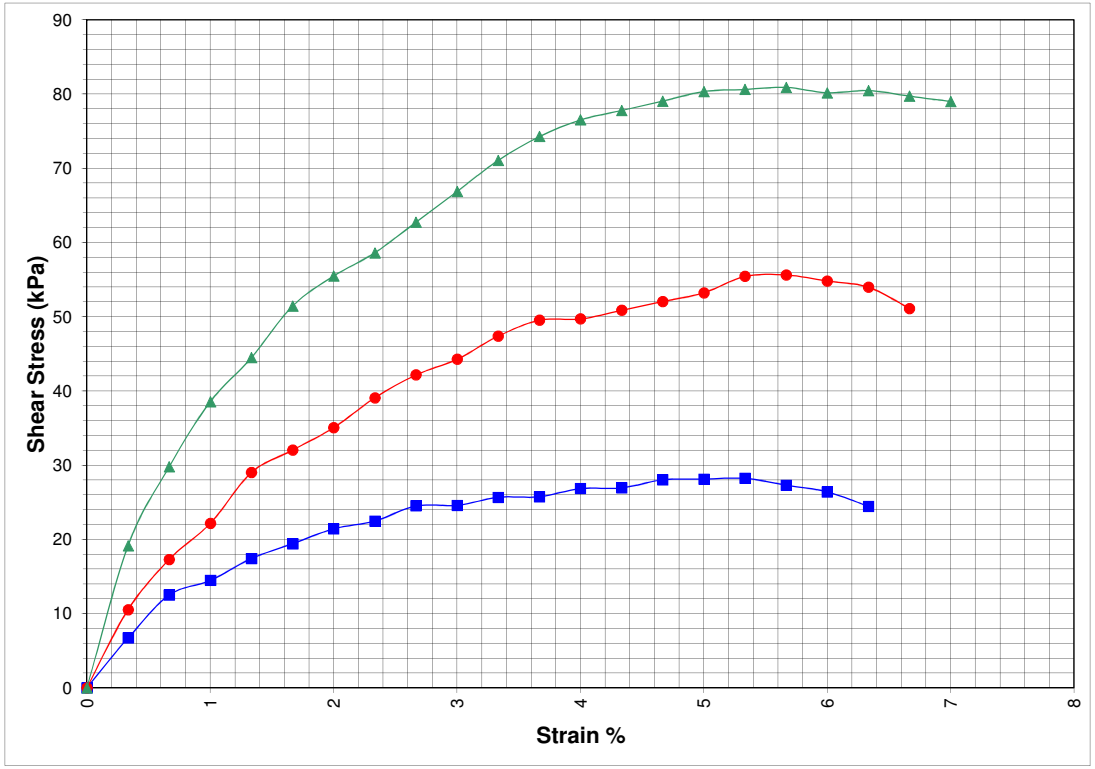
**Borehole: MBH-20**

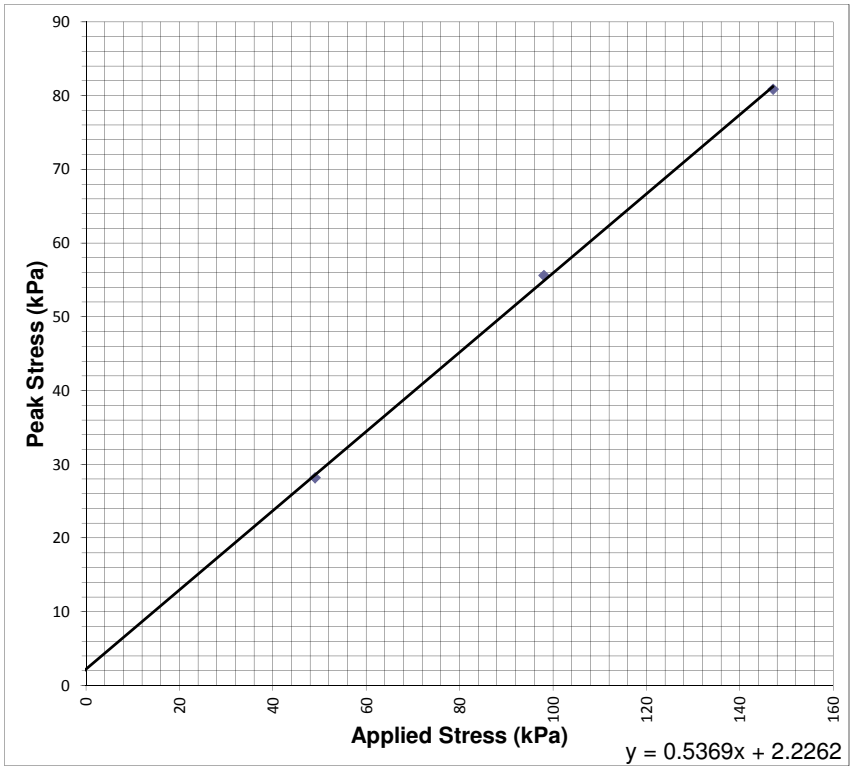
**Sample Type: SPT-03**

**Depth: 5.65-5.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 56 |
| | Stage 3 | 147 | 81 |

| | | |
|---|---|---|
| Angle of Friction | **28.2** | ° |
| Apparent Cohesion | **2.23** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

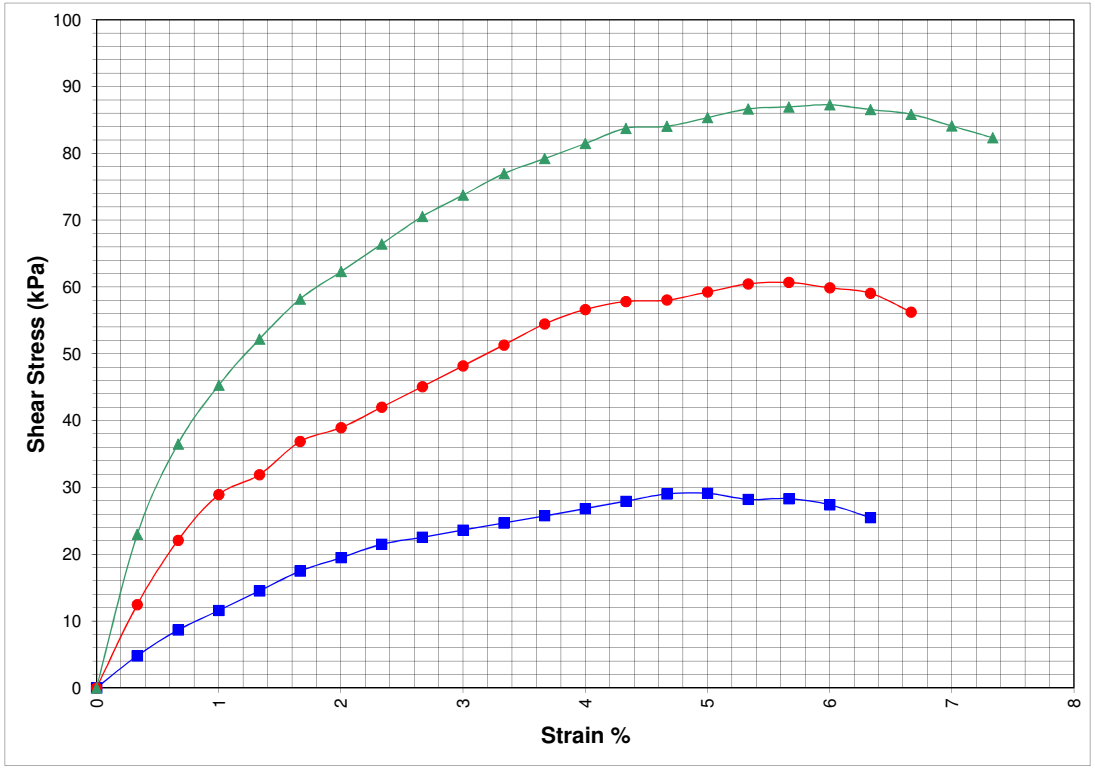
**Borehole: MBH-20**

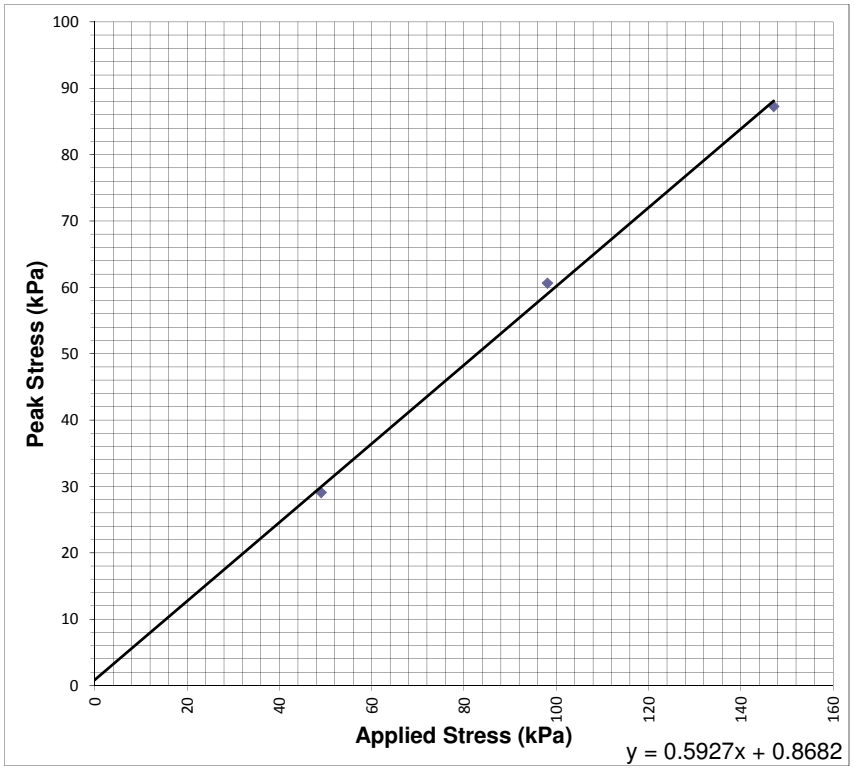
**Sample Type: SPT-04**

**Depth: 7.00-7.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 29 |
| | Stage 2 | 98 | 61 |
| | Stage 3 | 147 | 87 |

| | | |
|---|---|---|
| Angle of Friction | **30.6** | ° |
| Apparent Cohesion | **0.87** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

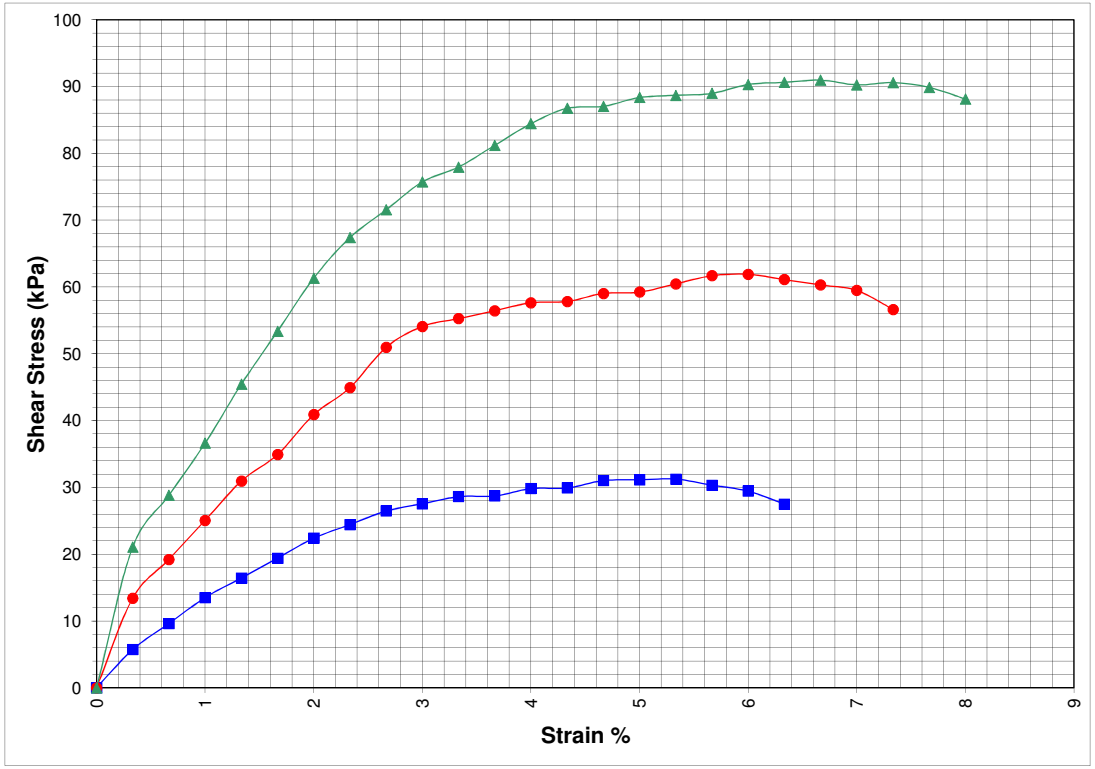
**Borehole: MBH-20**

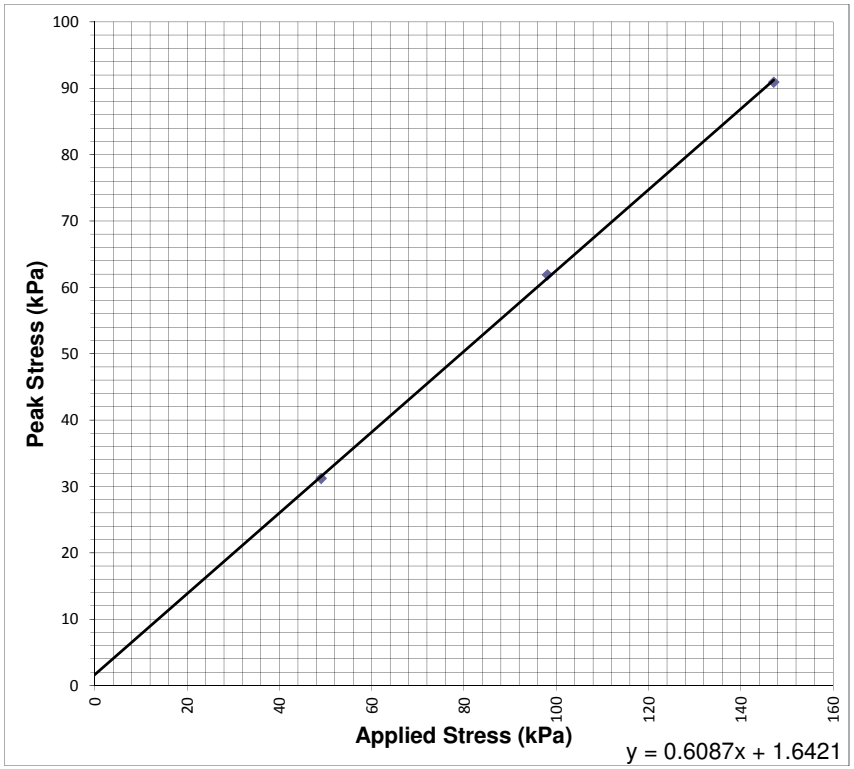
**Sample Type: SPT-07**

**Depth: 11.50-11.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 31 |
| | Stage 2 | 98 | 62 |
| | Stage 3 | 147 | 91 |

| | | |
|---|---|---|
| Angle of Friction | **31.3** | ° |
| Apparent Cohesion | **1.64** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: MBH-20**

**Sample Type: SPT-08**

**Depth: 13.00-13.45 m**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| UDS-1 | 0.00-1.00 | CL | 29.1 | 14.4 | 14.7 | 48.8 | 17.14 | 7.08 | 11.52 | 2.53 | 0 | 26 | 55 | 19 | 74 | | | | | | | | | 10.0 | | | | | | | | | |
| SPT-1 | 1.50-1.95 | SC | | | | 19.8 | 18.78 | 8.72 | 12.62 | 2.57 | 0 | 66 | 24 | 10 | 34 | | | | | | | | | | | | | | | | | | |
| SPT-2 | 3.00-3.45 | | 30.7 | 13.8 | 16.9 | 16.5 | 21.72 | 11.66 | 14.59 | 2.56 | 0 | 62 | 15 | 23 | 38 | | | | | | | | | 55.6 | | | | | | | | | |
| SPT-3 | 4.50-4.95 | SM \ SC | | | | 16.1 | 18.52 | 8.46 | 15.95 | | 0 | 83 | <--> | <--> | 17 | DST | | | 2.89 | 29.5 | | | | | | | | | | | | | |
| SPT-4 | 6.00-6.45 | | | | | 19.1 | 18.60 | 8.54 | 15.62 | 2.57 | 0 | 83 | <--> | <--> | 17 | | | | | | | | | | | | | | | | | | |
| SPT-5 | 7.50-7.95 | | | | | 16.5 | 19.50 | 9.44 | 16.73 | | 1 | 87 | <--> | <--> | 12 | | | | | | | | | | | | | | | | | | |
| SPT-6 | 9.00-9.45 | | | | | 16.3 | 20.18 | 10.12 | 17.35 | 2.64 | 2 | 80 | <--> | <--> | 18 | DST | | | 1.13 | 32.1 | | | | | | | | | | | | | |
| SPT-7 | 10.50-10.95 | | | | | 19.3 | 19.57 | 9.51 | 16.40 | | 0 | 89 | <--> | <--> | 11 | DST | | | 1.75 | 31.8 | | | | | | | | | | 8.22 | 0.62 | 2.00 | 1900 | 8850 |
| SPT-8 | 12.00-12.45 | | | | | 23.3 | 18.89 | 8.83 | 15.32 | | 0 | 39 | <--> | <--> | 61 | | | | | | | | | | | | | | | | | | |
| SPT-9 | 13.70-14.15 | SM \ SC | | | | 25.4 | 19.07 | 9.01 | 15.21 | 2.61 | 1 | 61 | <--> | <--> | 38 | DST | | | 2.35 | 30.5 | | | | | | | | | | | | | |
| **END OF BOREHOLE** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

\# : Decayed Wood

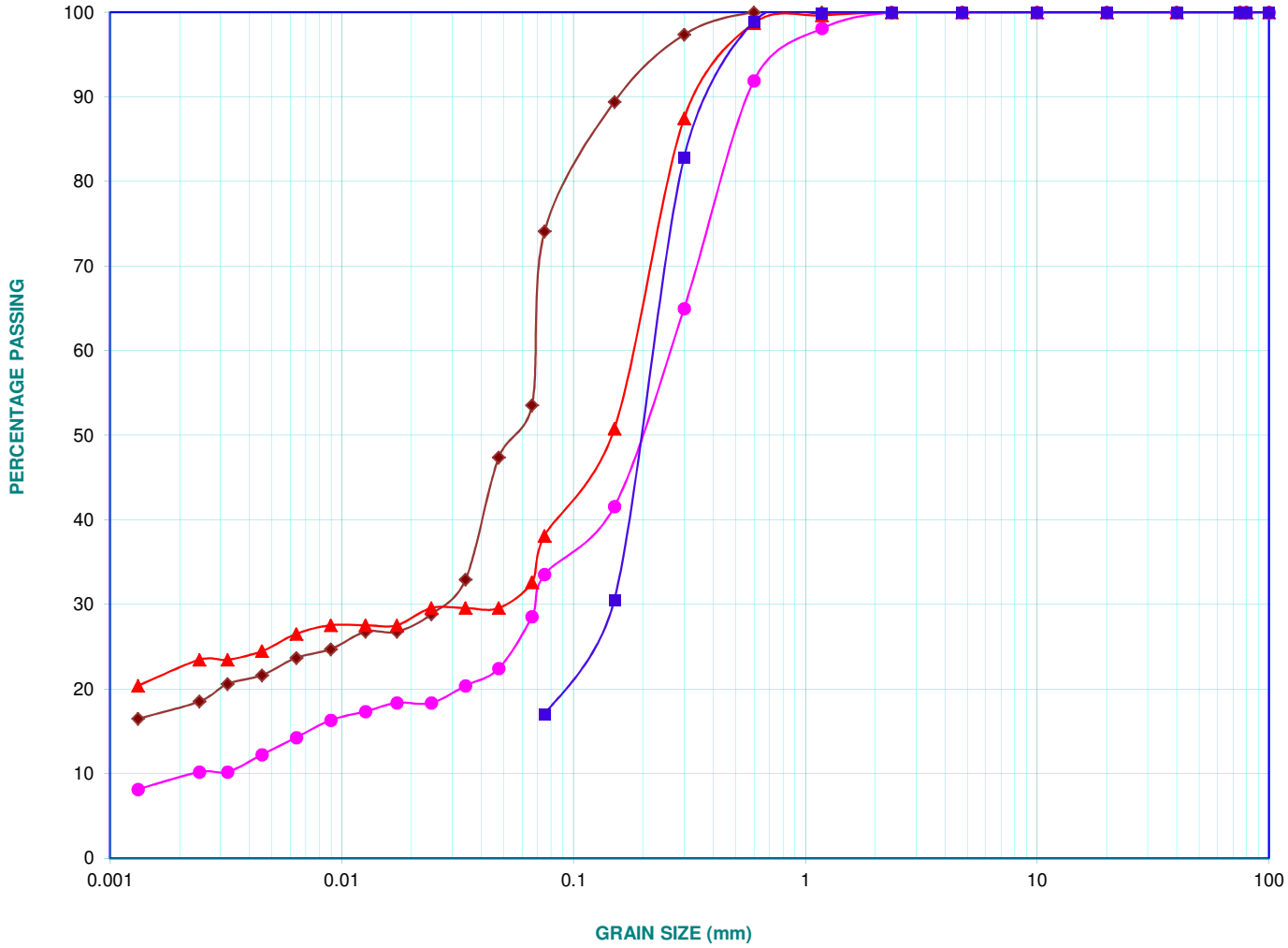
**Failure Type**
A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-21**

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-21** |
| **Date :** | **10-Apr-19** |

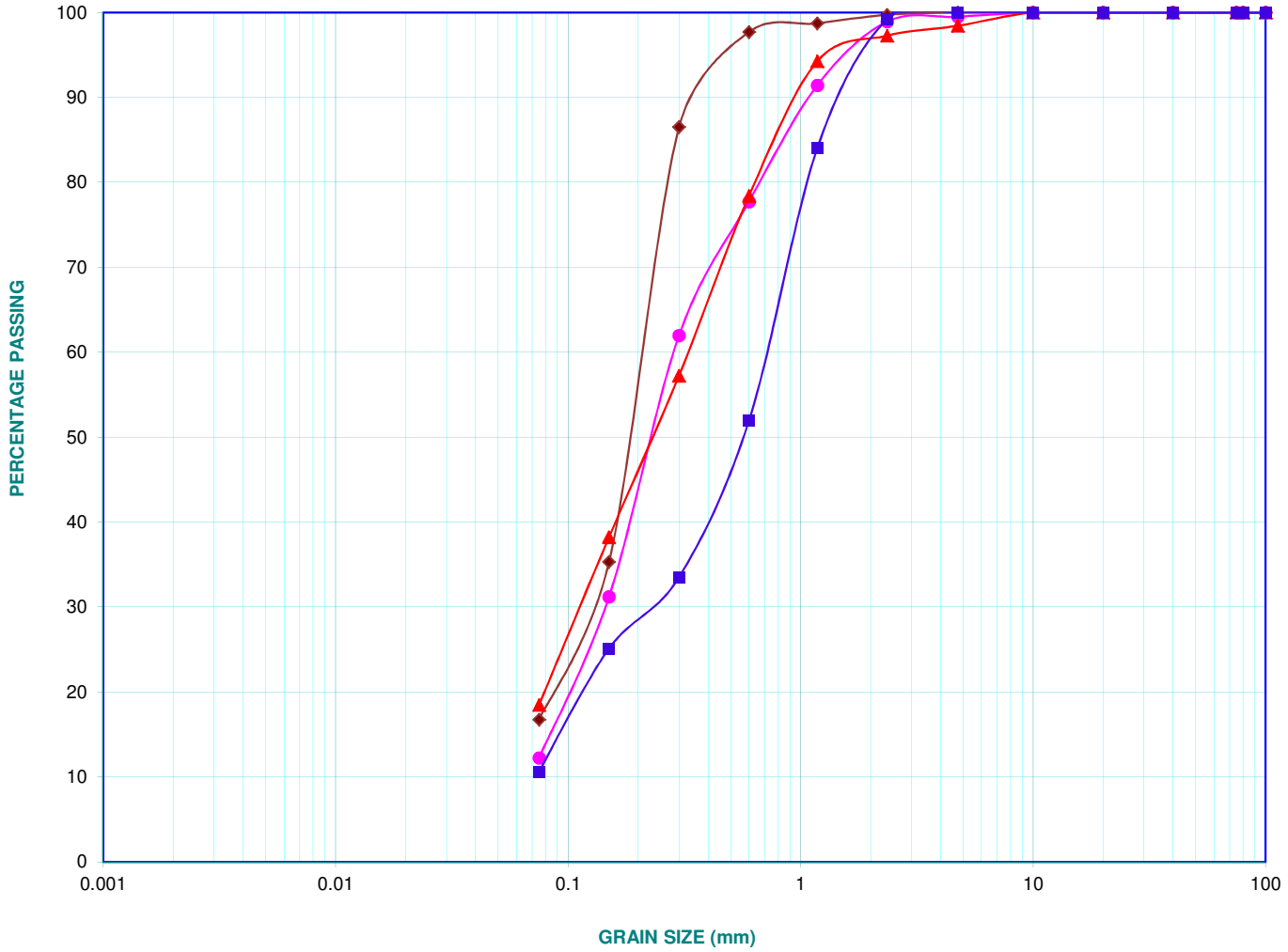
| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| Bore Hole . | MBH-21 | MBH-21 | MBH-21 | MBH-21 | | | | | | | | |
| Depth (m) | 0.00-1.00 | 1.50-1.95 | 3.00-3.45 | 4.50-4.95 | | | | | | | | |
| Sample Type | UDS-1 | SPT-1 | SPT-2 | SPT-3 | | | | | | | | |
| Classification | CL | SC | SC | SM \ SC | | | | | | | | |
| Gravel % | 0 | 0 | 0 | 0 | | | | | | | | |
| Sand % | 26 | 66 | 62 | 83 | | | | | | | | |
| Silt % | 55 | 24 | 15 | <----> | | | | | | | | |
| Clay % | 19 | 10 | 23 | <----> | | | | | | | | |
| Fines % (Silt+Clay) | 74 | 34 | 38 | 17 | | | | | | | | |
| D60 mm | | | | | | | | | | | | |
| D30 mm | | | | | | | | | | | | |
| D10 mm | | | | | | | | | | | | |
| Cu | | | | | | | | | | | | |
| Cc | | | | | | | | | | | | |
| Liquid Limit % | 29.1 | --- | 30.7 | --- | | | | | | | | |
| Plastic Limit % | 14.4 | --- | 13.8 | --- | | | | | | | | |
| Plasticity Index | 14.7 | --- | 16.9 | --- | | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

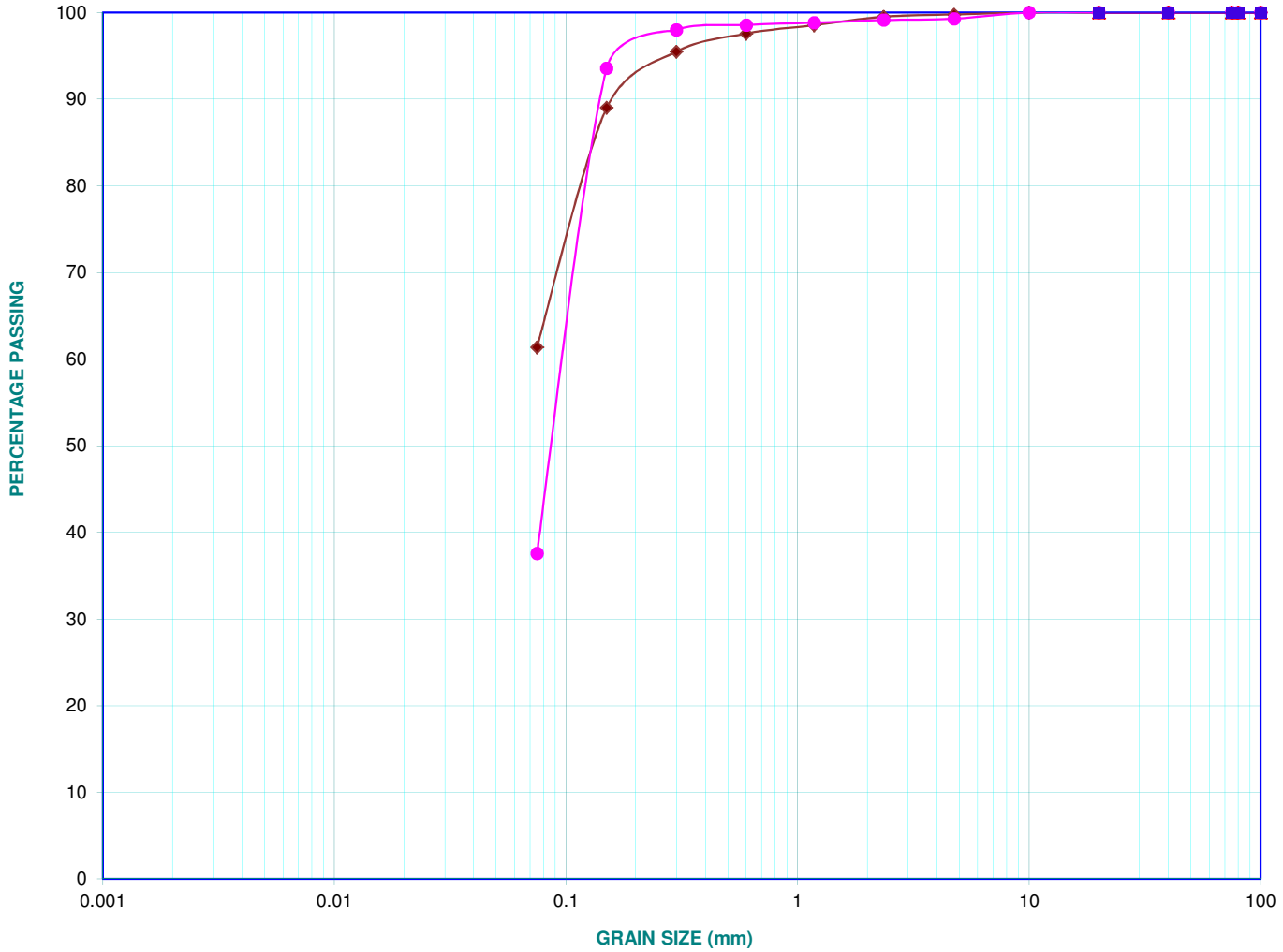
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | | **Borehole No.** | **: MBH-21** | | | | **Date :** | **10-Apr-19** | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-21 | MBH-21 | MBH-21 | MBH-21 | | | | | | | | |
| **Depth (m)** | 6.00-6.45 | 7.50-7.95 | 9.00-9.45 | 10.50-10.95 | | | | | | | | |
| **Sample Type** | SPT-4 | SPT-5 | SPT-6 | SPT-7 | | | | | | | | |
| **Classification** | SM \ SC | SM \ SC | SM \ SC | SM \ SC | | | | | | | | |
| **Gravel %** | 0 | 1 | 2 | 0 | | | | | | | | |
| **Sand %** | 83 | 87 | 80 | 89 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 17 | 12 | 18 | 11 | | | | | | | | |
| **D60 mm** | | | | | | | | | | | | |
| **D30 mm** | | | | | | | | | | | | |
| **D10 mm** | | | | | | | | | | | | |
| **Cu** | | | | | | | | | | | | |
| **Cc** | | | | | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |




Checked By :

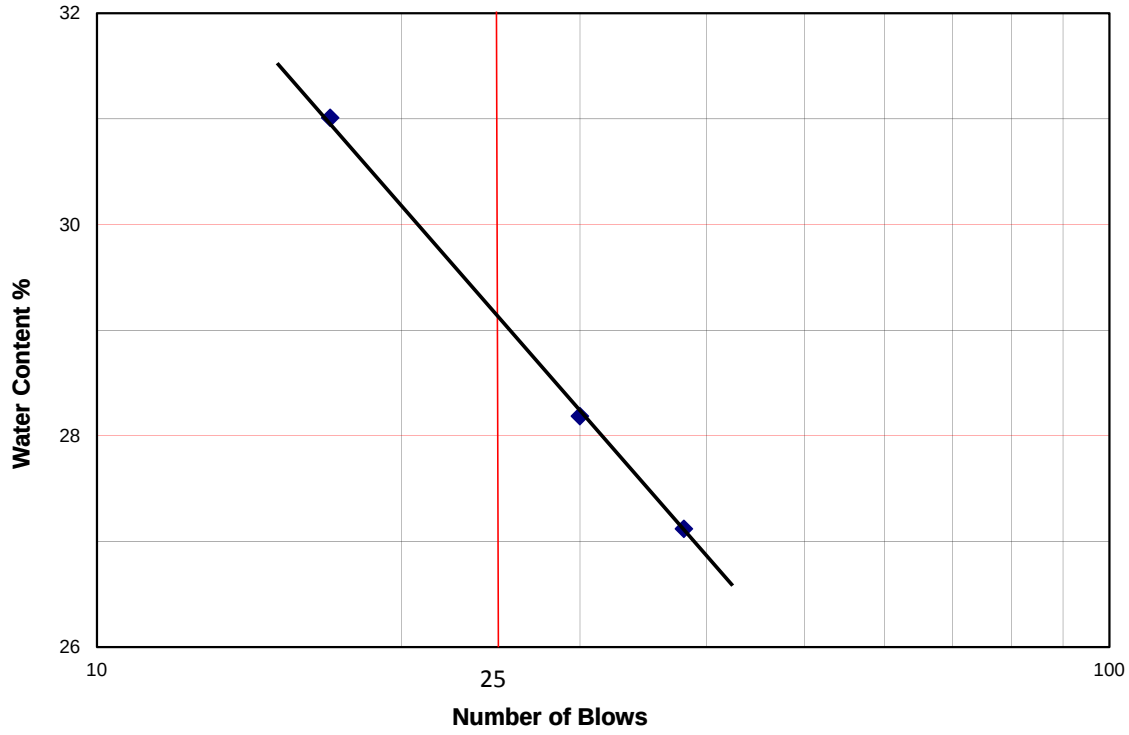
# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist Jagatsinghpur, Odisha** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | **Borehole No.** | **: MBH-21** | | | | **Date :** | **10-Apr-19** | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-21 | MBH-21 | | | | | | | | | | |
| **Depth (m)** | 12.00-12.45 | 13.70-14.15 | | | | | | | | | | |
| **Sample Type** | SPT-8 | SPT-9 | | | | | | | | | | |
| **Classification** | | SM \ SC | | | | | | | | | | |
| **Gravel %** | 0 | 1 | | | | | | | | | | |
| **Sand %** | 39 | 61 | | | | | | | | | | |
| **Silt %** | <----> | <----> | | | | | | | | | | |
| **Clay %** | <----> | <----> | | | | | | | | | | |
| **Fines % (Silt+Clay)** | 61 | 38 | | | | | | | | | | |
| **D60 mm** | | | | | | | | | | | | |
| **D30 mm** | | | | | | | | | | | | |
| **D10 mm** | | | | | | | | | | | | |
| **Cu** | | | | | | | | | | | | |
| **Cc** | | | | | | | | | | | | |
| **Liquid Limit %** | --- | --- | | | | | | | | | | |
| **Plastic Limit %** | --- | --- | | | | | | | | | | |
| **Plasticity Index** | --- | --- | | | | | | | | | | |




Checked By :

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 28.98 | 27.83 | 35.07 | | |
| Dry Weight + Can (g) | 25.59 | 23.74 | 29.78 | | |
| Can Weight (g) | 13.09 | 9.23 | 12.72 | | |
| Water Content, % | 27.1 | 28.2 | 31.0 | | |
| Number of Blows | 38 | 30 | 17 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 16.03 | 18.45 | 18.58 |
| Dry Weight + Can (g) | 15.21 | 17.64 | 17.87 |
| Can Weight (g) | 9.52 | 11.99 | 12.93 |
| Water Content, % | 14.4 | 14.3 | 14.4 |

Liquid Limit % 29.1

Plastic Limit % 14.4

Plasticity Index % 14.7

Preparation of Sample :
Dry State

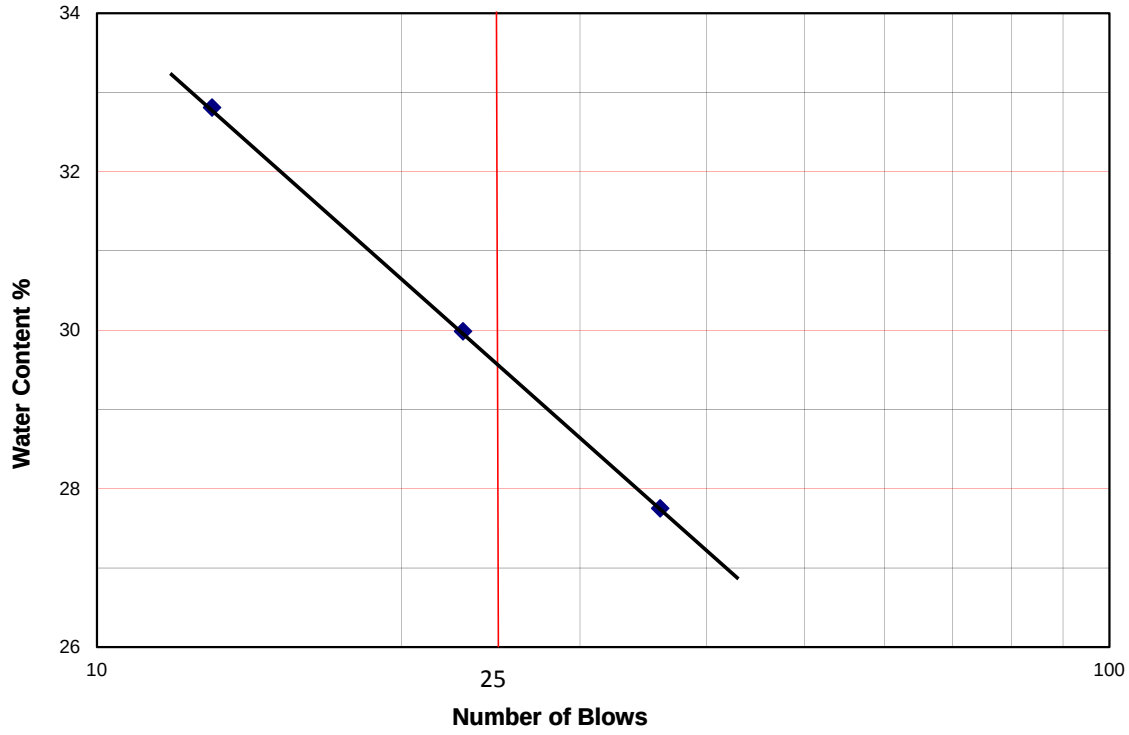
Sample Type: UDS-01

Borehole no.: MBH-21

Depth :0.00-0.10

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 29.46 | 25.24 | 32.99 | | |
| Dry Weight + Can (g) | 25.00 | 21.54 | 28.00 | | |
| Can Weight (g) | 8.93 | 9.20 | 12.79 | | |
| Water Content, % | 27.8 | 30.0 | 32.8 | | |
| Number of Blows | 36 | 23 | 13 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 17.75 | 18.42 | 18.58 |
| Dry Weight + Can (g) | 17.15 | 17.85 | 18.00 |
| Can Weight (g) | 12.82 | 13.63 | 13.85 |
| Water Content, % | 13.9 | 13.5 | 14.0 |

Liquid Limit % 30.7

Plastic Limit % 13.8

Plasticity Index % 16.9

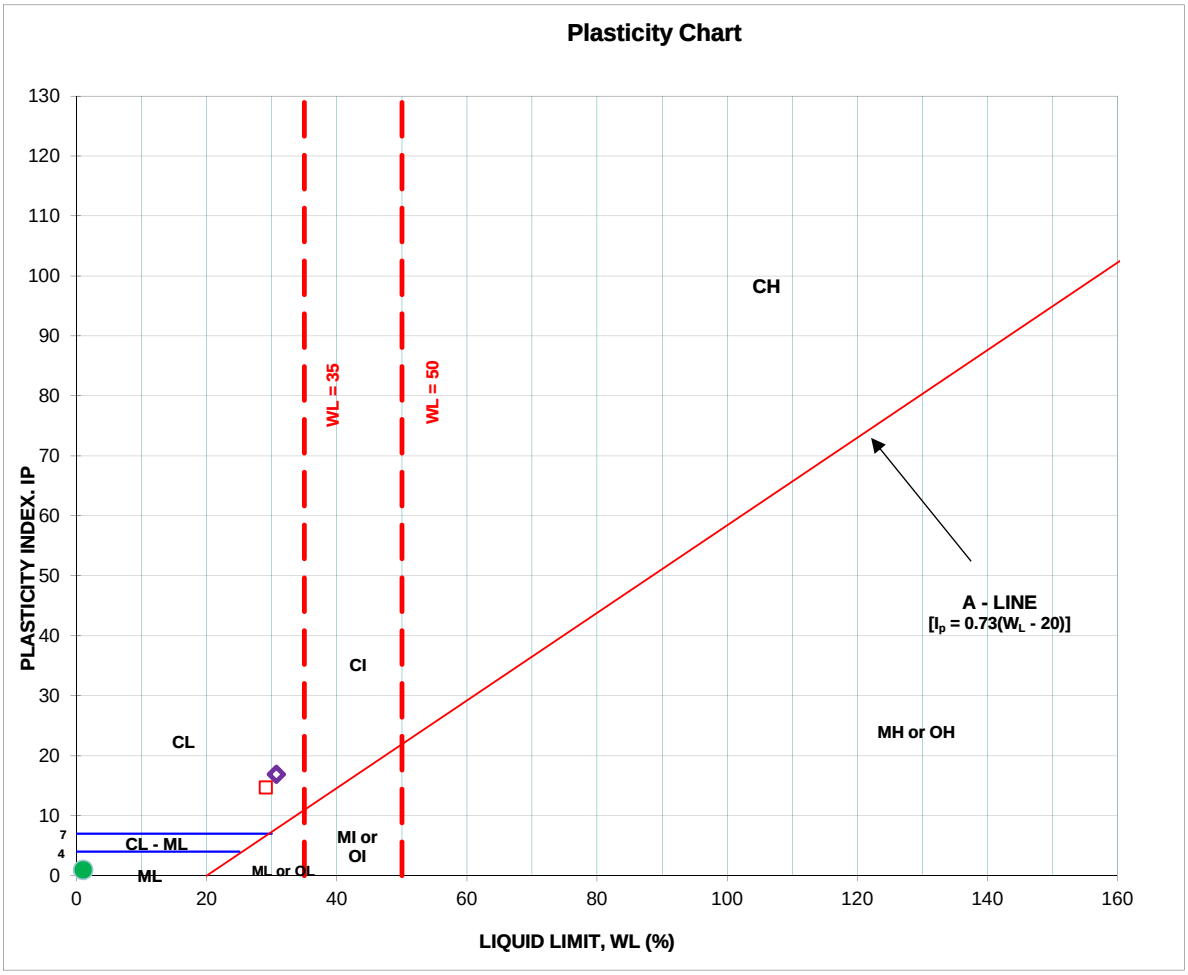
Preparation of Sample :
Dry State

Sample Type: SPT-02

Borehole no.: MBH-21

Depth :3.00-3.45

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.




| | Sample Type | Depth (m) | $W_L$ | $W_P$ | $I_P$ | Remarks |
|---|---|---|---|---|---|---|
| □ | UDS-01 | 0.00-1.00 | 29.1 | 14.4 | 14.7 | CL: Inorganic clays of low to medium plasticity. |
| ◇ | SPT-02 | 3.00-3.45 | 30.7 | 13.8 | 16.9 | CL: Inorganic clays of low to medium plasticity. |
| △ | | | | | p | |
| ● | | | | | | |
| + | | | | | | |
| ■ | | | | | | |

| | | | |
|---|---|---|---|
| ML | Inorganic silts, very fine sands, rock flour, silty or clayey fine sands | MH | Inorganic silts, or diatomaceous fine sands or silts, elastic silts |
| CL | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays | CH | Inorganic clays of high plasticity, fat clays |
| OL | Organic silts and organic silty clays of low plasticity | OH | Organic silts and organic clays of medium t high plasticity |
| CI | Clays with Intermediate plasticity | MI | Silt with intermediate plasticity |

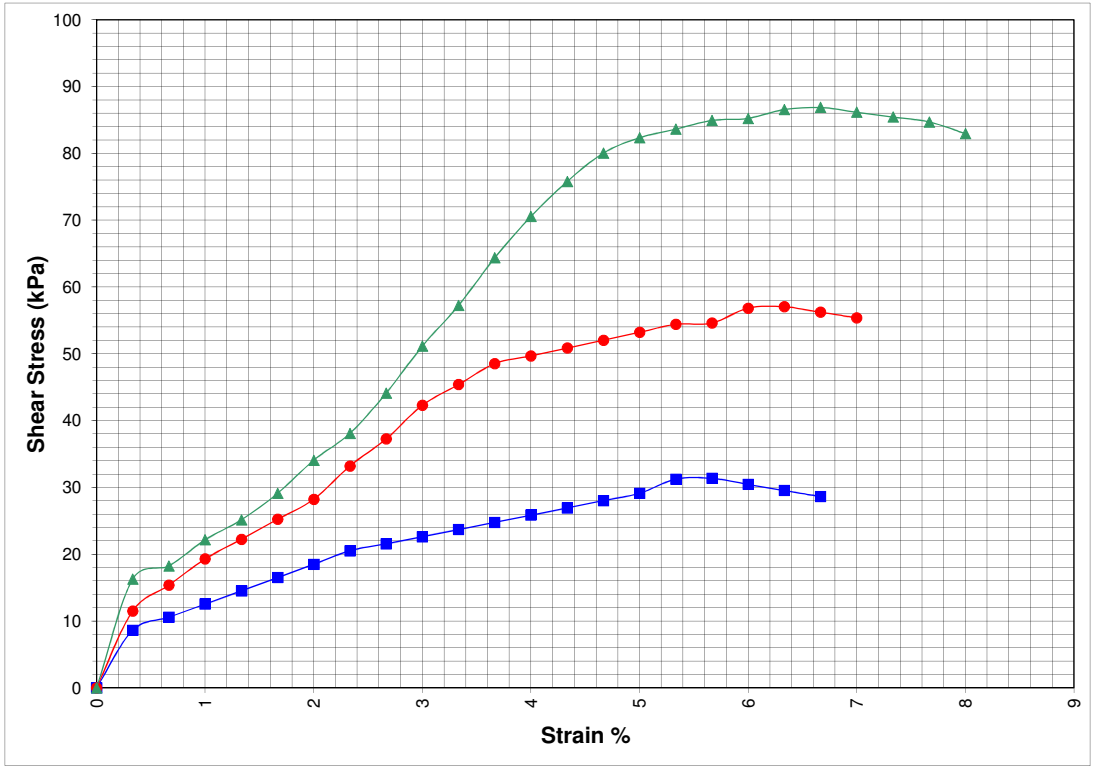
## PLASTICITY CHART (IS : 1498 - 1987)

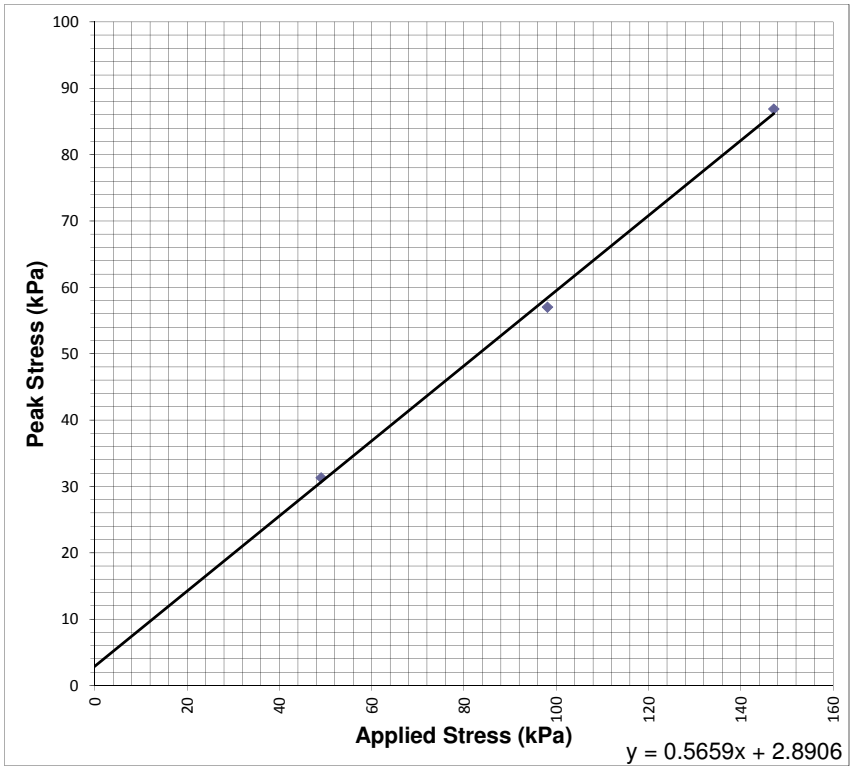
BOREHOLE NAME : MBH-21

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 31 |
| | Stage 2 | 98 | 57 |
| | Stage 3 | 147 | 87 |

| | | |
|---|---|---|
| Angle of Friction | **29.5** | ° |
| Apparent Cohesion | **2.89** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

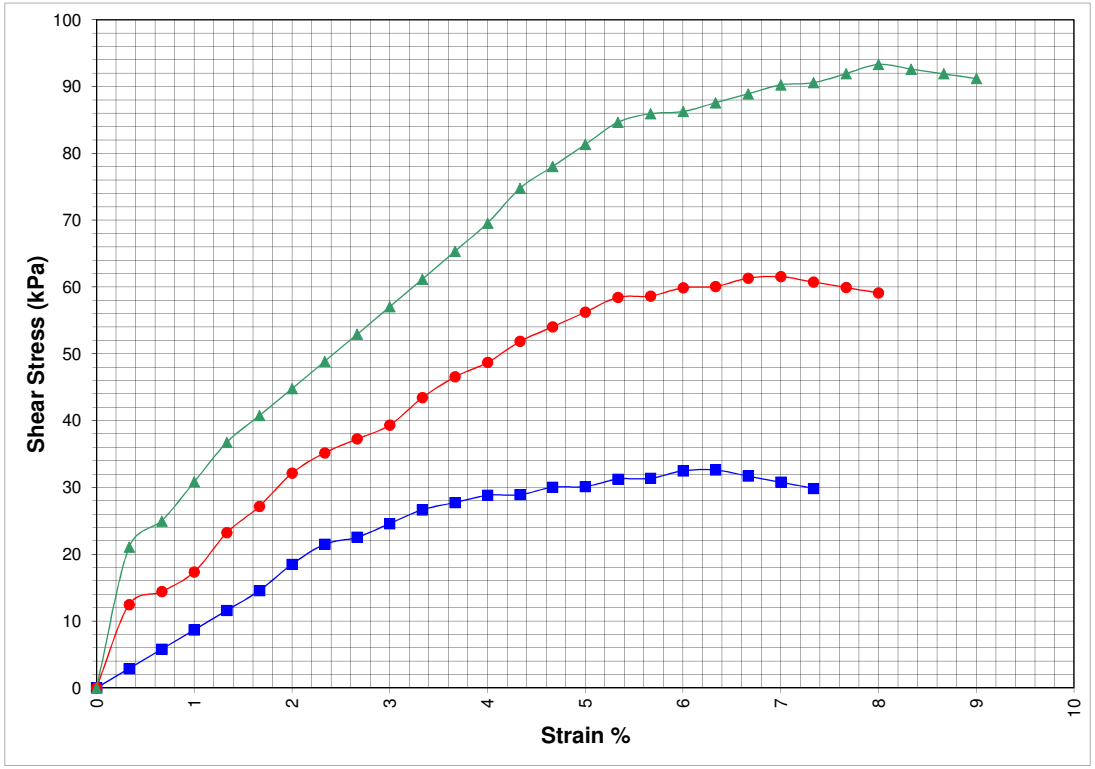
**Borehole: MBH-21**

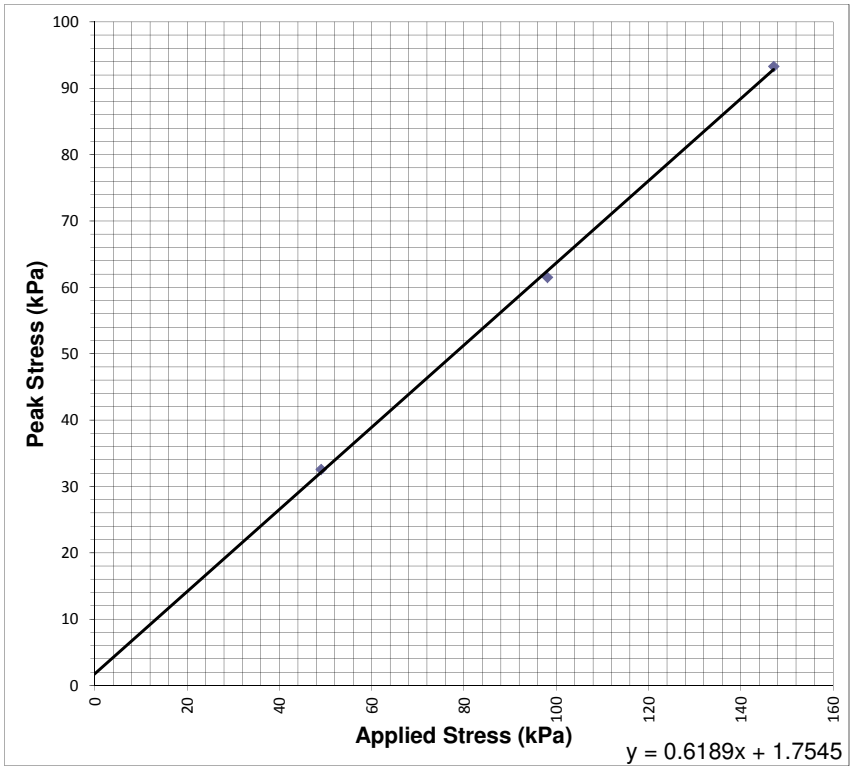
**Sample Type: SPT-3**

**Depth: 4.50-4.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 33 |
| | Stage 2 | 98 | 62 |
| | Stage 3 | 147 | 93 |

| | | |
|---|---|---|
| Angle of Friction | **31.8** | ° |
| Apparent Cohesion | **1.75** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

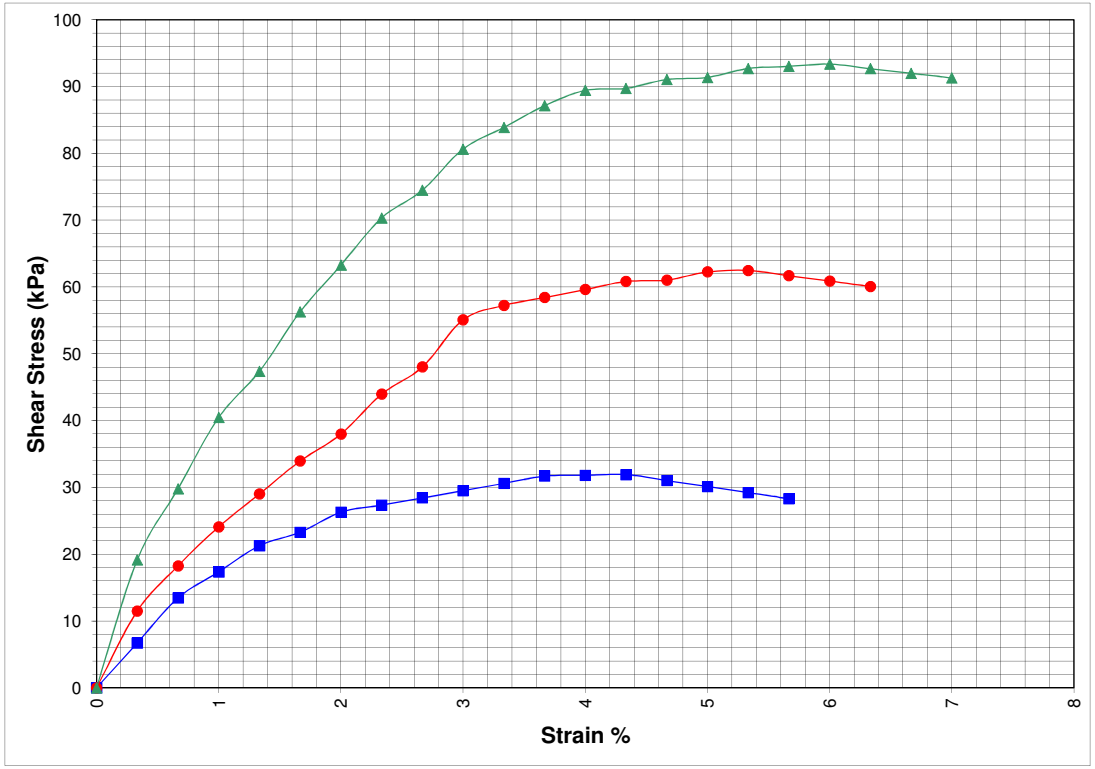
**Borehole: MBH-21**

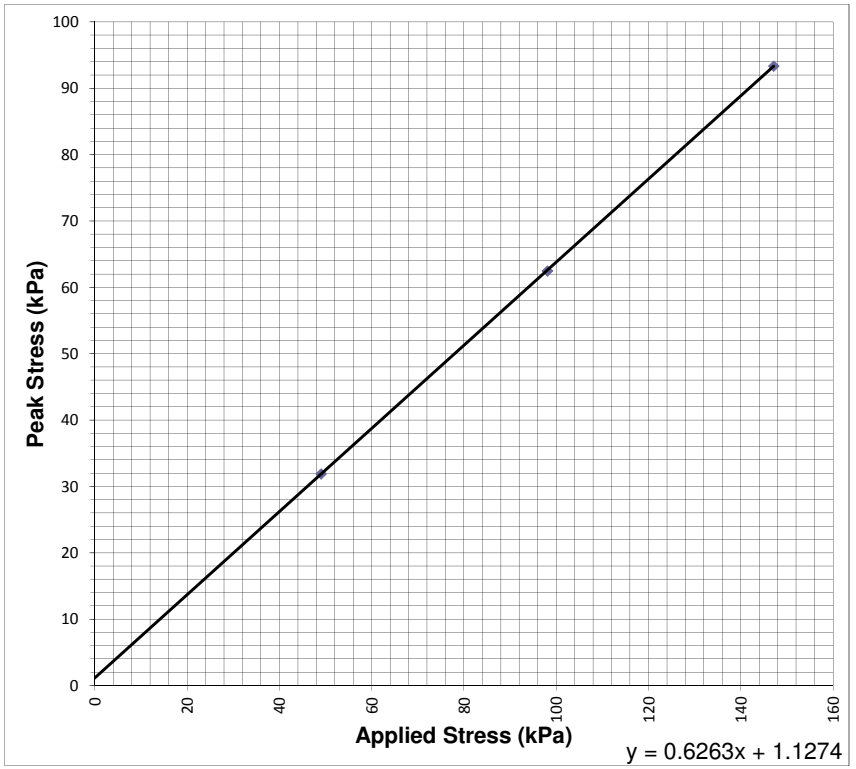
**Sample Type: SPT-7**

**Depth: 10.50-10.95 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 32 |
| | Stage 2 | 98 | 62 |
| | Stage 3 | 147 | 93 |

| | | |
|---|---|---|
| Angle of Friction | **32.1** | ° |
| Apparent Cohesion | **1.13** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

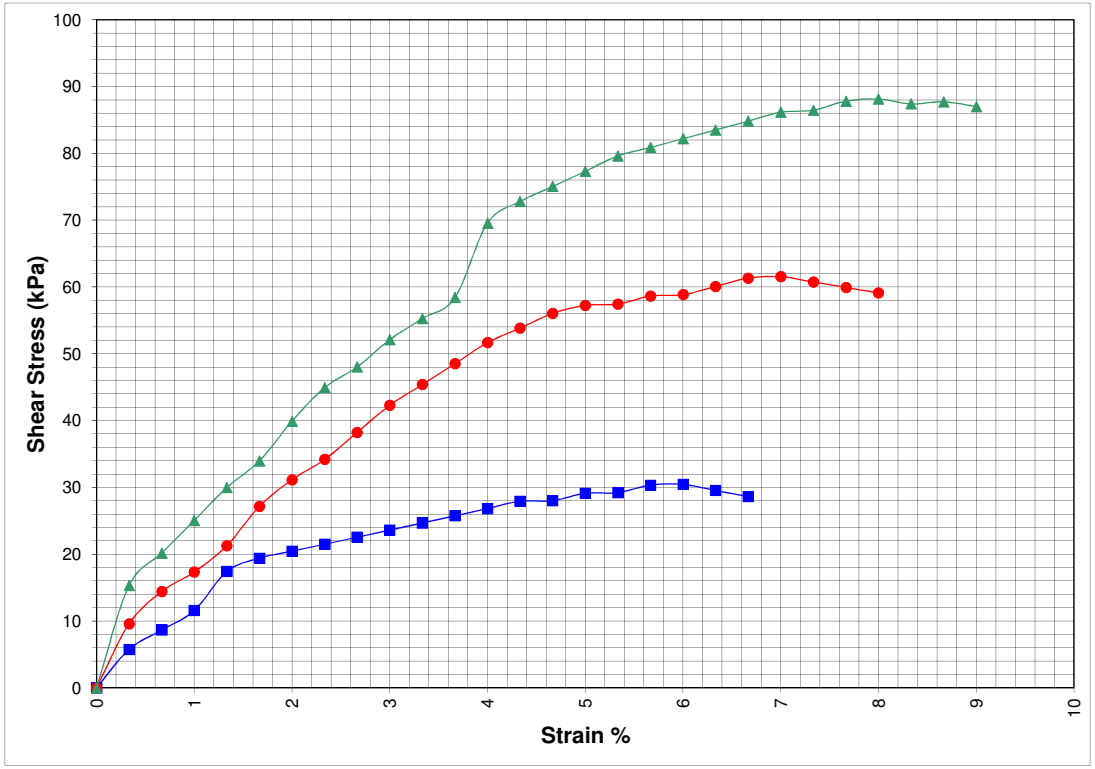
**Borehole: MBH-21**

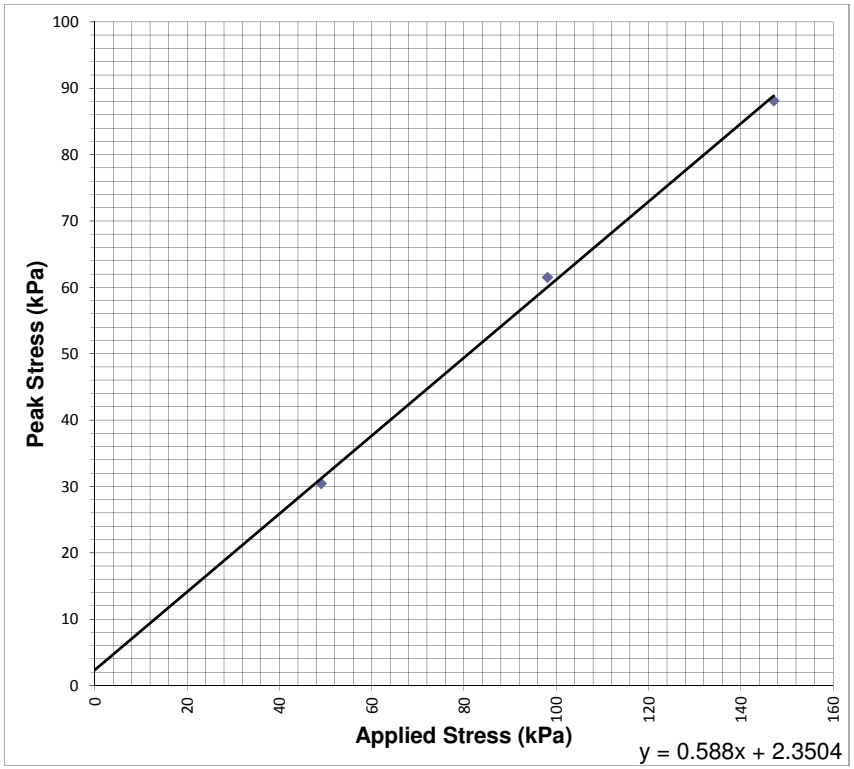
**Sample Type: SPT-6**

**Depth: 9.00-9.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 30 |
| | Stage 2 | 98 | 62 |
| | Stage 3 | 147 | 88 |

| | | |
|---|---|---|
| Angle of Friction | **30.5** | ° |
| Apparent Cohesion | **2.35** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: MBH-21**

**Sample Type: SPT-9**

**Depth: 13.70-14.15 m**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-1 | 0.00-0.45 | SP-SM | | | | 17.4 | 19.99 | 9.93 | 17.03 | | 0 | 90 | <--> | <--> | 10 | DST | | | 2.03 | 29.4 | | | | | | | | | | | | | |
| SPT-2 | 1.50-1.80 | | | | | 17.8 | 18.47 | 8.41 | 15.68 | 2.62 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-3 | 3.00-3.10 | | | | | 21.2 | 18.54 | 8.48 | 15.30 | | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-4 | 4.50-4.65 | | | | | 21.1 | 19.29 | 9.23 | 15.93 | 2.61 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-5 | 6.00-6.20 | | | | | 18.6 | 18.76 | 8.70 | 15.82 | 2.60 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-6 | 7.50-7.80 | | | | | 19.7 | 18.21 | 8.15 | 15.22 | | | | | | | DST | | | 1.65 | 28.7 | | | | | | | | | | | | | |
| SPT-7 | 9.00-9.30 | SM / SC | | | | 17.7 | 19.35 | 9.29 | 16.43 | | 0 | 67 | <--> | <--> | 33 | | | | | | | | | | | | | | | | | | |
| SPT-8 | 10.50-10.80 | SM / SC | | | | 20.0 | 18.22 | 8.16 | 15.19 | 2.59 | 0 | 84 | <--> | <--> | 16 | | | | | | | | | | | | | | | | | | |
| SPT-9 | 12.00-12.25 | | | | | 13.5 | 20.30 | 10.24 | 17.89 | | | | | | | DST | | | 2.15 | 29.7 | | | | | | | | | | | | | |
| SPT-10 | 13.50-13.80 | SM / SC | | | | 15.2 | 19.58 | 9.52 | 17.00 | | 0 | 79 | <--> | <--> | 21 | | | | | | | | | | | | | | | | | | |
| SPT-11 | 15.00-15.20 | | | | | 16.0 | 18.70 | 8.64 | 16.13 | 2.63 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-12 | 16.50-16.70 | | | | | 21.9 | 19.92 | 9.86 | 16.33 | | | | | | | | | | | | | | | | | | | | 8.30 | 1.20 | 2.00 | 2500 | 14160 |
| SPT-13 | 18.00-18.25 | | | | | 18.2 | 17.48 | 7.42 | 14.79 | | | | | | | DST | | | 1.59 | 25.2 | | | | | | | | | | | | | |
| SPT-14 | 19.50-19.75 | SP-SM | | | | 15.2 | 18.90 | 8.84 | 16.40 | | 1 | 93 | <--> | <--> | 6 | | | | | | | | | | | | | | | | | | |
| SPT-15 | 21.00-21.20 | SP-SM | | | | 19.7 | 18.81 | 8.75 | 15.71 | 2.64 | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | | | | |
| SPT-16 | 22.50-22.70 | | | | | 17.5 | 18.85 | 8.79 | 16.04 | | | | | | | DST | | | 0.90 | 26.4 | | | | | | | | | | | | | |
| SPT-17 | 24.00-24.25 | | | | | 19.7 | 18.70 | 8.64 | 15.62 | 2.62 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-18 | 25.50-25.70 | SM / SC | | | | 18.8 | 18.15 | 8.09 | 15.28 | | 0 | 85 | <--> | <--> | 15 | | | | | | | | | | | | | | | | | | |
| SPT-19 | 27.00-27.15 | | | | | 21.0 | 18.10 | 8.04 | 14.96 | | | | | | | DST | | | 2.10 | 27.0 | | | | | | | | | | | | | |
| SPT-20 | 28.50-28.70 | SM / SC | | | | 17.3 | 17.32 | 7.26 | 14.77 | 2.60 | 0 | 78 | <--> | <--> | 22 | | | | | | | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

\# : Decayed Wood

**Failure Type**

A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-22**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density ($kN/m^3$) | Submerged Unit Weight ($kN/m^3$) | Dry Density ($kN/m^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-21 | 30.00-30.20 | | | | | 21.7 | 17.33 | 7.27 | 14.24 | | | | | | | | | | | | | | | | | | | | 8.22 | 1.10 | 2.00 | 3600 | 3540 |
| SPT-22 | 31.50-31.65 | | | | | 22.1 | 17.29 | 7.23 | 14.16 | 2.59 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-23 | 33.00-33.15 | | | | | 22.5 | 17.40 | 7.34 | 14.21 | | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-24 | 34.50-34.65 | | | | | 22.2 | 17.48 | 7.42 | 14.30 | 2.60 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-25 | 36.00-36.30 | | | | | 20.9 | 17.51 | 7.45 | 14.48 | | | | | | | DST | | | 3.26 | 26.5 | | | | | | | | | | | | |
| SPT-26 | 37.50-37.65 | SM / SC | | | | 16.8 | 17.29 | 7.23 | 14.80 | | 0 | 79 | <--> | <--> | 21 | | | | | | | | | | | | | | | | | | |
| SPT-27 | 39.00-39.20 | | | | | 17.2 | 18.22 | 8.16 | 15.55 | | | | | | | DST | | | 2.60 | 26.6 | | | | | | | | | | | | |
| SPT-28 | 40.50-40.60 | | | | | 16.0 | 17.82 | 7.76 | 15.35 | 2.61 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-29 | 42.00-42.10 | SM / SC | | | | 12.8 | 17.35 | 7.29 | 15.37 | | 0 | 84 | <--> | <--> | 16 | | | | | | | | | | | | | | | | | | |
| SPT-30 | 43.50-43.65 | SM / SC | | | | 13.0 | 17.16 | 7.10 | 15.18 | | 0 | 85 | <--> | <--> | 15 | | | | | | | | | | | | | | | | | | |
| SPT-31 | 45.00-45.10 | | | | | 14.0 | 17.21 | 7.15 | 15.10 | | | | | | | | | | | | | | | | | | | | | | | | |
| **END OF BOREHOLE** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
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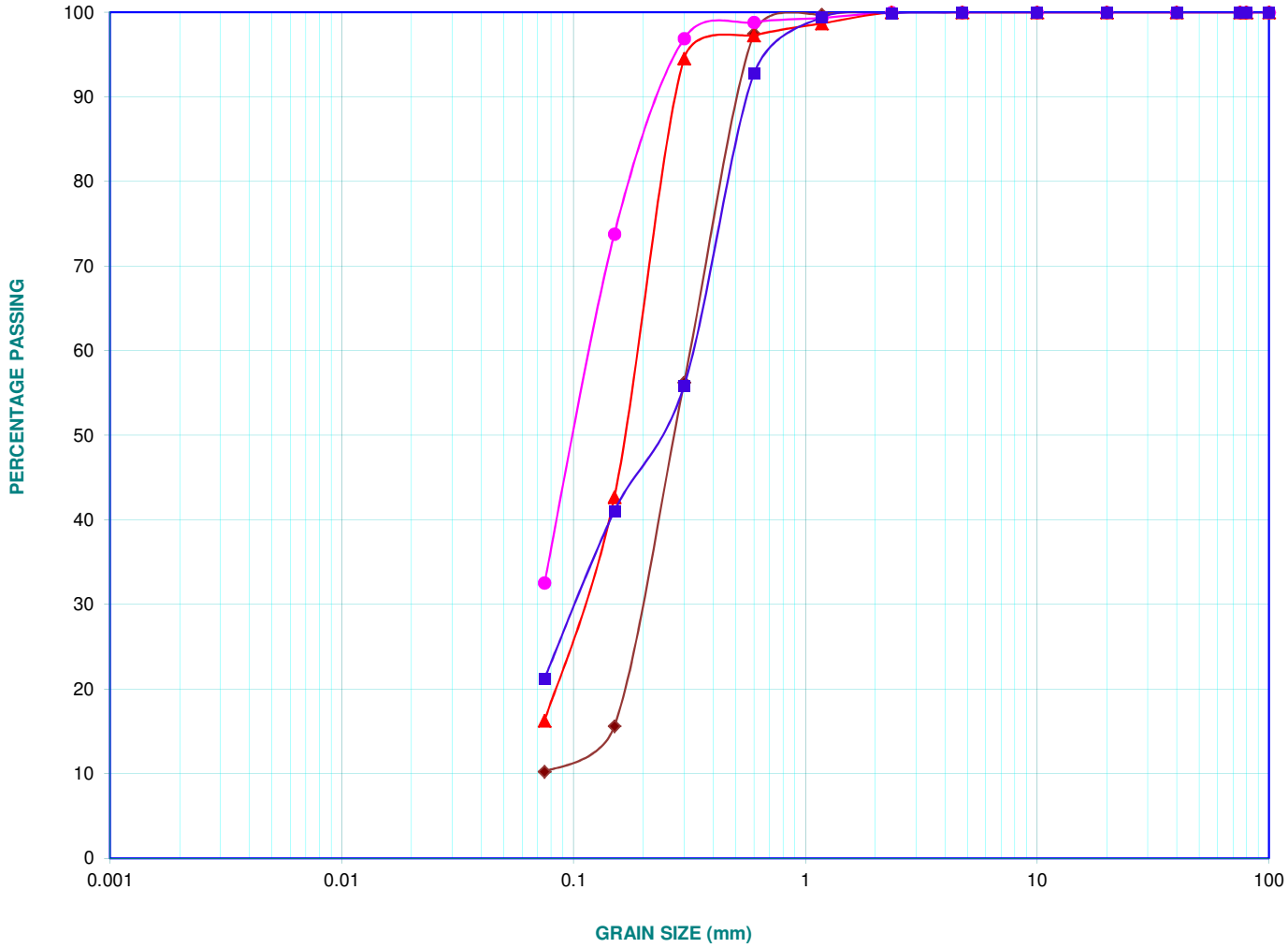
**Failure Type**

A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-22**

# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | : Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha. | | | | | | | | | | |
| **Job No.** | : CM 19 01 03 | | | **Borehole No.** | | : MBH-22 | | | **Date :** | | 9-Jun-19 |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | . | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-22 | MBH-22 | MBH-22 | MBH-22 | | | | | | | | |
| **Depth (m)** | 0.00-0.45 | 9.00-9.30 | 10.50-10.80 | 13.50-13.80 | | | | | | | | |
| **Sample Type** | SPT-01 | SPT-07 | SPT-08 | SPT-10 | | | | | | | | |
| **Classification** | SP-SM | SM / SC | SM / SC | SM / SC | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 90 | 67 | 84 | 79 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 10 | 33 | 16 | 21 | | | | | | | | |
| **D60 mm** | 0.310 | | | | | | | | | | | |
| **D30 mm** | 0.200 | | | | | | | | | | | |
| **D10 mm** | 0.075 | | | | | | | | | | | |
| **Cu** | 4.13 | | | | | | | | | | | |
| **Cc** | 1.72 | | | | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |

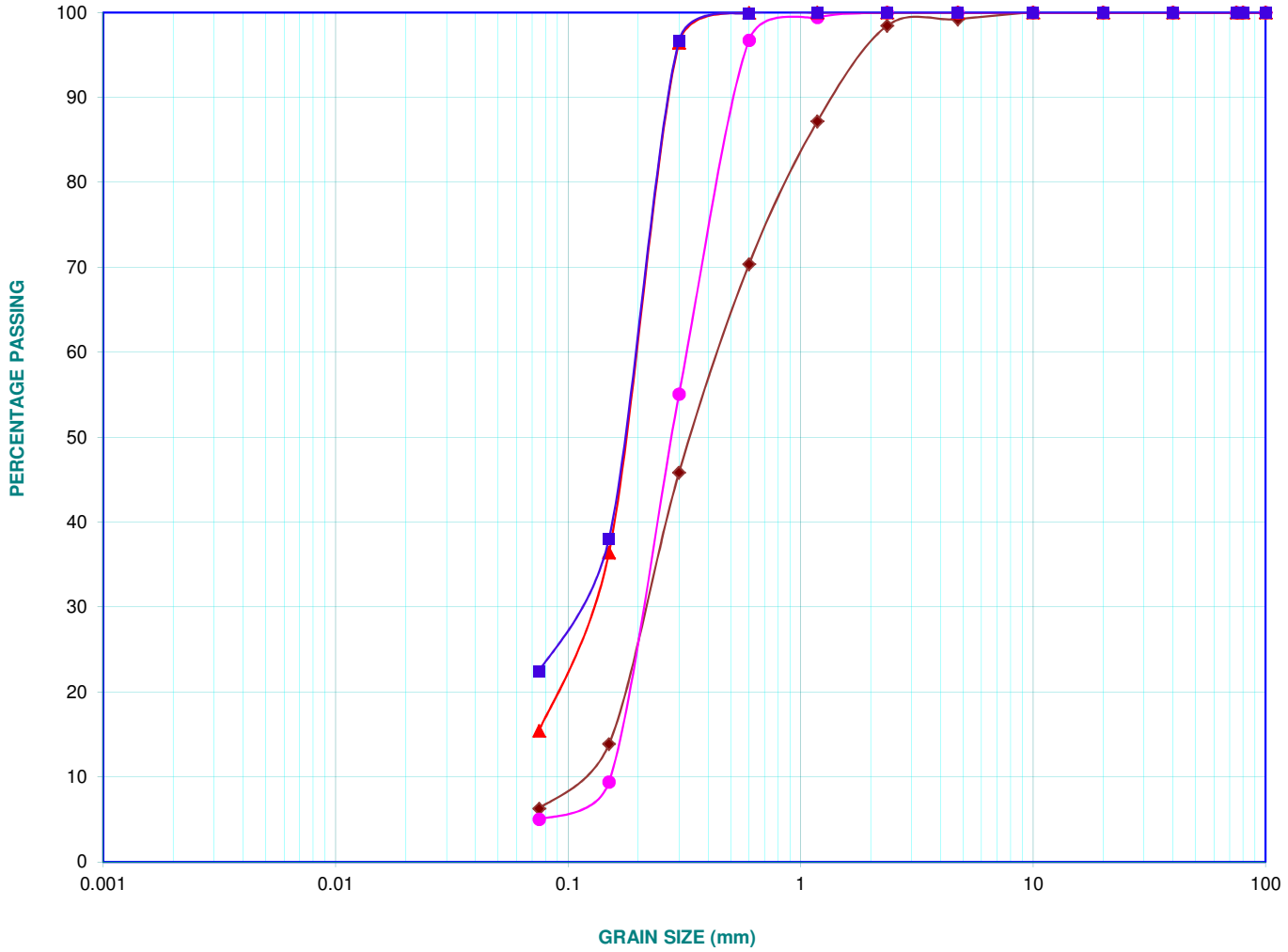



Checked By :

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-22** |
| **Date :** | **9-Jun-19** |

| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-22 | MBH-22 | MBH-22 | MBH-22 | | | | | | | | |
| **Depth (m)** | 19.50-19.75 | 21.00-21.20 | 25.50-25.70 | 28.50-28.70 | | | | | | | | |
| **Sample Type** | SPT-14 | SPT-15 | SPT-18 | SPT-20 | | | | | | | | |
| **Classification** | SP-SM | SP-SM | SM / SC | SM / SC | | | | | | | | |
| **Gravel %** | 1 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 93 | 95 | 85 | 78 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 6 | 5 | 15 | 22 | | | | | | | | |
| **D60 mm** | 0.450 | 0.310 | | | | | | | | | | |
| **D30 mm** | 0.210 | 0.210 | | | | | | | | | | |
| **D10 mm** | 0.120 | 0.150 | | | | | | | | | | |
| **Cu** | 3.75 | 2.07 | | | | | | | | | | |
| **Cc** | 0.82 | 0.95 | | | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |

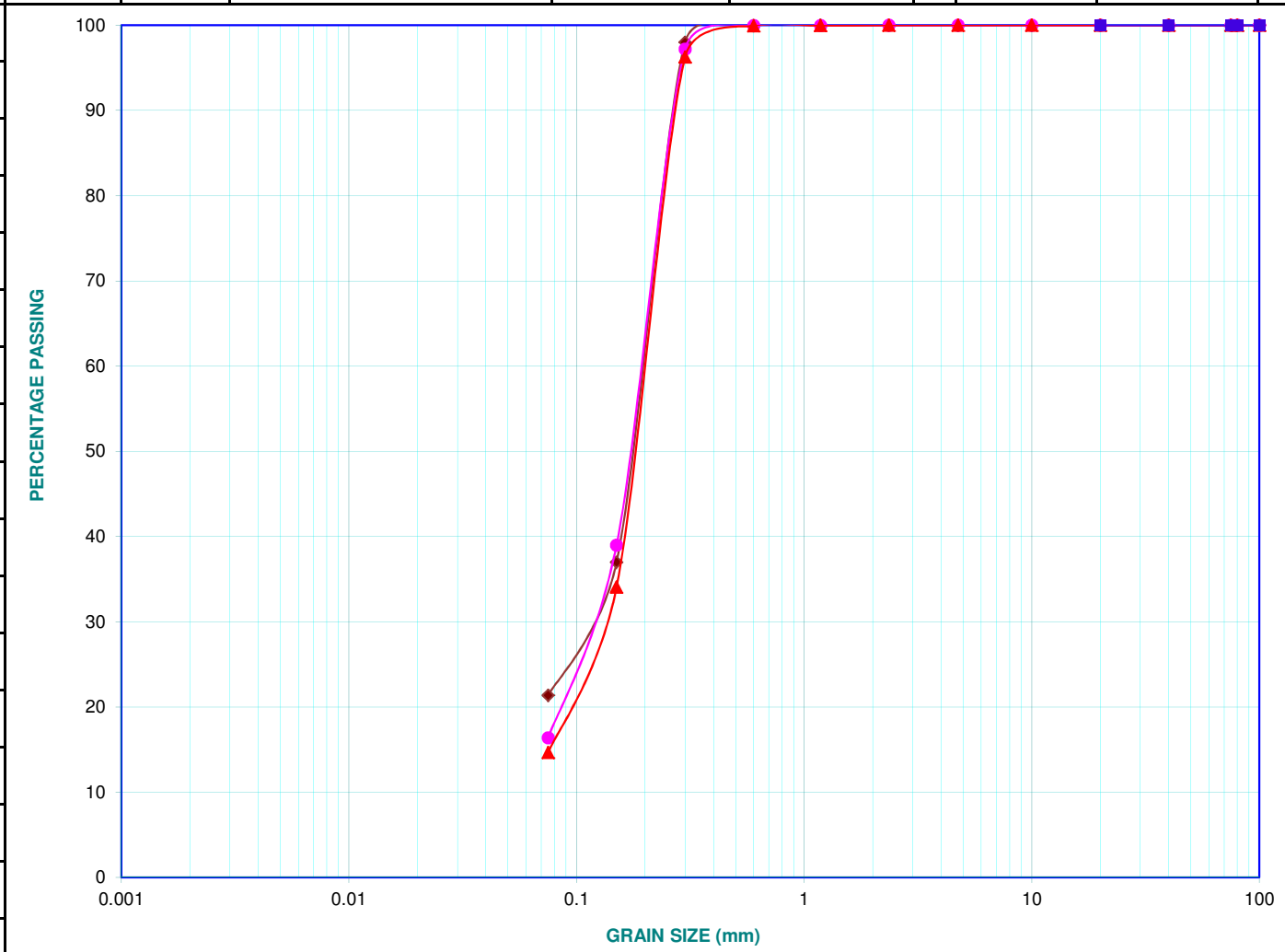



Checked By :

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-22** |
| **Date :** | **9-Jun-19** |

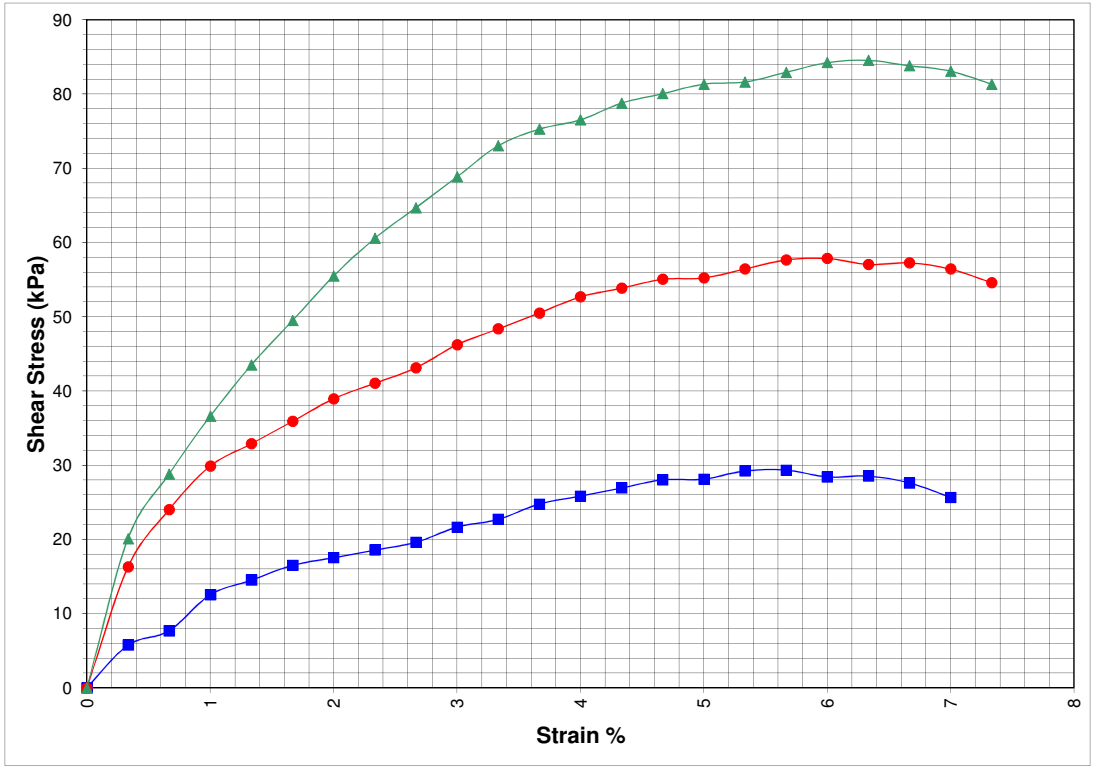
| Symbol | | | | |
|---|---|---|---|---|
| Bore Hole . | MBH-22 | MBH-22 | MBH-22 | |
| Depth (m) | 37.50-37.65 | 42.00-42.10 | 43.50-43.65 | |
| Sample Type | SPT-26 | SPT-29 | SPT-30 | |
| Classification | SM / SC | SM / SC | SM / SC | |
| Gravel % | 0 | 0 | 0 | |
| Sand % | 79 | 84 | 85 | |
| Silt % | <----> | <----> | <----> | |
| Clay % | <----> | <----> | <----> | |
| Fines % (Silt+Clay) | 21 | 16 | 15 | |
| D60 mm | | | | |
| D30 mm | | | | |
| D10 mm | | | | |
| Cu | | | | |
| Cc | | | | |
| Liquid Limit % | --- | --- | --- | |
| Plastic Limit % | --- | --- | --- | |
| Plasticity Index | --- | --- | --- | |

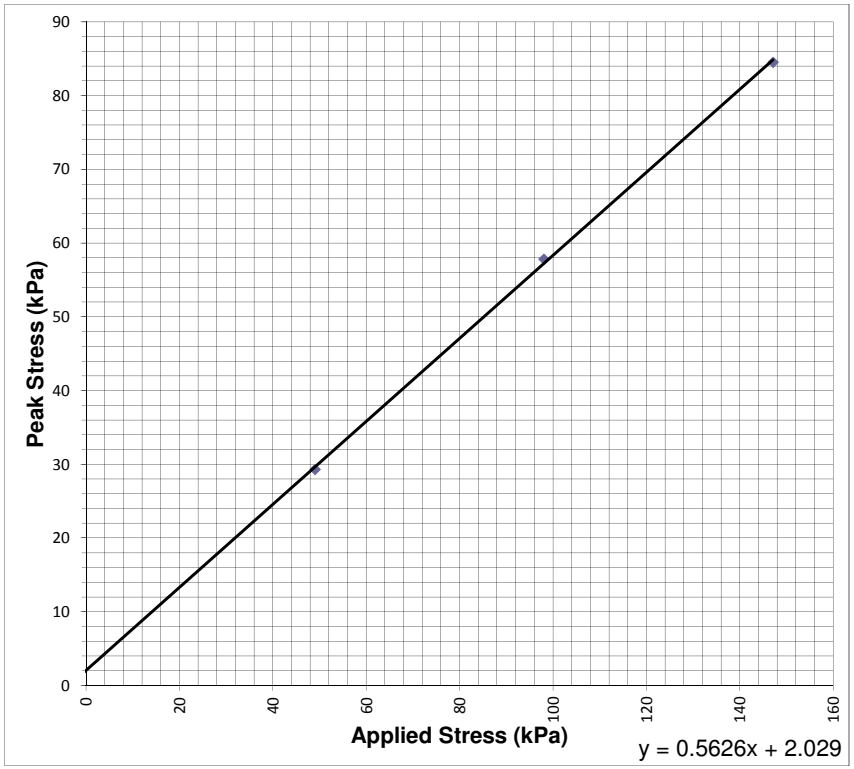



Checked By :

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 29 |
| | Stage 2 | 98 | 58 |
| | Stage 3 | 147 | 85 |

| | | |
|---|---|---|
| Angle of Friction | **29.36** | ° |
| Apparent Cohesion | **2.03** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

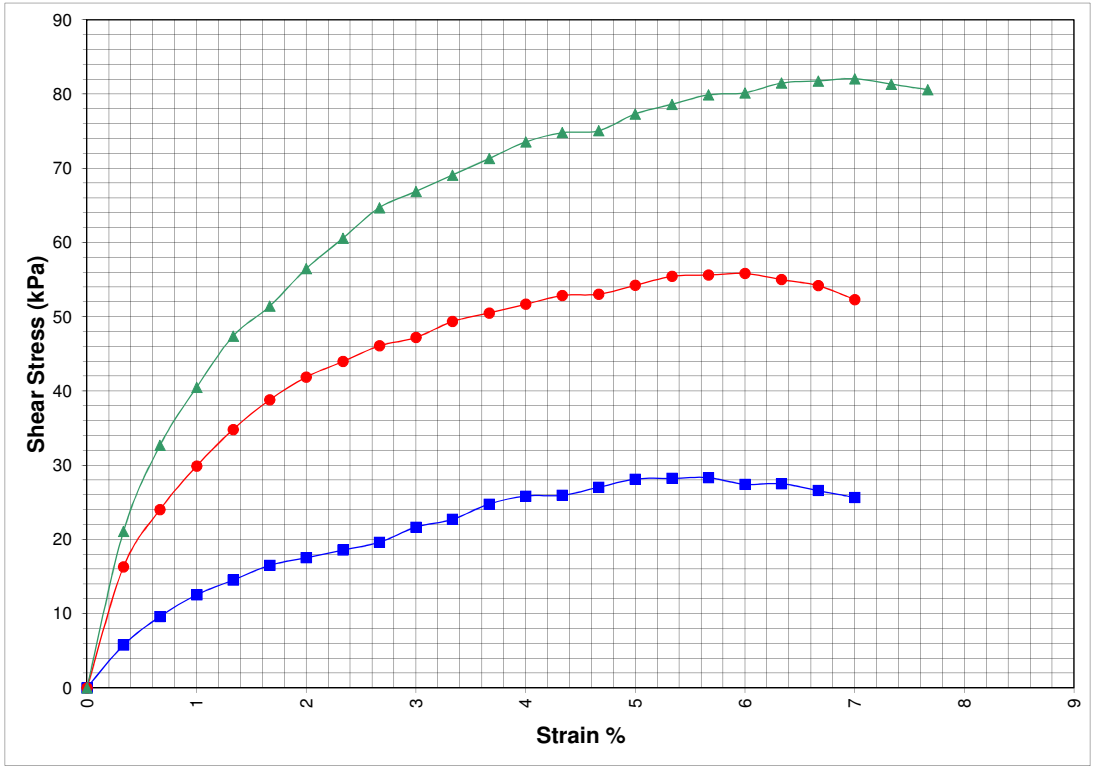
**Borehole: MBH-22**

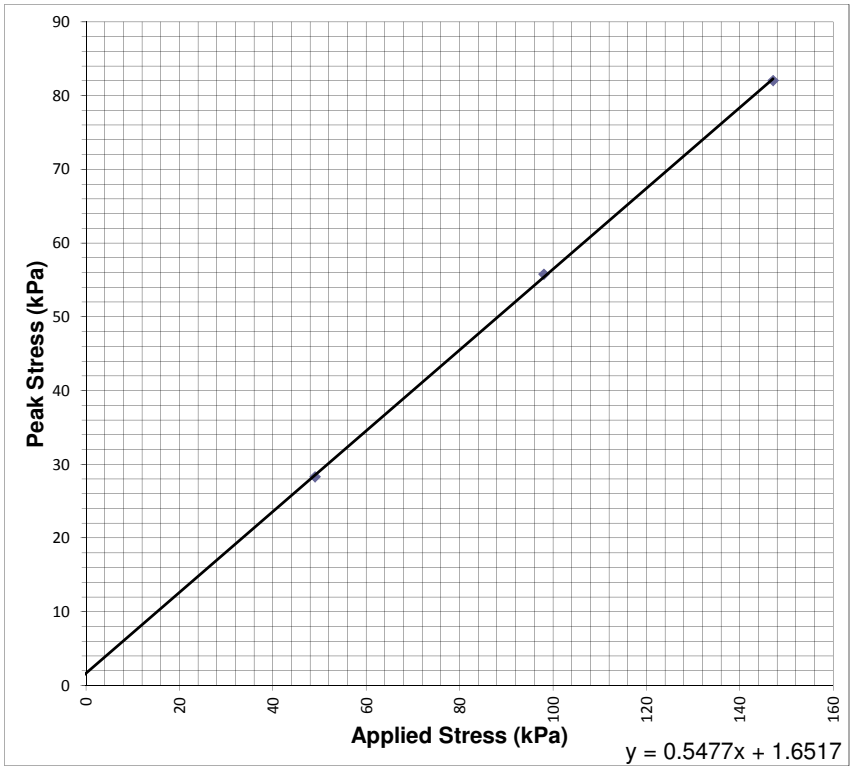
**Sample Type: SPT-01**

**Depth: 0.00-0.45 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 56 |
| | Stage 3 | 147 | 82 |

| | | |
|---|---|---|
| Angle of Friction | **28.7** | ° |
| Apparent Cohesion | **1.65** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

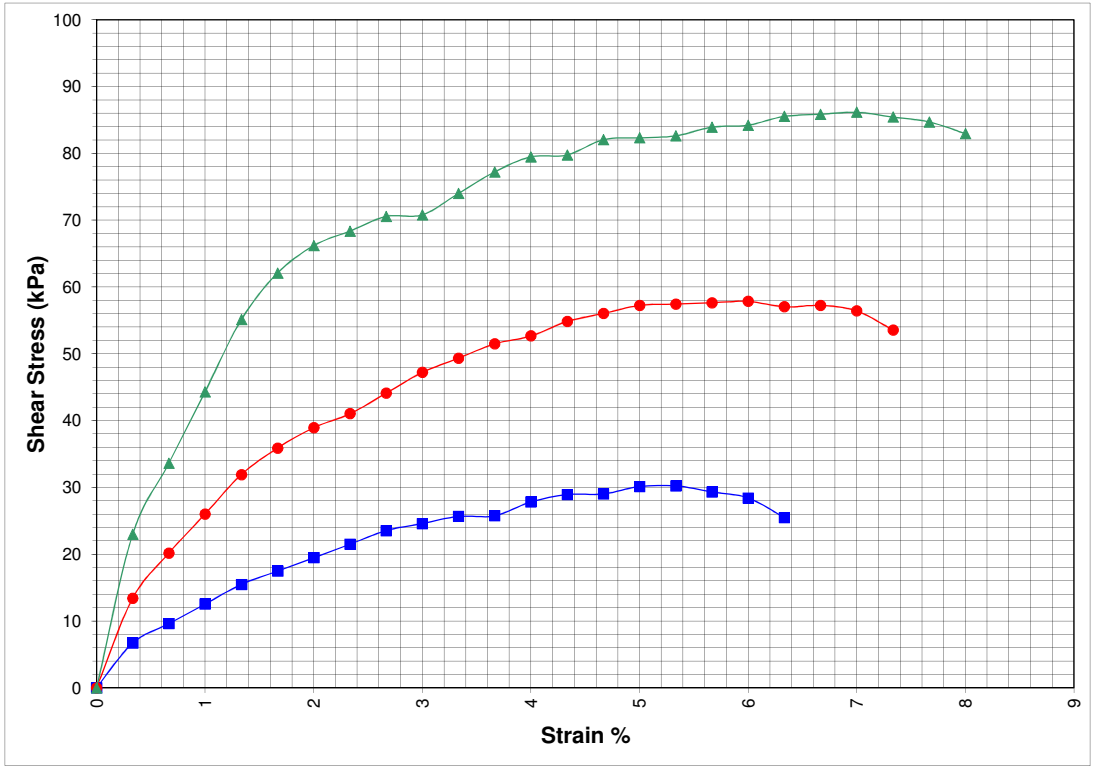
**Borehole: MBH-22**

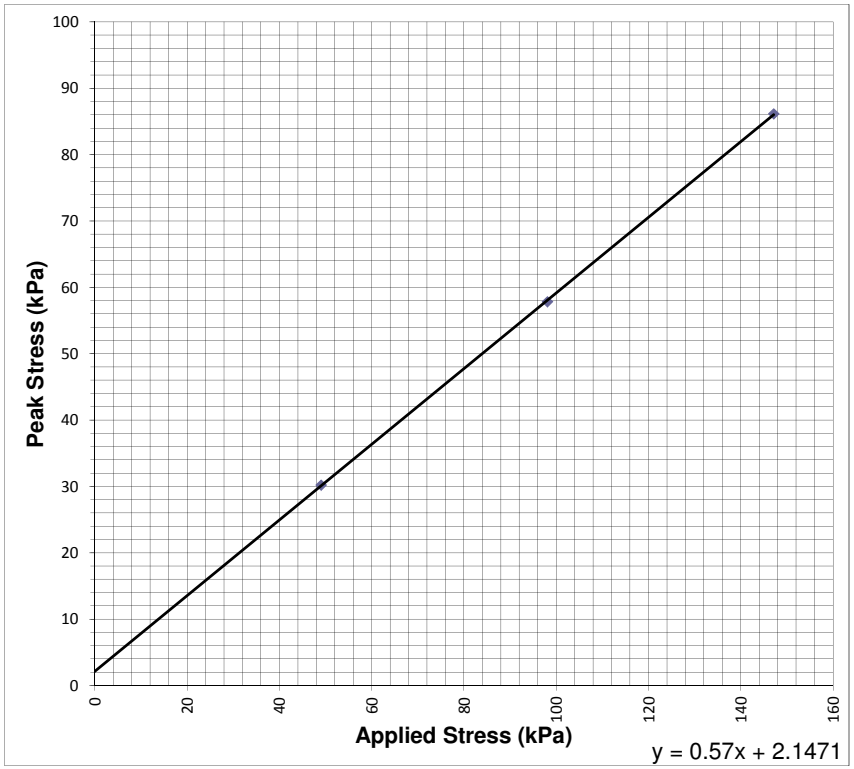
**Sample Type: SPT-06**

**Depth: 7.50-7.80 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 30 |
| | Stage 2 | 98 | 58 |
| | Stage 3 | 147 | 86 |

| | | |
|---|---|---|
| Angle of Friction | **29.7** | ° |
| Apparent Cohesion | **2.15** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

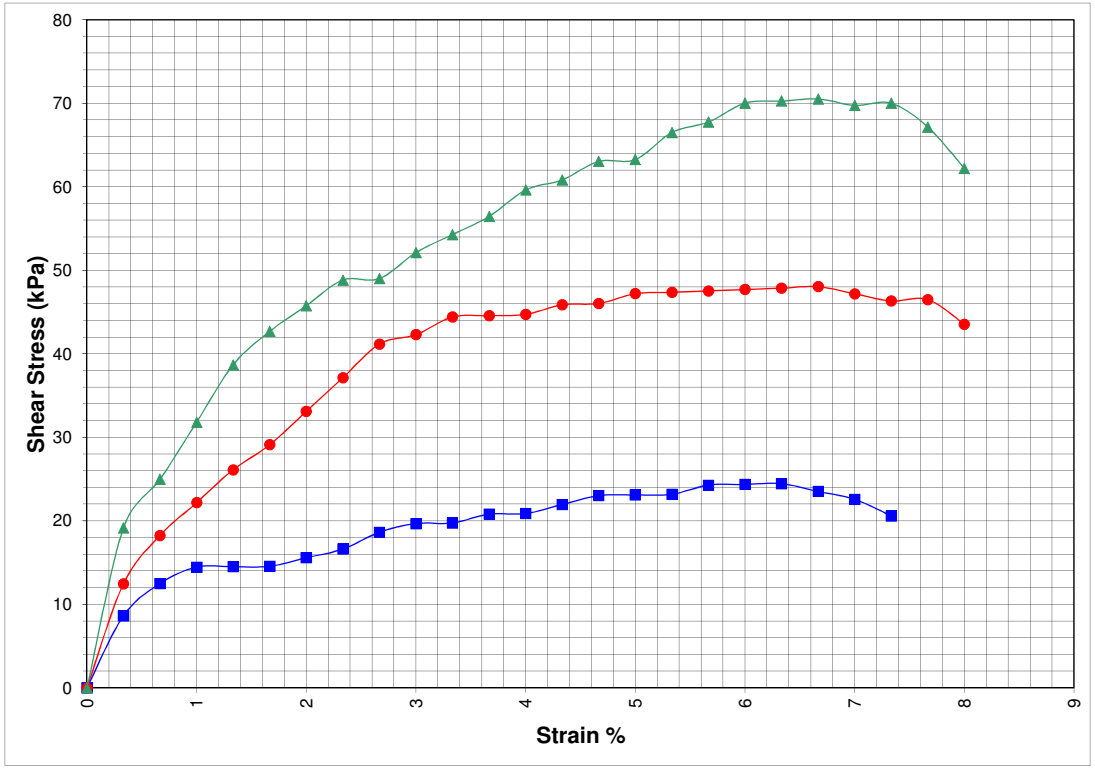
**Borehole: MBH-22**

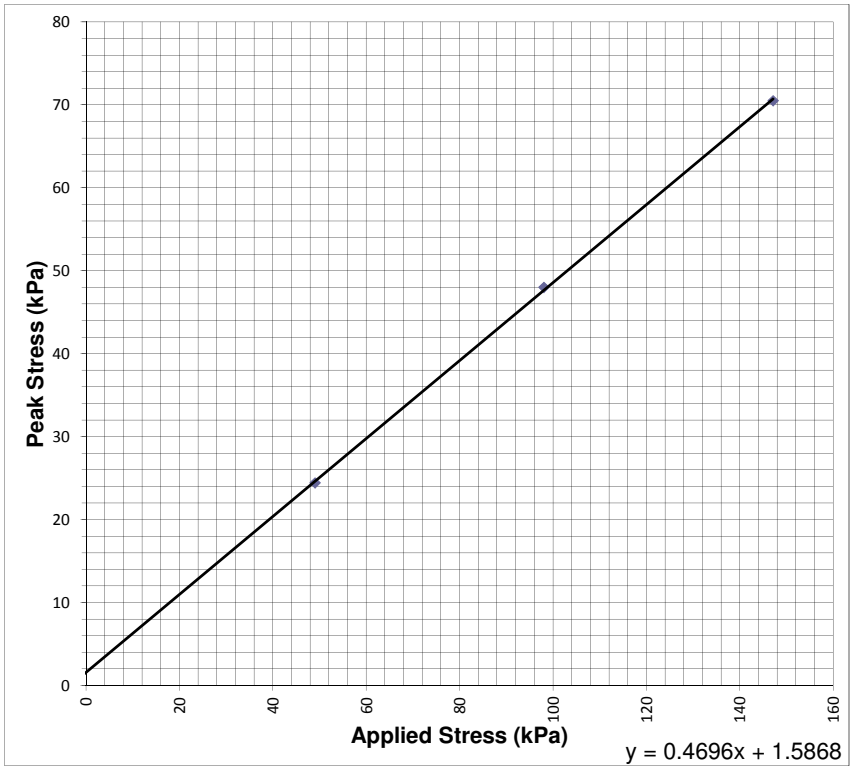
**Sample Type: SPT-09**

**Depth: 12.00-12.25 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 24 |
| | Stage 2 | 98 | 48 |
| | Stage 3 | 147 | 71 |

| | | |
|---|---|---|
| Angle of Friction | **25.2** | ° |
| Apparent Cohesion | **1.59** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

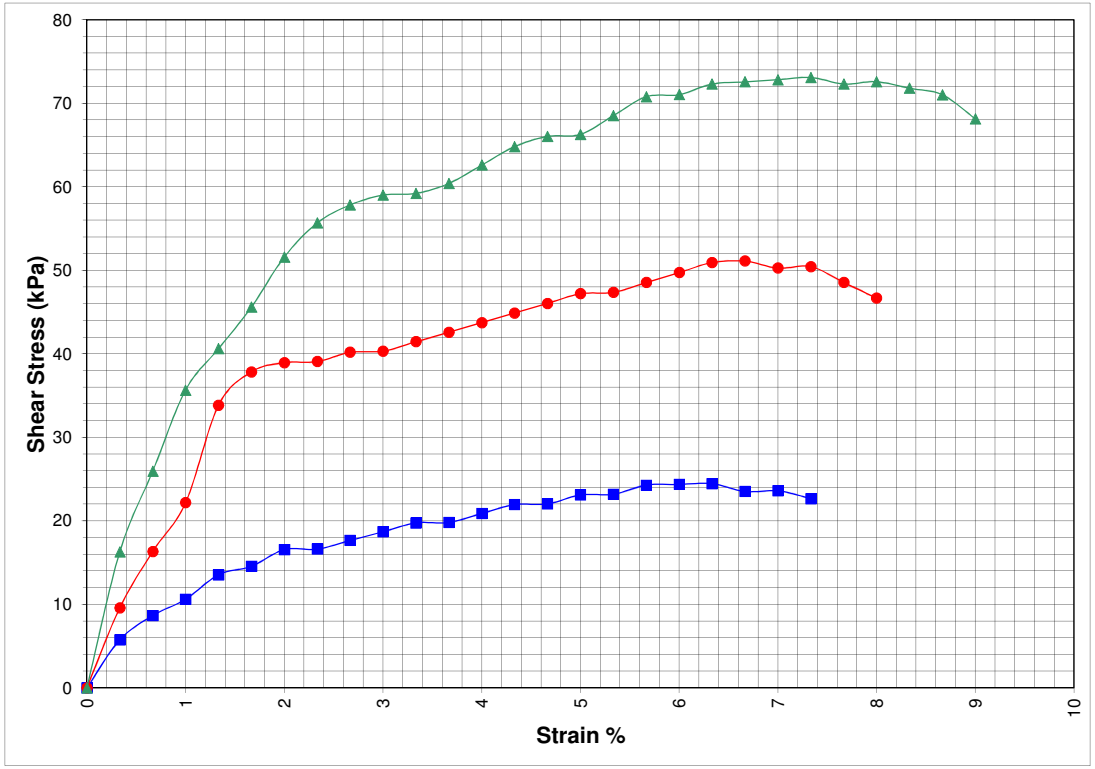
**Borehole: MBH-22**

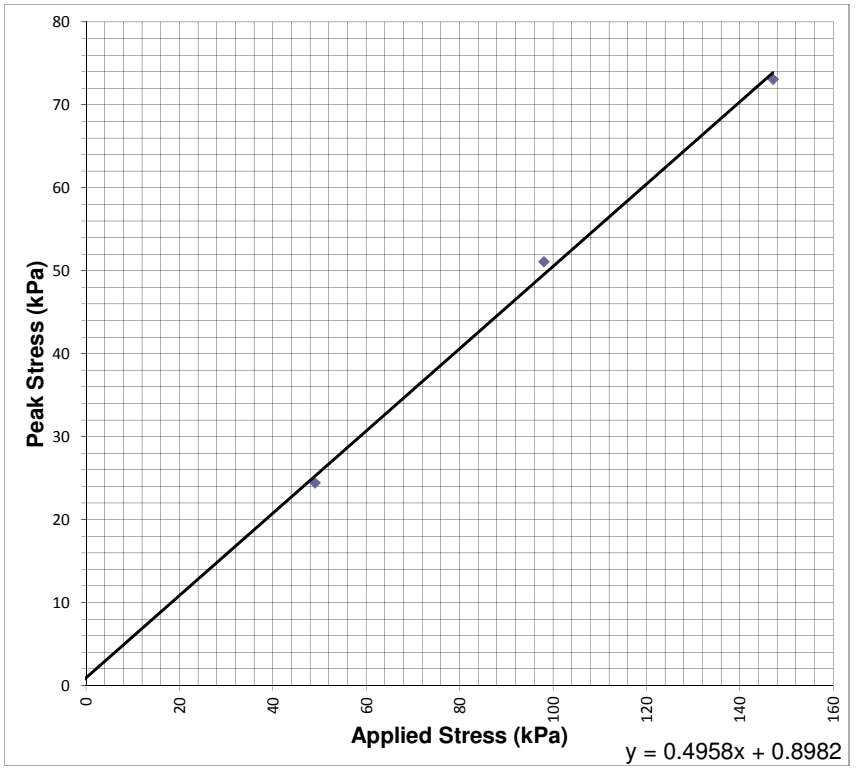
**Sample Type: SPT-13**

**Depth: 18.00-18.25 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 24 |
| | Stage 2 | 98 | 51 |
| | Stage 3 | 147 | 73 |

| | | |
|---|---|---|
| Angle of Friction | **26.4** | ° |
| Apparent Cohesion | **0.90** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

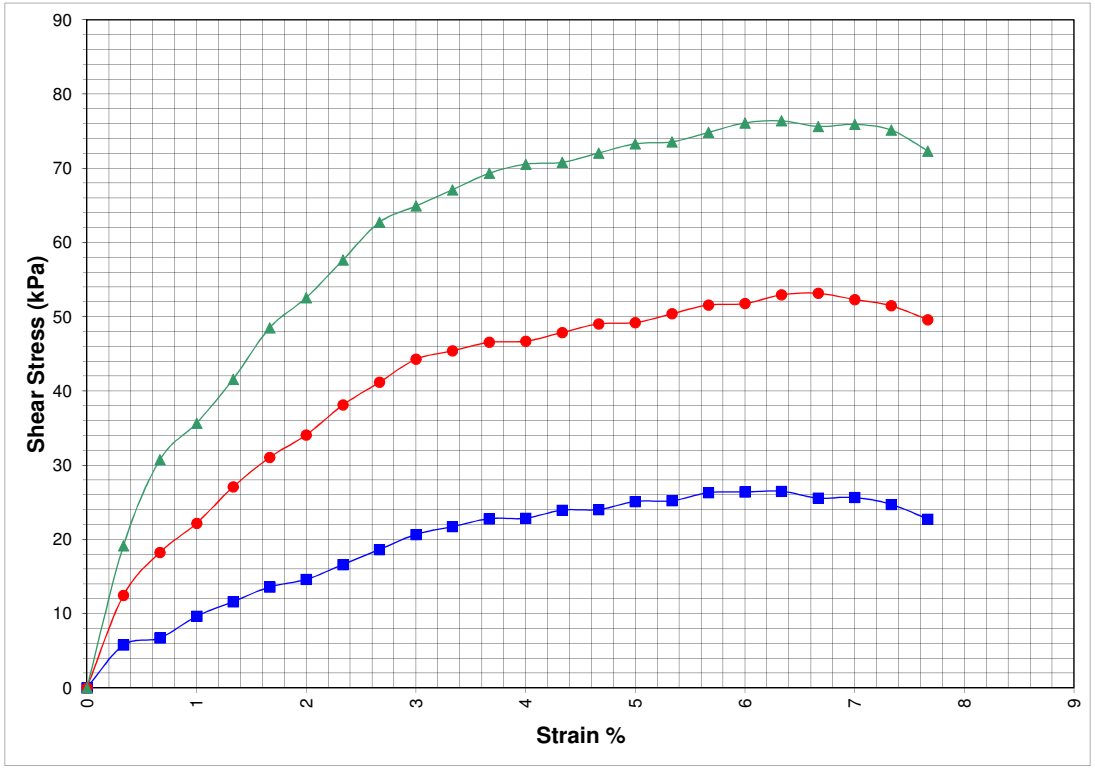
**Borehole: MBH-22**

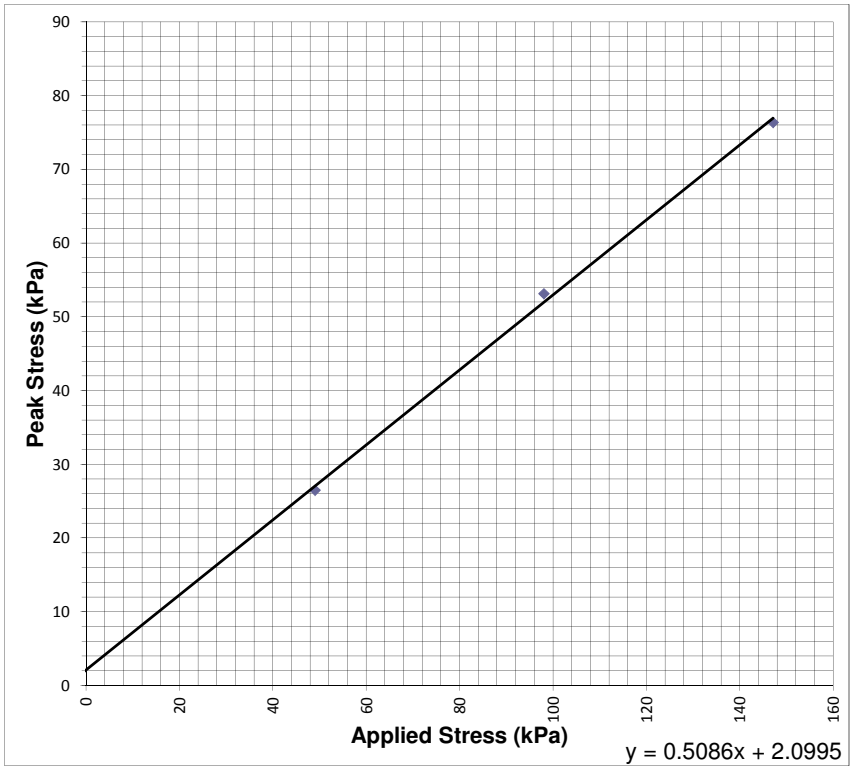
**Sample Type: SPT-16**

**Depth: 22.50-22.70 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 53 |
| | Stage 3 | 147 | 76 |

| | | |
|---|---|---|
| Angle of Friction | **27.0** | ° |
| Apparent Cohesion | **2.10** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

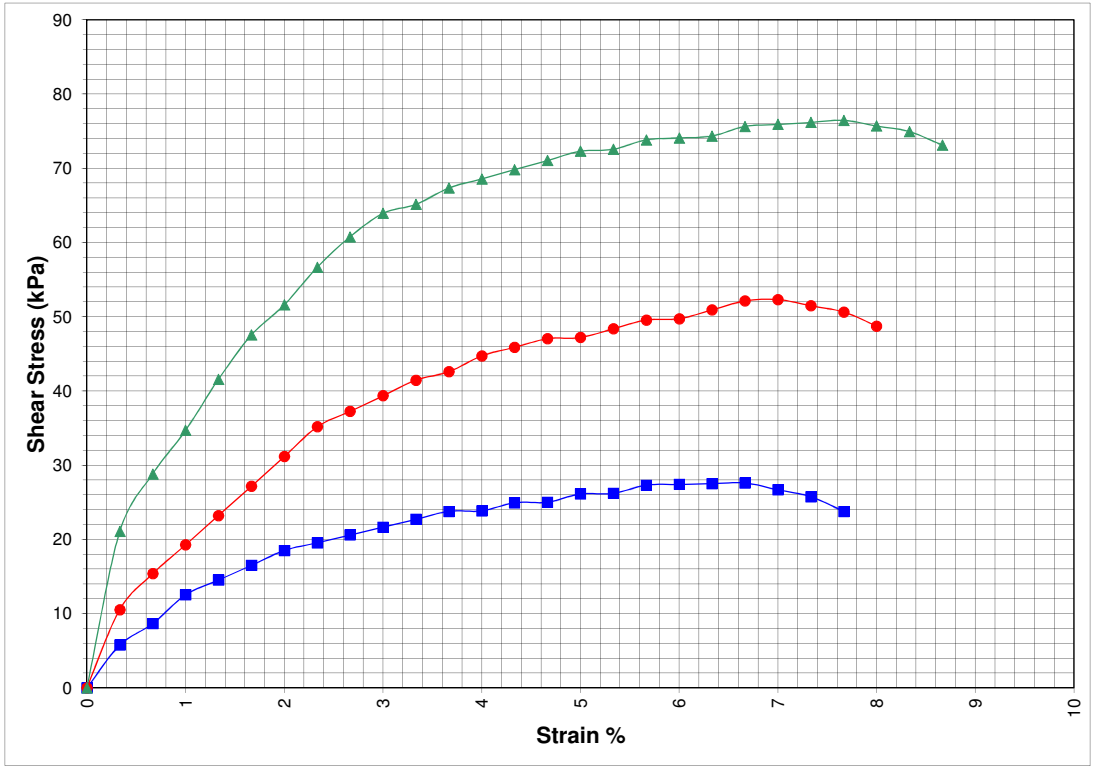
**Borehole: MBH-22**

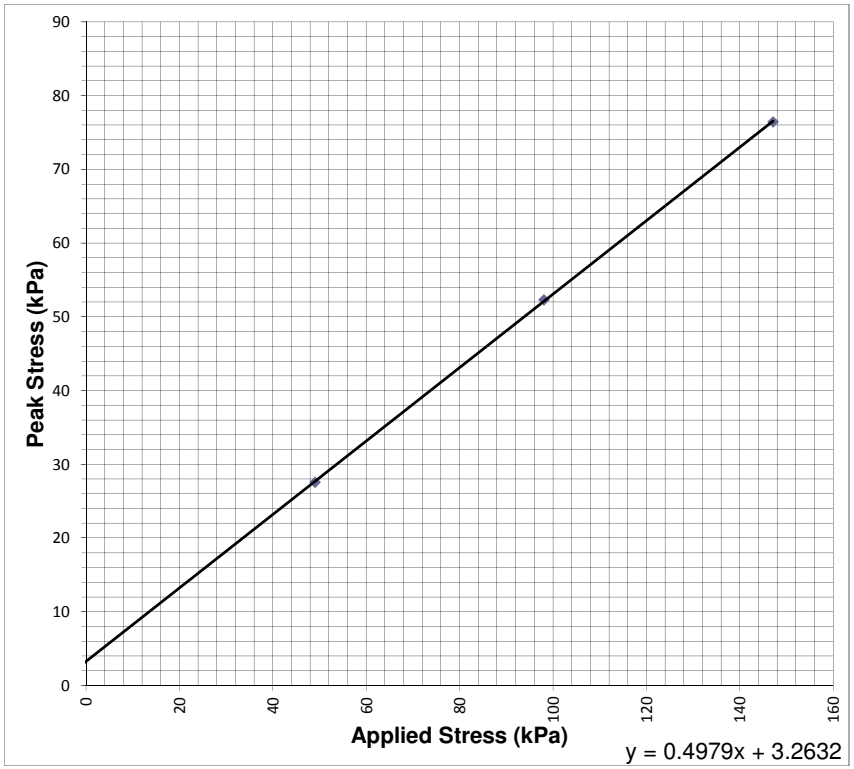
**Sample Type: SPT-19**

**Depth: 27.00-27.15 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 52 |
| | Stage 3 | 147 | 76 |

| | | |
|---|---|---|
| Angle of Friction | **26.5** | ° |
| Apparent Cohesion | **3.26** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

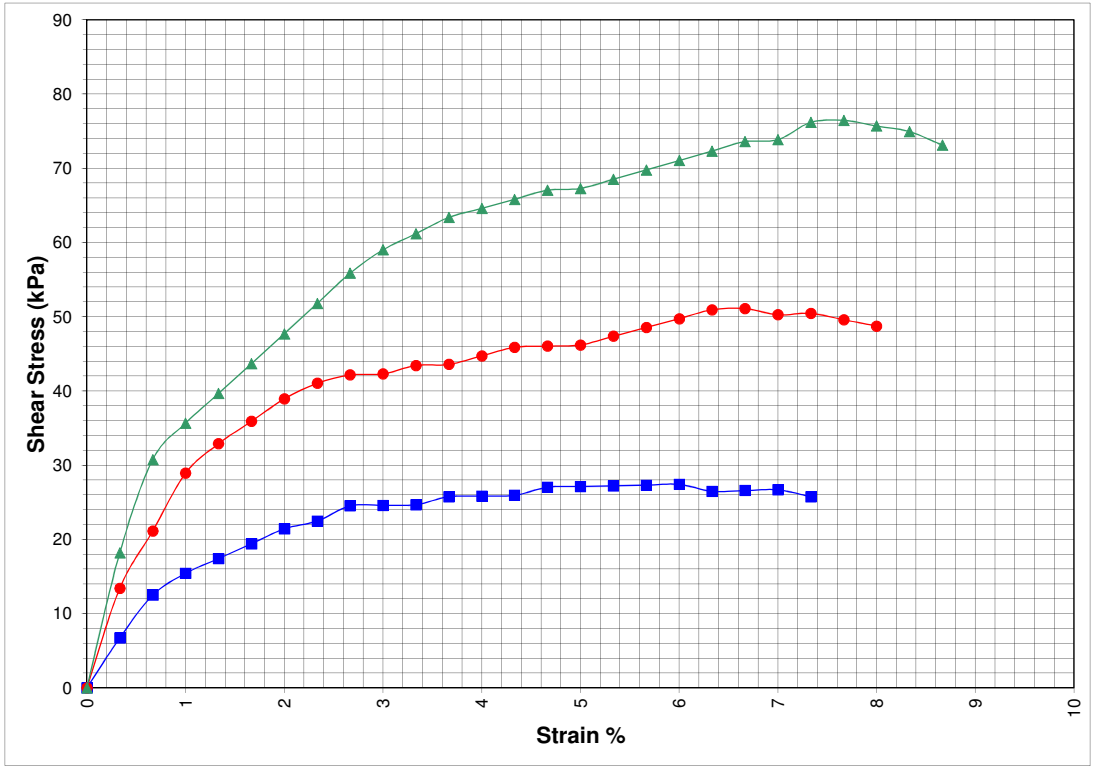
**Borehole: MBH-22**

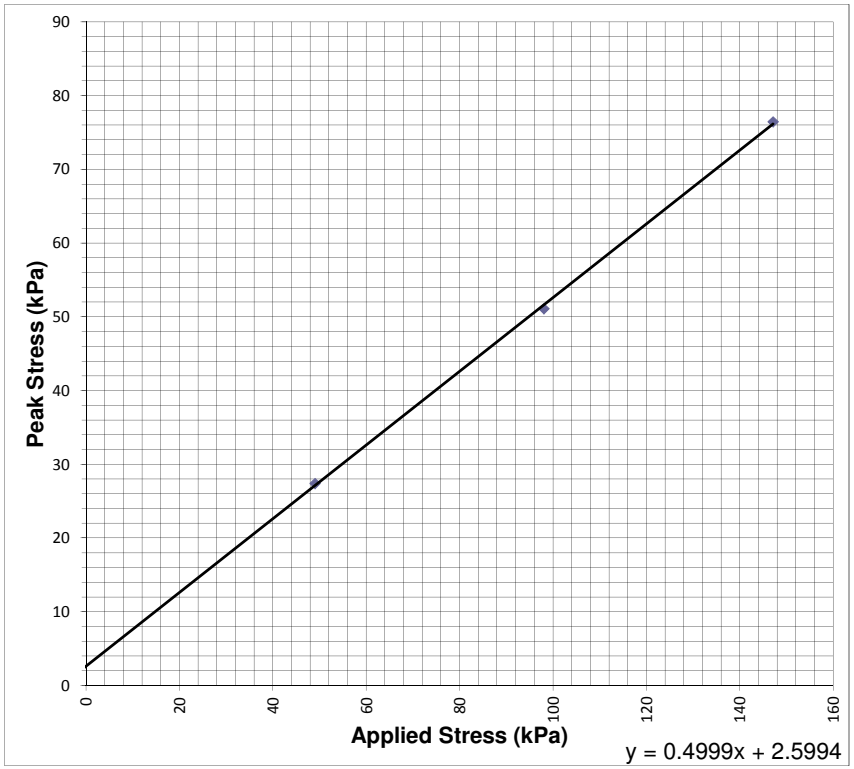
**Sample Type: SPT-25**

**Depth: 36.00-36.30 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 51 |
| | Stage 3 | 147 | 76 |

| | | |
|---|---|---|
| Angle of Friction | **26.6** | ° |
| Apparent Cohesion | **2.60** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: MBH-22**

**Sample Type: SPT-27**

**Depth: 39.00-39.20 m**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density ($kN/m^3$) | Submerged Unit Weight ($kN/m^3$) | Dry Density ($kN/m^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-1 | 0.00-0.25 | SP-SM | | | | 16.1 | 18.33 | 8.27 | 15.78 | | 0 | 89 | <--> | <--> | 11 | DST | | | 1.16 | 26.9 | | | | | | | | | | | | | |
| SPT-2 | 1.50-1.85 | SM / SC | | | | 15.3 | 18.39 | 8.33 | 15.95 | 2.59 | 0 | 74 | <--> | <--> | 26 | | | | | | | | | | | | | | | | | | |
| SPT-3 | 3.00-3.20 | | | | | 17.4 | 19.69 | 9.63 | 16.77 | | | | | | | DST | | | 0.81 | 30.6 | | | | | | | | | | | | |
| SPT-4 | 4.50-4.85 | SP-SM | | | | 17.1 | 18.62 | 8.56 | 15.90 | 2.65 | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | | | | |
| SPT-5 | 6.00-6.30 | | | | | 16.4 | 19.17 | 9.11 | 16.46 | | | | | | | DST | | | 1.37 | 29.8 | | | | | | | | | | | | |
| SPT-6 | 7.50-7.75 | SM / SC | | | | 22.8 | 19.12 | 9.06 | 15.57 | 2.61 | 0 | 81 | <--> | <--> | 19 | | | | | | | | | | | | | | | 8.32 | 0.80 | 1.00 | 2700 | 8850 |
| SPT-7 | 9.00-9.25 | | | | | 19.7 | 19.28 | 9.22 | 16.10 | | | | | | | DST | | | 0.86 | 28.8 | | | | | | | | | | | | |
| SPT-8 | 10.50-10.70 | SM / SC | | | | 21.6 | 19.40 | 9.34 | 15.95 | | 0 | 81 | <--> | <--> | 19 | | | | | | | | | | | | | | | | | | |
| SPT-9 | 12.00-12.30 | SP-SM | | | | 17.6 | 20.41 | 10.35 | 17.35 | 2.62 | 0 | 93 | <--> | <--> | 7 | | | | | | | | | | | | | | | | | | |
| SPT-10 | 13.50-13.80 | SM / SC | | | | 20.9 | 19.92 | 9.86 | 16.48 | 2.61 | 0 | 71 | 23 | 6 | 29 | | | | | | | | | | | | | | | | | | |
| SPT-11 | 15.00-15.25 | SP-SM | | | | 13.4 | 17.65 | 7.59 | 15.57 | | 0 | 90 | <--> | <--> | 10 | | | | | | | | | | | | | | | | | | |
| SPT-12 | 16.50-16.80 | | | | | 17.7 | 18.06 | 8.00 | 15.35 | | | | | | | DST | | | 1.16 | 26.1 | | | | | | | | | | | | |
| SPT-13 | 18.00-18.30 | SP | | | | 16.9 | 19.75 | 9.69 | 16.89 | 2.62 | 0 | 97 | <--> | <--> | 3 | | | | | | | | | | | | | | | | | | |
| SPT-14 | 19.50-19.75 | SP-SM | | | | 16.5 | 19.79 | 9.73 | 16.98 | | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | | | | |
| SPT-15 | 21.00-21.30 | | | | | 16.4 | 19.76 | 9.70 | 16.98 | 2.64 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-16 | 22.50-22.70 | | | | | 6.4 | 19.78 | 9.72 | 18.59 | | | | | | | DST | | | 1.66 | 25.1 | | | | | | | | | | | | |
| SPT-17 | 24.00-24.25 | SP | | | | 11.8 | 19.80 | 9.74 | 17.70 | | 0 | 96 | <--> | <--> | 4 | | | | | | | | | | | | | | | | | | |
| SPT-18 | 25.50-25.70 | | | | | 12.0 | 19.84 | 9.78 | 17.72 | | | | | | | DST | | | 1.62 | 25.7 | | | | | | | | | | | | |
| SPT-19 | 27.00-27.20 | SP-SM | | | | 9.5 | 19.78 | 9.72 | 18.06 | 2.61 | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | | | | |
| SPT-20 | 28.50-28.65 | SP | | | | 10.9 | 16.06 | 6.00 | 14.48 | | 0 | 97 | <--> | <--> | 3 | | | | | | | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

\# : Decayed Wood

**Failure Type**

A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-23**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-21 | 30.00-30.15 | SP | | | | 11.0 | 15.72 | 5.66 | 14.16 | | 0 | 96 | <--> | <--> | 4 | | | | | | | | | | | | | | | | | | |
| SPT-22 | 31.50-31.70 | | | | | 16.5 | 15.68 | 5.62 | 13.45 | 2.65 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-23 | 33.00-33.25 | | | | | 12.5 | 15.63 | 5.57 | 13.89 | | | | | | | DST | | | 1.04 | 24.9 | | | | | | | | | | | | |
| SPT-24 | 34.50-34.65 | SP | | | | 13.1 | 15.92 | 5.86 | 14.07 | | 0 | 97 | <--> | <--> | 3 | | | | | | | | | | | | | | | | | | |
| SPT-25 | 36.00-36.20 | | | | | 10.3 | 15.95 | 5.89 | 14.47 | | | | | | | DST | | | 2.60 | 25.0 | | | | | | | | | | | | |
| SPT-26 | 37.50-37.65 | SP-SM | | | | 17.0 | 15.91 | 5.85 | 13.60 | | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | | | | |
| SPT-27 | 39.00-39.15 | | | | | 11.0 | 15.95 | 5.89 | 14.36 | | | | | | | DST | | | 0.62 | 25.5 | | | | | | | | | | | | |
| SPT-28 | 40.50-40.65 | | | | | 16.4 | 15.95 | 5.89 | 13.70 | 2.63 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-29 | 42.00-42.20 | | | | | 11.7 | 15.90 | 5.84 | 14.23 | | | | | | | | | | | | | | | | | | | | 8.34 | 0.50 | 1.00 | 1900 | 10620 |
| SPT-30 | 43.50-43.65 | SP-SM | | | | 13.6 | 15.81 | 5.75 | 13.92 | | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | | | | |
| SPT-31 | 45.00-45.10 | | | | | 12.6 | 17.96 | 7.90 | 15.95 | 2.65 | | | | | | | | | | | | | | | | | | | | | | | |
| **END OF BOREHOLE** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

\# : Decayed Wood

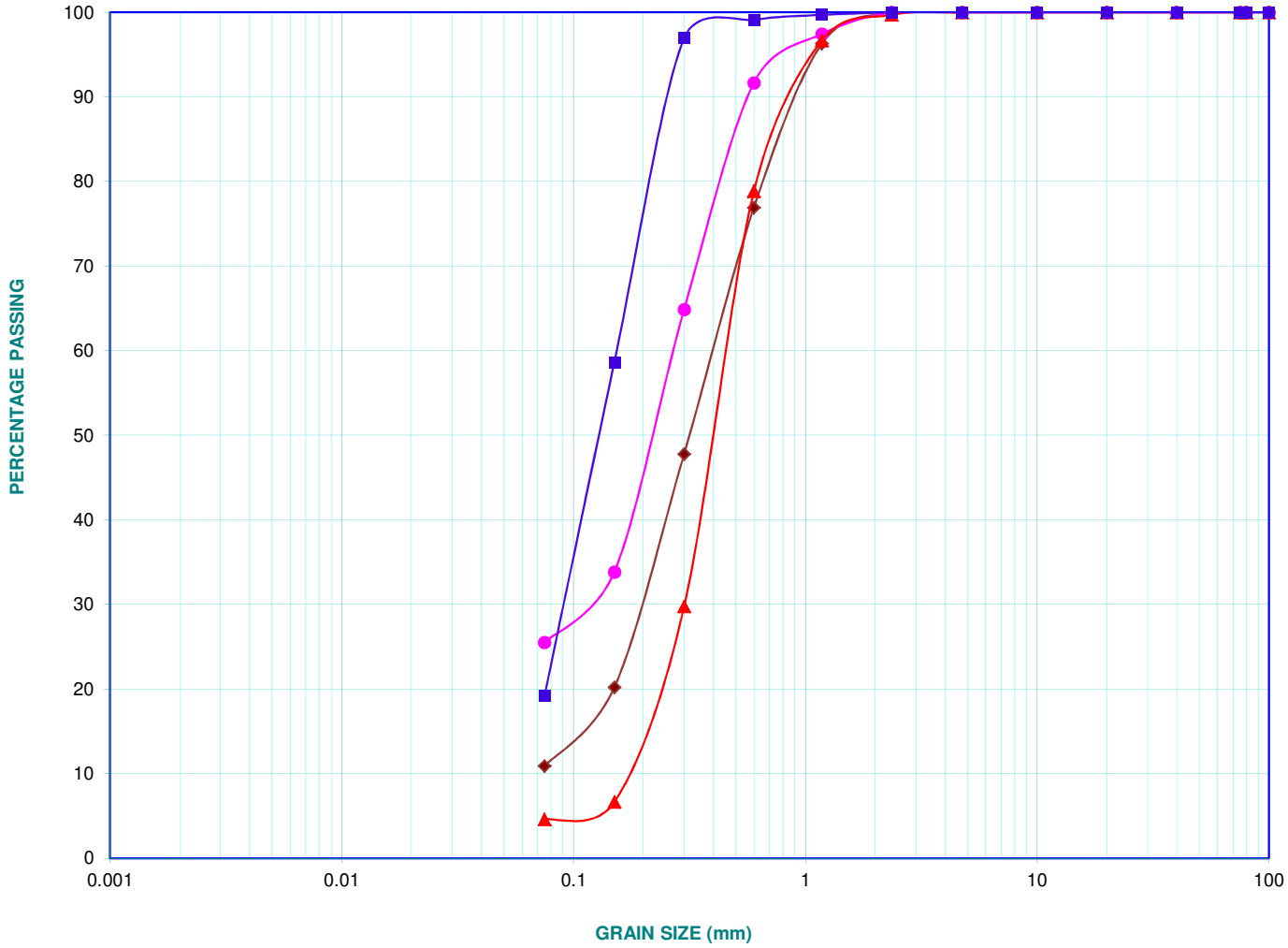
**Failure Type**

A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-23**

# GRAIN SIZE ANALYSIS

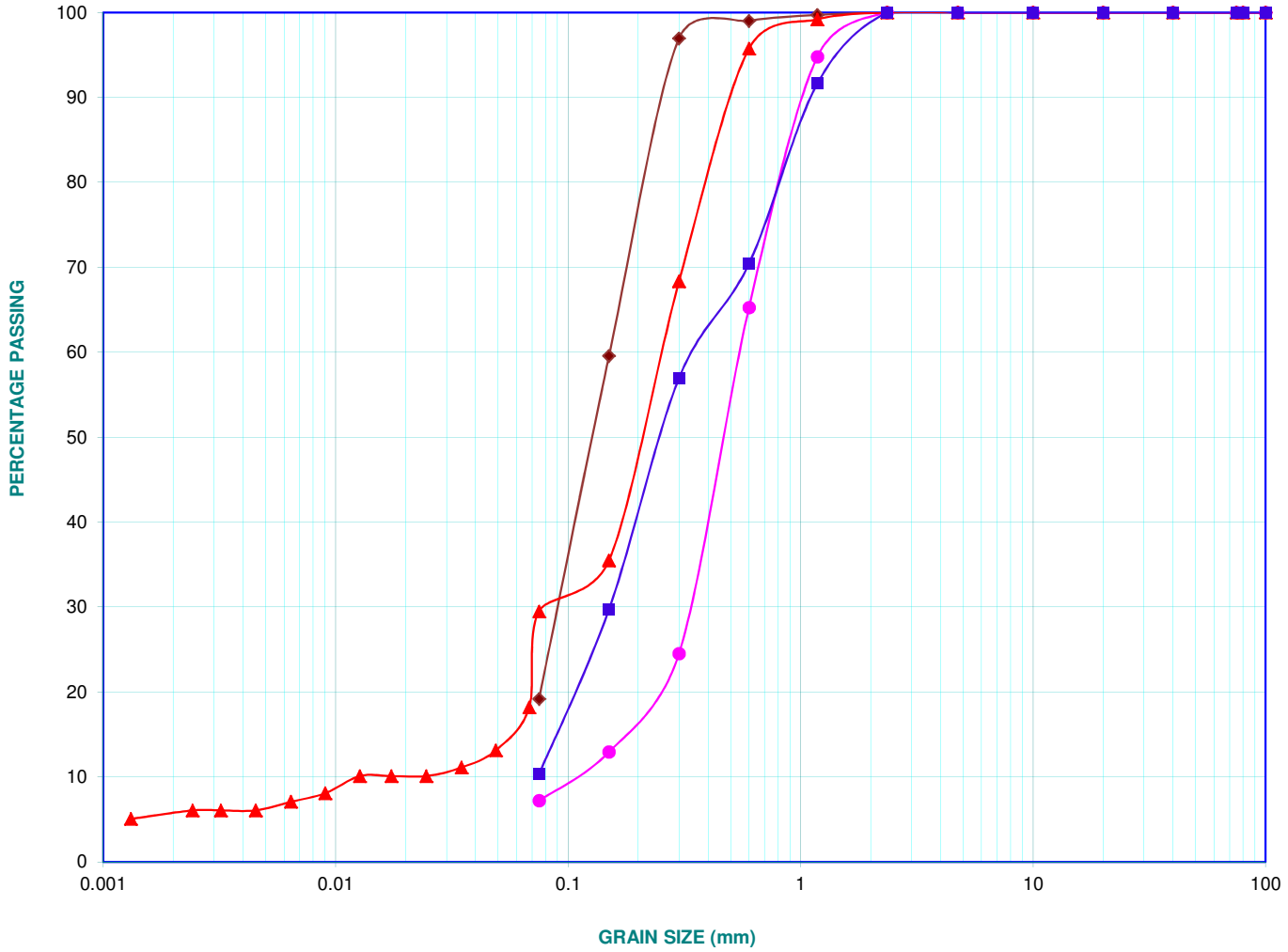
| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | : Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha. | | | | | | | | | | |
| **Job No.** | : CM 19 01 03 | | | | **Borehole No.** | : MBH-23 | | | **Date :** | 7-Jun-19 | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | . | SAND F | SAND M | SAND C | GRAVEL F / GRAVEL C |
| **Bore Hole .** | MBH-23 | MBH-23 | MBH-23 | MBH-23 | | | | | | | |
| **Depth (m)** | 0.00-0.25 | 1.50-1.85 | 4.50-4.85 | 7.50-7.75 | | | | | | | |
| **Sample Type** | SPT-01 | SPT-02 | SPT-04 | SPT-06 | | | | | | | |
| **Classification** | SP-SM | SM / SC | SP-SM | SM / SC | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | |
| **Sand %** | 89 | 74 | 95 | 81 | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | |
| **Fines % (Silt+Clay)** | 11 | 26 | 5 | 19 | | | | | | | |
| **D60 mm** | 0.400 | | 0.460 | | | | | | | | |
| **D30 mm** | 0.200 | | 0.300 | | | | | | | | |
| **D10 mm** | 0.075 | | 0.180 | | | | | | | | |
| **Cu** | 5.33 | | 2.56 | | | | | | | | |
| **Cc** | 1.33 | | 1.09 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | **Borehole No.** | **: MBH-23** | | | | | **Date :** | **7-Jun-19** | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-23 | MBH-23 | MBH-23 | MBH-23 | | | | | | | | |
| **Depth (m)** | 10.50-10.70 | 12.00-12.30 | 13.50-13.80 | 15.00-15.25 | | | | | | | | |
| **Sample Type** | SPT-08 | SPT-09 | SPT-10 | SPT-11 | | | | | | | | |
| **Classification** | SM / SC | SP-SM | SM / SC | SP-SM | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 81 | 93 | 71 | 90 | | | | | | | | |
| **Silt %** | <----> | <----> | 23 | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | 6 | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 19 | 7 | 29 | 10 | | | | | | | | |
| **D60 mm** | | 0.550 | 0.260 | 0.340 | | | | | | | | |
| **D30 mm** | | 0.340 | 0.075 | 0.150 | | | | | | | | |
| **D10 mm** | | 0.110 | 0.025 | 0.075 | | | | | | | | |
| **Cu** | | 5.00 | 10.40 | 4.53 | | | | | | | | |
| **Cc** | | 1.91 | 0.87 | 0.88 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |

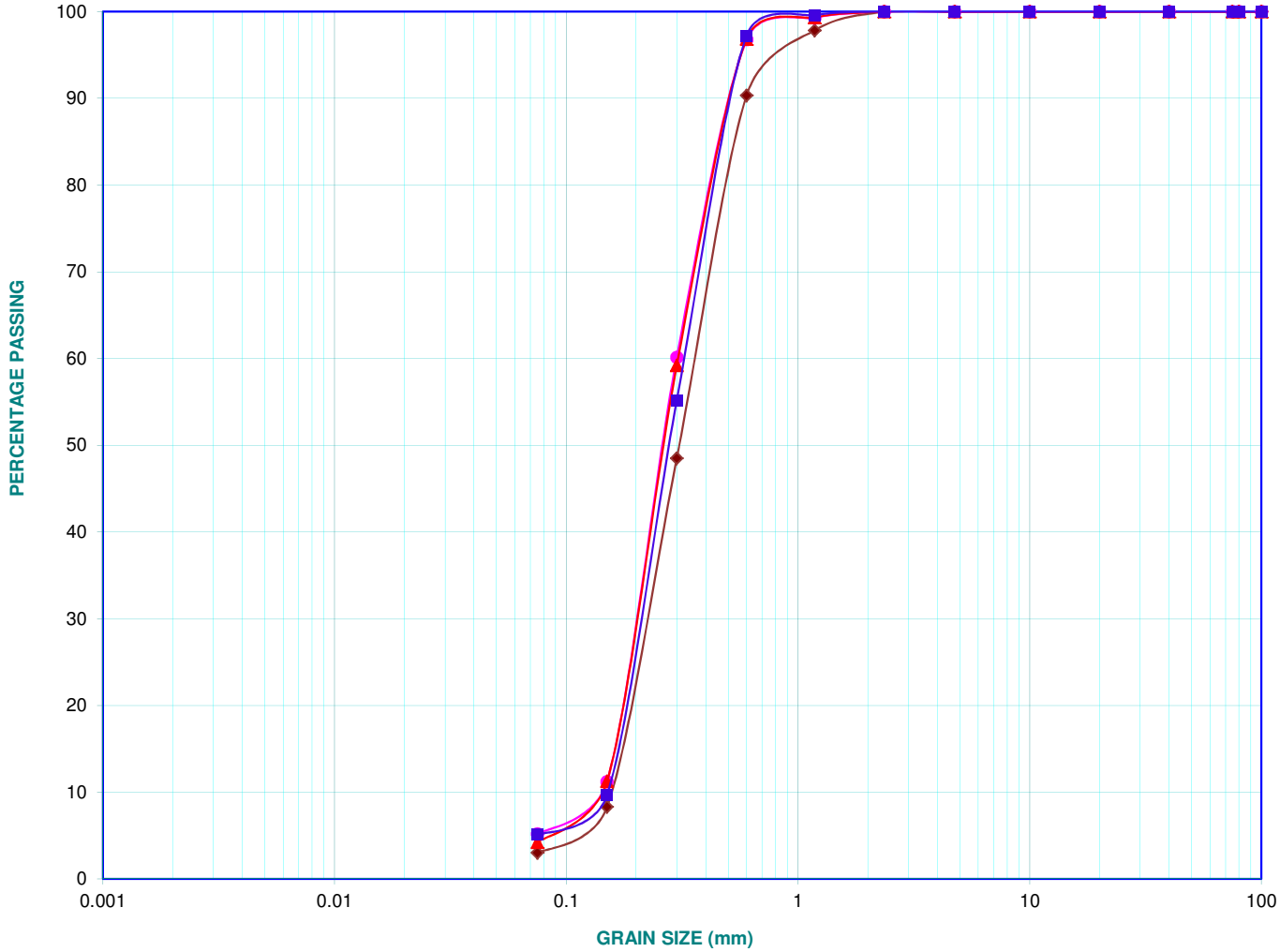



Checked By :

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-23** |
| **Date :** | **7-Jun-19** |

| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-23 | MBH-23 | MBH-23 | MBH-23 | | | | | | | | |
| **Depth (m)** | 18.00-18.30 | 19.50-19.75 | 24.00-24.25 | 27.00-27.20 | | | | | | | | |
| **Sample Type** | SPT-13 | SPT-14 | SPT-17 | SPT-19 | | | | | | | | |
| **Classification** | SP | SP-SM | SP | SP-SM | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 97 | 95 | 96 | 95 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 3 | 5 | 4 | 5 | | | | | | | | |
| **D60 mm** | 0.370 | 0.300 | 0.300 | 0.310 | | | | | | | | |
| **D30 mm** | 0.220 | 0.200 | 0.200 | 0.210 | | | | | | | | |
| **D10 mm** | 0.160 | 0.150 | 0.150 | 0.150 | | | | | | | | |
| **Cu** | 2.31 | 2.00 | 2.00 | 2.067 | | | | | | | | |
| **Cc** | 0.82 | 0.89 | 0.89 | 0.948 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |



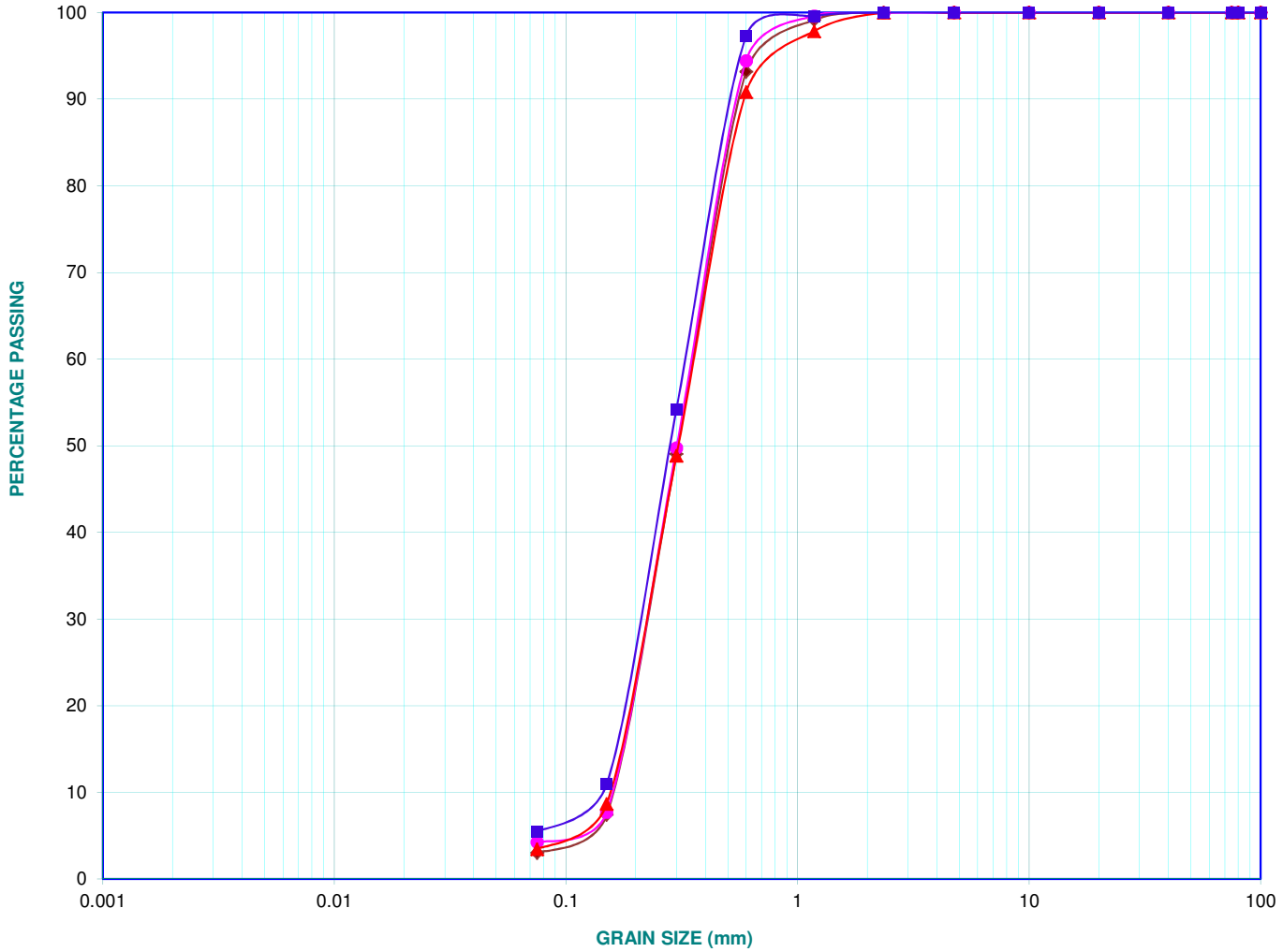

Checked By :

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Job No.** | **: CM 19 01 03** | | **Borehole No.** | **: MBH-23** | | **Date :** | **7-Jun-19** |

| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| Bore Hole . | MBH-23 | MBH-23 | MBH-23 | MBH-23 | | | | | | | | |
| Depth (m) | 28.50-28.65 | 30.00-30.15 | 34.50-34.65 | 37.50-37.65 | | | | | | | | |
| Sample Type | SPT-20 | SPT-21 | SPT-24 | SPT-26 | | | | | | | | |
| Classification | SP | SP | SP | SP-SM | | | | | | | | |
| Gravel % | 0 | 0 | 0 | 0 | | | | | | | | |
| Sand % | 97 | 96 | 97 | 95 | | | | | | | | |
| Silt % | <----> | <----> | <----> | <----> | | | | | | | | |
| Clay % | <----> | <----> | <----> | <----> | | | | | | | | |
| Fines % (Silt+Clay) | 3 | 4 | 3 | 5 | | | | | | | | |
| D60 mm | 0.360 | 0.360 | 0.360 | 0.340 | | | | | | | | |
| D30 mm | 0.220 | 0.220 | 0.220 | 0.210 | | | | | | | | |
| D10 mm | 0.160 | 0.160 | 0.160 | 0.150 | | | | | | | | |
| Cu | 2.25 | 2.25 | 2.25 | 2.27 | | | | | | | | |
| Cc | 0.84 | 0.84 | 0.84 | 0.86 | | | | | | | | |
| Liquid Limit % | --- | --- | --- | --- | | | | | | | | |
| Plastic Limit % | --- | --- | --- | --- | | | | | | | | |
| Plasticity Index | --- | --- | --- | --- | | | | | | | | |

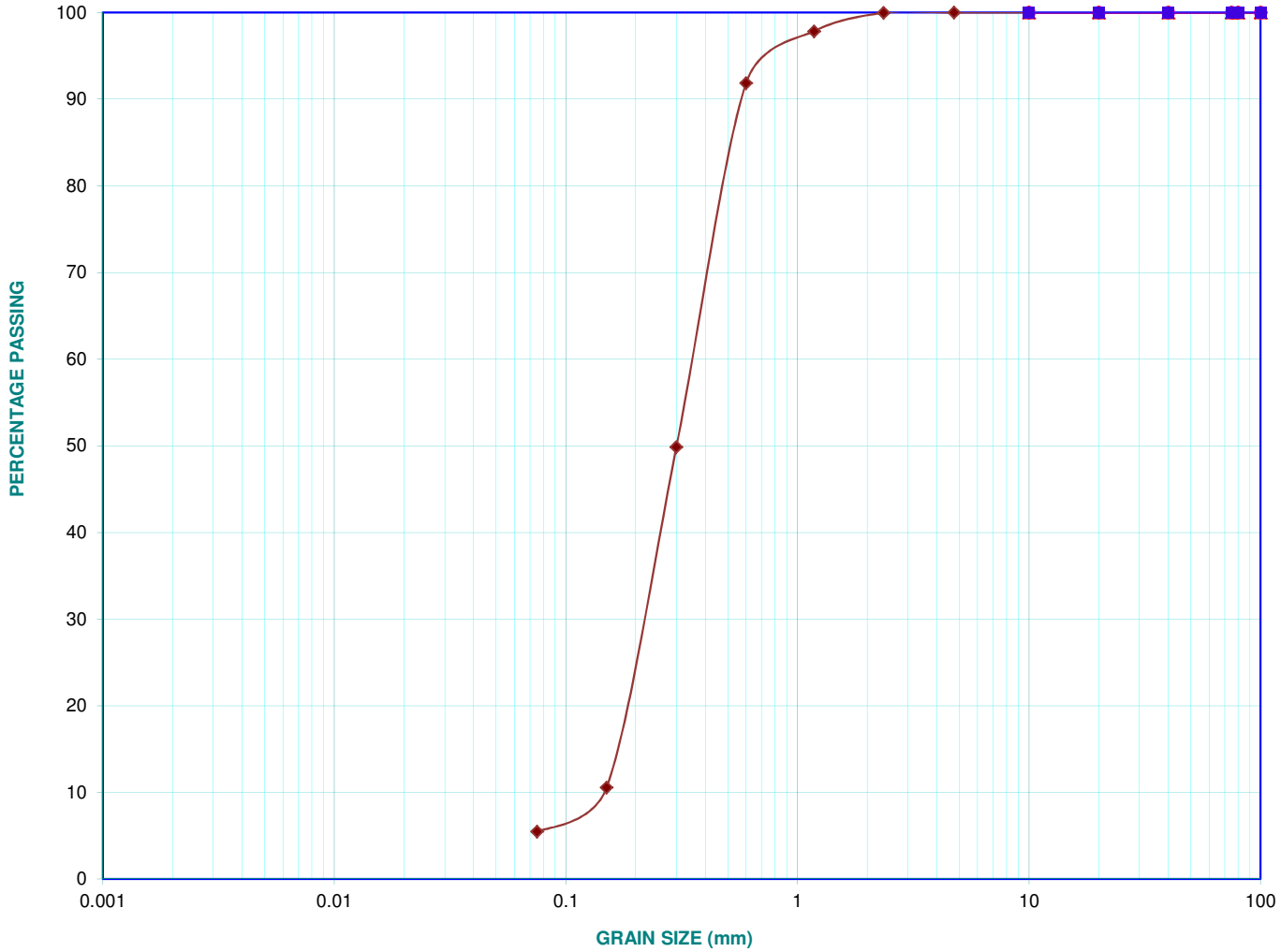



Checked By :

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-23** |
| **Date :** | **7-Jun-19** |

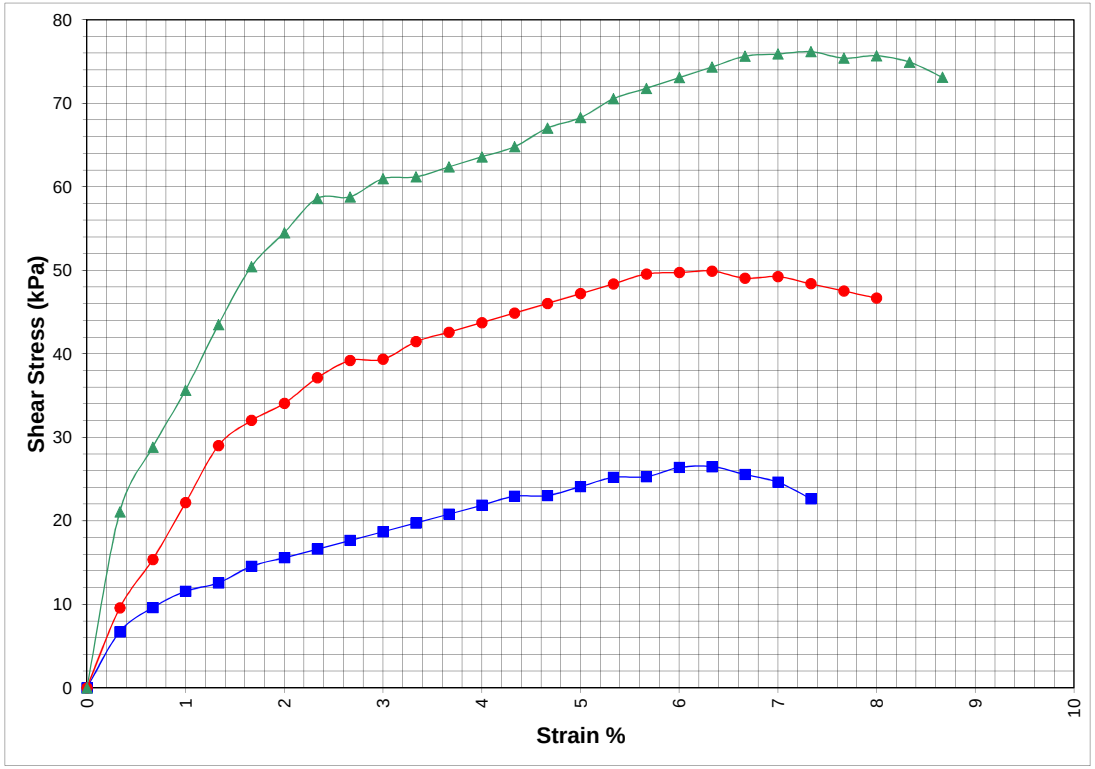
| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| Bore Hole . | MBH-23 | | | | | | | | | | | |
| Depth (m) | 43.50-43.65 | | | | | | | | | | | |
| Sample Type | SPT-30 | | | | | | | | | | | |
| Classification | SP-SM | | | | | | | | | | | |
| Gravel % | 0 | | | | | | | | | | | |
| Sand % | 95 | | | | | | | | | | | |
| Silt % | <----> | | | | | | | | | | | |
| Clay % | <----> | | | | | | | | | | | |
| Fines % (Silt+Clay) | 5 | | | | | | | | | | | |
| D60 mm | 0.350 | | | | | | | | | | | |
| D30 mm | 0.220 | | | | | | | | | | | |
| D10 mm | 0.150 | | | | | | | | | | | |
| Cu | 2.33 | | | | | | | | | | | |
| Cc | 0.92 | | | | | | | | | | | |
| Liquid Limit % | --- | | | | | | | | | | | |
| Plastic Limit % | --- | | | | | | | | | | | |
| Plasticity Index | --- | | | | | | | | | | | |

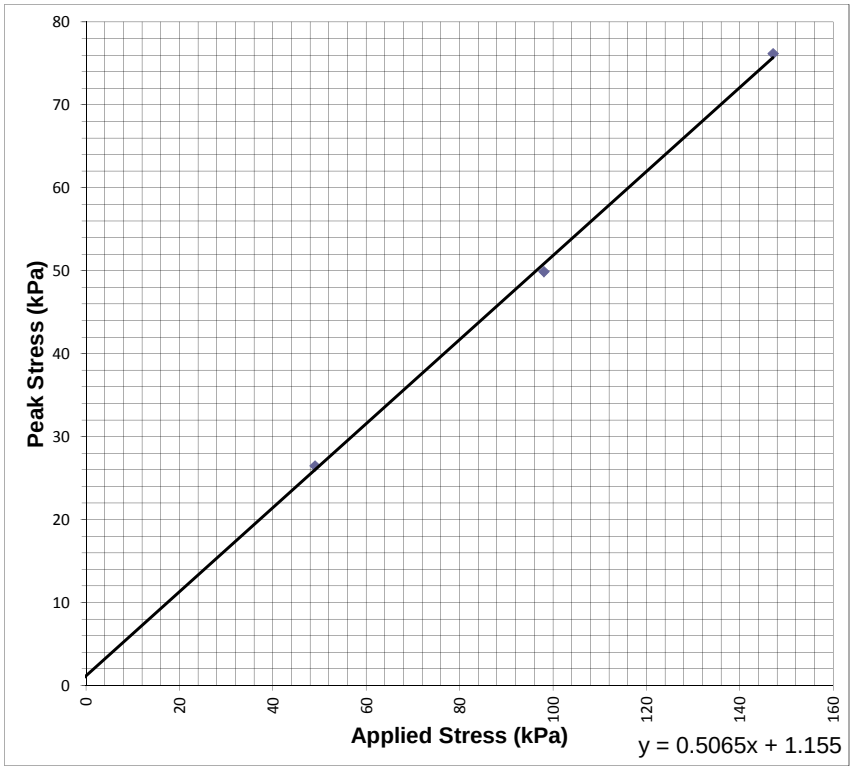



Checked By :

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 50 |
| | Stage 3 | 147 | 76 |

| | | |
|---|---|---|
| Angle of Friction | **26.86** | ° |
| Apparent Cohesion | **1.16** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

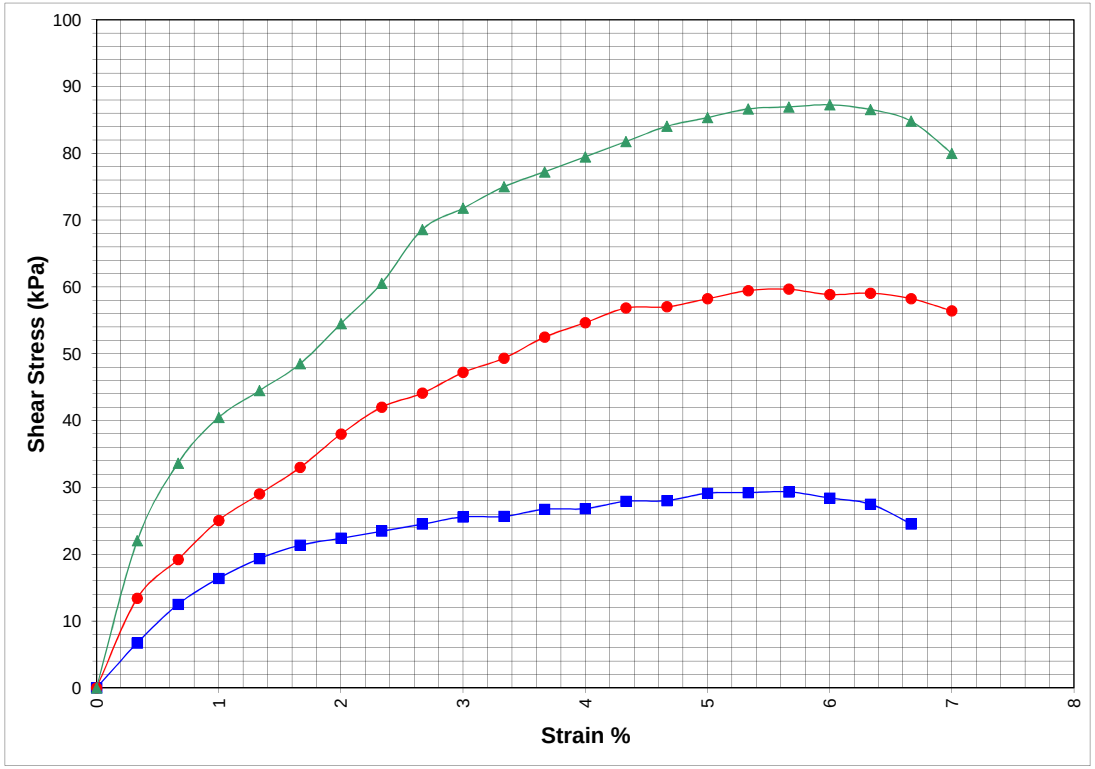
**Borehole: MBH-23**

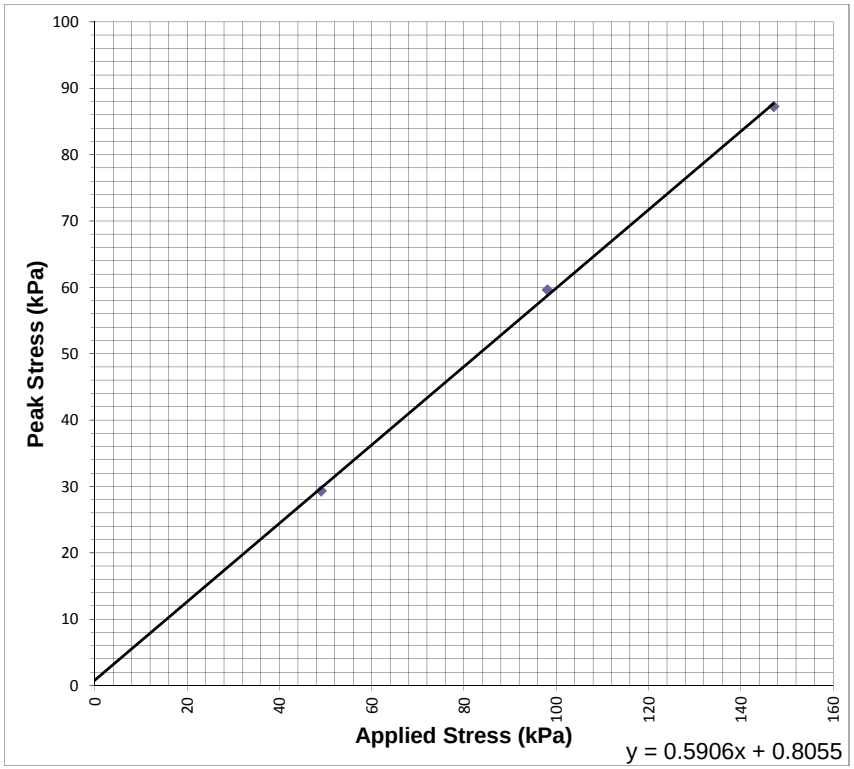
**Sample Type: SPT-01**

**Depth: 0.00-0.25 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 29 |
| | Stage 2 | 98 | 60 |
| | Stage 3 | 147 | 87 |

| | | |
|---|---|---|
| Angle of Friction | **30.57** | ° |
| Apparent Cohesion | **0.81** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

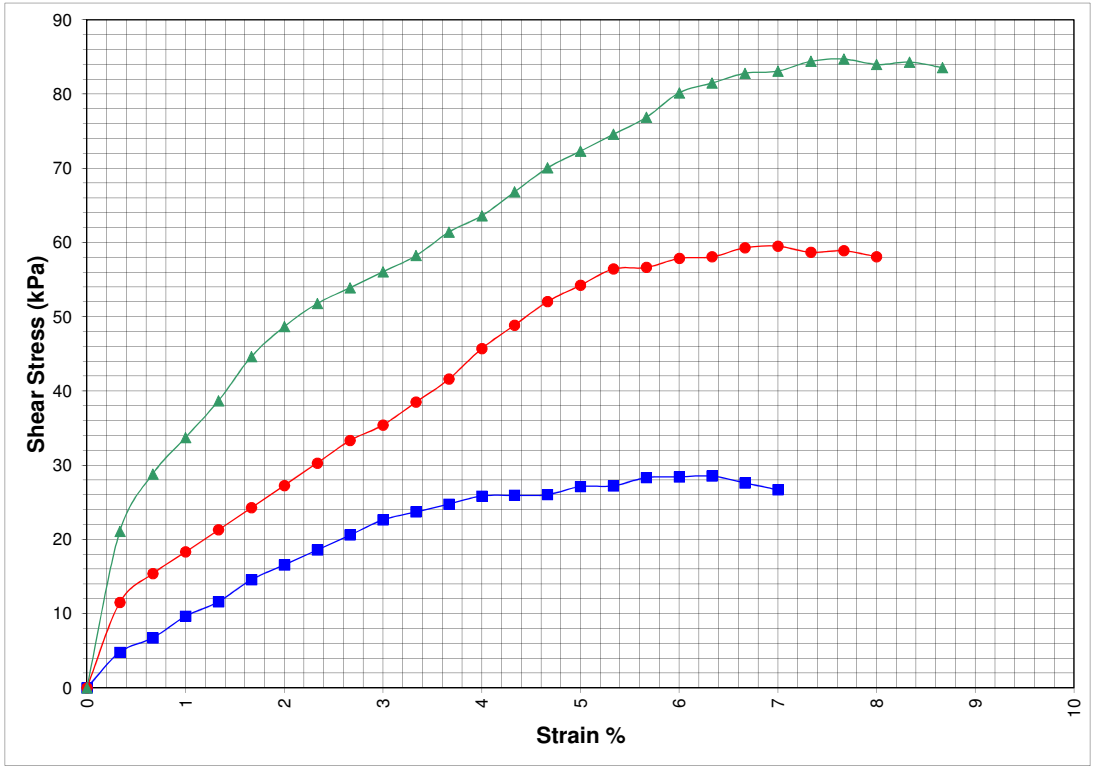
**Borehole: MBH-23**

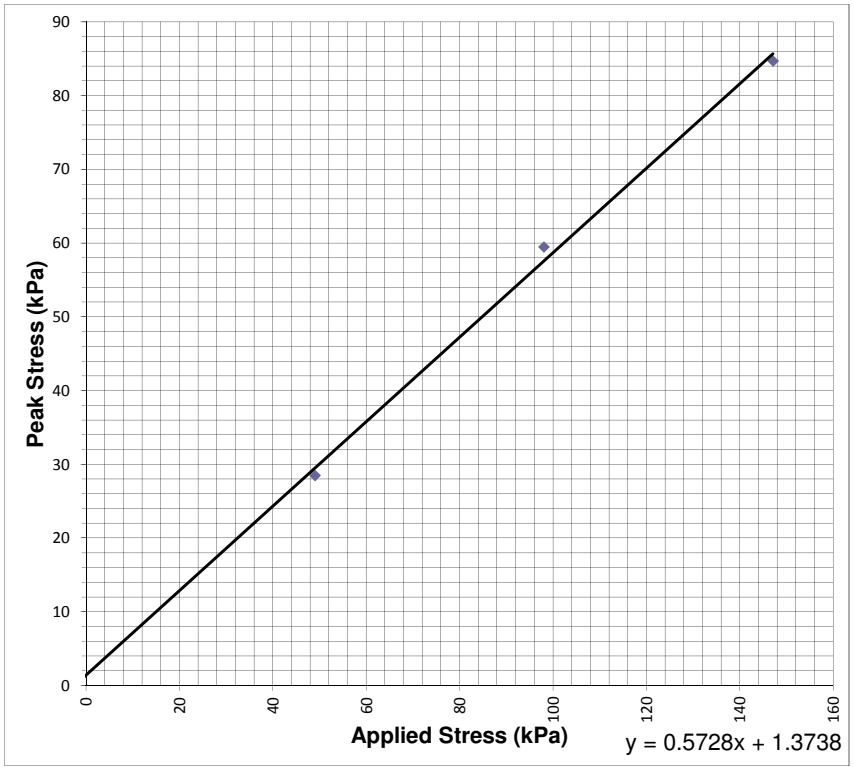
**Sample Type: SPT-03**

**Depth: 3.00-3.20 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 29 |
| | Stage 2 | 98 | 59 |
| | Stage 3 | 147 | 85 |

| | | |
|---|---|---|
| Angle of Friction | **29.8** | ° |
| Apparent Cohesion | **1.37** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

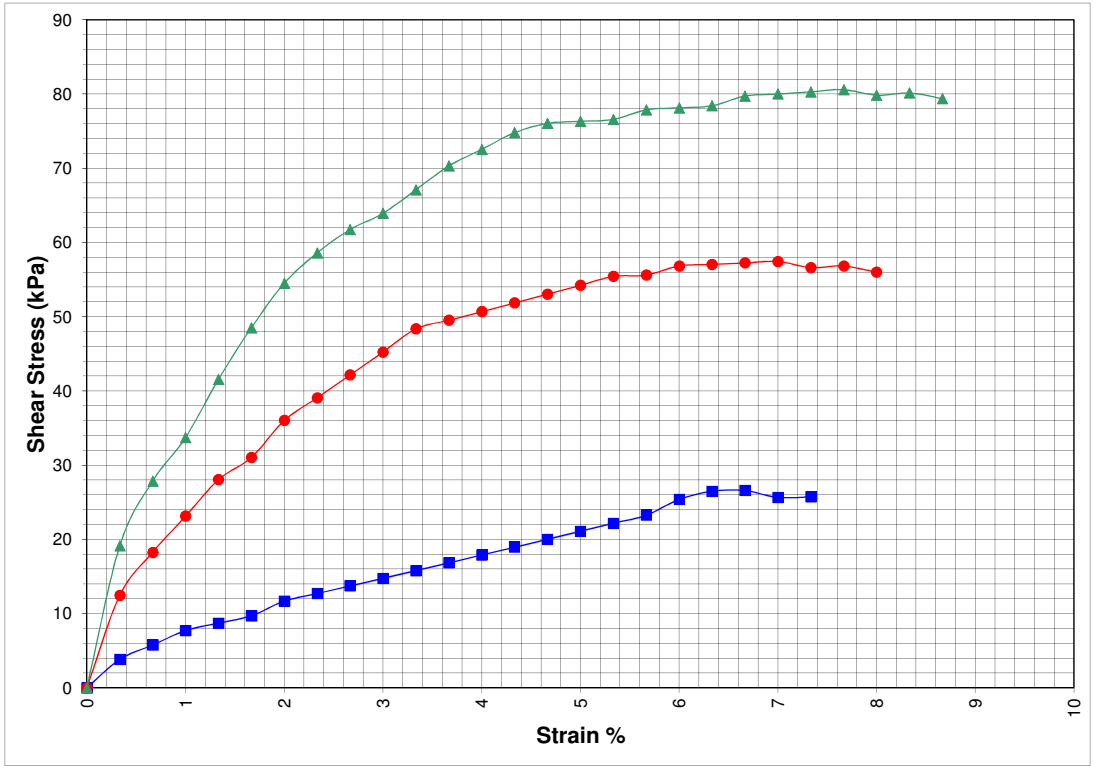
**Borehole: MBH-23**

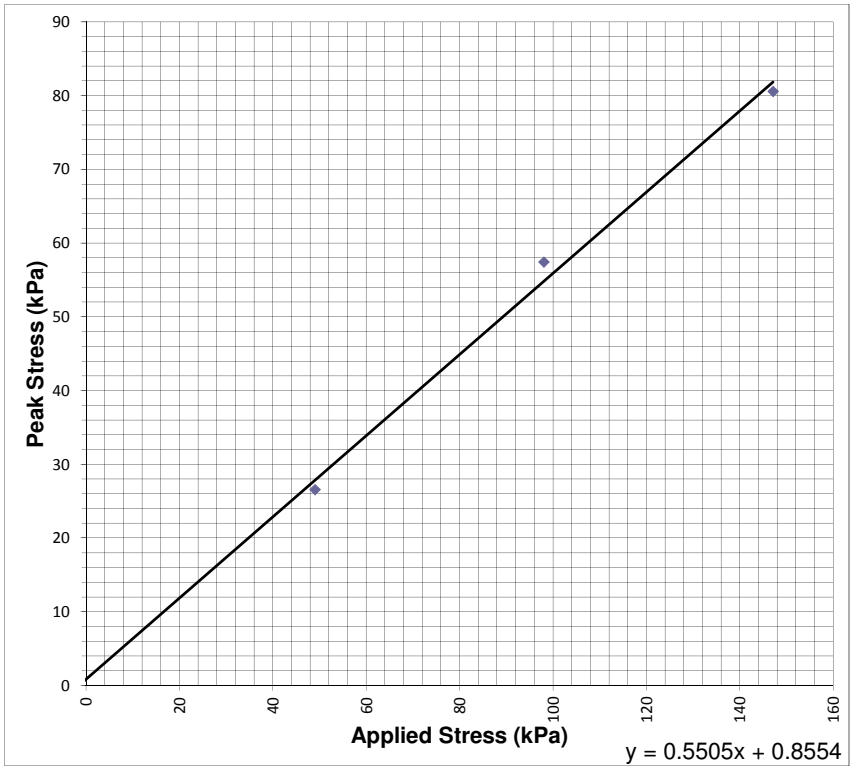
**Sample Type: SPT-05**

**Depth: 6.00-6.30 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 57 |
| | Stage 3 | 147 | 81 |

| | | |
|---|---|---|
| Angle of Friction | **28.8** | ° |
| Apparent Cohesion | **0.86** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

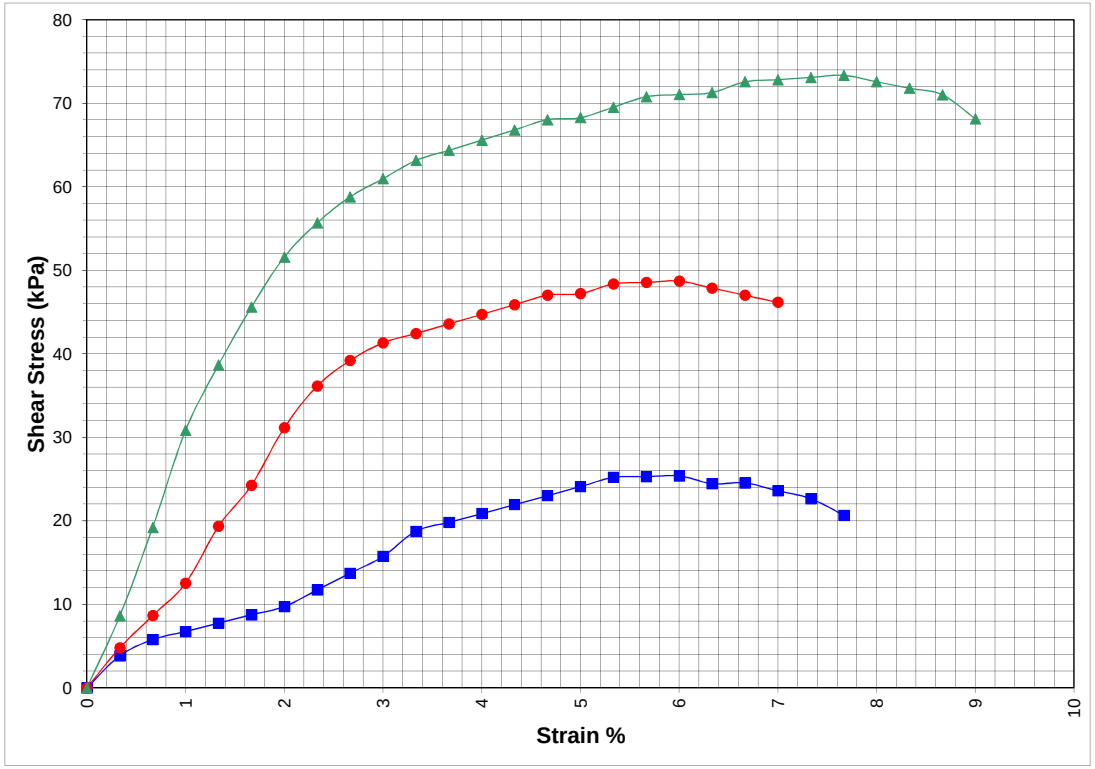
**Borehole: MBH-23**

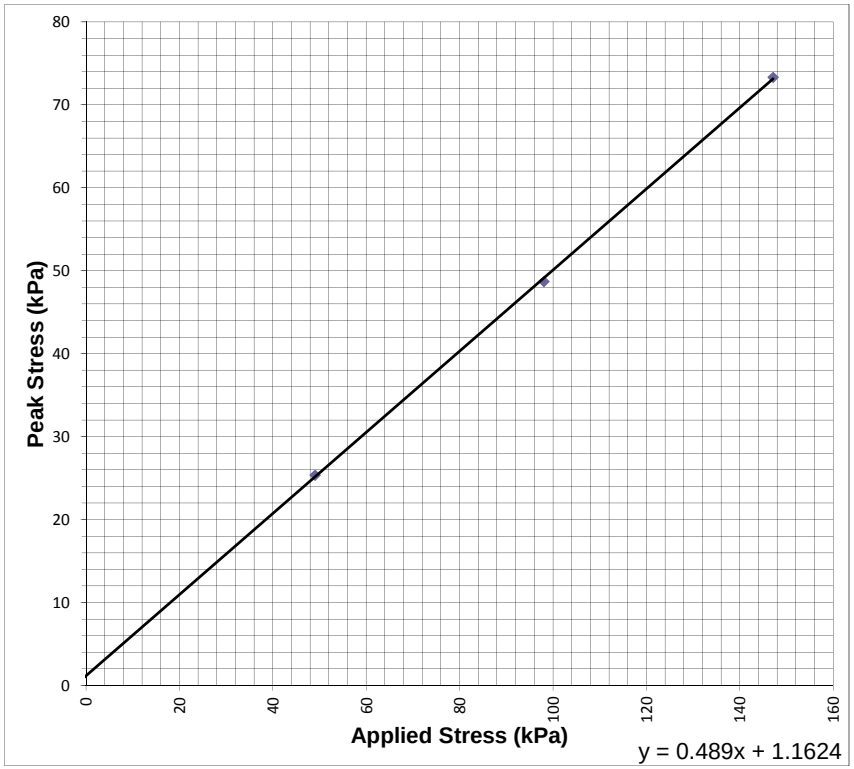
**Sample Type: SPT-07**

**Depth: 9.00-9.25 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 25 |
| | Stage 2 | 98 | 49 |
| | Stage 3 | 147 | 73 |

| | | |
|---|---|---|
| Angle of Friction | **26.06** | ° |
| Apparent Cohesion | **1.16** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

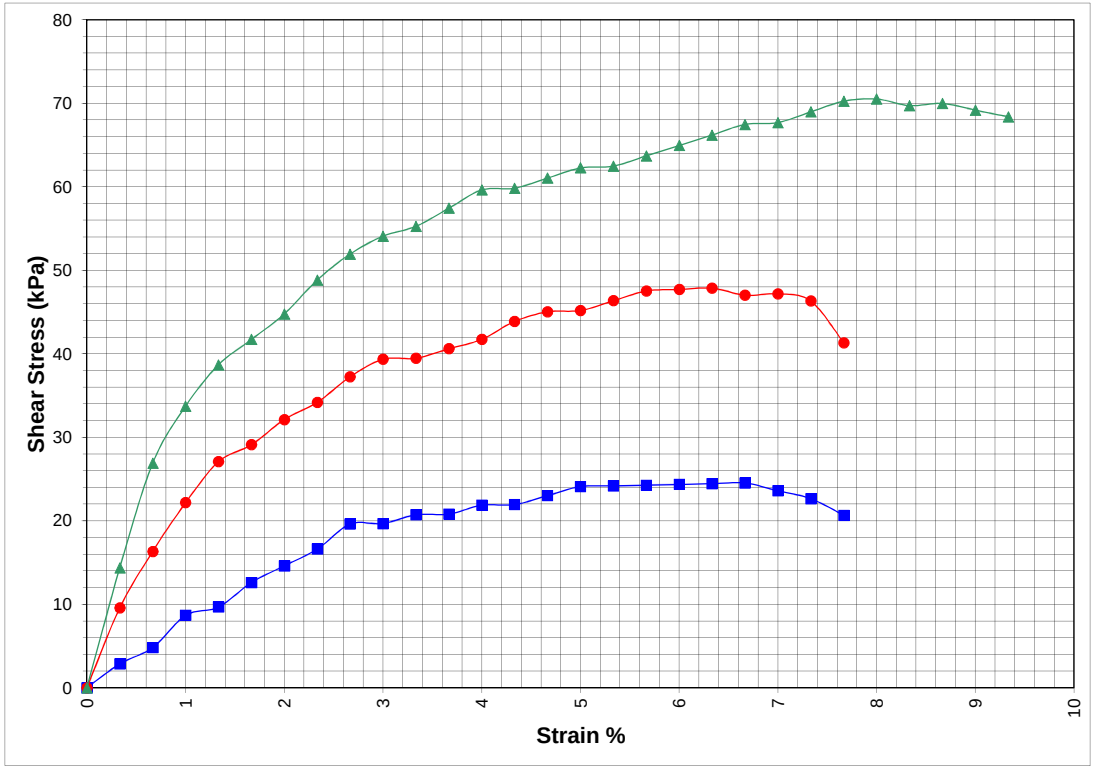
**Borehole: MBH-23**

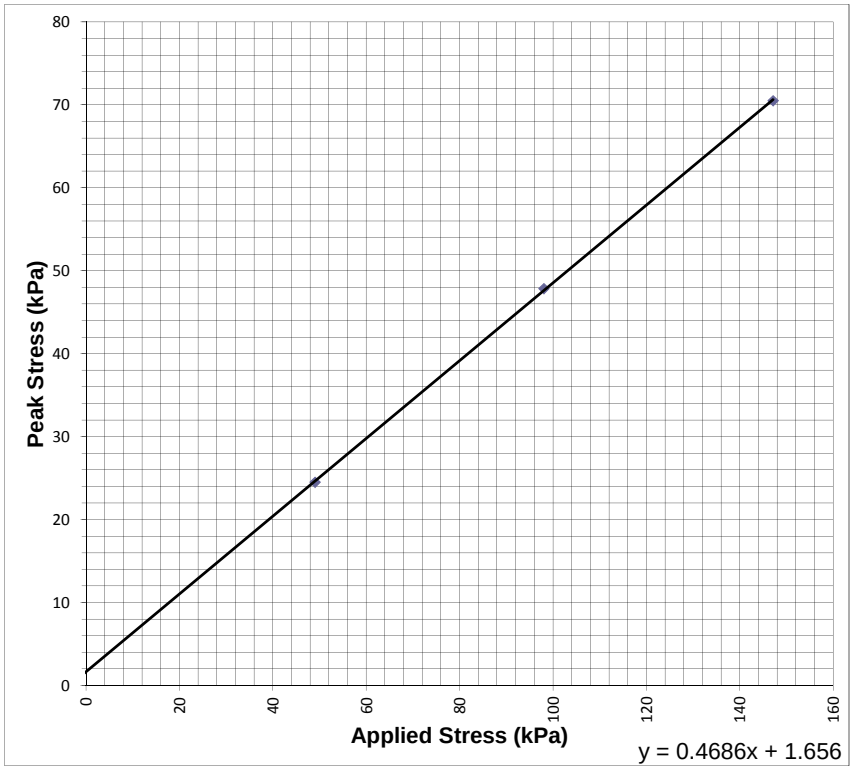
**Sample Type: SPT-12**

**Depth: 16.50-16.80 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 25 |
| | Stage 2 | 98 | 48 |
| | Stage 3 | 147 | 70 |

| | | |
|---|---|---|
| Angle of Friction | **25.11** | ° |
| Apparent Cohesion | **1.66** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

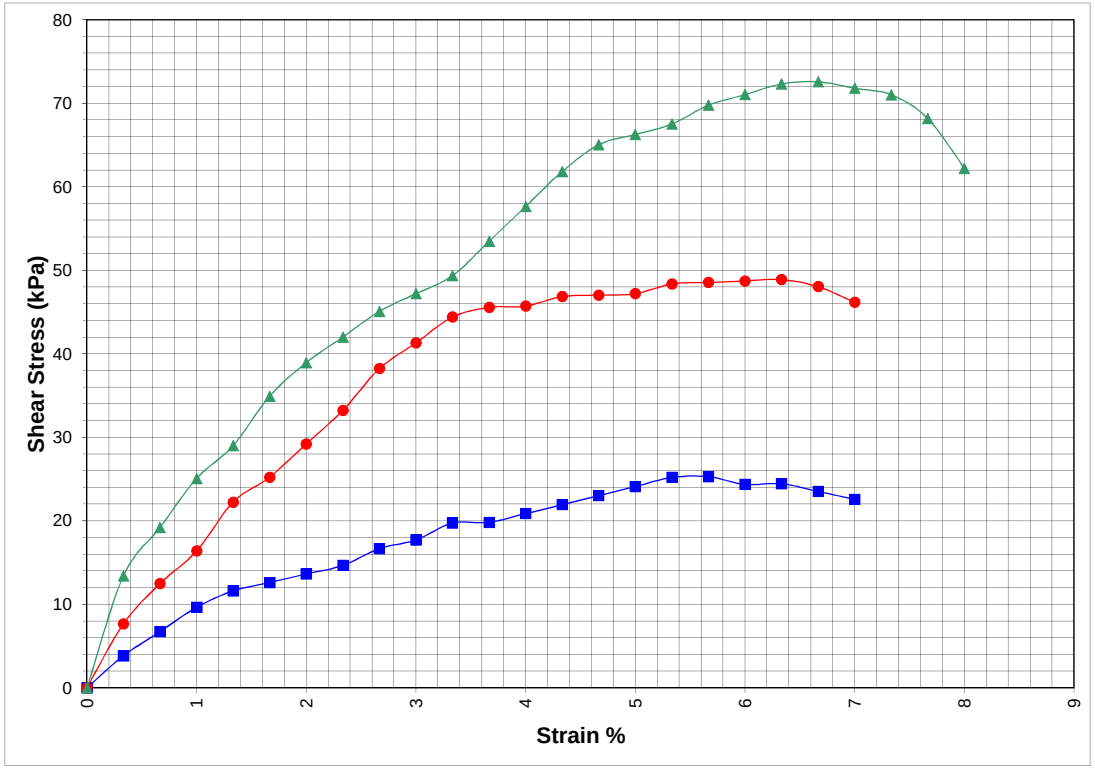
**Borehole: MBH-23**

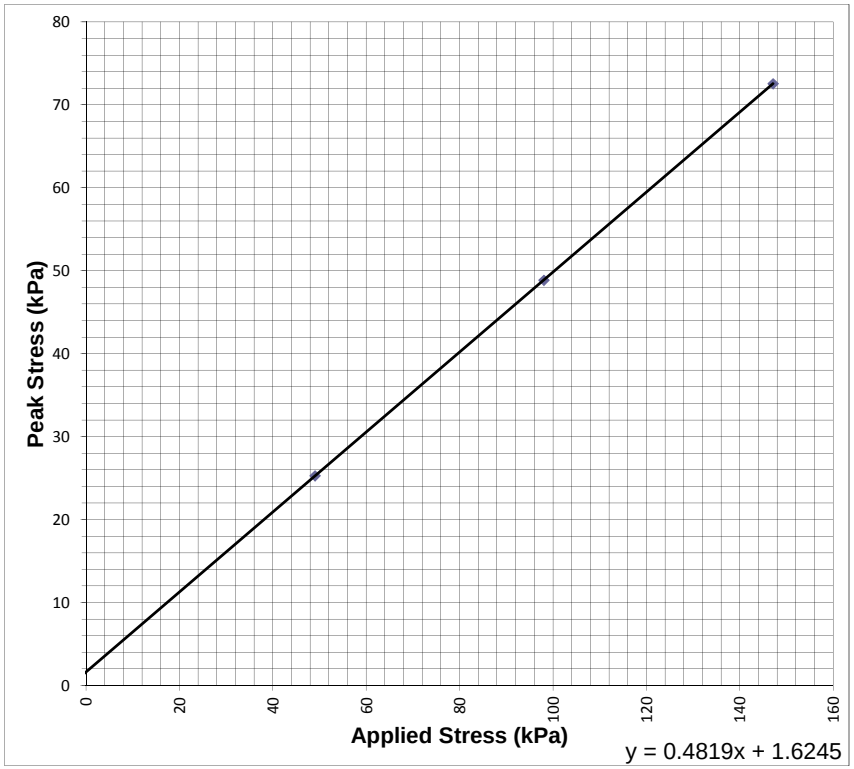
**Sample Type: SPT-16**

**Depth: 22.50-22.70 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 25 |
| | Stage 2 | 98 | 49 |
| | Stage 3 | 147 | 73 |

| | | |
|---|---|---|
| Angle of Friction | **25.73** | ° |
| Apparent Cohesion | **1.62** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

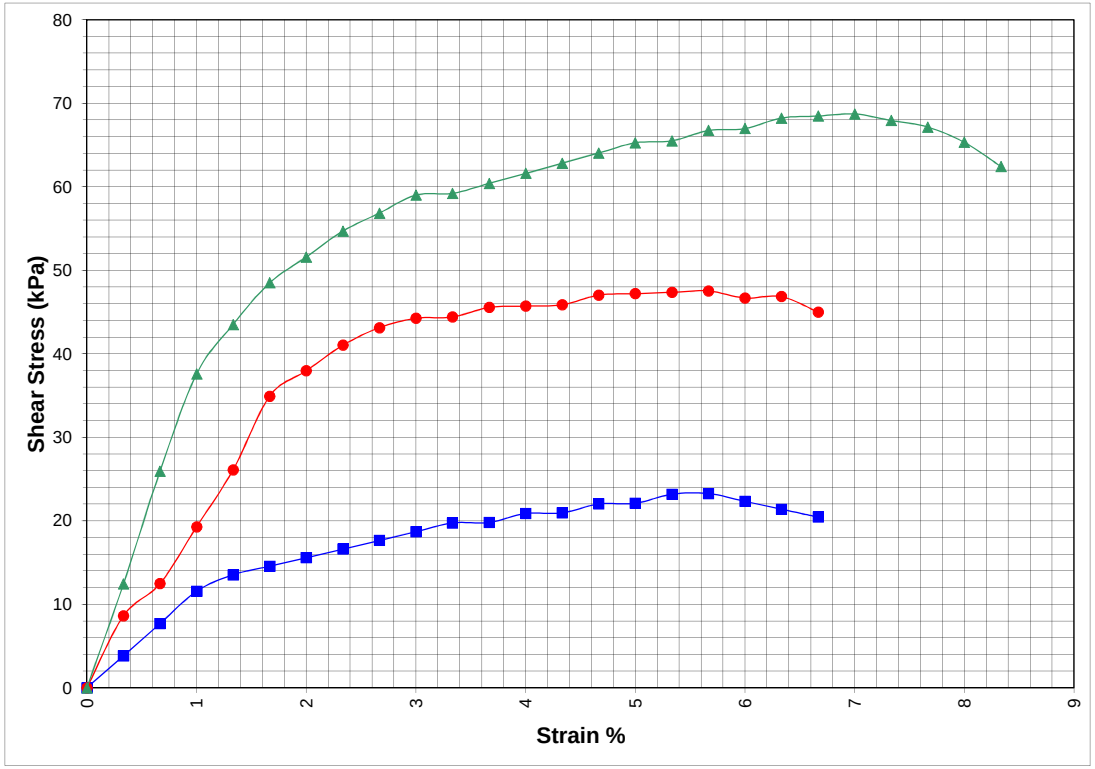
**Borehole: MBH-23**

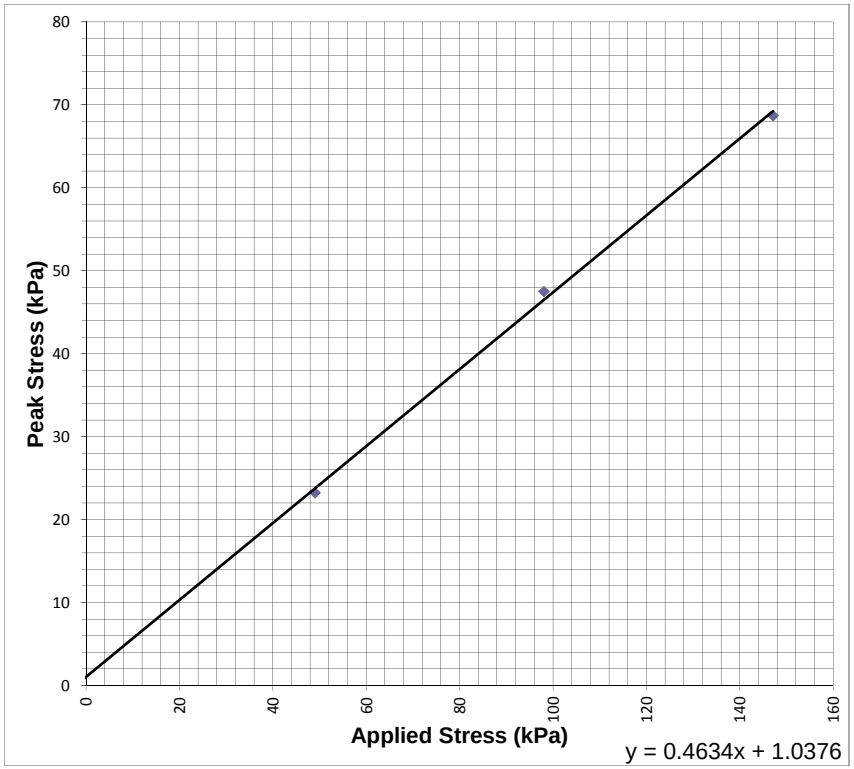
**Sample Type: SPT-18**

**Depth: 25.50-25.70 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 23 |
| | Stage 2 | 98 | 48 |
| | Stage 3 | 147 | 69 |

| | | |
|---|---|---|
| Angle of Friction | **24.86** | ° |
| Apparent Cohesion | **1.04** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

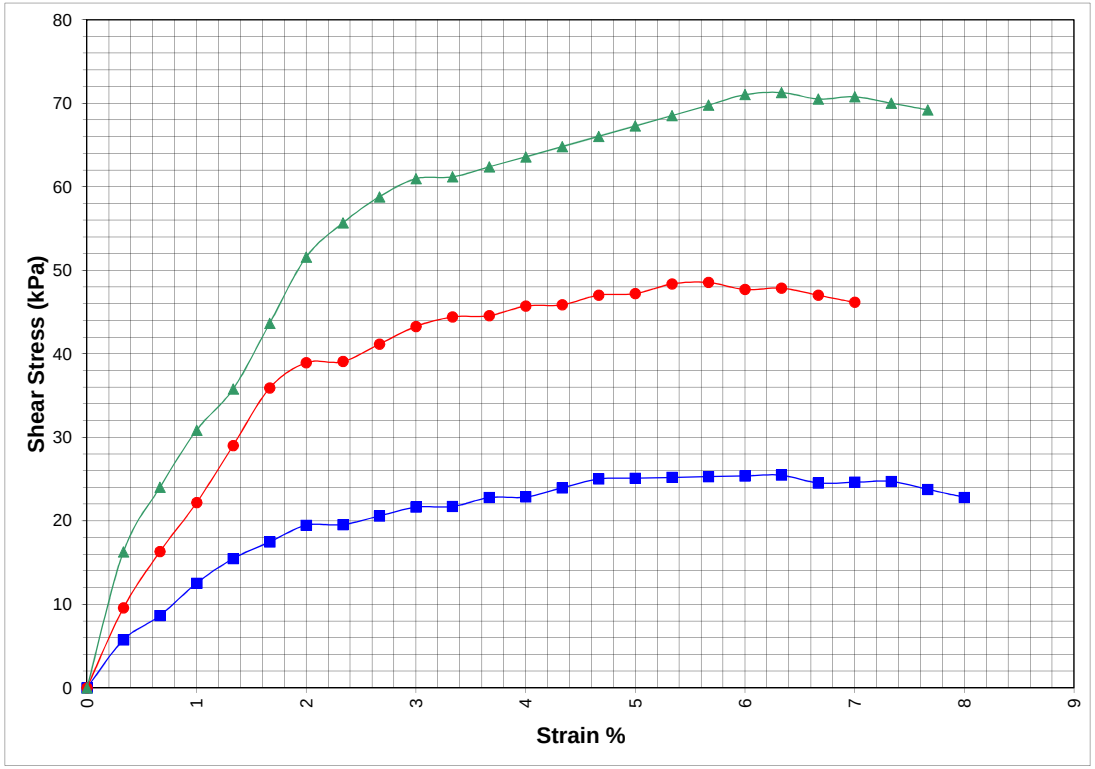
**Borehole: MBH-23**

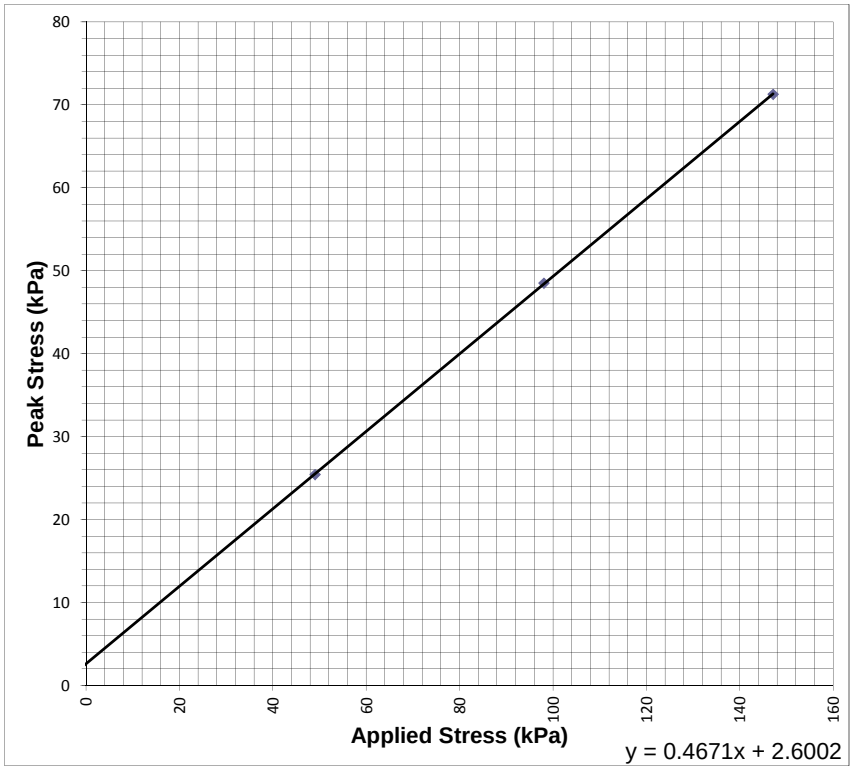
**Sample Type: SPT-23**

**Depth: 33.00-33.25 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 25 |
| | Stage 2 | 98 | 49 |
| | Stage 3 | 147 | 71 |

| | | |
|---|---|---|
| Angle of Friction | **25.04** | ° |
| Apparent Cohesion | **2.60** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

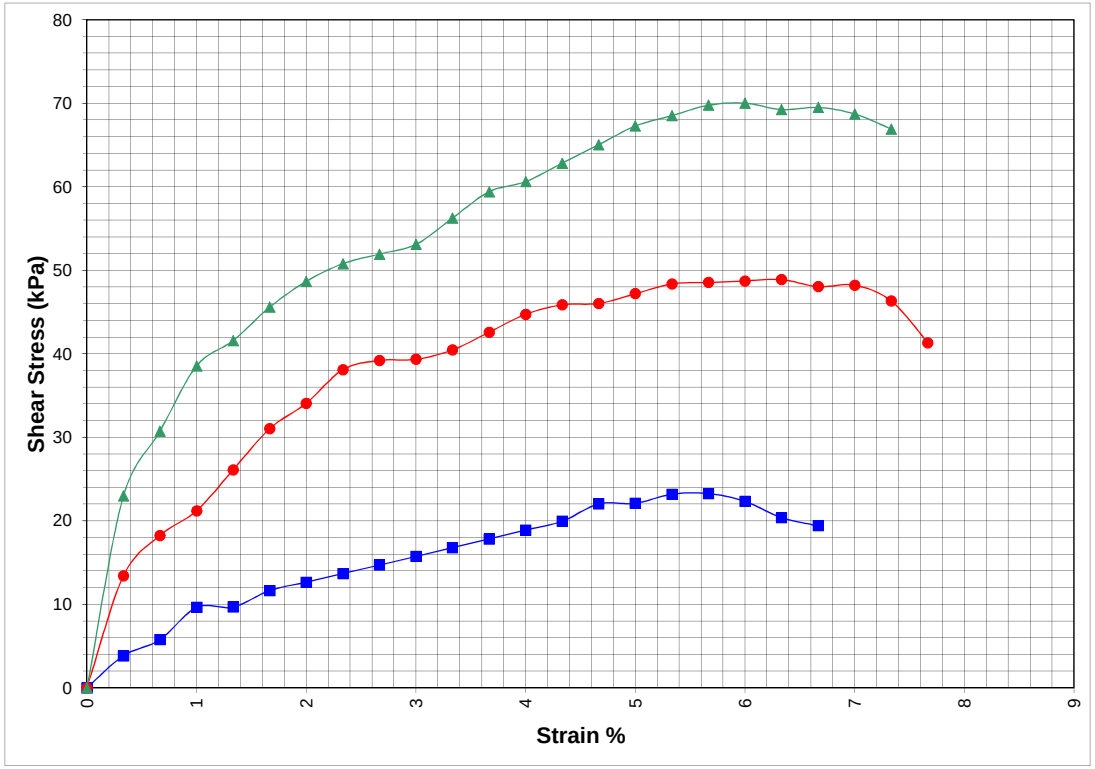
**Borehole: MBH-23**

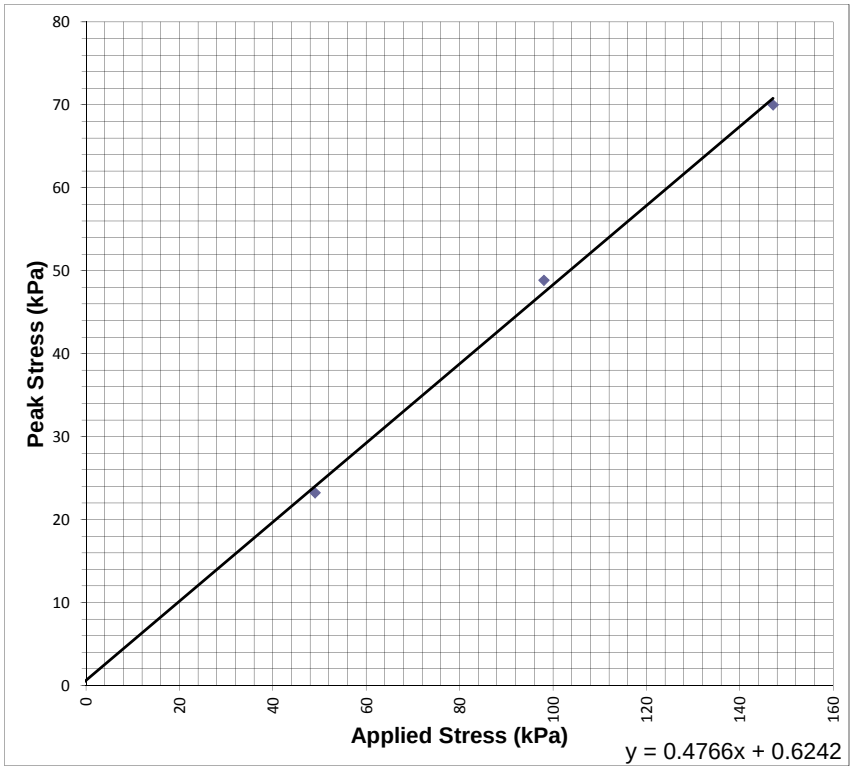
**Sample Type: SPT-25**

**Depth: 36.00-36.20 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 23 |
| | Stage 2 | 98 | 49 |
| | Stage 3 | 147 | 70 |

| | | |
|---|---|---|
| Angle of Friction | **25.48** | ° |
| Apparent Cohesion | **0.62** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: MBH-23**

**Sample Type: SPT-27**

**Depth: 39.00-39.15 m**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-1 | 0.00-0.23 | | | | | 20.1 | 17.96 | 7.90 | 14.95 | 2.61 | | | | | | DST | | | 2.62 | 32.9 | | | | | | | | | | | | | |
| SPT-2 | 1.50-1.70 | SP-SM | | | | 14.0 | 18.49 | 8.43 | 16.21 | | 0 | 93 | <--> | <--> | 7 | | | | | | | | | | | | | | | | | | |
| SPT-3 | 3.00-3.20 | SP | | | | 17.4 | 18.54 | 8.48 | 15.79 | | 0 | 96 | <--> | <--> | 4 | | | | | | | | | | | | | | | | | | |
| SPT-4 | 4.50-4.70 | | | | | 14.5 | 18.48 | 8.42 | 16.14 | 2.65 | | | | | | DST | | | 0.41 | 33.4 | | | | | | | | | | | | | |
| SPT-5 | 6.00-6.18 | SP | | | | 19.1 | 18.39 | 8.33 | 15.44 | | 0 | 96 | <--> | <--> | 4 | | | | | | | | | | | | | | | | | | |
| SPT-6 | 7.50-7.72 | SP | | | | 18.0 | 18.12 | 8.06 | 15.36 | | 0 | 98 | <--> | <--> | 2 | | | | | | | | | | | | | | | | 8.18 | 0.40 | 2.00 | 1300 | 8850 |
| SPT-7 | 9.00-9.20 | | | | | 20.6 | 17.91 | 7.85 | 14.85 | | | | | | | DST | | | 1.35 | 28.5 | | | | | | | | | | | | | |
| SPT-8 | 10.50-10.72 | SP | | | | 19.1 | 18.03 | 7.97 | 15.14 | | 0 | 97 | <--> | <--> | 3 | | | | | | | | | | | | | | | | | | |
| SPT-9 | 12.00-12.25 | | | | | 20.4 | 17.57 | 7.51 | 14.60 | 2.59 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-10 | 13.50-13.73 | | | | | 20.2 | 18.14 | 8.08 | 15.10 | 2.60 | | | | | | DST | | | 1.45 | 29.9 | | | | | | | | | | | | | |
| SPT-11 | 15.00-15.35 | CL | 29.1 | 13.0 | 16.1 | 26.9 | 19.86 | 9.80 | 15.65 | | 0 | 77 | 9 | 14 | 23 | | | | | | | | | | | | | | | | | | |
| SPT-12 | 16.50-16.73 | SM/SC | | | | 21.5 | 17.96 | 7.90 | 14.79 | 2.62 | 0 | 82 | <--> | <--> | 18 | | | | | | | | | | | | | | | | | | |
| SPT-13 | 18.00-18.20 | | | | | 20.8 | 18.04 | 7.98 | 14.93 | | | | | | | DST | | | 0.54 | 26.7 | | | | | | | | | | | | | |
| SPT-14 | 19.50-19.68 | SP-SM | | | | 17.9 | 18.14 | 8.08 | 15.38 | | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | | | | |
| SPT-15 | 21.00-21.20 | | | | | 17.2 | 18.58 | 8.52 | 15.86 | 2.63 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-16 | 22.50-22.73 | | | | | 19.9 | 18.94 | 8.88 | 15.80 | | | | | | | DST | | | 0.90 | 26.1 | | | | | | | | | | | | | |
| SPT-17 | 24.00-24.20 | SP | | | | 16.5 | 17.52 | 7.46 | 15.04 | 2.62 | 0 | 97 | <--> | <--> | 3 | | | | | | | | | | | | | | | | | | |
| SPT-18 | 25.50-25.65 | | | | | 16.4 | 16.76 | 6.70 | 14.40 | | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-19 | 27.00-27.20 | SP-SM | | | | 19.5 | 17.54 | 7.48 | 14.68 | 2.62 | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | | | | |
| SPT-20 | 28.50-28.72 | | | | | 18.8 | 18.49 | 8.43 | 15.57 | | | | | | | DST | | | 1.34 | 25.5 | | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

\# : Decayed Wood

**Failure Type**

A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-24**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-21 | 30.00-30.25 | SP | | | | 17.0 | 17.47 | 7.41 | 14.93 | | 0 | 97 | <--> | <--> | 3 | | | | | | | | | | | | | | 8.05 | 0.70 | 1.00 | 800 | 12390 |
| SPT-22 | 31.50-31.68 | | | | | 21.5 | 17.88 | 7.82 | 14.72 | 2.59 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-23 | 33.00-33.20 | SP-SM | | | | 20.2 | 17.63 | 7.57 | 14.67 | | 0 | 93 | <--> | <--> | 7 | | | | | | | | | | | | | | | | | | |
| SPT-24 | 34.50-34.77 | | | | | 20.0 | 17.54 | 7.48 | 14.62 | | | | | | | DST | | | 1.68 | 25.6 | | | | | | | | | | | | |
| SPT-25 | 36.00-36.18 | | | | | 20.8 | 18.08 | 8.02 | 14.97 | 2.60 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-26 | 38.00-38.15 | | | | | 19.5 | 17.56 | 7.50 | 14.70 | | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-27 | 40.00-40.22 | | | | | 18.0 | 17.65 | 7.59 | 14.96 | | | | | | | DST | | | 1.72 | 25.9 | | | | | | | | | | | | |
| **END OF BOREHOLE** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

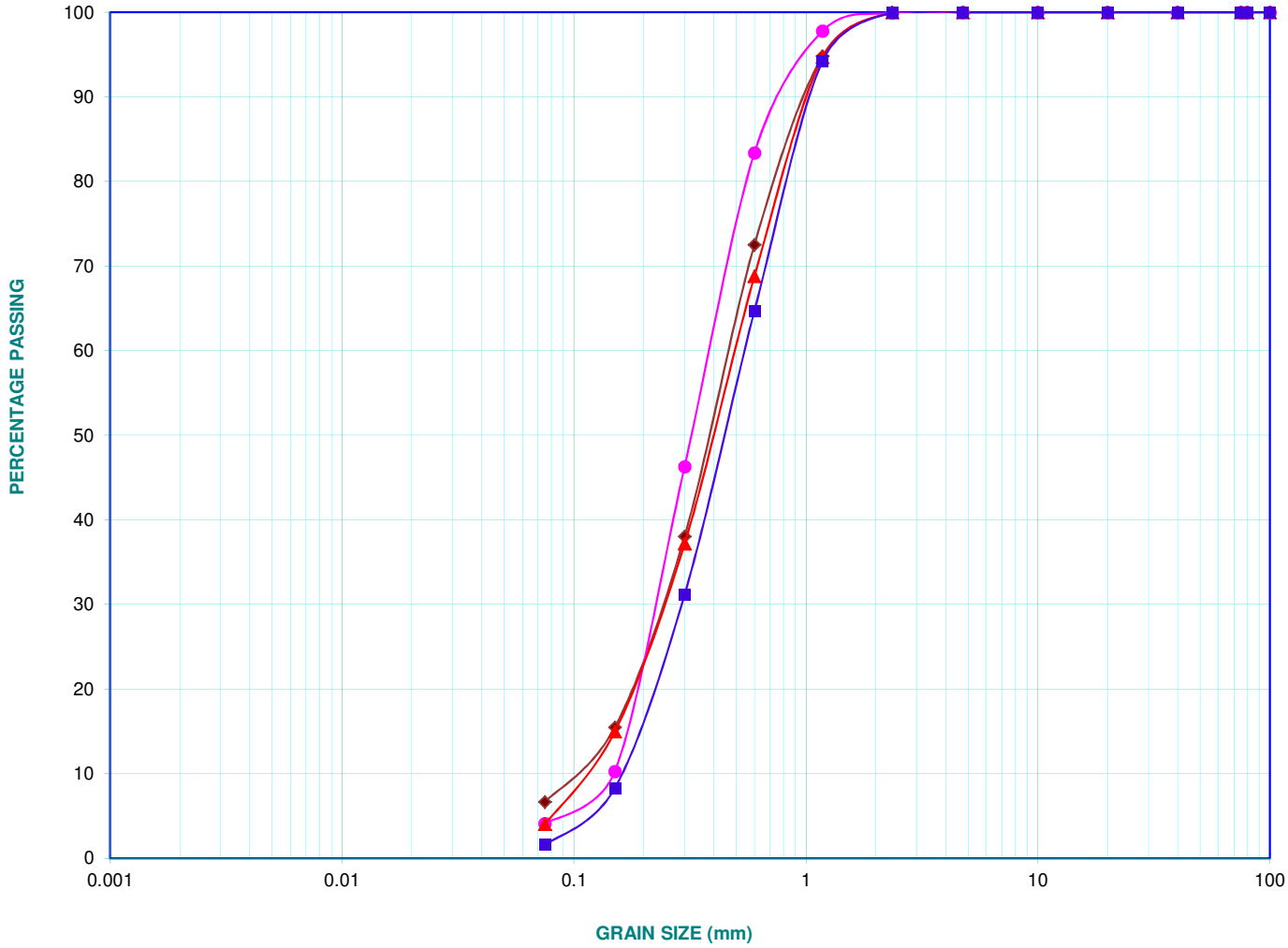
\# : Decayed Wood

**Failure Type**
A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-24**

# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** | | | | | | | | | | | |
| **Job No.** | **: CM 19 01 03** | | | **Borehole No.** | **: MBH-24** | | | | | **Date :** | **15-Jun-19** | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-24 | MBH-24 | MBH-24 | MBH-24 | | | | | | | | |
| **Depth (m)** | 1.50-1.70 | 3.00-3.20 | 6.00-6.18 | 7.50-7.72 | | | | | | | | |
| **Sample Type** | SPT-01 | SPT-03 | SPT-05 | SPT-06 | | | | | | | | |
| **Classification** | SP-SM | SP | SP | SP | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 93 | 96 | 96 | 98 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 7 | 4 | 4 | 2 | | | | | | | | |
| **D60 mm** | 0.480 | 0.400 | 0.460 | 0.560 | | | | | | | | |
| **D30 mm** | 0.250 | 0.220 | 0.250 | 0.300 | | | | | | | | |
| **D10 mm** | 0.100 | 0.150 | 0.120 | 0.180 | | | | | | | | |
| **Cu** | 4.80 | 2.67 | 3.83 | 3.11 | | | | | | | | |
| **Cc** | 1.30 | 0.81 | 1.13 | 0.89 | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |

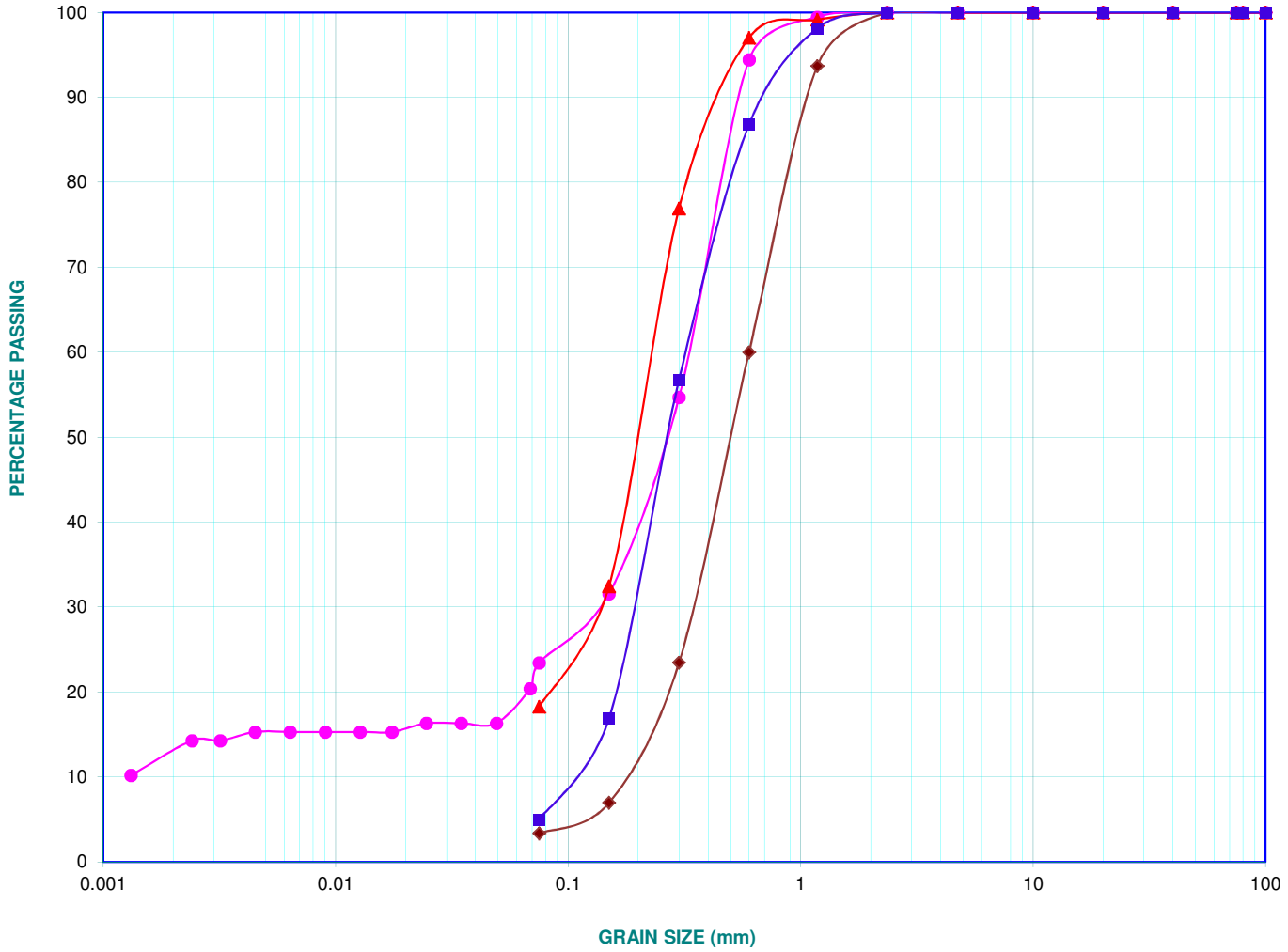



Checked By :

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-24** |
| **Date :** | **15-Jun-19** |

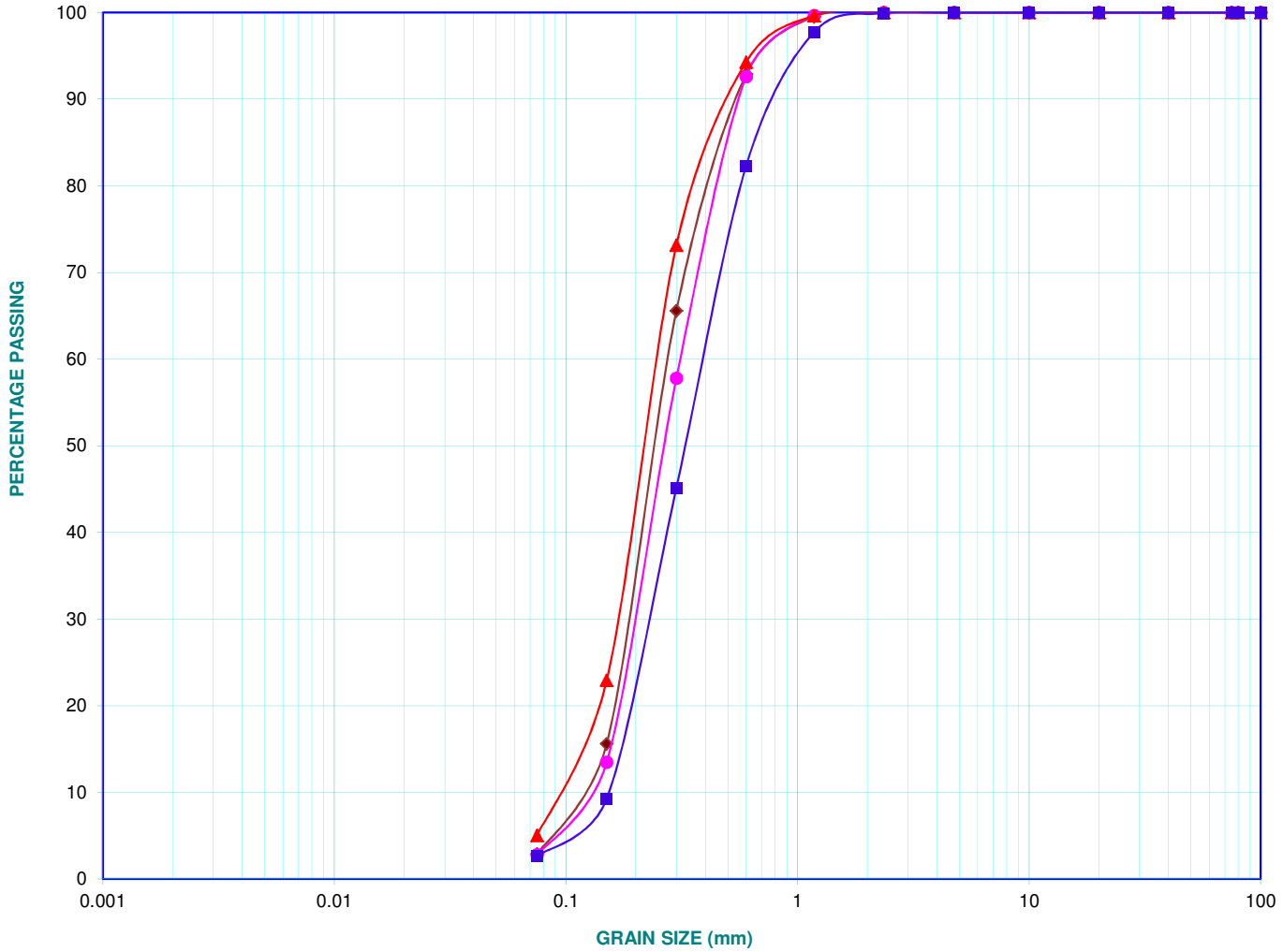
| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-24 | MBH-24 | MBH-24 | MBH-24 | | | | | | | | |
| **Depth (m)** | 10.50-10.72 | 15.00-15.35 | 16.50-16.73 | 19.50-19.68 | | | | | | | | |
| **Sample Type** | SPT-08 | SPT-11 | SPT-12 | SPT-14 | | | | | | | | |
| **Classification** | SP | CL | SM/SC | SP-SM | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 97 | 77 | 82 | 95 | | | | | | | | |
| **Silt %** | <----> | 9 | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | 14 | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 3 | 23 | 18 | 5 | | | | | | | | |
| **D60 mm** | 0.600 | 0.320 | | 0.310 | | | | | | | | |
| **D30 mm** | 0.350 | 0.150 | | 0.200 | | | | | | | | |
| **D10 mm** | 0.190 | 0.001 | | 0.110 | | | | | | | | |
| **Cu** | 3.16 | 246.15 | | 2.82 | | | | | | | | |
| **Cc** | 1.07 | 54.09 | | 1.17 | | | | | | | | |
| **Liquid Limit %** | --- | 29.1 | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | 13.0 | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | 16.1 | --- | --- | | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | : Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha. | | | | | | | | | | |
| **Job No.** | : CM 19 01 03 | | | **Borehole No.** | : MBH-24 | | | **Date :** | 15-Jun-19 | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND F | SAND M | SAND C | GRAVEL F / GRAVEL C |
| **Bore Hole .** | MBH-24 | MBH-24 | MBH-24 | MBH-24 | | | | | | | |
| **Depth (m)** | 24.00-24.20 | 25.50-25.65 | 27.00-27.20 | 30.00-30.25 | | | | | | | |
| **Sample Type** | SPT-17 | SPT-18 | SPT-19 | SPT-21 | | | | | | | |
| **Classification** | SP | SP | SP-SM | SP | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | |
| **Sand %** | 97 | 97 | 95 | 97 | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | |
| **Fines % (Silt+Clay)** | 3 | 3 | 5 | 3 | | | | | | | |
| **D60 mm** | 0.280 | 0.300 | 0.250 | 0.400 | | | | | | | |
| **D30 mm** | 0.190 | 0.200 | 0.170 | 0.250 | | | | | | | |
| **D10 mm** | 0.130 | 0.140 | 0.095 | 0.150 | | | | | | | |
| **Cu** | 2.15 | 2.14 | 2.63 | 2.67 | | | | | | | |
| **Cc** | 0.99 | 0.95 | 1.22 | 1.04 | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | |



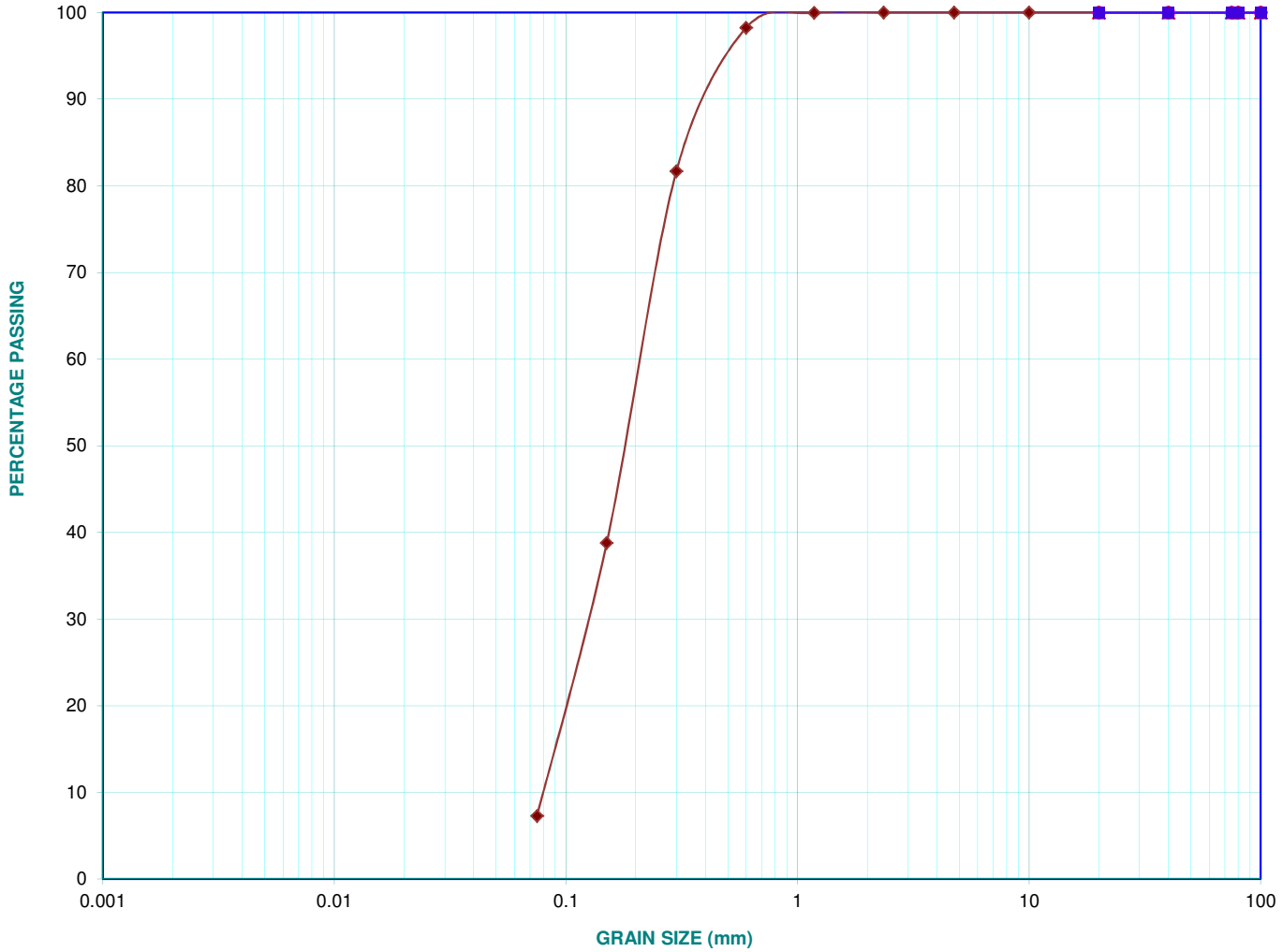

Checked By :

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-24** |
| **Date :** | **15-Jun-19** |

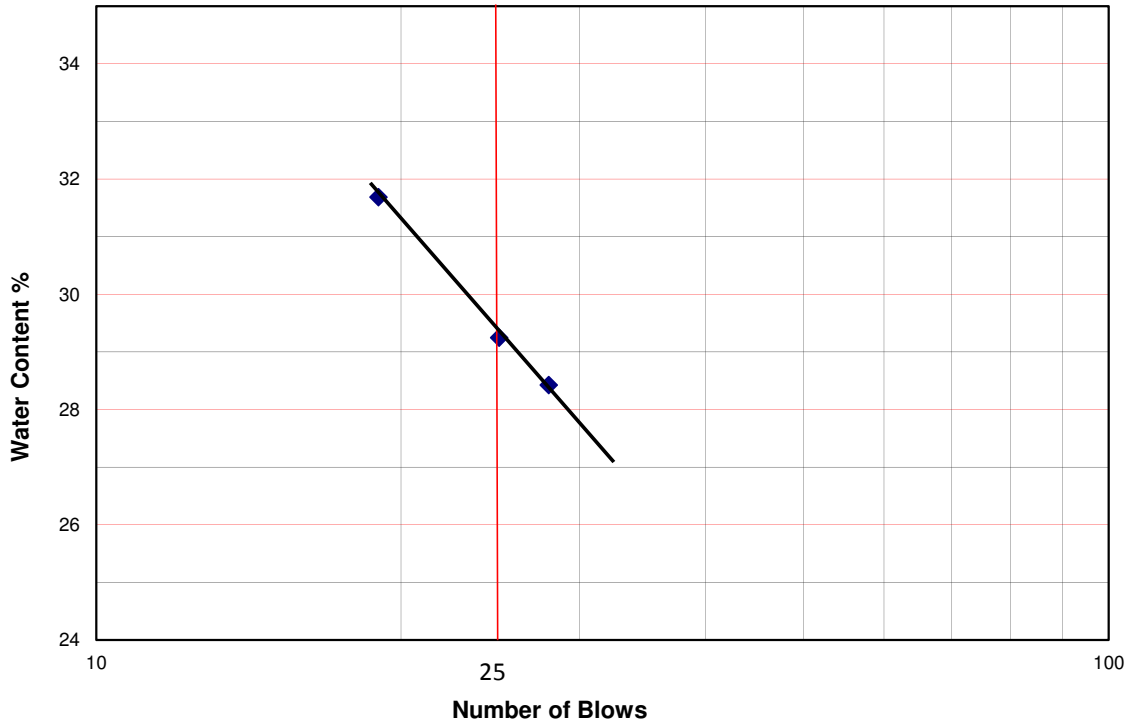
| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |

| | | | | |
|---|---|---|---|---|
| **Bore Hole .** | MBH-24 | | | |
| **Depth (m)** | 33.00-33.20 | | | |
| **Sample Type** | SPT-23 | | | |
| **Classification** | SP-SM | | | |
| **Gravel %** | 0 | | | |
| **Sand %** | 93 | | | |
| **Silt %** | <----> | | | |
| **Clay %** | <----> | | | |
| **Fines % (Silt+Clay)** | 7 | | | |
| **D60 mm** | 0.200 | | | |
| **D30 mm** | 0.120 | | | |
| **D10 mm** | 0.080 | | | |
| **Cu** | 2.50 | | | |
| **Cc** | 0.90 | | | |
| **Liquid Limit %** | --- | | | |
| **Plastic Limit %** | --- | | | |
| **Plasticity Index** | --- | | | |




Checked By :

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 38.63 | 39.14 | 45.73 | | |
| Dry Weight + Can (g) | 32.86 | 33.13 | 37.93 | | |
| Can Weight (g) | 12.56 | 12.58 | 13.31 | | |
| Water Content, % | 28.4 | 29.2 | 31.7 | | |
| Number of Blows | 28 | 25 | 19 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 17.24 | 16.58 | 17.40 |
| Dry Weight + Can (g) | 16.35 | 15.75 | 16.47 |
| Can Weight (g) | 9.48 | 9.49 | 9.22 |
| Water Content, % | 13.0 | 13.3 | 12.8 |

| | |
|---|---|
| Liquid Limit % | 29.1 |
| Plastic Limit % | 13.0 |
| Plasticity Index % | 16.1 |

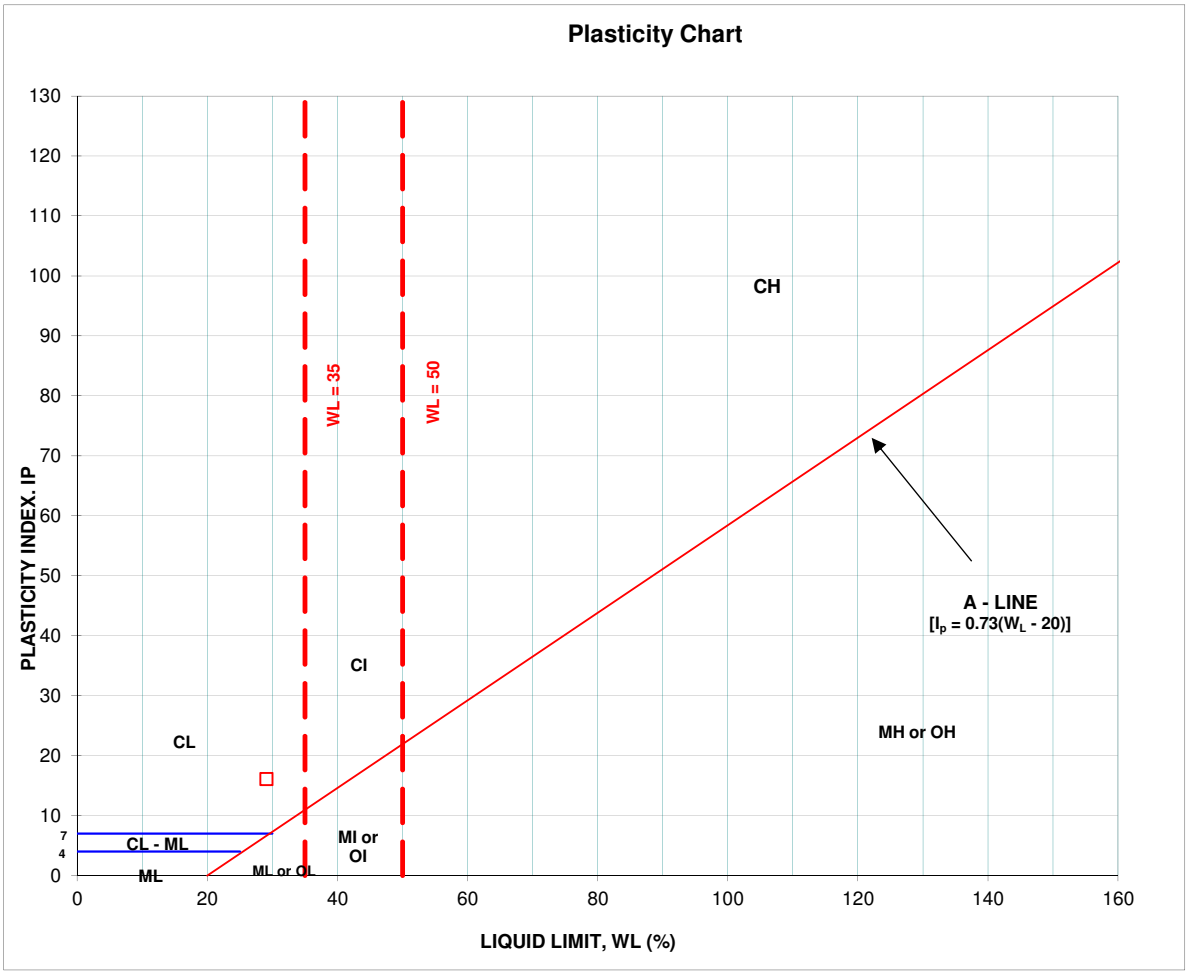
Preparation of Sample :
Dry State

Sample Type: SPT-02

Borehole no.: MBH-24

Depth :15.00-15.35

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.




| | Sample Type | Depth (m) | $W_L$ | $W_P$ | $I_P$ | Remarks |
|---|---|---|---|---|---|---|
| □ | SPT-11 | 15.00-15.35 | 29.1 | 13.0 | 16.1 | CL: Inorganic clays of low to medium plasticity. |
| ◇ | | | | | | |
| △ | | | | | p | |
| ● | | | | | | |
| + | | | | | | |
| ■ | | | | | | |

| | | | |
|---|---|---|---|
| ML | Inorganic silts, very fine sands, rock flour, silty or clayey fine sands | MH | Inorganic silts, or diatomaceous fine sands or silts, elastic silts |
| CL | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays | CH | Inorganic clays of high plasticity, fat clays |
| OL | Organic silts and organic silty clays of low plasticity | OH | Organic silts and organic clays of medium t high plasticity |
| CI | Clays with Intermediate plasticity | MI | Silt with intermediate plasticity |

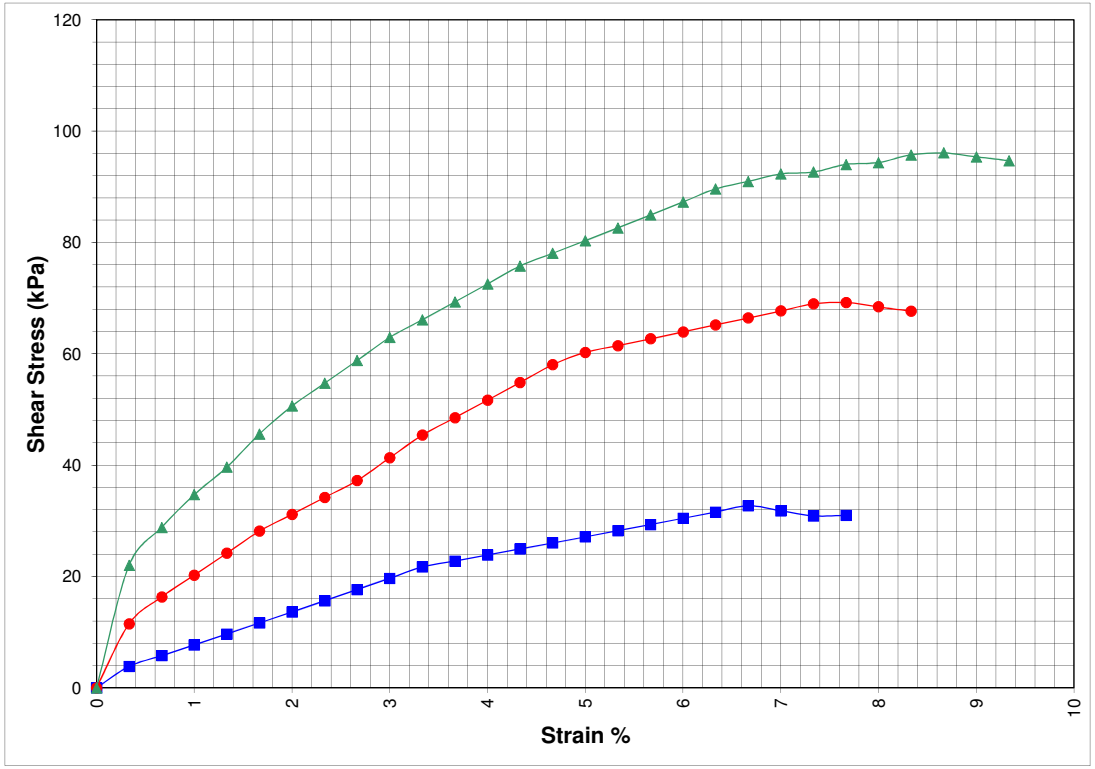
## PLASTICITY CHART (IS : 1498 - 1987)

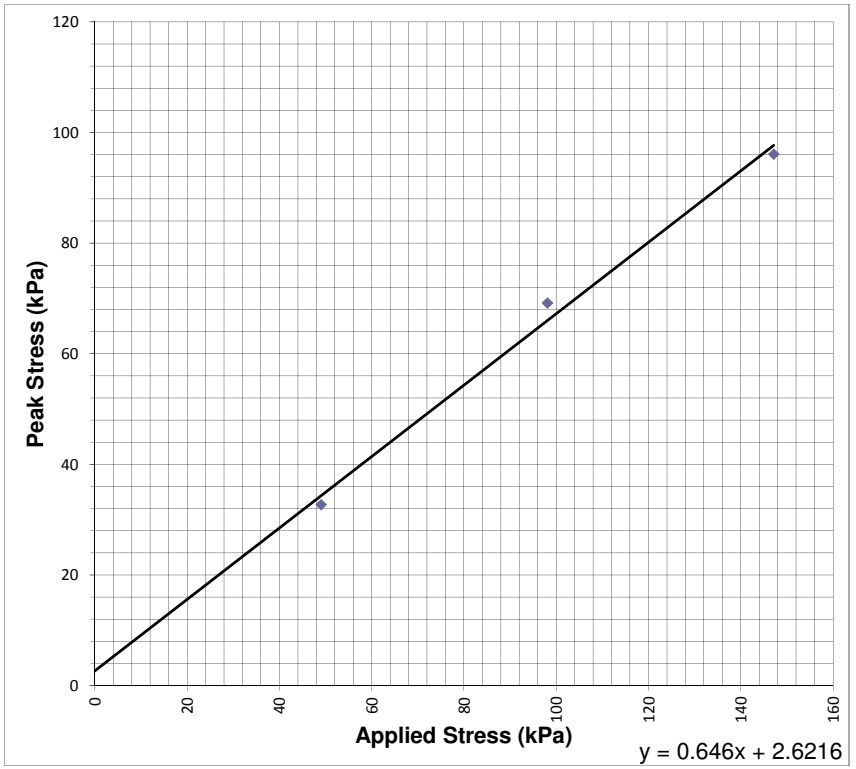
BOREHOLE NAME : MBH-24

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 33 |
| | Stage 2 | 98 | 69 |
| | Stage 3 | 147 | 96 |

| | | |
|---|---|---|
| Angle of Friction | **32.86** | ° |
| Apparent Cohesion | **2.62** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

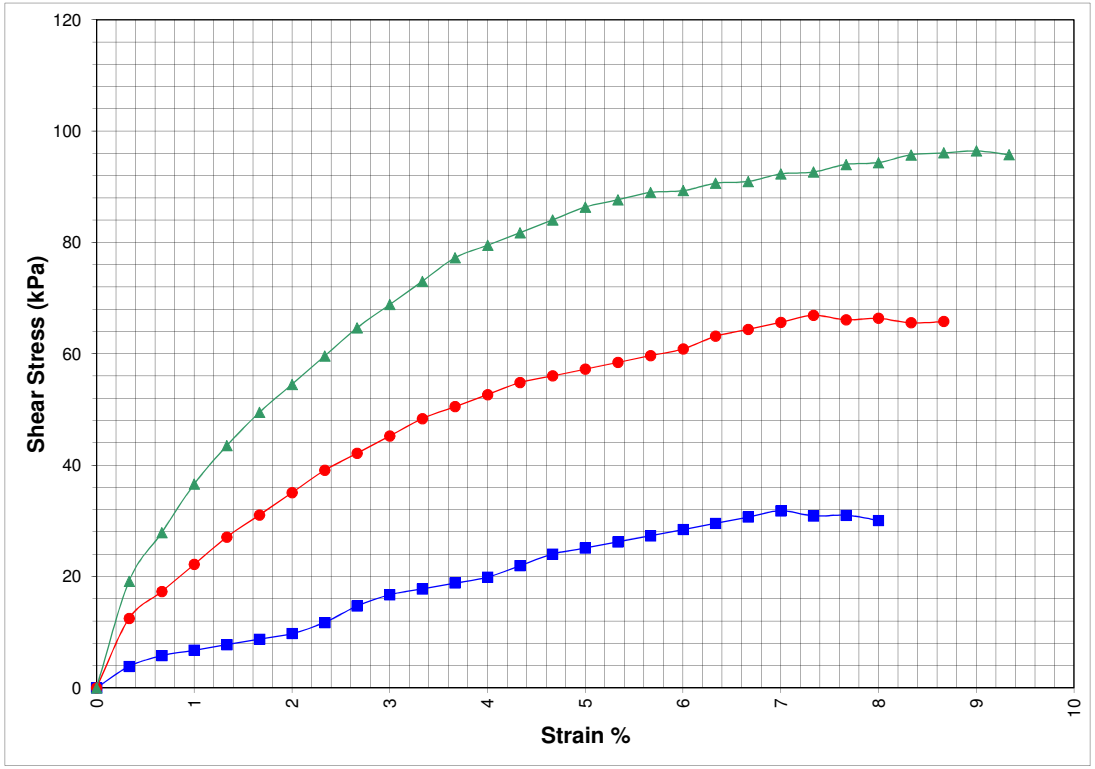
**Borehole: MBH-24**

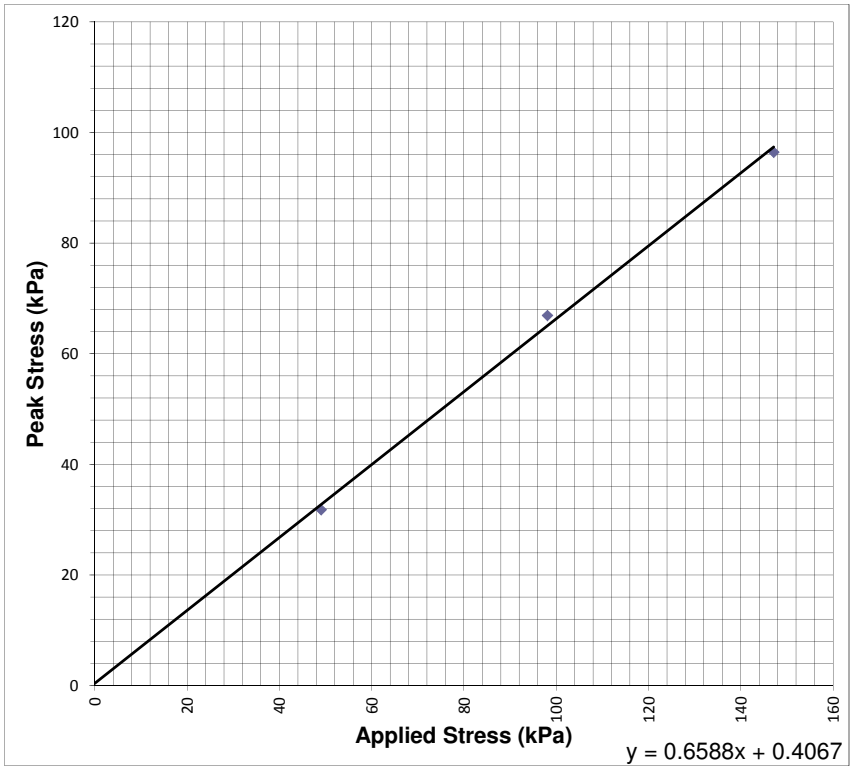
**Sample Type: SPT-01**

**Depth: 0.00-0.23 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 32 |
| | Stage 2 | 98 | 67 |
| | Stage 3 | 147 | 96 |

| | | |
|---|---|---|
| Angle of Friction | **33.38** | ° |
| Apparent Cohesion | **0.41** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

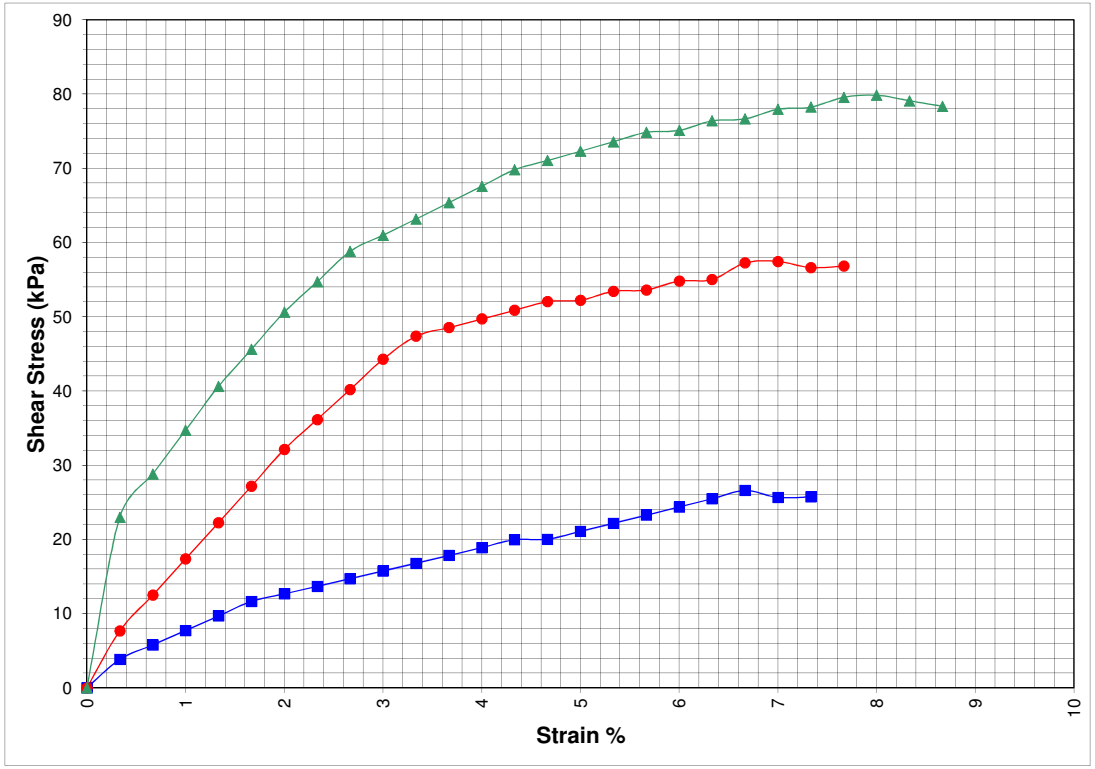
**Borehole: MBH-24**

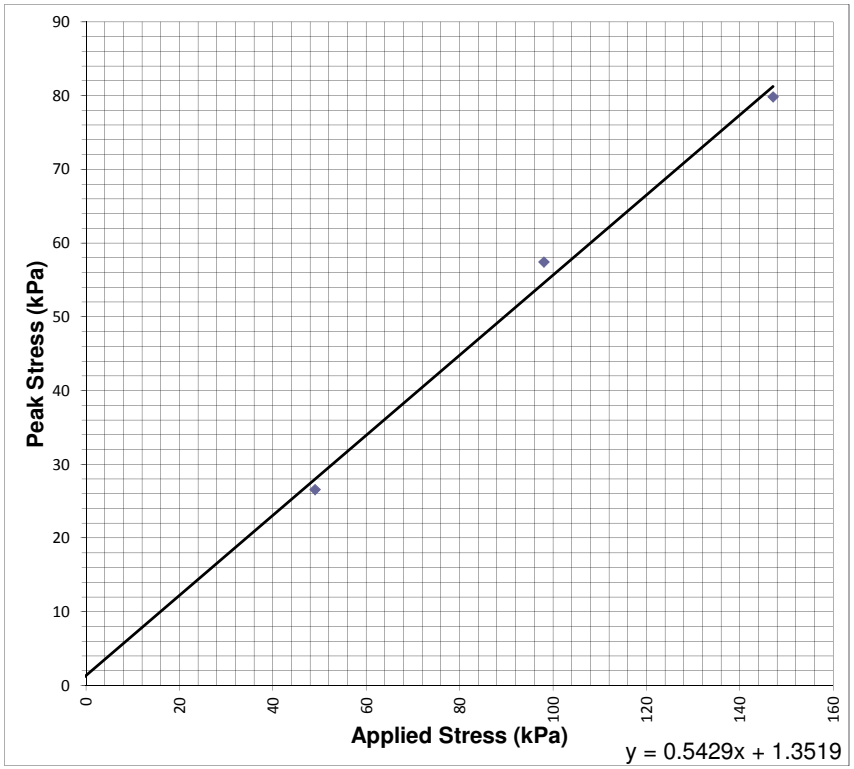
**Sample Type: SPT-04**

**Depth: 4.50-4.70 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 27 |
| | Stage 2 | 98 | 57 |
| | Stage 3 | 147 | 80 |

| | | |
|---|---|---|
| Angle of Friction | **28.50** | ° |
| Apparent Cohesion | **1.35** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

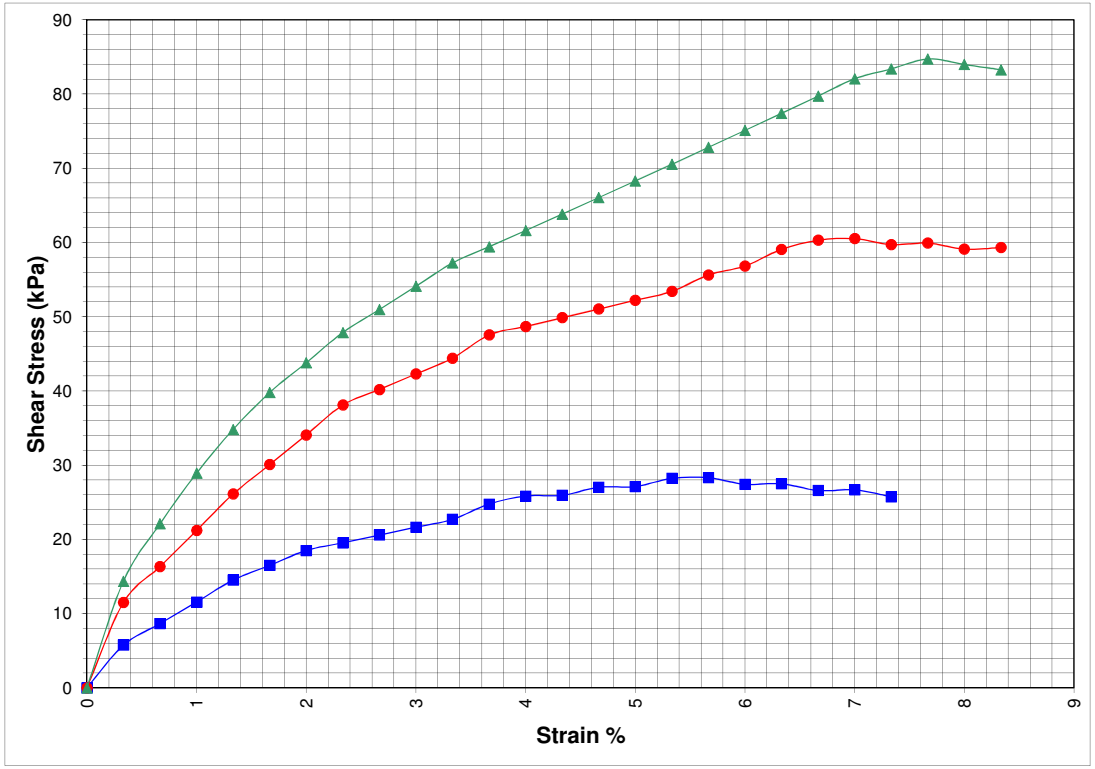
**Borehole: MBH-24**

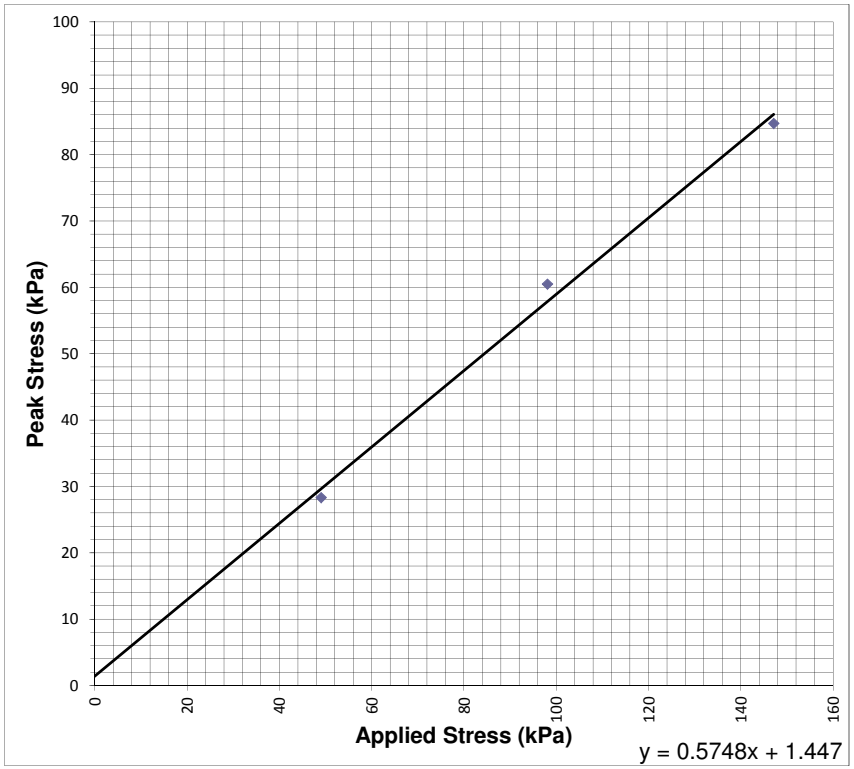
**Sample Type: SPT-07**

**Depth: 9.00-9.20 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 61 |
| | Stage 3 | 147 | 85 |

| | | |
|---|---|---|
| Angle of Friction | **29.89** | ° |
| Apparent Cohesion | **1.45** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

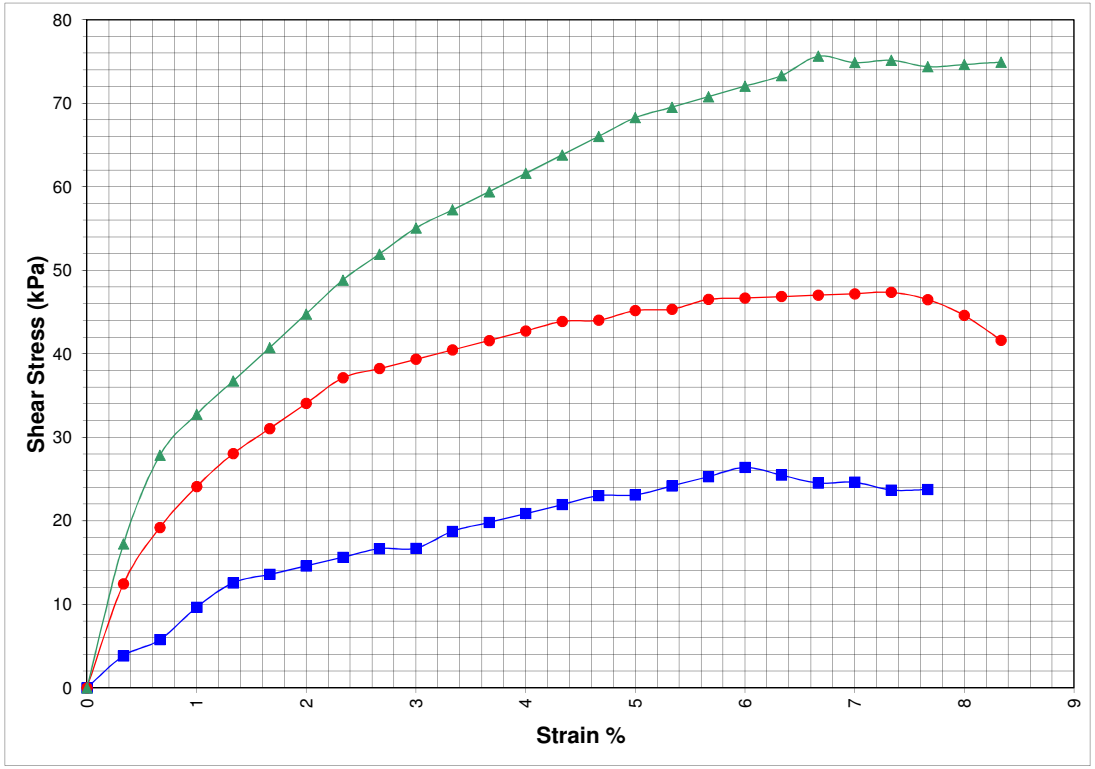
**Borehole: MBH-24**

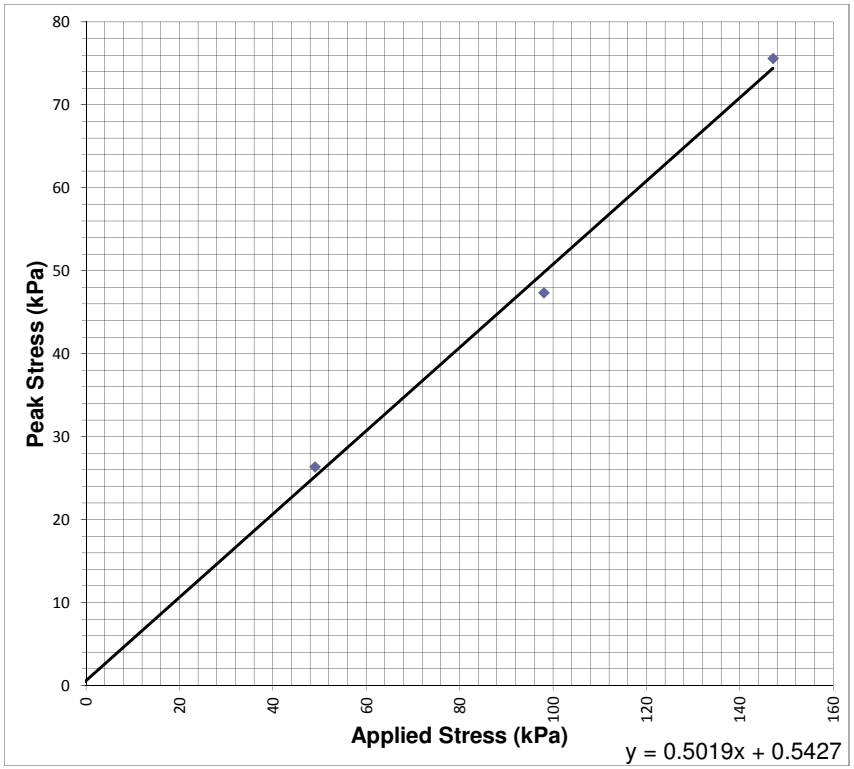
**Sample Type: SPT-10**

**Depth: 13.50-13.73 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 47 |
| | Stage 3 | 147 | 76 |

| | | |
|---|---|---|
| Angle of Friction | **26.65** | ° |
| Apparent Cohesion | **0.54** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

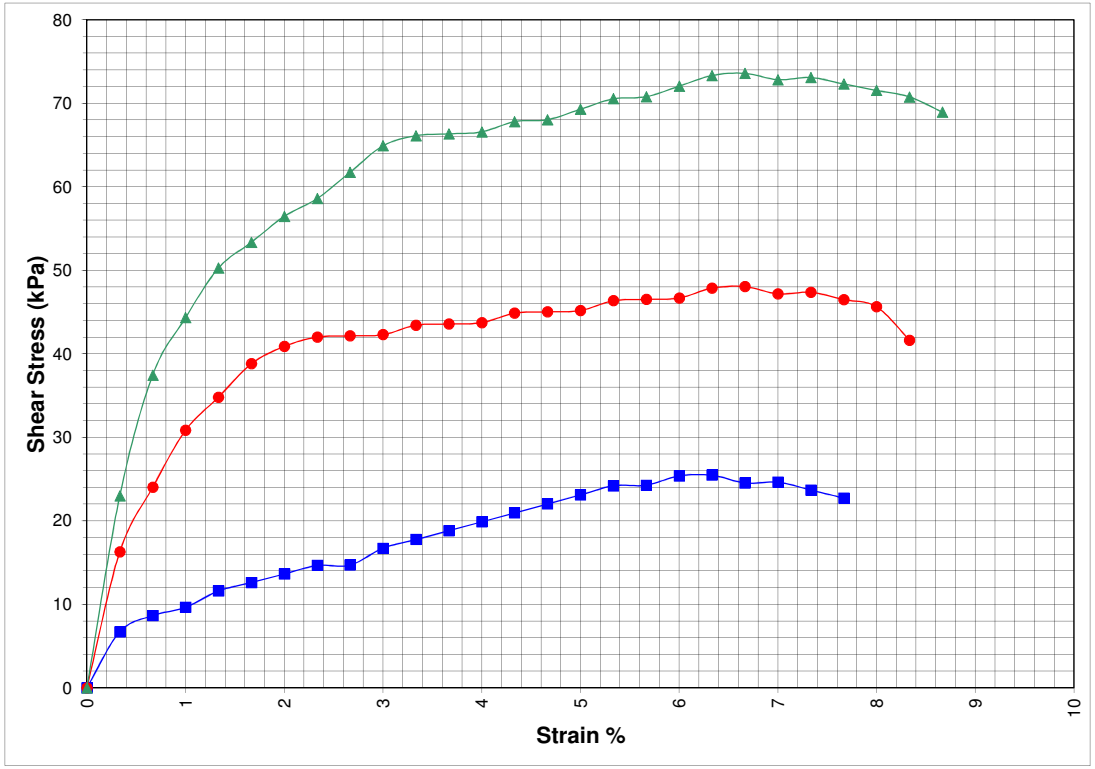
**Borehole: MBH-24**

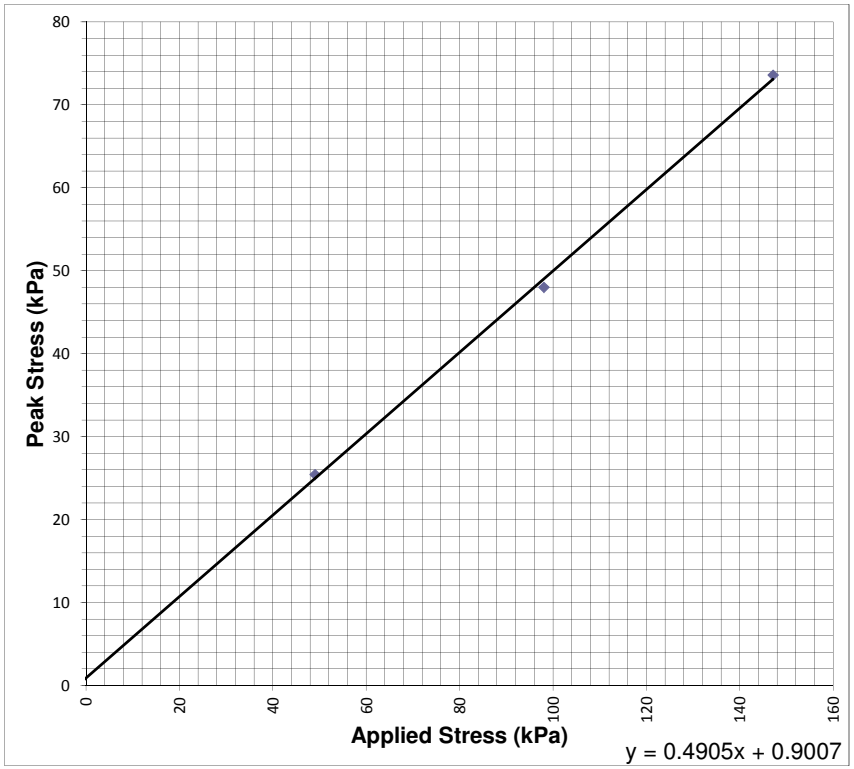
**Sample Type: SPT-13**

**Depth: 18.00-18.20 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 25 |
| | Stage 2 | 98 | 48 |
| | Stage 3 | 147 | 74 |

| | | |
|---|---|---|
| Angle of Friction | **26.13** | ° |
| Apparent Cohesion | **0.90** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

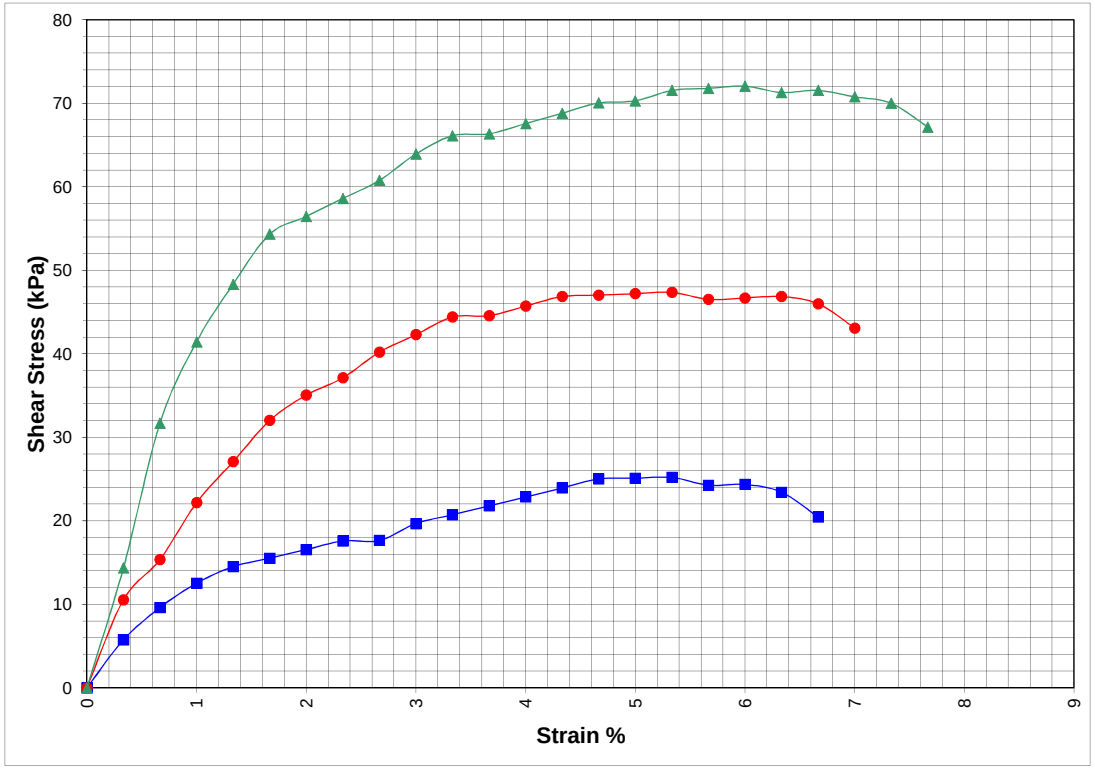
**Borehole: MBH-24**

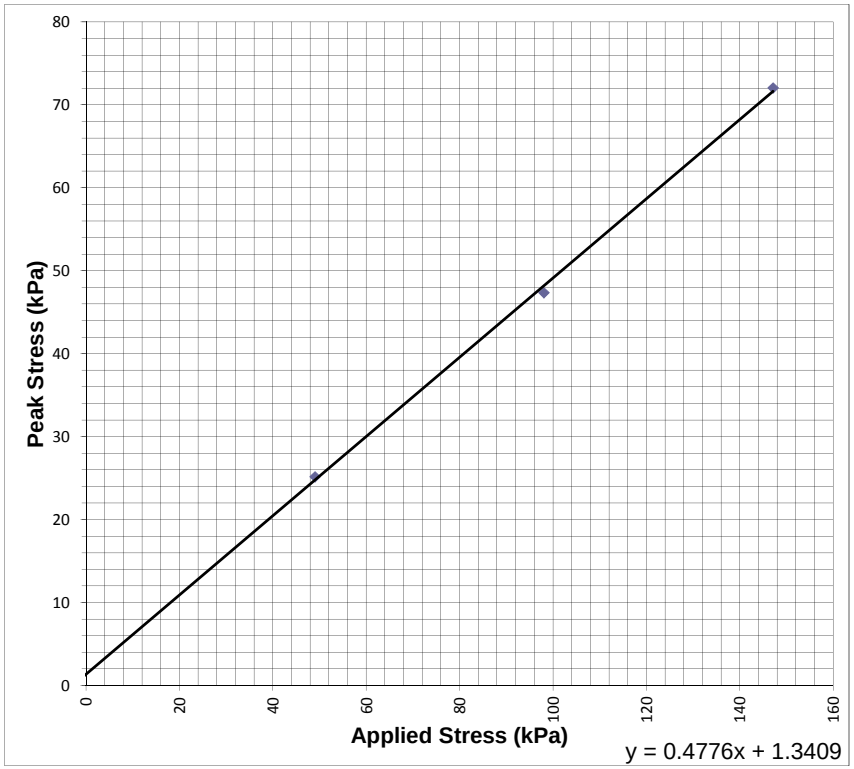
**Sample Type: SPT-16**

**Depth: 22.50-22.73 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 25 |
| | Stage 2 | 98 | 47 |
| | Stage 3 | 147 | 72 |

| | | |
|---|---|---|
| Angle of Friction | **25.53** | ° |
| Apparent Cohesion | **1.34** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

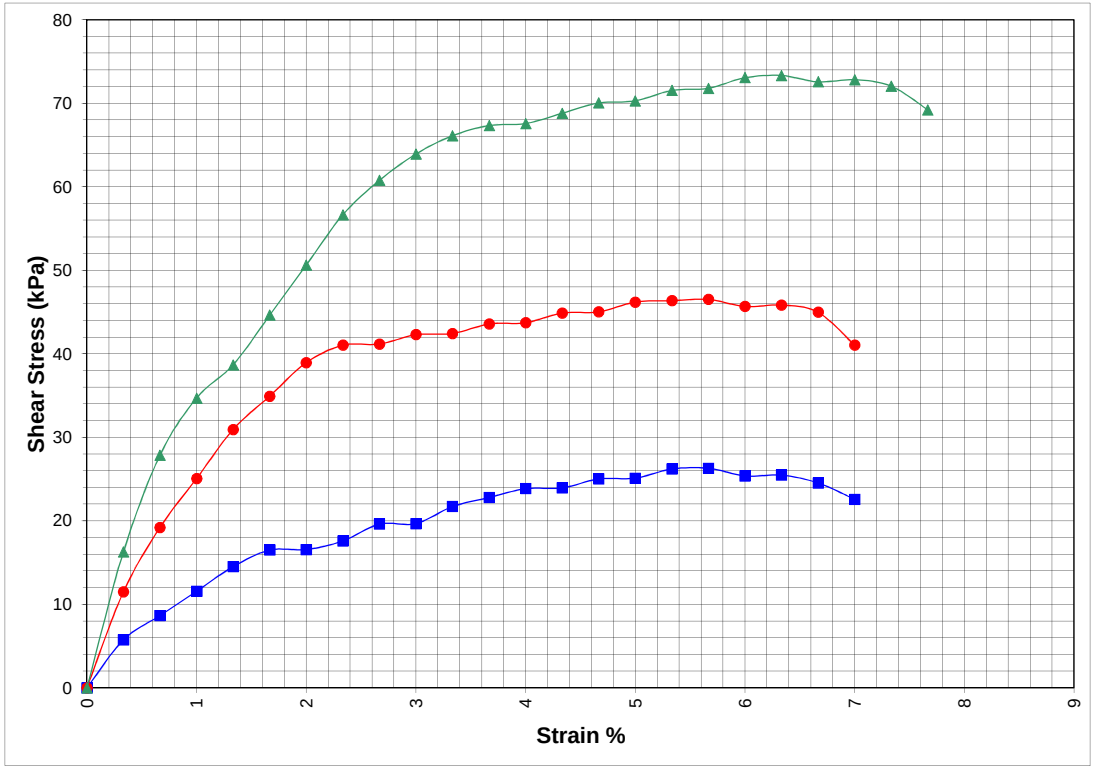
**Borehole: MBH-24**

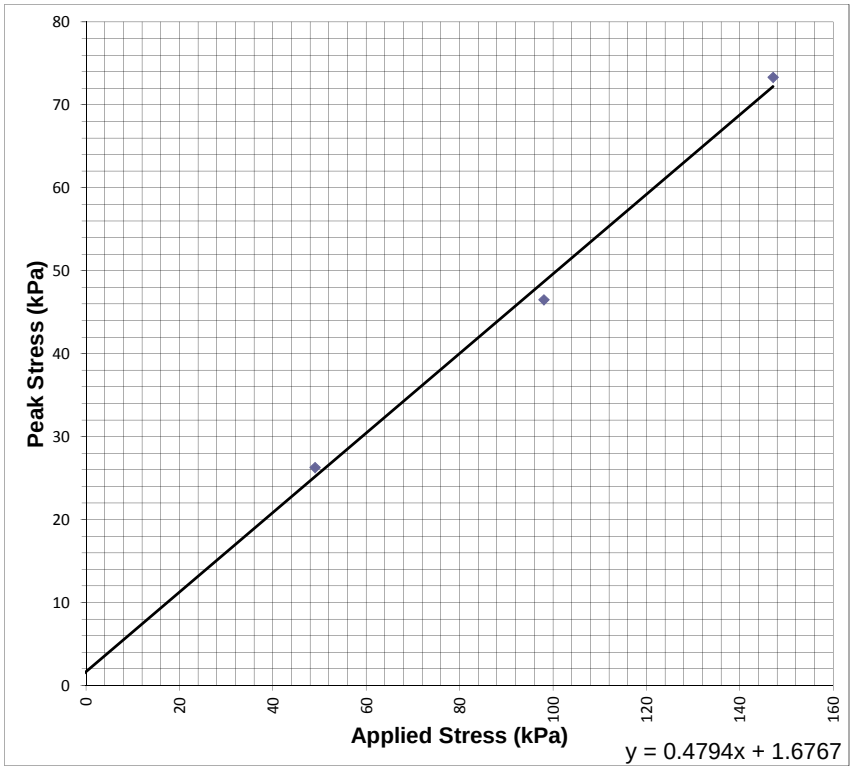
**Sample Type: SPT-20**

**Depth: 28.50-28.72 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 47 |
| | Stage 3 | 147 | 73 |

| | | |
|---|---|---|
| Angle of Friction | **25.61** | ° |
| Apparent Cohesion | **1.68** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

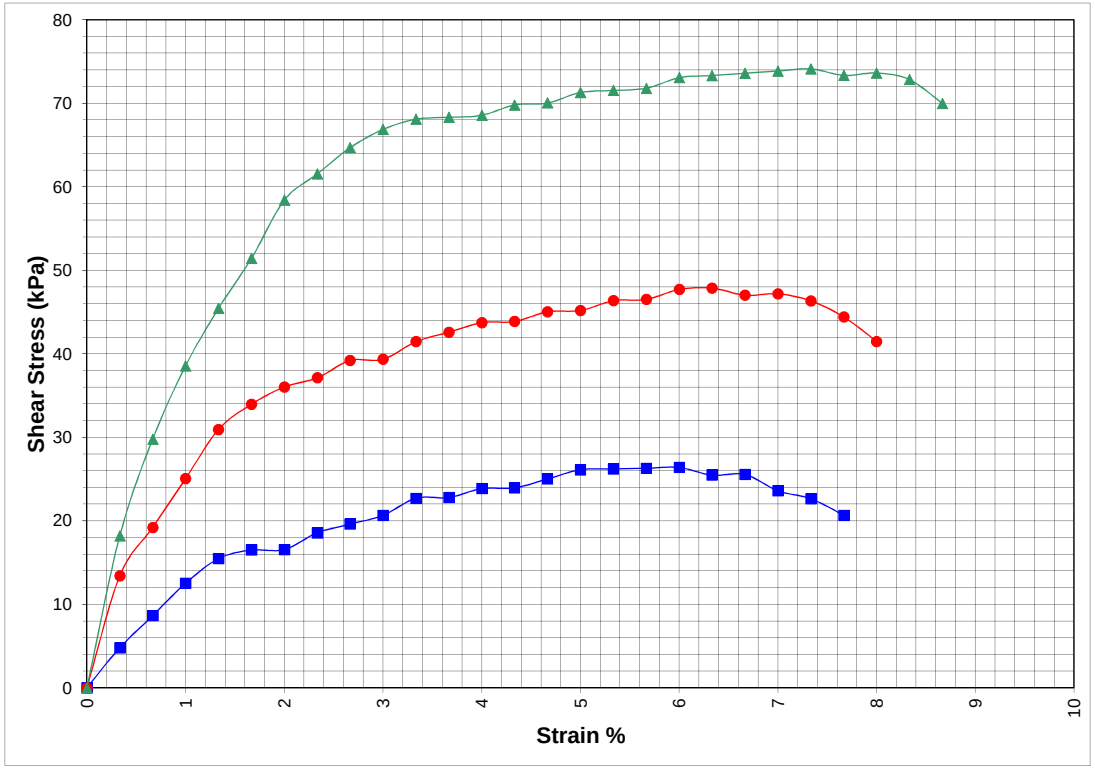
**Borehole: MBH-24**

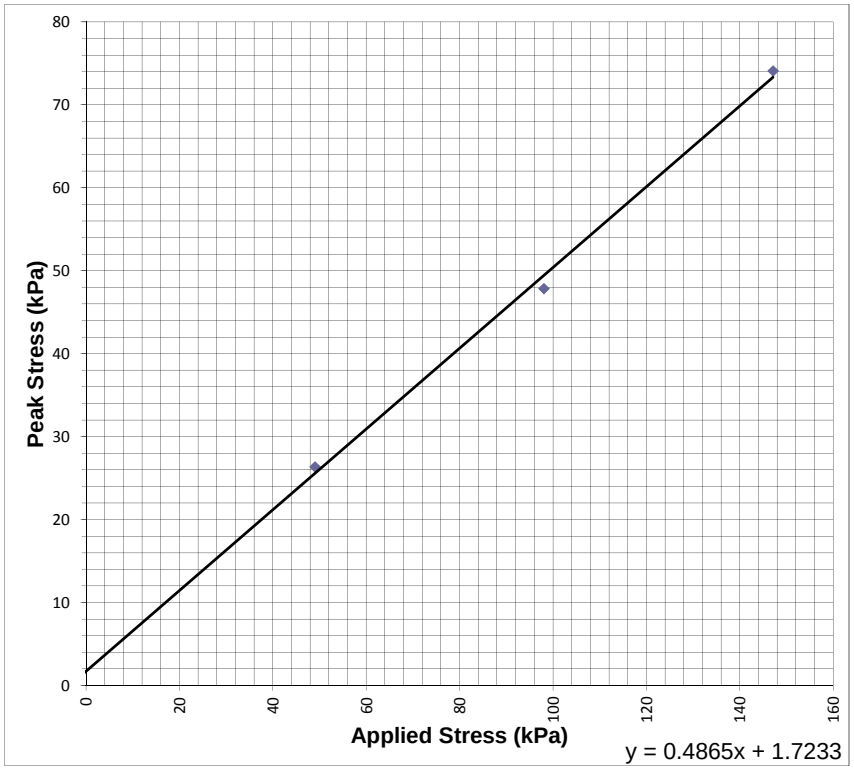
**Sample Type: SPT-24**

**Depth: 34.50-34.77 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 26 |
| | Stage 2 | 98 | 48 |
| | Stage 3 | 147 | 74 |

| | | |
|---|---|---|
| Angle of Friction | **25.94** | ° |
| Apparent Cohesion | **1.72** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: MBH-24**

**Sample Type: SPT-27**

**Depth: 40.00-40.22 m**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density (kN/m$^3$) | Submerged Unit Weight (kN/m$^3$) | Dry Density (kN/m$^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-1 | 0.00-0.13 | | | | | 15.5 | 18.20 | 8.14 | 15.76 | 2.61 | | | | | | | | | | | | | | | | | | | 8.20 | 0.90 | 1.00 | 2200 | 14160 |
| SPT-2 | 1.50-1.70 | | | | | 18.2 | 18.49 | 8.43 | 15.64 | | | | | | | DST | | | 1.80 | 32.3 | | | | | | | | | | | | | |
| SPT-3 | 3.00-3.20 | SP-SM | | | | 18.0 | 18.56 | 8.50 | 15.73 | 2.60 | 0 | 93 | <--> | <--> | 7 | | | | | | | | | | | | | | | | | | |
| SPT-4 | 4.50-4.72 | | | | | 14.9 | 18.49 | 8.43 | 16.09 | | | | | | | DST | | | 0.85 | 32.4 | | | | | | | | | | | | | |
| SPT-5 | 6.00-6.20 | SP | | | | 16.5 | 18.54 | 8.48 | 15.91 | 2.59 | 0 | 97 | <--> | <--> | 3 | | | | | | | | | | | | | | | | | | |
| SPT-6 | 7.50-7.80 | | | | | 14.8 | 18.51 | 8.45 | 16.12 | 2.63 | | | | | | DST | | | 0.94 | 31.0 | | | | | | | | | | | | | |
| SPT-7 | 9.00-9.24 | SP | | | | 16.1 | 18.54 | 8.48 | 15.97 | | 0 | 97 | <--> | <--> | 3 | | | | | | | | | | | | | | | | | | |
| SPT-8 | 10.50-10.75 | | | | | 20.8 | 18.00 | 7.94 | 14.91 | 2.62 | | | | | | DST | | | 1.04 | 31.3 | | | | | | | | | | | | | |
| SPT-9 | 12.00-12.20 | | | | | 21.6 | 18.02 | 7.96 | 14.82 | | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-10 | 13.50-13.73 | | | | | 24.2 | 18.03 | 7.97 | 14.52 | 2.64 | | | | | | DST | | | 2.06 | 28.7 | | | | | | | | | | | | | |
| SPT-11 | 15.00-15.20 | SM/SC | | | | 22.6 | 17.56 | 7.50 | 14.33 | 2.61 | 0 | 85 | <--> | <--> | 15 | | | | | | | | | | | | | | | | | | |
| SPT-12 | 16.50-16.80 | CL | 31.9 | 13.8 | 18 | 25.5 | 17.14 | 7.08 | 13.66 | | | | | | | | | | | | | | | 10.0 | | | | | | | | | |
| SPT-13 | 18.00-18.20 | | | | | 20.9 | 18.17 | 8.11 | 15.02 | 2.62 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-14 | 19.50-19.72 | | | | | 20.1 | 18.00 | 7.94 | 14.99 | | | | | | | DST | | | 2.88 | 27.9 | | | | | | | | | | | | | |
| SPT-15 | 21.00-21.20 | SP-SM | | | | 19.4 | 18.11 | 8.05 | 15.17 | 2.63 | 0 | 91 | <--> | <--> | 9 | | | | | | | | | | | | | | | | | | |
| SPT-16 | 22.50-22.70 | | | | | 18.8 | 17.91 | 7.85 | 15.08 | | | | | | | DST | | | 0.73 | 27.3 | | | | | | | | | | | | | |
| SPT-17 | 24.00-24.23 | SP-SM | | | | 19.2 | 18.13 | 8.07 | 15.22 | 2.61 | 0 | 92 | <--> | <--> | 8 | | | | | | | | | | | | | | | | | | |
| SPT-18 | 25.50-25.68 | SP-SM | | | | 19.6 | 18.20 | 8.14 | 15.23 | 2.60 | 0 | 95 | <--> | <--> | 5 | | | | | | | | | | | | | | | | | | |
| SPT-19 | 27.00-27.27 | | | | | 18.6 | 18.01 | 7.95 | 15.19 | | | | | | | DST | | | 0.90 | 26.2 | | | | | | | | | | | | | |
| SPT-20 | 28.50-28.68 | | | | | 17.4 | 18.06 | 8.00 | 15.39 | 2.62 | | | | | | | | | | | | | | | | | | | | | | | |

**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

\# : Decayed Wood

**Failure Type**

A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-25**

# SUMMARY OF TEST RESULTS

| SAMPLE DETAILS | | Soil Classification | CLASSIFICATION & INDEX | | | | | | | | | | | | | SHEAR STRENGTH TEST | | | | | | | | Free swell Index % | Consolidation Tests | | | | Chemical tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atterberg Limits | | | Physical Properties | | | | | Grain Size Distribution | | | | | Lateral & Vertical Loading Tests | | | | | | | | | | | | | | | | | |
| Sample Type | Depth, m | | Liquid Limit LL % | Plastic Limit PL % | Plasticity Index PI % | Water Content % | Bulk Density ($kN/m^3$) | Submerged Unit Weight ($kN/m^3$) | Dry Density ($kN/m^3$) | Specific Gravity | Gravel % | Sand % | Silt % | Clay % | Fines % (Silt +Clay) | Type of Test | Shear Strength Su (kpa) | Type of Failure | Cohesion C (kpa) | Internal friction angle Φ ° | Torvane (Kpa) | Pocket penetrometer (Kpa) | Miniature Vane | | Initial Void Ratio | Degree of Saturation % | Preconsolidation Pressure (kPa)) | Compression Index | pH | Organic content (%) | Carbonate content (%) | Chloride content (ppm) | Sulphate content (ppm) |
| SPT-21 | 30.00-30.20 | | | | | 16.8 | 18.08 | 8.02 | 15.49 | | | | | | | DST | | | 0.89 | 26.1 | | | | | | | | | | | | |
| SPT-22 | 31.50-31.65 | | | | | 19.0 | 18.12 | 8.06 | 15.22 | 2.64 | | | | | | | | | | | | | | | | | | | | | | |
| SPT-23 | 33.00-33.22 | SP | | | | 17.6 | 18.00 | 7.94 | 15.31 | | 0 | 97 | <--> | <--> | 3 | | | | | | | | | | | | | | 8.08 | 0.70 | 1.00 | 700 | 8850 |
| SPT-24 | 34.50-34.68 | SP | | | | 17.7 | 18.08 | 8.02 | 15.36 | 2.62 | 0 | 97 | <--> | <--> | 3 | | | | | | | | | | | | | | | | | | |
| SPT-25 | 36.00-36.10 | | | | | 20.1 | 17.98 | 7.92 | 14.97 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-26 | 37.50-37.78 | | | | | 19.7 | 18.07 | 8.01 | 15.10 | | | | | | | DST | | | 2.10 | 24.1 | | | | | | | | | | | | |
| SPT-27 | 39.00-39.10 | | | | | 20.6 | 18.02 | 7.96 | 14.93 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-28 | 40.50-40.70 | SP-SM | | | | 20.3 | 18.07 | 8.01 | 15.03 | 2.59 | 0 | 94 | <--> | <--> | 6 | | | | | | | | | | | | | | | | | | |
| SPT-29 | 42.00-42.10 | | | | | 19.0 | 18.11 | 8.05 | 15.22 | | | | | | | | | | | | | | | | | | | | | | | |
| SPT-30 | 43.50-43.68 | | | | | 18.3 | 18.01 | 7.95 | 15.22 | 2.66 | | | | | | | | | | | | | | | | | | | | | | |
| SPT-31 | 45.00-45.15 | | | | | 19.4 | 18.10 | 8.04 | 15.16 | | | | | | | | | | | | | | | | | | | | | | | |
| **END OF BOREHOLE** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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**Notes :**

DS : Disturbed Sample
WAX/UDS :Undisturbed Sample
TUU : Triaxial Test (Unconsolidated Undrained)
DST : Direct Shear Test
Φ : ° (deg) Angle of internal friction

* : Insufficient sample
LL : Liquid Limit
PL : Plastic Limit
NP : Non Plastic
NS : Not Suitable

\# : Decayed Wood

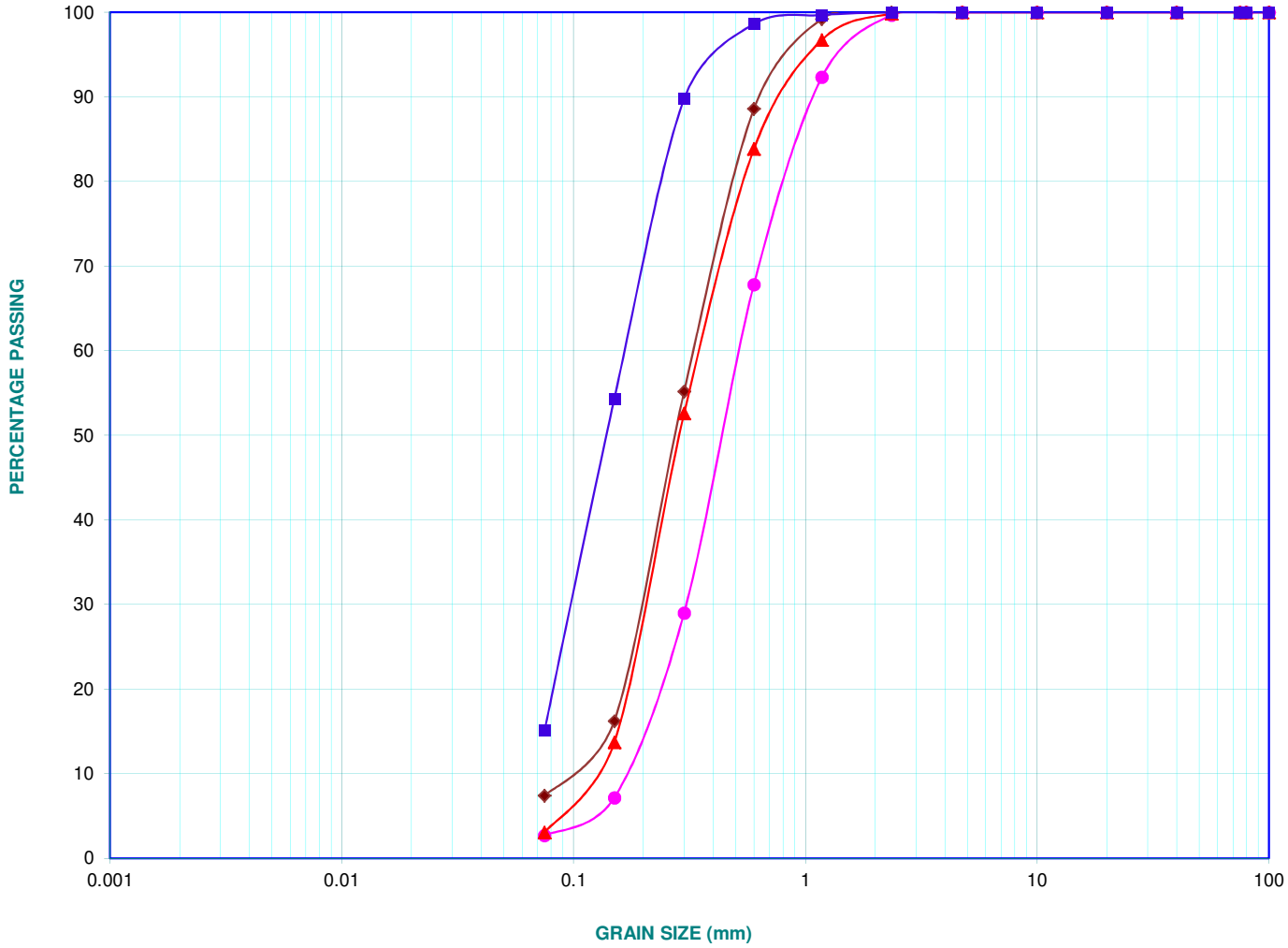
**Failure Type**
A : Bulge
B : Inclined Shear
C : Multiple Shear
D : Vertical Shear

Project : **Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha**
Project Code : **CM 19 01 03**
Borehole No. : **MBH-25**

# GRAIN SIZE ANALYSIS

| | |
|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-25** |
| **Date :** | **15-Jun-19** |

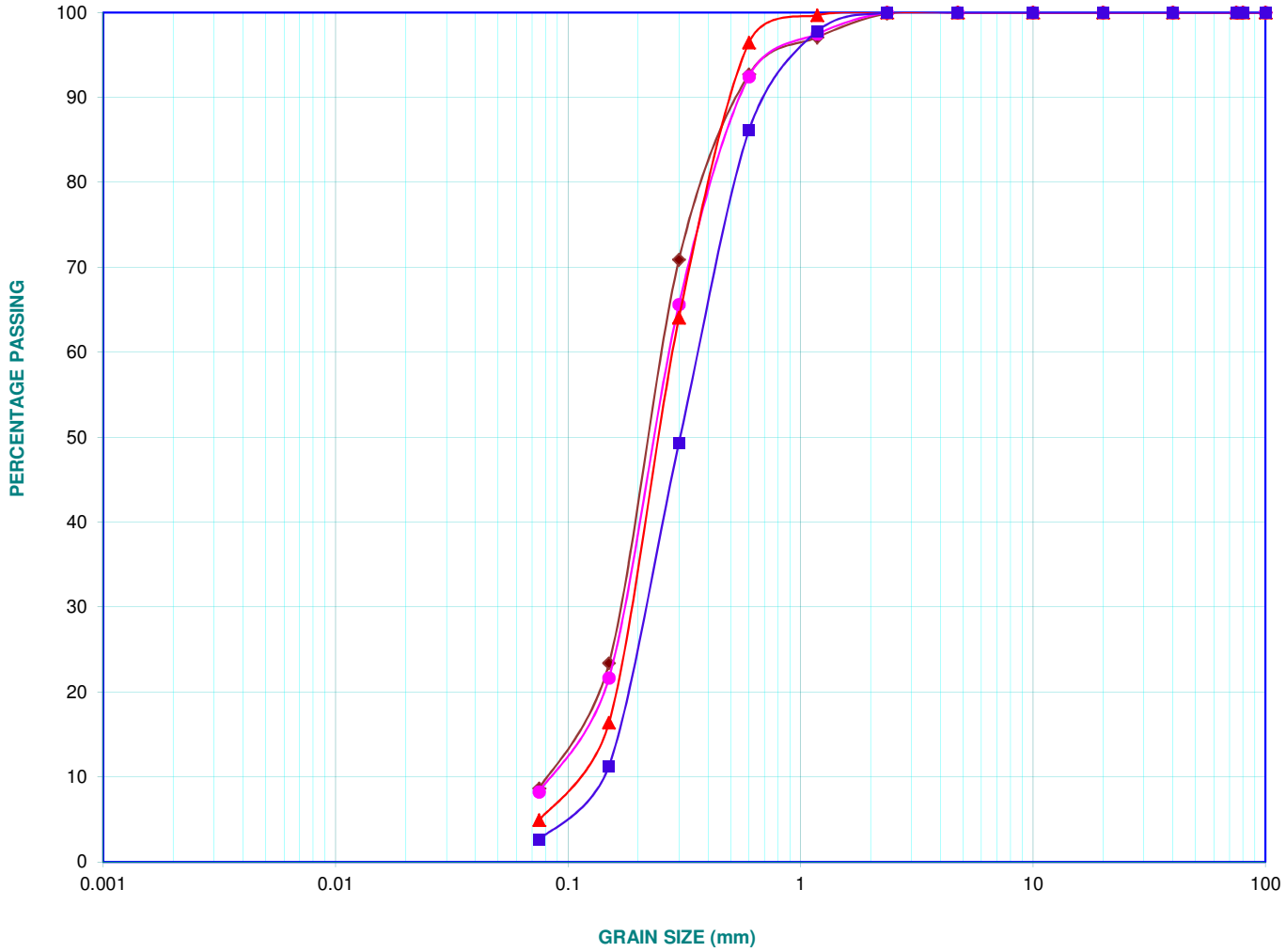
| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-25 | MBH-25 | MBH-25 | MBH-25 | | | | | | | | |
| **Depth (m)** | 3.00-3.20 | 6.00-6.20 | 9.00-9.24 | 15.00-15.20 | | | | | | | | |
| **Sample Type** | SPT-03 | SPT-05 | SPT-07 | SPT-11 | | | | | | | | |
| **Classification** | SP-SM | SP | SP | SM/SC | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 93 | 97 | 97 | 85 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 7 | 3 | 3 | 15 | | | | | | | | |
| **D60 mm** | 0.320 | 0.500 | 0.330 | | | | | | | | | |
| **D30 mm** | 0.200 | 0.300 | 0.200 | | | | | | | | | |
| **D10 mm** | 0.100 | 0.170 | 0.140 | | | | | | | | | |
| **Cu** | 3.20 | 2.94 | 2.36 | --- | | | | | | | | |
| **Cc** | 1.25 | 1.06 | 0.87 | --- | | | | | | | | |
| **Liquid Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | --- | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |




Checked By :

# GRAIN SIZE ANALYSIS

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project** | : Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha. | | | | | | | | | | | |
| **Job No.** | : CM 19 01 03 | | | | **Borehole No.** | : MBH-25 | | | **Date :** | 15-Jun-19 | | |
| **Symbol** | ◆ | ● | ▲ | ■ | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-25 | MBH-25 | MBH-25 | MBH-25 | | | | | | | | |
| **Depth (m)** | 21.00-21.20 | 24.00-24.23 | 25.50-25.68 | 33.00-33.22 | | | | | | | | |
| **Sample Type** | SPT-15 | SPT-17 | SPT-18 | SPT-23 | | | | | | | | |
| **Classification** | SP-SM | SP-SM | SP-SM | SP | | | | | | | | |
| **Gravel %** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Sand %** | 91 | 92 | 95 | 97 | | | | | | | | |
| **Silt %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Clay %** | <----> | <----> | <----> | <----> | | | | | | | | |
| **Fines % (Silt+Clay)** | 9 | 8 | 5 | 3 | | | | | | | | |
| **D60 mm** | 0.250 | 0.270 | 0.290 | 0.380 | | | | | | | | |
| **D30 mm** | 0.170 | 0.180 | 0.190 | 0.210 | | | | | | | | |
| **D10 mm** | 0.080 | 0.085 | 0.110 | 0.150 | | | | | | | | |
| **Cu** | 3.13 | 3.18 | 2.64 | 2.53 | | | | | | | | |
| **Cc** | 1.45 | 1.41 | 1.13 | 0.77 | | | | | | | | |
| **Liquid Limit %** | --- | | --- | --- | | | | | | | | |
| **Plastic Limit %** | --- | | --- | --- | | | | | | | | |
| **Plasticity Index** | --- | --- | --- | --- | | | | | | | | |

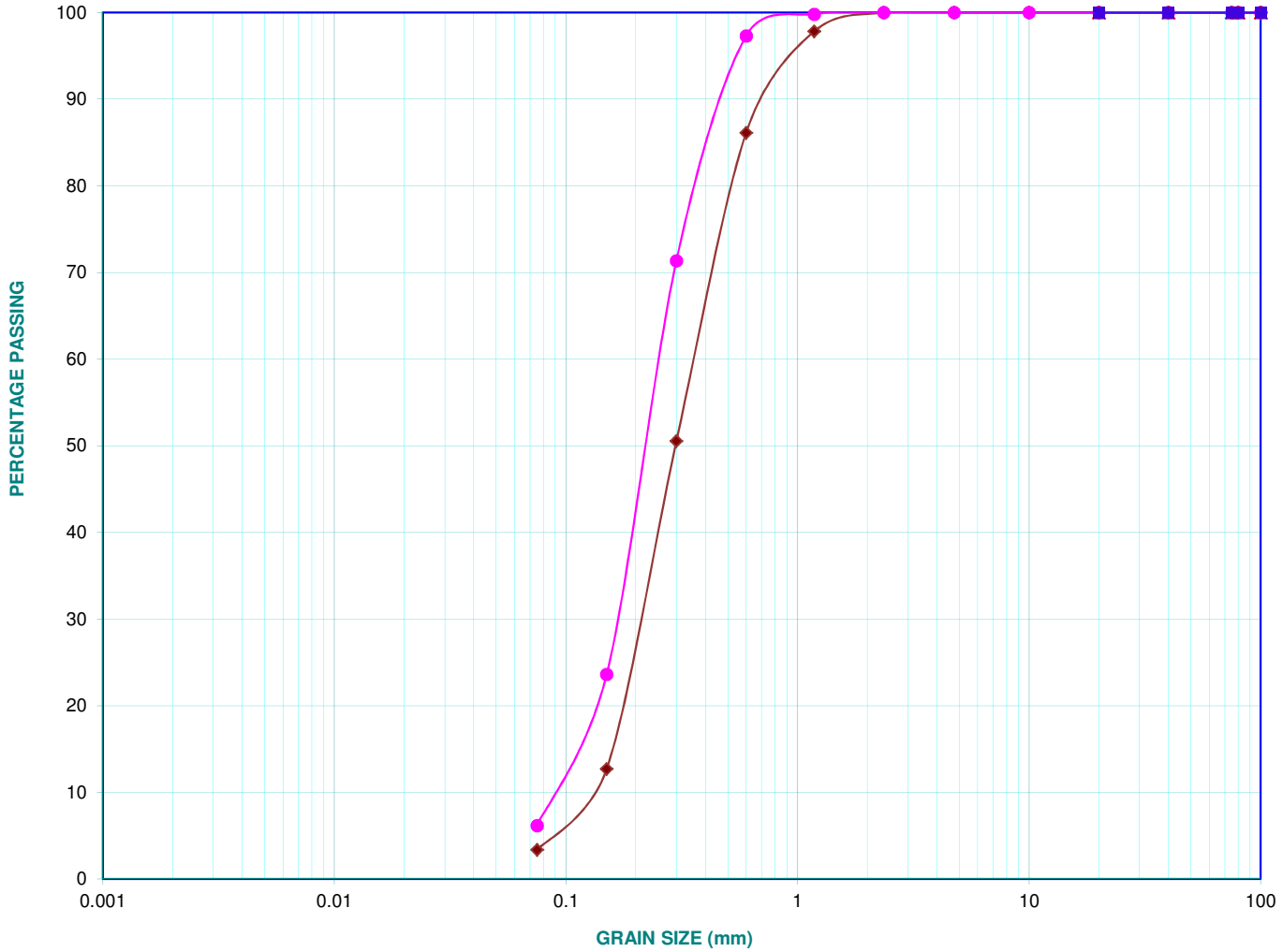



Checked By :

# GRAIN SIZE ANALYSIS

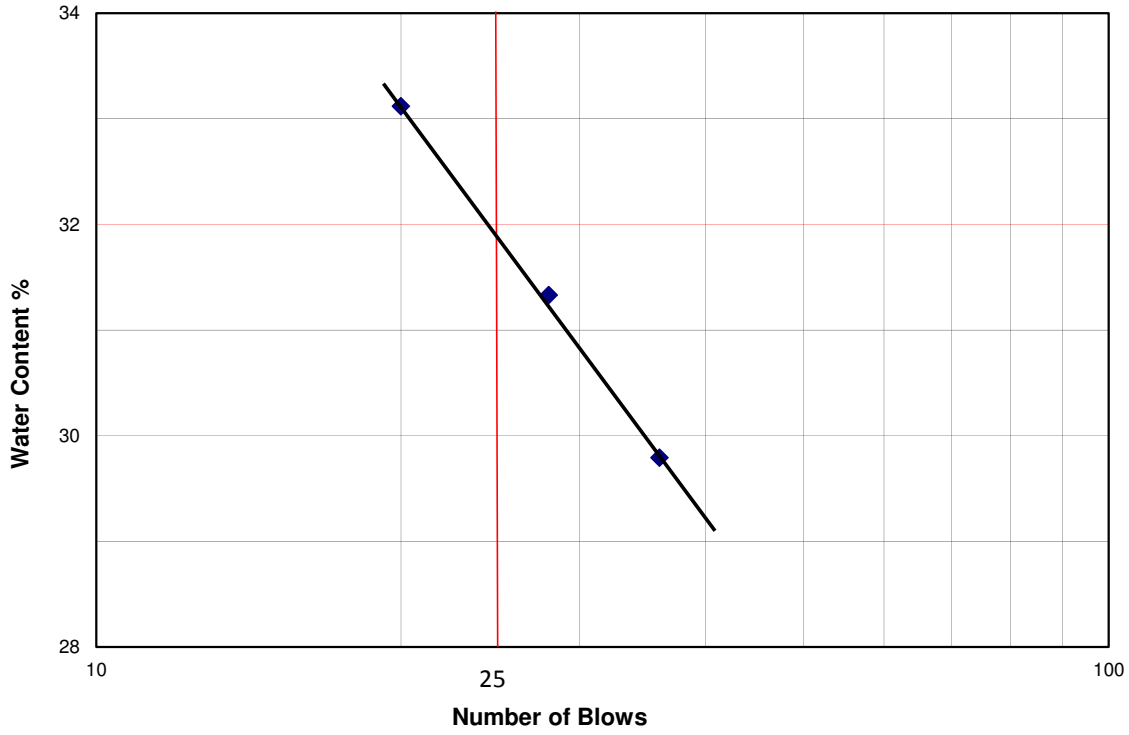
| | |
|---|---|
| **Project** | **: Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist Jagatsinghpur, Odisha.** |
| **Job No.** | **: CM 19 01 03** |
| **Borehole No.** | **: MBH-25** |
| **Date :** | **15-Jun-19** |

| Symbol | | | | | Particle size mm | CLAY | SILT | SAND | | | GRAVEL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F | M | C | F | C |
| **Bore Hole .** | MBH-25 | MBH-25 | | | | | | | | | | |
| **Depth (m)** | 34.50-34.68 | 40.50-40.70 | | | | | | | | | | |
| **Sample Type** | SPT-24 | SPT-28 | | | | | | | | | | |
| **Classification** | SP | SP-SM | | | | | | | | | | |
| **Gravel %** | 0 | 0 | | | | | | | | | | |
| **Sand %** | 97 | 94 | | | | | | | | | | |
| **Silt %** | <----> | <----> | | | | | | | | | | |
| **Clay %** | <----> | <----> | | | | | | | | | | |
| **Fines % (Silt+Clay)** | 3 | 6 | | | | | | | | | | |
| **D60 mm** | 0.360 | 0.240 | | | | | | | | | | |
| **D30 mm** | 0.200 | 0.180 | | | | | | | | | | |
| **D10 mm** | 0.140 | 0.090 | | | | | | | | | | |
| **Cu** | 2.57 | 2.67 | | | | | | | | | | |
| **Cc** | 0.79 | 1.50 | | | | | | | | | | |
| **Liquid Limit %** | --- | --- | | | | | | | | | | |
| **Plastic Limit %** | --- | --- | | | | | | | | | | |
| **Plasticity Index** | --- | --- | | | | | | | | | | |




Checked By :

## LL, PL & PI of Soils - IS : 2720 (part-5) & ASTM D 4318 - 1998




### Liquid Limit %

| | | | | | |
|---|---|---|---|---|---|
| Wet Weight + Can (g) | 32.64 | 43.74 | 41.65 | | |
| Dry Weight + Can (g) | 27.34 | 36.65 | 34.50 | | |
| Can Weight (g) | 9.55 | 14.02 | 12.91 | | |
| Water Content, % | 29.8 | 31.3 | 33.1 | | |
| Number of Blows | 36 | 28 | 20 | | |

### Plastic Limit %

| | | | |
|---|---|---|---|
| Wet Weight + Can (g) | 17.37 | 13.82 | 16.91 |
| Dry Weight + Can (g) | 16.86 | 13.26 | 16.44 |
| Can Weight (g) | 13.15 | 9.20 | 13.07 |
| Water Content, % | 13.7 | 13.8 | 13.9 |

Liquid Limit % 31.9

Plastic Limit % 13.8

Plasticity Index % 18.1

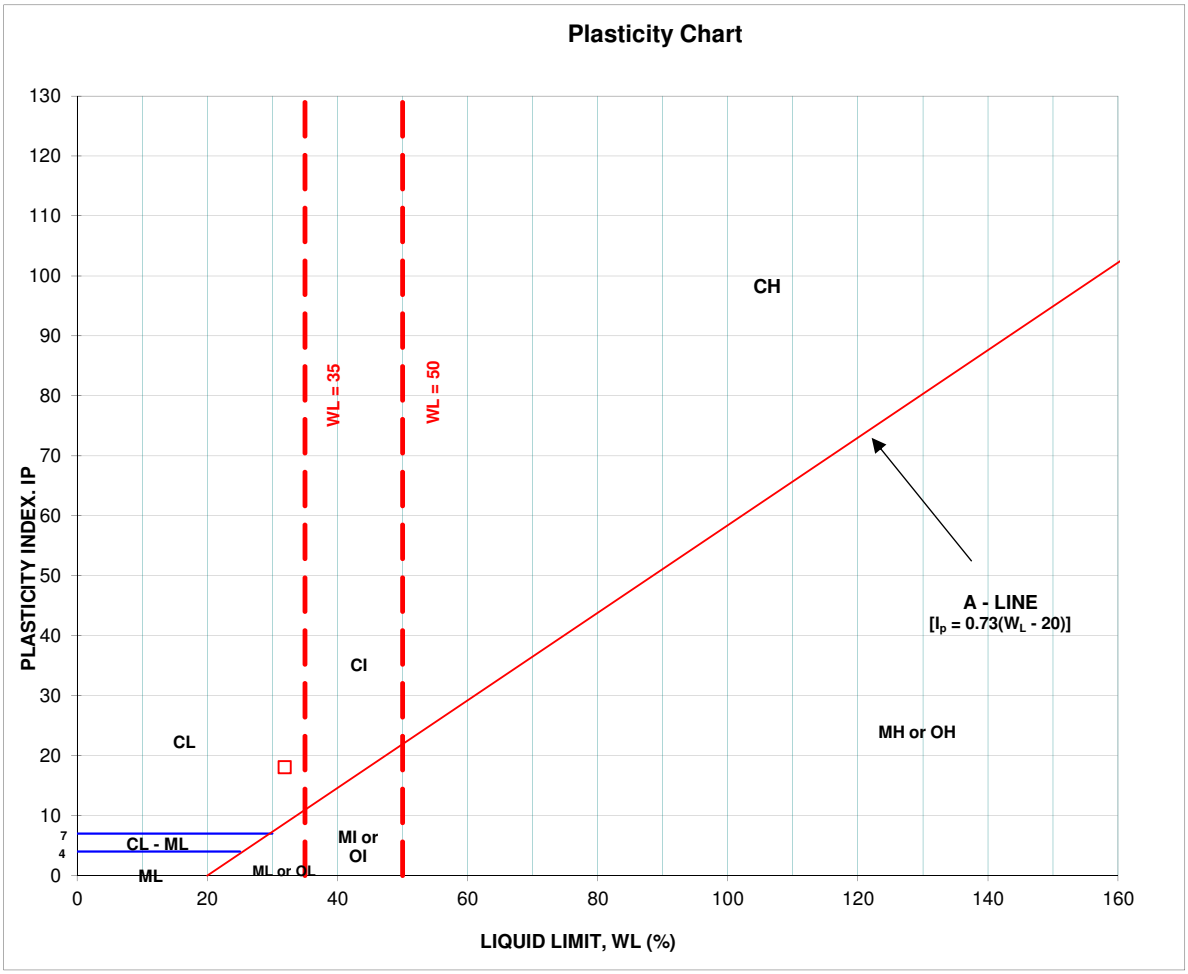
Preparation of Sample :
Dry State

Sample Type: SPT-02

Borehole no.: MBH-25

Depth :16.50-16.80

Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.




| | Sample Type | Depth (m) | $W_L$ | $W_P$ | $I_P$ | Remarks |
|---|---|---|---|---|---|---|
| □ | SPT-12 | 16.50-16.80 | 31.9 | 13.8 | 18.1 | CL: Inorganic clays of low to medium plasticity. |
| ◇ | | | | | | |
| △ | | | | | | |
| ● | | | | | | |
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| | | | |
|---|---|---|---|
| ML | Inorganic silts, very fine sands, rock flour, silty or clayey fine sands | MH | Inorganic silts, or diatomaceous fine sands or silts, elastic silts |
| CL | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays | CH | Inorganic clays of high plasticity, fat clays |
| OL | Organic silts and organic silty clays of low plasticity | OH | Organic silts and organic clays of medium t high plasticity |
| CI | Clays with Intermediate plasticity | MI | Silt with intermediate plasticity |

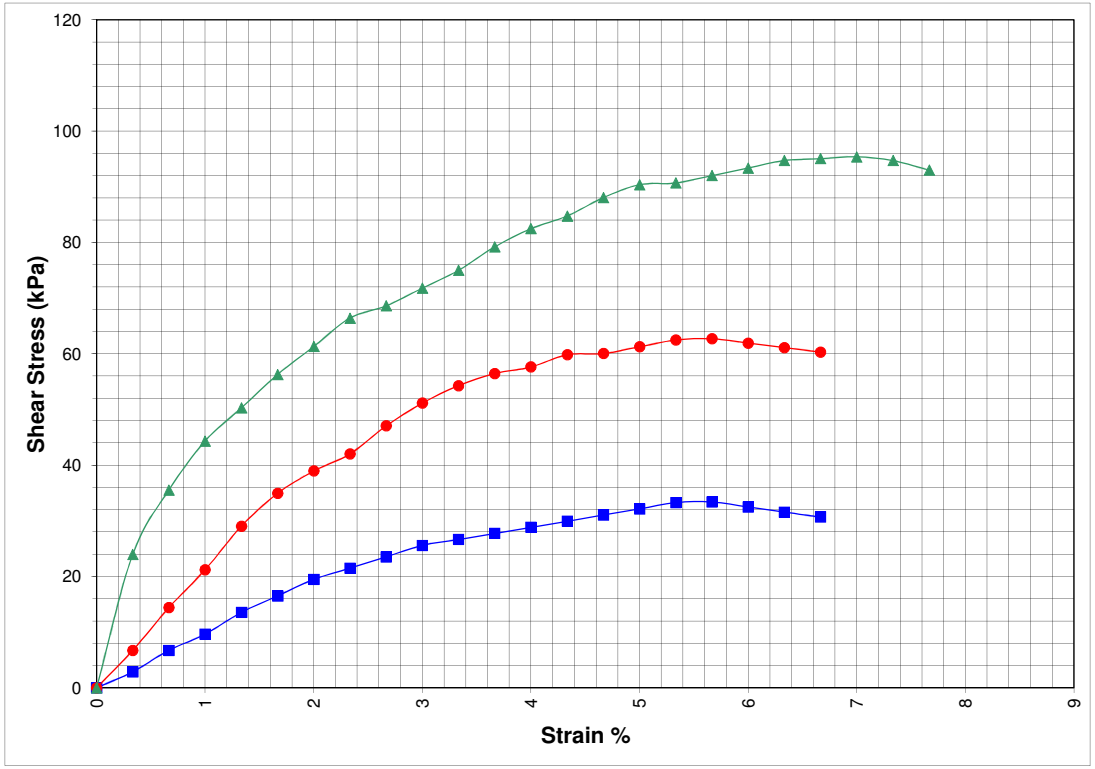
## PLASTICITY CHART (IS : 1498 - 1987)

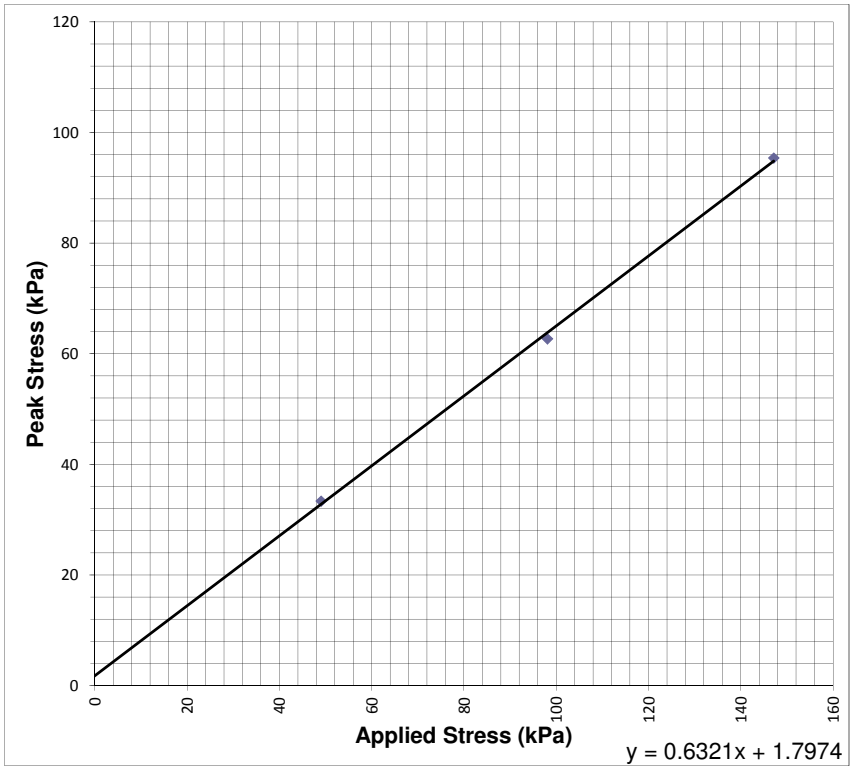
BOREHOLE NAME : MBH-25

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 33 |
| | Stage 2 | 98 | 63 |
| | Stage 3 | 147 | 95 |

| | | |
|---|---|---|
| Angle of Friction | **32.30** | ° |
| Apparent Cohesion | **1.80** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

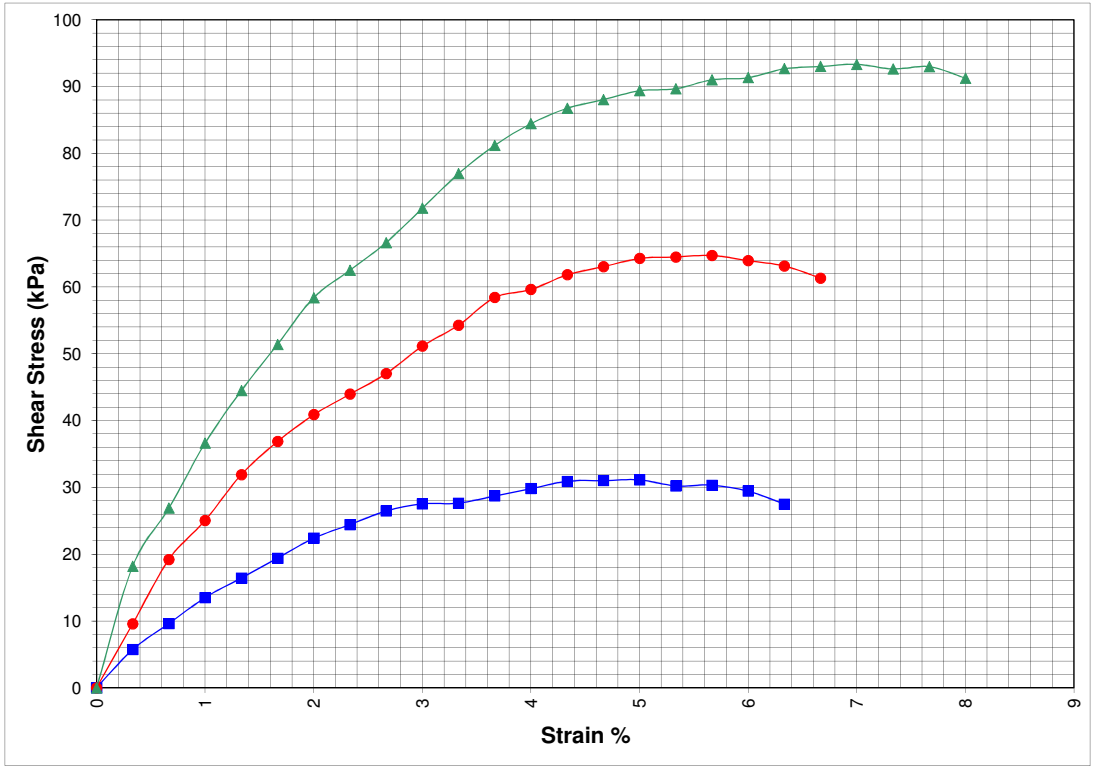
**Borehole: MBH-25**

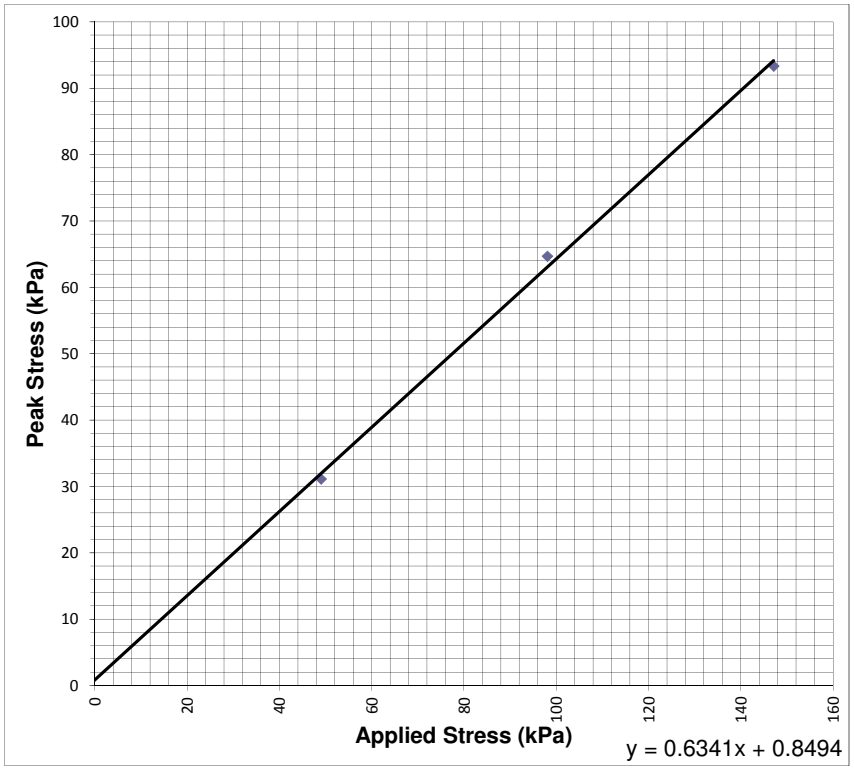
**Sample Type: SPT-02**

**Depth: 1.50-1.70 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 31 |
| | Stage 2 | 98 | 65 |
| | Stage 3 | 147 | 93 |

| | | |
|---|---|---|
| Angle of Friction | **32.38** | ° |
| Apparent Cohesion | **0.85** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

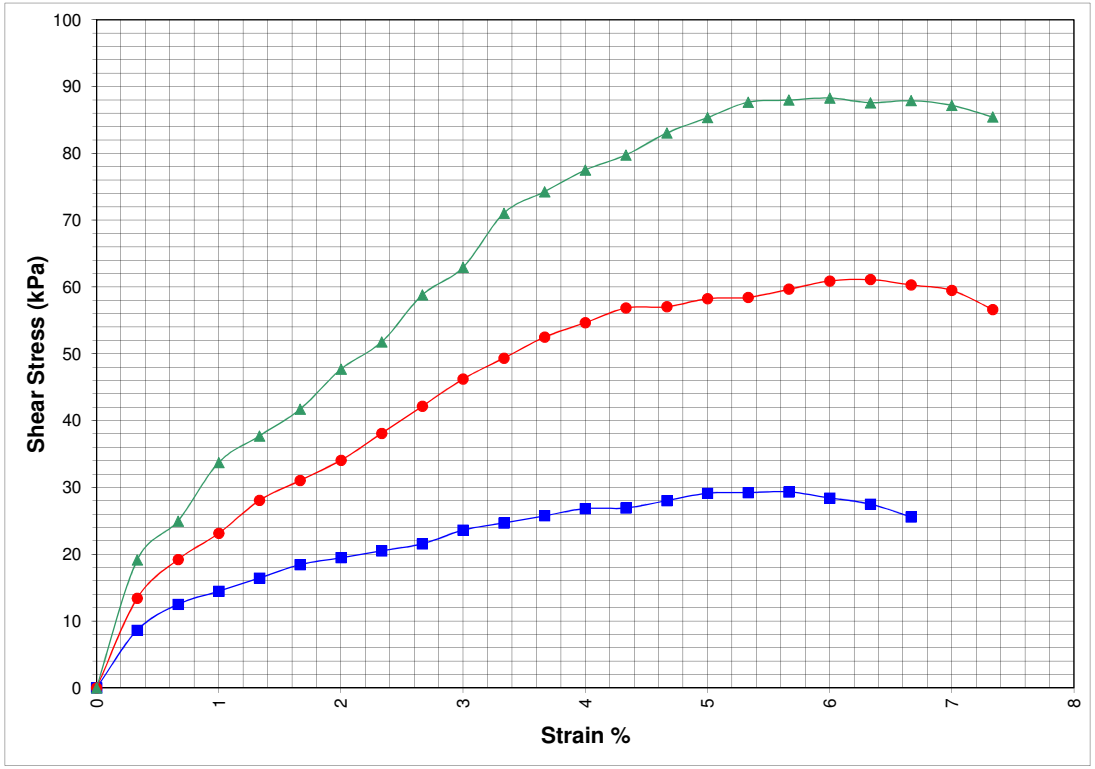
**Borehole: MBH-25**

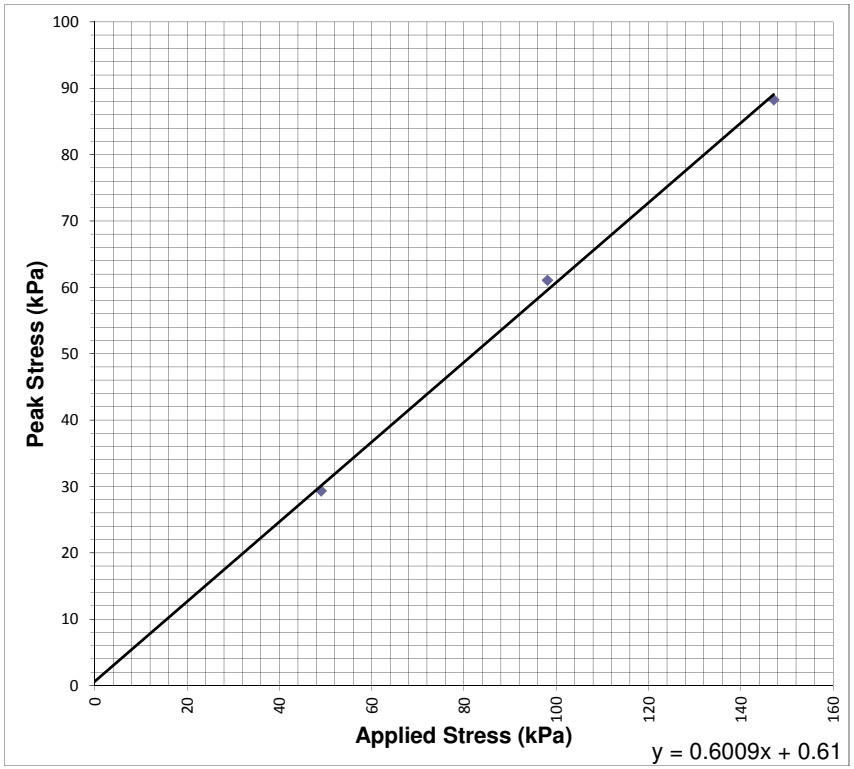
**Sample Type: SPT-04**

**Depth: 4.50-4.72 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 29 |
| | Stage 2 | 98 | 61 |
| | Stage 3 | 147 | 88 |

| | | |
|---|---|---|
| Angle of Friction | **31.00** | ° |
| Apparent Cohesion | **0.94** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

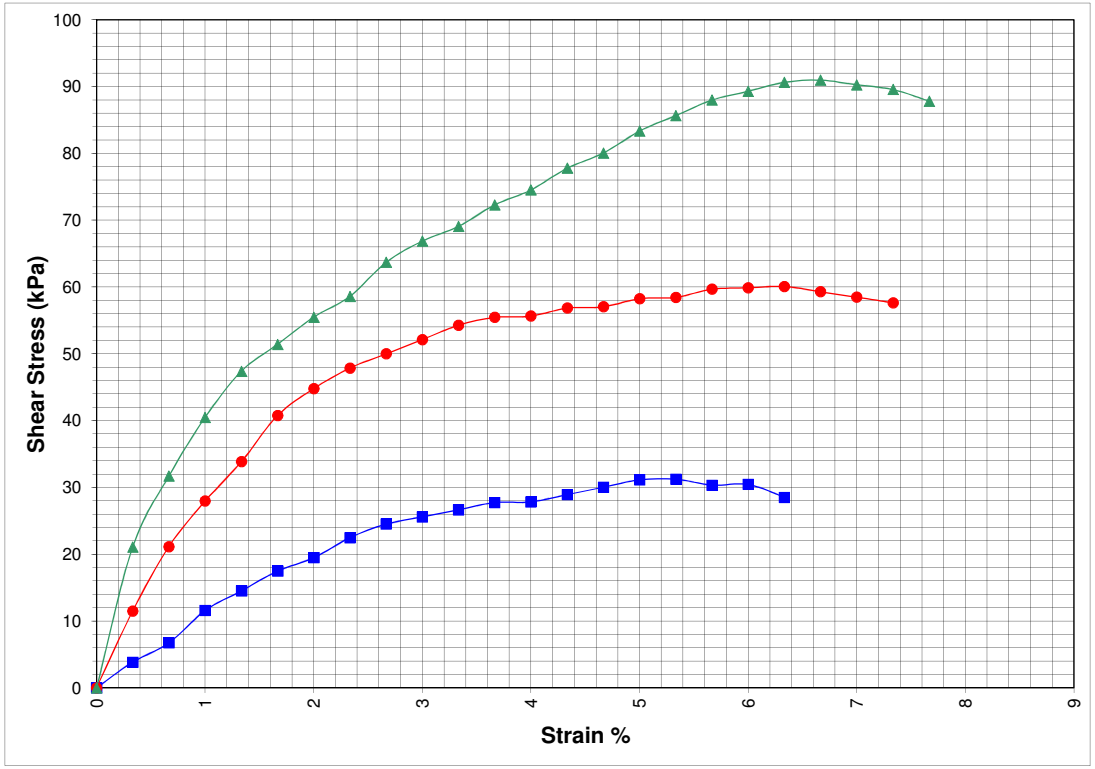
**Borehole: MBH-25**

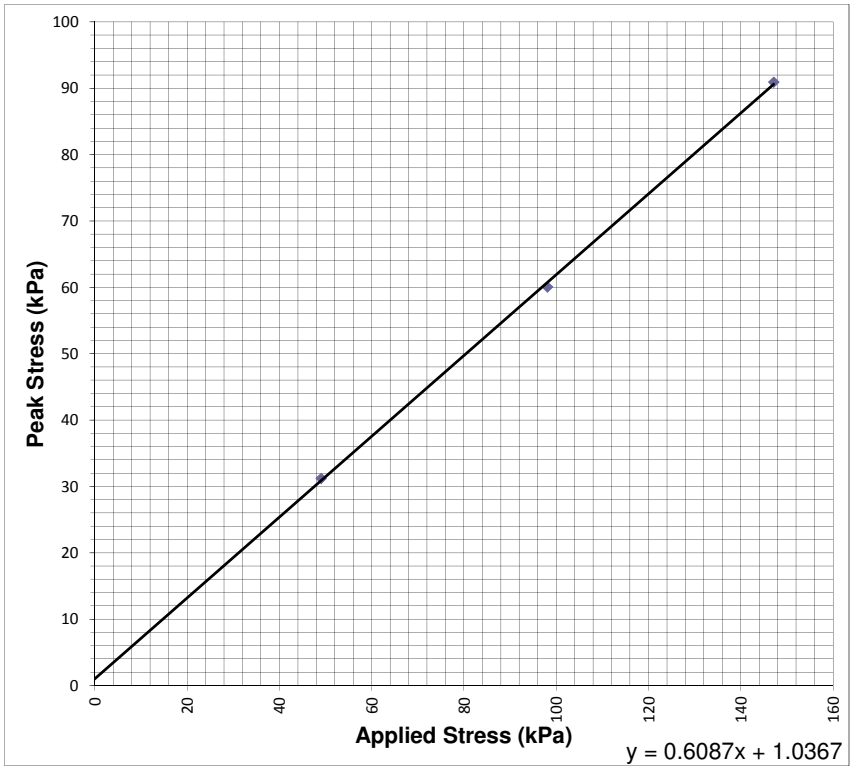
**Sample Type: SPT-06**

**Depth: 7.50-7.80 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 31 |
| | Stage 2 | 98 | 60 |
| | Stage 3 | 147 | 91 |

| | | |
|---|---|---|
| Angle of Friction | **31.33** | ° |
| Apparent Cohesion | **1.04** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

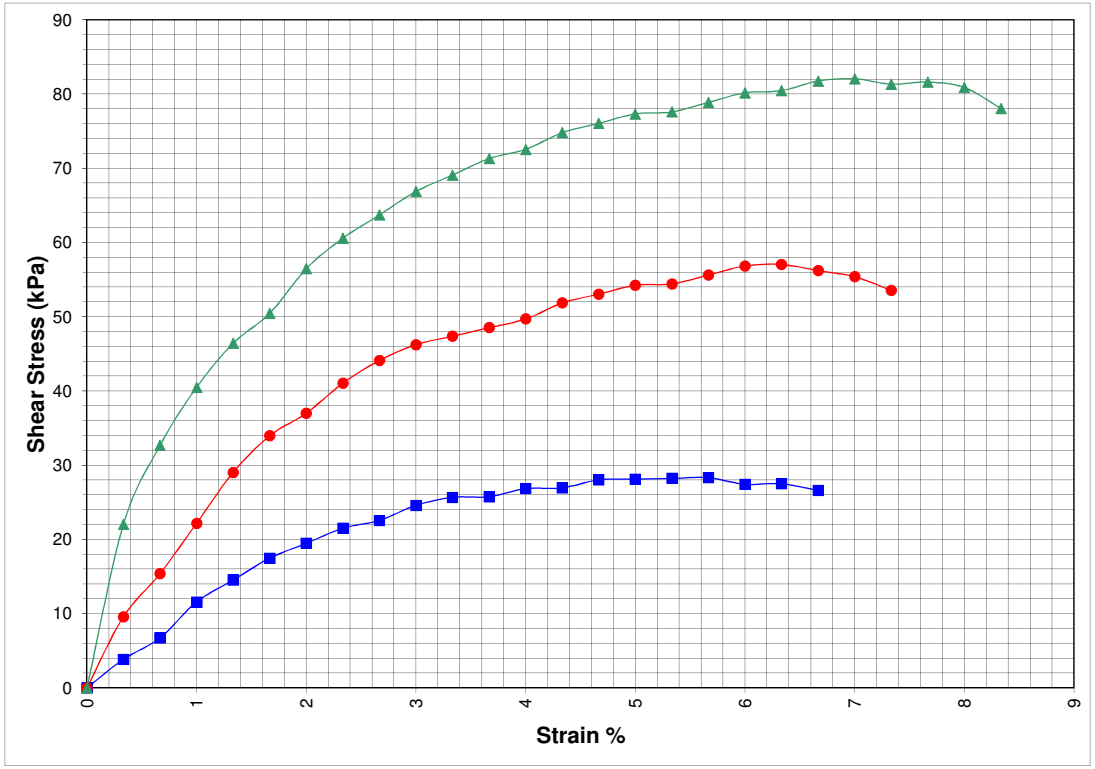
**Borehole: MBH-25**

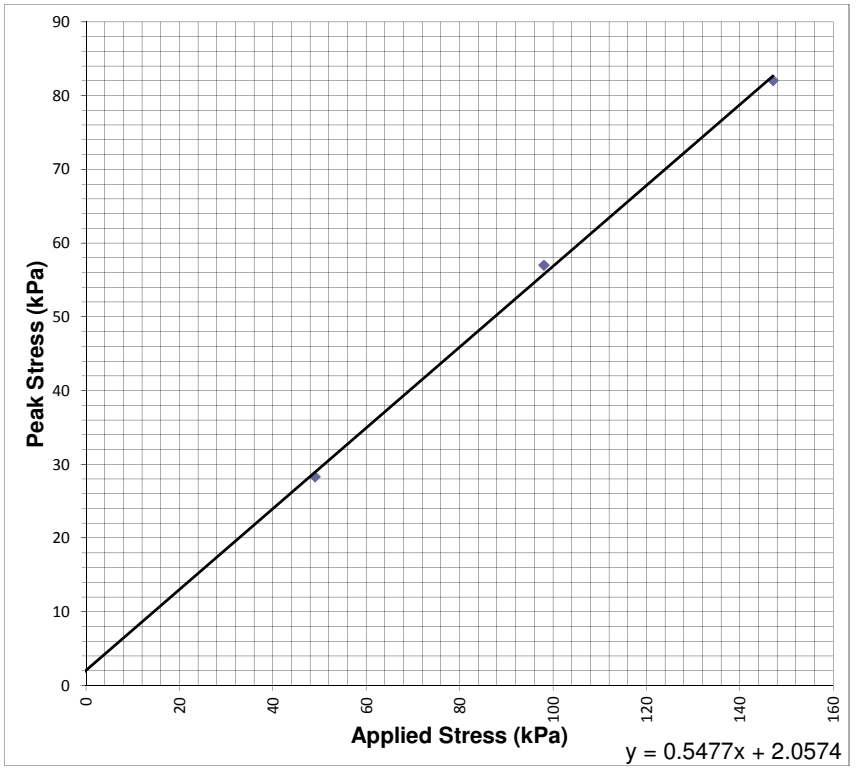
**Sample Type: SPT-08**

**Depth: 10.50-10.75 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 28 |
| | Stage 2 | 98 | 57 |
| | Stage 3 | 147 | 82 |

| | | |
|---|---|---|
| Angle of Friction | **28.71** | ° |
| Apparent Cohesion | **2.06** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

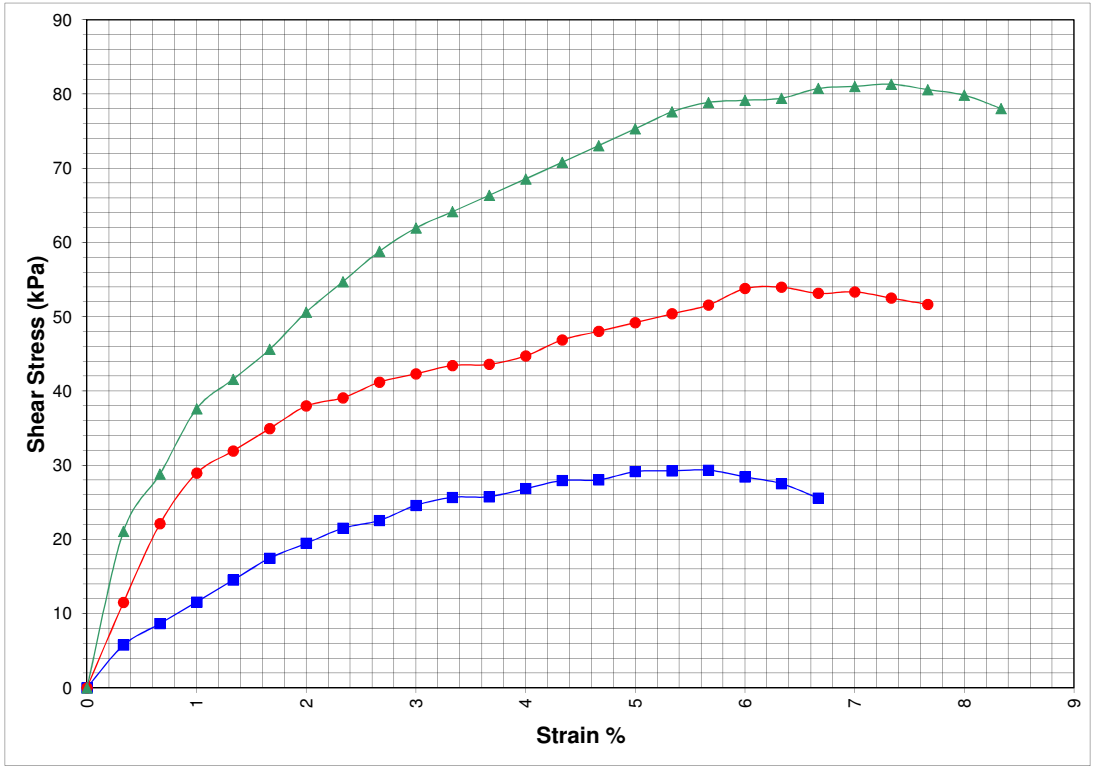
**Borehole: MBH-25**

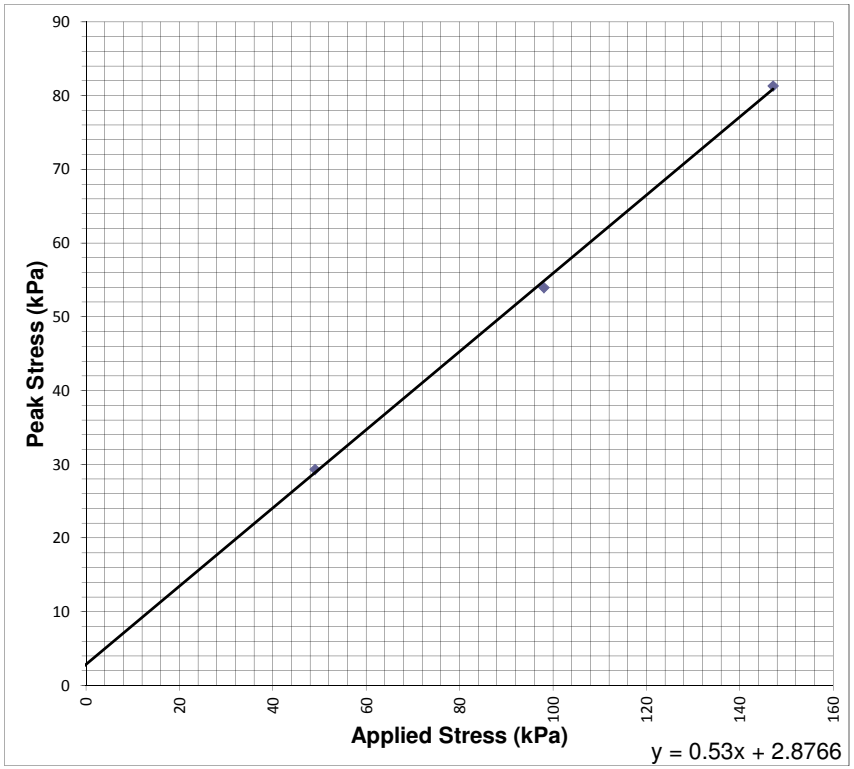
**Sample Type: SPT-10**

**Depth: 13.50-13.73 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 29 |
| | Stage 2 | 98 | 54 |
| | Stage 3 | 147 | 81 |

| | | |
|---|---|---|
| Angle of Friction | **27.92** | ° |
| Apparent Cohesion | **2.88** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

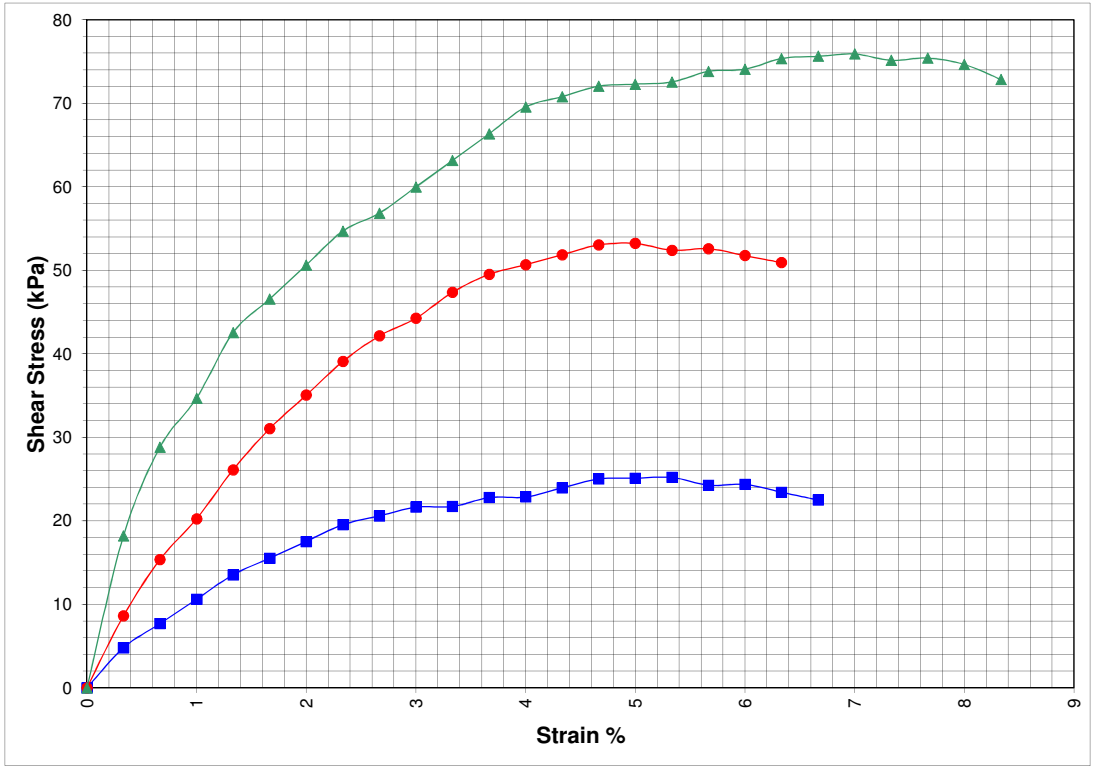
**Borehole: MBH-25**

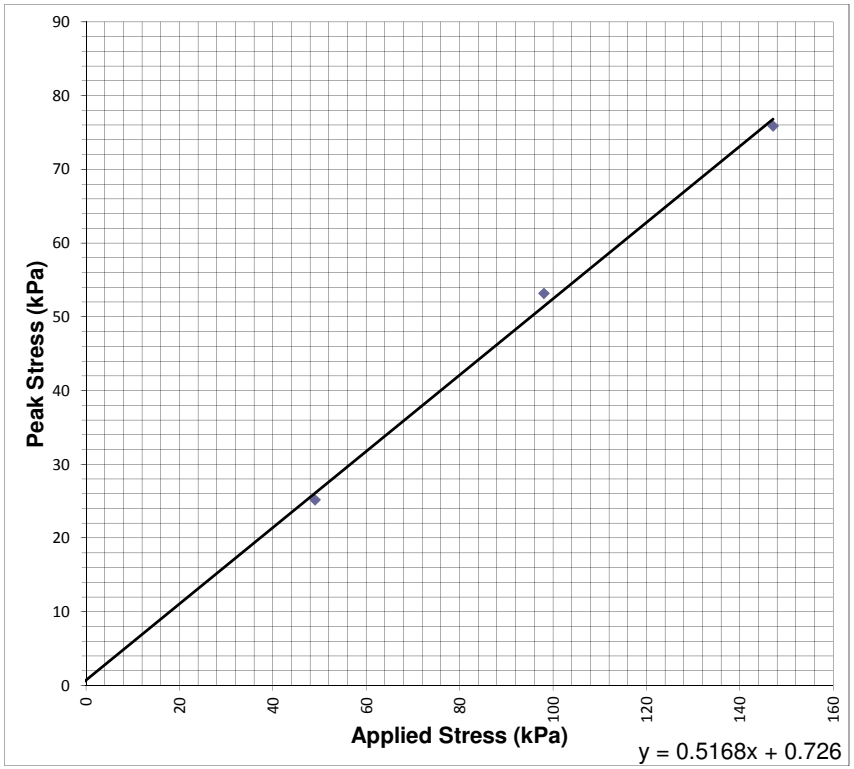
**Sample Type: SPT-14**

**Depth: 19.50-19.72 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 25 |
| | Stage 2 | 98 | 53 |
| | Stage 3 | 147 | 76 |

| | | |
|---|---|---|
| Angle of Friction | **27.33** | ° |
| Apparent Cohesion | **0.73** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

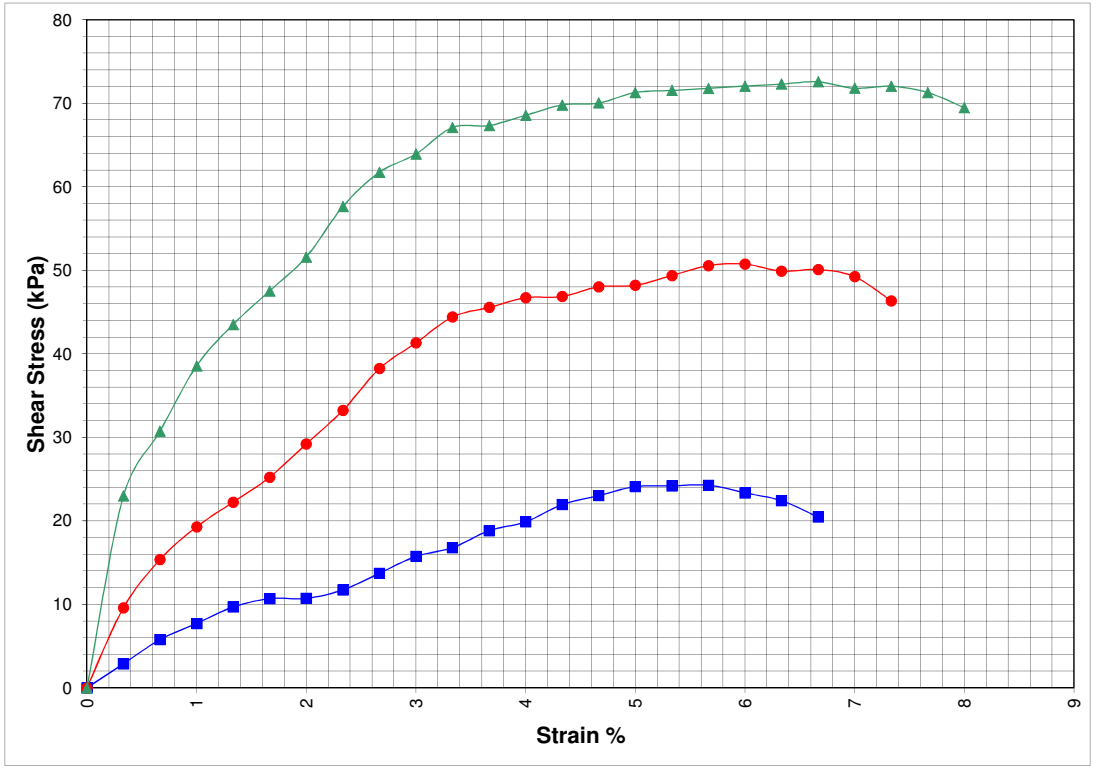
**Borehole: MBH-25**

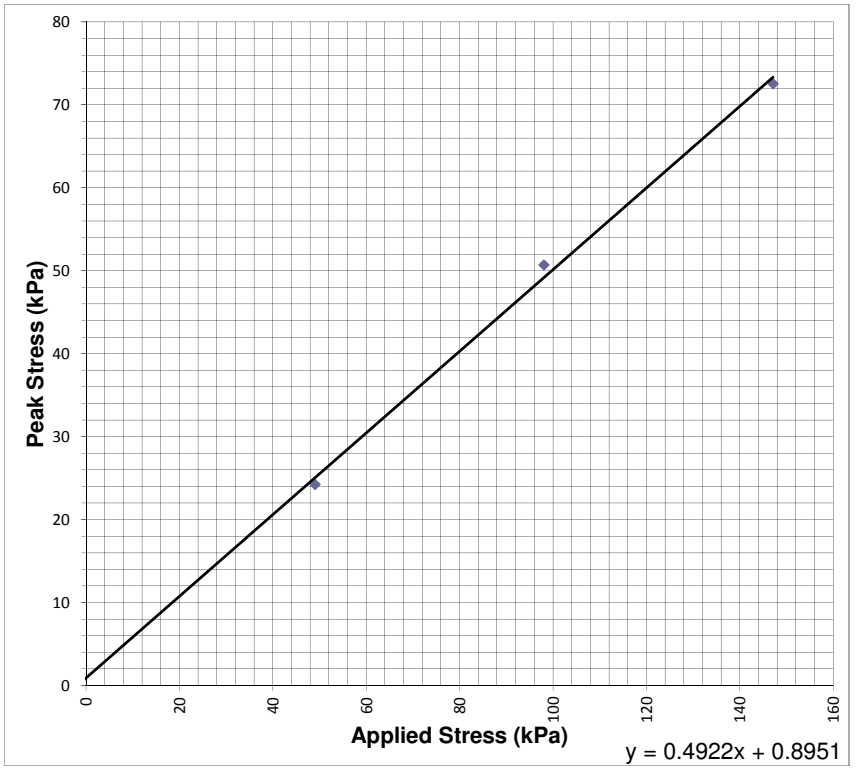
**Sample Type: SPT-16**

**Depth: 22.50-22.70 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 24 |
| | Stage 2 | 98 | 51 |
| | Stage 3 | 147 | 73 |

| | | |
|---|---|---|
| Angle of Friction | **26.21** | ° |
| Apparent Cohesion | **0.90** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

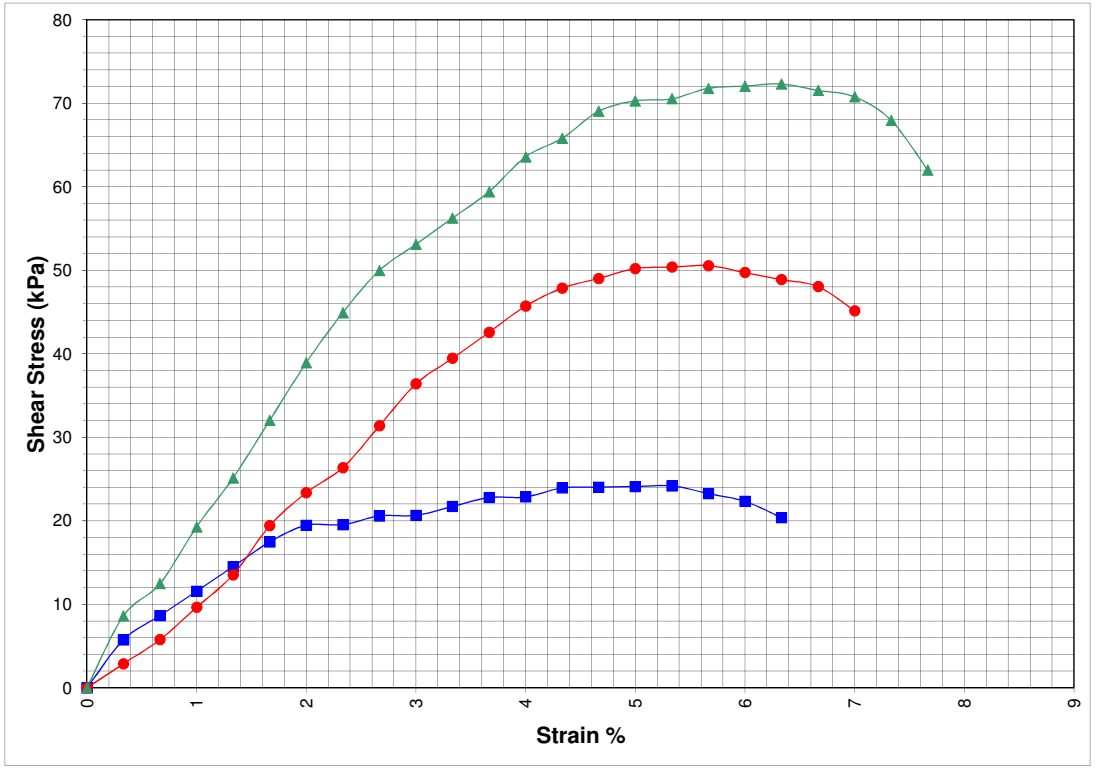
**Borehole: MBH-25**

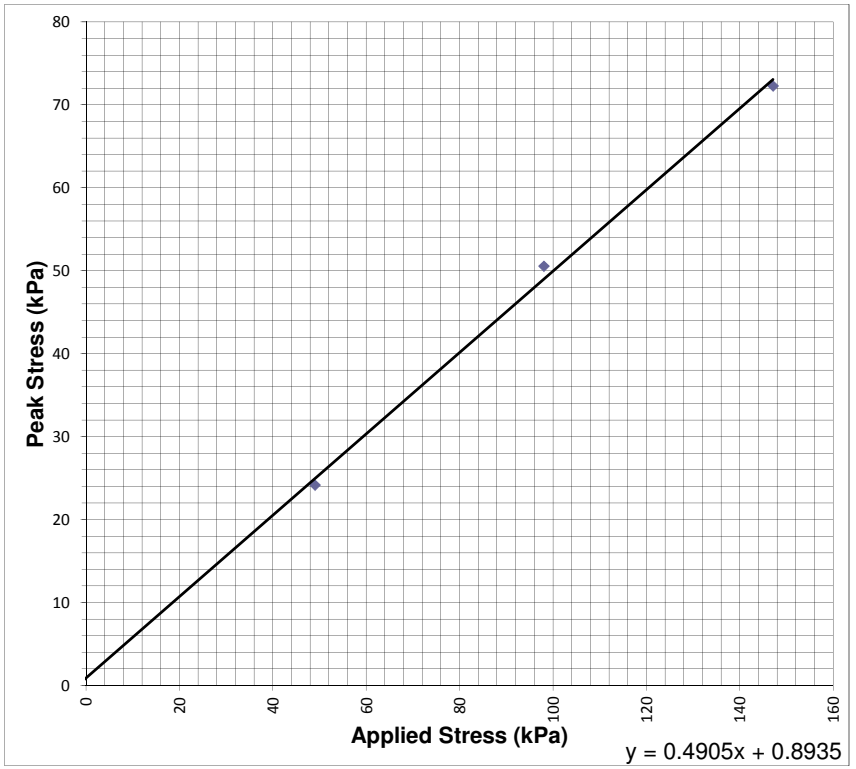
**Sample Type: SPT-19**

**Depth: 27.00-27.27 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 24 |
| | Stage 2 | 98 | 51 |
| | Stage 3 | 147 | 72 |

| | | |
|---|---|---|
| Angle of Friction | **26.13** | ° |
| Apparent Cohesion | **0.89** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

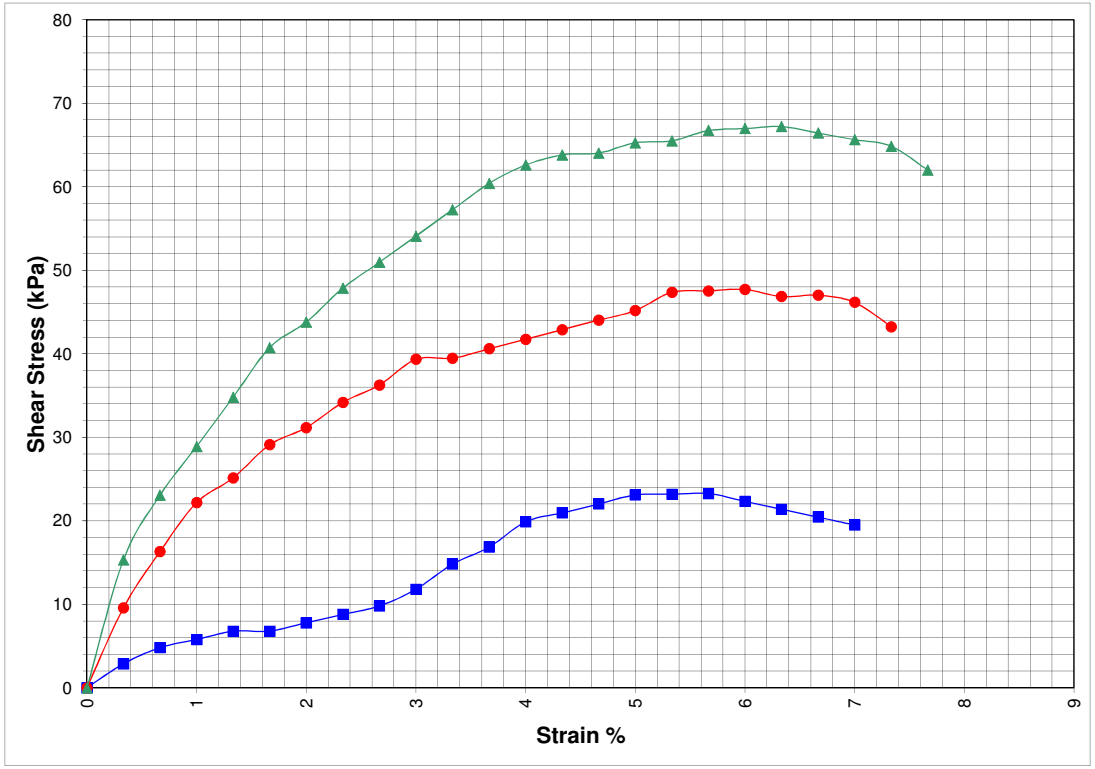
**Borehole: MBH-25**

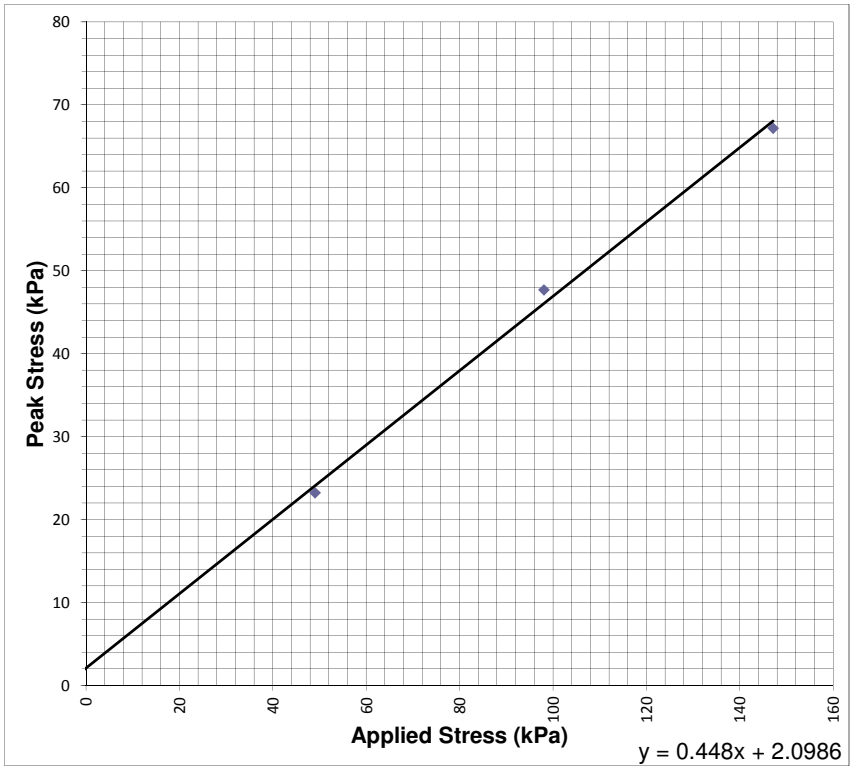
**Sample Type: SPT-21**

**Depth: 30.00-30.20 m**

# Direct Shear Test Results

**Stress - Strain Curves**




| Legend | Stage No | Applied Stress (kPa) | Peak Stress (kPa) |
|---|---|---|---|
| | Stage 1 | 49 | 23 |
| | Stage 2 | 98 | 48 |
| | Stage 3 | 147 | 67 |

| | | |
|---|---|---|
| Angle of Friction | **24.13** | ° |
| Apparent Cohesion | **2.10** | kPa |

Area of the specimen = 3600 $mm^2$
Height of the specimen = 25.4 mm
Rate of Displacement = 1.25 mm/min

**Project: Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha.**

**Borehole: MBH-25**

**Sample Type: SPT-26**

**Depth: 37.50-37.78 m**

**CHEMICAL ANALYSIS OF WATER SAMPLE**

**Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, Dist: Jagatsinghpur, Odisha.**

**Project Code: CM 19 01 03**

| Sr. No. | Borehole No. | pH (IS:3025, P-11) | Sulphate (IS:3025, P-24) (Mg/l) | Chloride (IS:3025, P-32) (Mg/l) |
|---|---|---|---|---|
| 1 | LBH-01 | 7.38 | 130.03 | 87.97 |
| 2 | LBH-02 | 8.32 | 146.49 | 159.95 |
| 3 | LBH-03 | 7.52 | 125.10 | 21.99 |
| 4 | MBH-04 | 8.21 | 2311.81 | 1431.56 |
| 5 | LBH-05A | 7.54 | 165.42 | 125.96 |
| 6 | LBH-06A | 8.30 | 2668.17 | 827.74 |
| 7 | LBH-07 Opt.1 | 7.52 | 187.64 | 51.98 |
| 8 | LBH-08 | 7.42 | 120.57 | 89.97 |
| 9 | MBH-09 | 7.88 | 2467.35 | 1333.59 |
| 10 | MBH-10 | 7.69 | 2584.22 | 967.70 |
| 11 | MBH-11 | 8.24 | 2576.81 | 1367.58 |
| 12 | MBH-12 | 7.49 | 2588.34 | 1311.59 |
| 13 | MBH-13 | 8.38 | 2266.54 | 1203.63 |
| 14 | LBH-14 | 7.24 | 134.56 | 79.98 |
| 15 | MBH-15 | 8.45 | 2271.07 | 703.78 |
| 16 | MBH-16 | 7.92 | 2245.14 | 685.79 |
| 17 | MBH-17 | 7.83 | 2190.00 | 1119.65 |
| 18 | MBH-18 | 8.23 | 2338.97 | 747.77 |
| 19 | MBH-19 | 8.46 | 2228.68 | 1093.66 |
| 20 | MBH-20 | 7.82 | 2354.60 | 1153.64 |
| 21 | MBH-21 | 8.52 | 2312.22 | 725.77 |
| 22 | MBH-22 | 7.93 | 2553.36 | 1527.53 |
| 23 | MBH-23 | 8.10 | 2009.77 | 1325.59 |
| 24 | MBH-24 | 7.99 | 2535.66 | 1071.67 |
| 25 | MBH-25 | 8.33 | 2560.35 | 1385.57 |
| | | | | |
| | | | | |
| | | | | |

**CHEMICAL ANALYSIS OF WATER SAMPLE**

**Geotechnical Investigation For Capive Jetty at Jatadharmuhan, Near Paradip, Dist. Jagatsinghpur, Odisha**

**Project Code: CM 19 01 03**

| Sr. No. | Borehole No. | pH | Sulphate (Mg/l) | Chloride (Mg/l) |
|---|---|---|---|---|
| 1 | LBH-01 | 7.38 | 130.03 | 87.97 |
| 2 | LBH-02 | 8.32 | 146.49 | 159.95 |
| 3 | LBH-03 | 7.52 | 125.10 | 21.99 |
| 4 | LBH-05A | 7.54 | 165.42 | 125.96 |
| 5 | LBH-07 Opt.1 | 7.52 | 187.64 | 51.98 |
| 6 | LBH-08 | 7.42 | 120.57 | 89.97 |
| 7 | LBH-14 | 7.24 | 134.56 | 79.98 |
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**PROJECT : Geotechnical Investigation for Development of Capative Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.**

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**Stratigraphy of borehole**

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| LBH-01 | 0.00 | 4.50 | 4.50 | Loose sandy soil |
| | 4.50 | 13.50 | 9.00 | Loose to medium dense sand |
| | 13.50 | 16.50 | 3.00 | Medium dense sand |
| | 16.50 | 24.00 | 7.50 | Loose to medium dense sand |
| | 24.00 | 30.45 | 6.45 | Medium dense sand |

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| LBH-02 | 0.00 | 10.50 | 10.50 | Loose to medium dense sand |
| | 10.50 | 13.50 | 3.00 | Medium dense sand |
| | 13.50 | 19.50 | 6.00 | Medium dense sand |
| | 19.50 | 30.45 | 10.95 | Medium dense sand |

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| LBH-03 | 0.00 | 9.00 | 9.00 | Loose to medium dense sand |
| | 9.00 | 14.00 | 5.00 | Medium dense sand |
| | 14.00 | 18.00 | 4.00 | Medium clayey silt |
| | 18.00 | 30.45 | 12.45 | Medium dense sand |

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| MBH-04 | 0.00 | 7.50 | 7.50 | Medium dense to dense sand |
| | 7.50 | 12.50 | 5.00 | Medium dense sand |
| | 12.50 | 15.00 | 2.50 | Medium clayey silt |
| | 15.00 | 30.00 | 15.00 | Medium dense sand |
| | 30.00 | 45.00 | 15.00 | Medium dense sand |

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| LBH-05 | 0.00 | 7.50 | 7.50 | Loose to medium dense sand |
| | 7.50 | 10.50 | 3.00 | Medium dense sand |
| | 10.50 | 27.45 | 16.95 | Medium dense sand |

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| LBH-06 | 0.00 | 3.00 | 3.00 | Medium dense sand |
| | 3.00 | 9.00 | 6.00 | Medium dense sand |
| | 9.00 | 11.00 | 2.00 | Medium dense sand |
| | 11.00 | 30.45 | 19.45 | Medium dense sand |

**Annexure 15.5**
**STRATIGRAPHY**
**BH 01 to 06.**

## Stratigraphy of borehole

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| LBH-07 | 0.00 | 4.00 | 4.00 | Loose sandy soil |
| | 4.00 | 9.00 | 5.00 | medium dense sand |
| | 9.00 | 17.00 | 8.00 | Medium dense sand |
| | 17.00 | 22.00 | 5.00 | Hard clay |
| | 22.00 | 30.45 | 8.45 | Medium dense sand |

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| LBH-08 | 0.00 | 3.45 | 3.45 | Very Loose to Loose, Silty Fine SAND. |
| | 3.45 | 9.45 | 6.00 | Loose, Silty Fine SAND. |
| | 9.45 | 24.45 | 15.00 | Medium Dense, Silty Fine SAND |
| | 24.45 | 30.45 | 6.00 | Dense, Silty Fine SAND |

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| MBH-09 | 0.00 | 0.45 | 0.45 | Loose, Silty Fine SAND with traces of shell fragments. |
| | 0.45 | 9.45 | 9.00 | Medium Dense to dense,silty Fine SAND. |
| | 12.45 | 13.50 | 1.05 | Firm clayey sand/ sandy clay |
| | 13.50 | 15.45 | 1.95 | Firm to Stiff, Sandy CLAY with traces of shell fragments. |
| | 15.45 | 25.95 | 10.5 | Medium Dense to dense,silty Fine SAND |
| | 25.95 | 40.45 | 14.5 | Dense to very dense, Silty Fine SAND |

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| MBH-10 | 0.00 | 0.45 | 0.45 | Loose, Silty Fine SAND with traces of shell fragments. |
| | 0.45 | 9.50 | 9.05 | Medium Dense, Fine to Medium SAND. |
| | 9.50 | 12.45 | 2.95 | Medium Dense, Silty Clayey SAND/ Sandy CLAY. |
| | 12.45 | 25.95 | 13.50 | Medium Dense, silty Fine SAND |
| | 25.95 | 40.45 | 14.50 | Dense to very dense, Silty Fine SAND |

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| MBH-11 | 0.00 | 7.95 | 7.95 | Medium Dense to Dense, Fine to Medium SAND. |
| | 7.95 | 10.95 | 3.00 | Dense, Silty Fine SAND |
| | 10.95 | 15.45 | 4.50 | Medium Dense, Silty Clayey SAND or Sandy CLAY. |
| | 15.45 | 40.45 | 25.00 | Dense to very dense, Silty Fine SAND |

## Stratigraphy of borehole

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| MBH-12 | 0.00 | 0.45 | 0.45 | Very Loose to Loose, Silty Fine SAND. |
| | 0.45 | 7.95 | 7.50 | Loose, Silty Fine SAND. |
| | 7.95 | 30.45 | 22.50 | Medium dense, Silty Fine SAND. |

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| MBH-13 | 0.00 | 1.50 | 1.50 | Loose to medium dense sand |
| | 1.50 | 9.50 | 8.00 | Dense sand |
| | 9.50 | 14.00 | 4.50 | Stiff to very stiff clay |
| | 14.00 | 18.00 | 4.00 | Medium dense sand |
| | 18.00 | 23.00 | 5.00 | Medium dense sand |
| | 23.00 | 26.95 | 3.95 | Stiff clay |

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| LBH-14 | 0.00 | 0.45 | 0.45 | Very Loose, Silty Fine SAND. |
| | 0.45 | 4.95 | 4.50 | Loose, Silty Fine SAND. |
| | 4.95 | 9.45 | 4.50 | Loose to medium dense, Silty Fine SAND. |
| | 9.45 | 25.95 | 16.50 | Medium Dense, Silty Fine SAND |
| | 25.95 | 30.45 | 4.50 | Dense, Silty Fine SAND |

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| MBH-15 | 0.00 | 3.00 | 3.00 | Medium dense to dense sand |
| | 3.00 | 6.00 | 3.00 | Medium dense to dense sand |
| | 6.00 | 10.00 | 4.00 | Medium dense to dense sand |
| | 10.00 | 14.00 | 4.00 | Stiff to very stiff clay |
| | 14.00 | 22.00 | 8.00 | Medium dense sand |
| | 22.00 | 27.45 | 5.45 | Stiff to very stiff clay |

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| MBH-16 | 0.00 | 4.50 | 4.50 | medium dense to dense sand |
| | 4.50 | 10.70 | 6.20 | Stiff clay |
| | 10.70 | 14.00 | 3.30 | Medium dense sand |
| | 14.00 | 21.45 | 7.45 | Stiff to very stiff clay |

## Stratigraphy of borehole

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| MBH-17 | 0.00 | 1.95 | 1.95 | Loose to Medium Dense, Silty Fine SAND. |
| | 1.95 | 6.45 | 4.50 | Soft to Very stiff, Sandy Silty CLAY, sand pockets and gravels. |
| | 6.45 | 12.45 | 6.00 | Medium Dense to Dense, Silty Fine SAND |
| | 12.45 | 15.45 | 3.00 | Stiff, Sandy SILT / Sandy CLAY with traces of fine Gravels. |
| | 15.45 | 17.05 | 1.60 | Medium Dense, Silty SAND / Sandy SILT. |

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| MBH-18 | 0.00 | 3.00 | 3.00 | Very soft clay |
| | 3.00 | 9.00 | 6.00 | Medium dense sand |
| | 9.00 | 14.00 | 5.00 | Medium dense sand |
| | 14.00 | 15.50 | 1.50 | Stiff clay |
| | 15.50 | 16.95 | 1.45 | Dense sand |

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| MBH-19 | 0.00 | 1.00 | 1.00 | Loose, Silty Fine SAND. |
| | 1.00 | 1.95 | 0.95 | Medium Dense, Clayey Silty SAND. |
| | 1.95 | 4.95 | 3.00 | Very Stiff, Fine Sandy Silty CLAY. |
| | 4.95 | 13.95 | 9.00 | Medium Dense to Dense, Silty Fine SAND |
| | 13.95 | 15.80 | 1.85 | Very Stiff, Silty CLAY. |

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| MBH-20 | 0.00 | 1.10 | 1.10 | Loose, Silty Fine SAND with traces of shell fragments and clay pockets. |
| | 1.10 | 5.65 | 4.55 | Soft to Very Stiff, Silty CLAY with traces of shell fragments and Fine SAND. |
| | 5.65 | 13.45 | 7.80 | Medium Dense to Dense, Fine to Medium Silty SAND. |
| | 13.45 | 14.95 | 1.50 | Hard, Silty Clay |

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| MBH-21 | 0.00 | 1.00 | 1.00 | Very Soft to Soft, Sandy CLAY with few shell fragments. |
| | 1.00 | 1.95 | 0.95 | Loose, Clayey SAND with traces of shell fragments. |
| | 1.95 | 3.45 | 1.50 | Very Stiff, Sandy Silty CLAY. |
| | 3.45 | 9.45 | 6.00 | Medium Dense to Dense, Silty Fine SAND |
| | 9.45 | 14.15 | 4.70 | Dense to Very Dense, Silty fine SAND with few of Clay pockets. |

## Stratigraphy of borehole

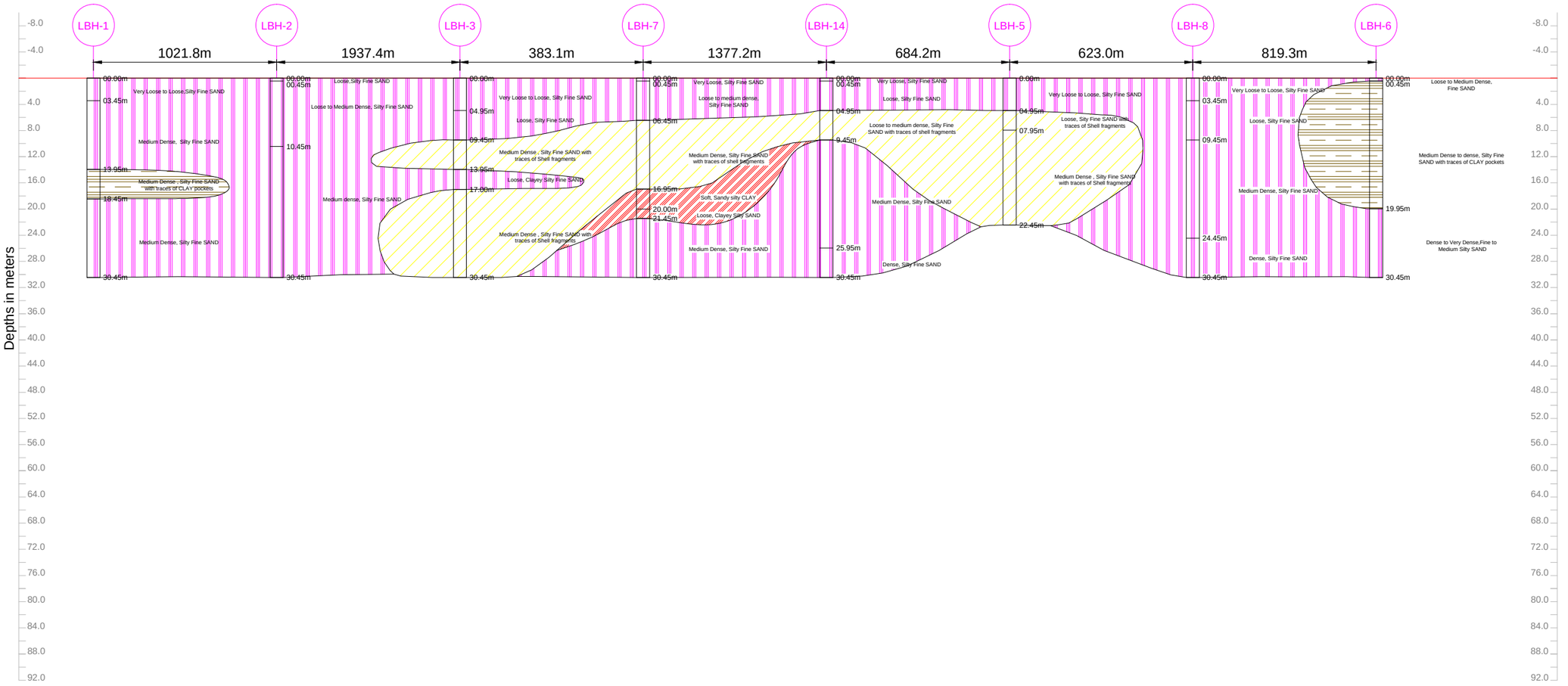
| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| MBH-22 | 0.00 | 3.45 | 3.45 | Medium Dense, Fine to Medium Silty SAND with traces of shell fragments. |
| | 3.45 | 15.45 | 12.00 | Medium Dense to Dense, Fine to Medium SAND with traces of shell fragments and clay pockets |
| | 15.45 | 16.95 | 1.50 | Firm to Stiff, Sandy Silty CLAY/ Clayey SAND. |
| | 16.95 | 21.45 | 4.50 | Medium Dense, Silty Fine SAND |
| | 21.45 | 34.95 | 13.50 | Dense, Fine to medium Silty SAND |
| | 34.95 | 45.45 | 10.50 | Dense to very dense, Silty Fine SAND |

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| MBH-23 | 0.00 | 1.95 | 1.95 | Very Loose, Silty Fine SAND with traces of shell fragments. |
| | 1.95 | 10.95 | 9.00 | Medium Dense, Silty Fine SAND with trace of shell fragments. |
| | 10.95 | 13.95 | 3.00 | Medium Dense, Silty Fine SAND with trace of Clay pockets. |
| | 13.95 | 31.95 | 18.00 | Medium Dense, Silty Fine SAND |
| | 31.95 | 45.45 | 13.50 | Dense to very dense, Silty Fine SAND |

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| MBH-24 | 0.00 | 0.45 | 0.45 | Loose to Medium Dense,Silty Fine SAND with traces of shell fragments. |
| | 0.45 | 1.95 | 1.50 | Medium Dense, Fine to Medium SAND with trace of shell fragments. |
| | 1.95 | 13.95 | 12.00 | Dense, Silty Fine SAND |
| | 13.95 | 15.45 | 1.50 | Firm to Stiff, Sandy Silty CLAY. |
| | 15.45 | 25.95 | 10.50 | Medium Dense, Silty Fine SAND |
| | 25.95 | 40.45 | 14.50 | Dense to very dense, Silty Fine SAND |

| BH.No | FROM | TO | LAYER THICKNESS | DESCRIPTION OF STRATA |
|---|---|---|---|---|
| MBH-25 | 0.00 | 10.00 | 10.00 | Medium dense sand |
| | 10.00 | 21.00 | 11.00 | Medium dense sand |
| | 21.00 | 27.00 | 6.00 | Medium dense sand |
| | 27.00 | 45.45 | 18.45 | Medium dense sand |

SOUTH-WEST ←——— SUBSURFACE SOIL PROFILE FOR LAND BOREHOLES ———→ NORTH-EAST




## NOTES :

1) All dimensions are in meters.
2) Depth mentioned are w.r.t. Chart Datum and MSL
3) The generalised sub soil profile shown in a diagrametical illustration of the information obtained from borehole logs. It is not necessarily representative of conditions at the site as a whole.

## LEGEND

- Medium dense, Silty Fine SAND/ Dense to very dense, Silty Fine SAND
- Medium Dense, Fine to Medium Silty SAND with traces of shell fragments
- Medium Dense, Silty Fine SAND with trace of Clay pockets.
- Medium Dense, Fine to Medium SAND
- Firm to Stiff, Sandy Silty CLAY/ Clayey SAND

*Owner*

JSW Utkal Steel Ltd.

*Geotechnical Contractor*

Coastal Marine Construction & Engineering Ltd.

*Project*

Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.

*Drawing Title*

Sub Surface Soil Profile for Land
LBH 01, LBH 02, LBH 03, LBH 07, LBH 14, LBH 05, LBH 08 & LBH 06

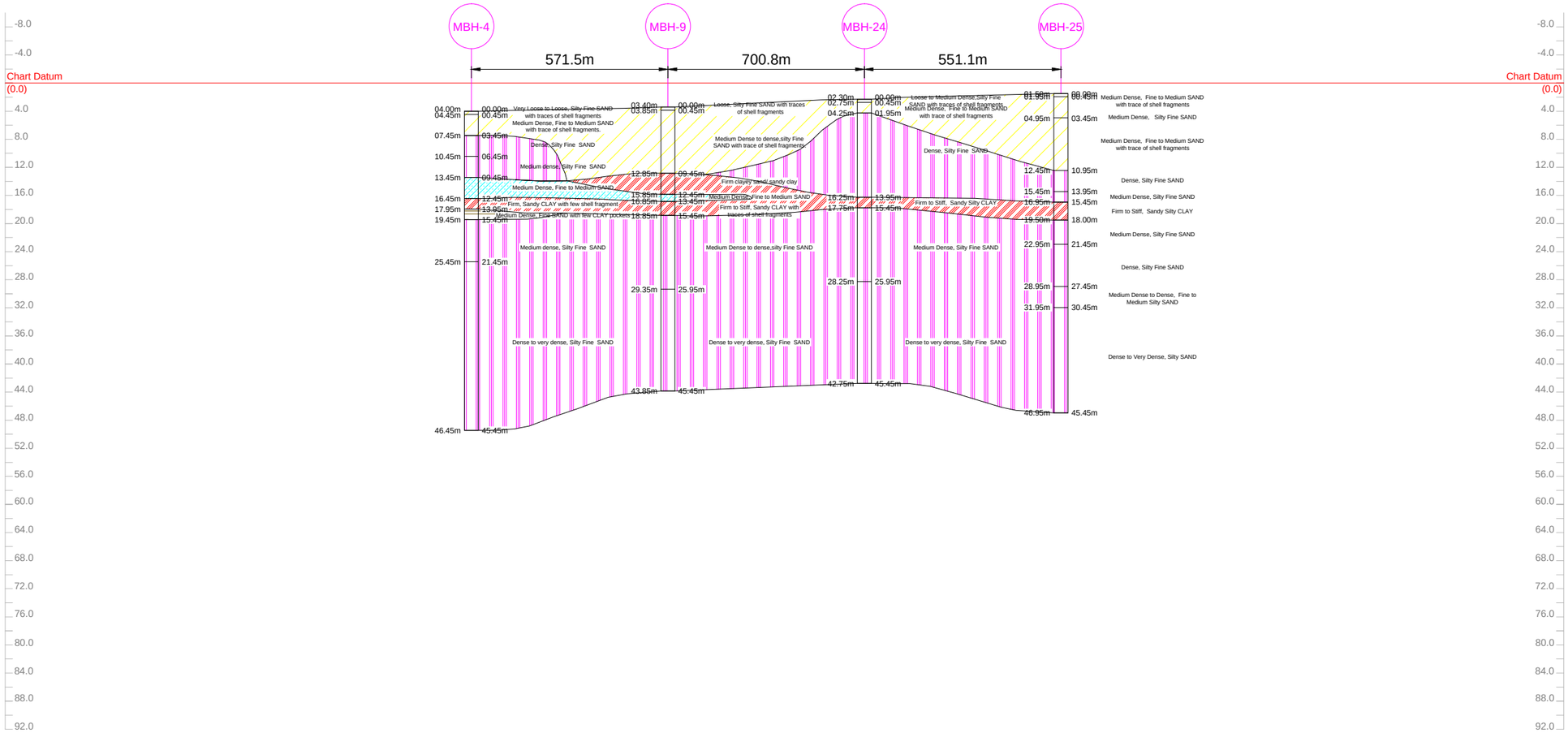
*Scale*

Not to Scale

*Drawing Number*

| Project Code | | | | Job Code | | | | | Type | Folio | | Sheet No. | | Rev. | PC | DPC | DPG | A-HDP | HDQC | DATE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CM | 19 | 01 | 03 | G | T | 0 | 0 | 1 | D | R | -- | -- | 1 | OF 1 | A | VP | JKS | ---- | ---- | HSP | 27/06/2019 |

SOUTH-WEST ◄——— SUBSURFACE SOIL PROFILE FOR MARINE BOREHOLES ——— NORTH-EAST




## NOTES :

1) All dimensions are in meters.
2) Depth mentioned are w.r.t. Chart Datum and MSL
3) The generalised sub soil profile shown in a diagrametical illustration of the information obtained from borehole logs. It is not necessarily representative of conditions at the site as a whole.

## LEGEND

- Medium dense, Silty Fine SAND/ Dense to very dense, Silty Fine SAND
- Medium Dense, Fine to Medium Silty SAND with traces of shell fragments
- Medium Dense, Silty Fine SAND with trace of Clay pockets.
- Medium Dense, Fine to Medium SAND
- Firm to Stiff, Sandy Silty CLAY/ Clayey SAND

*Owner*

JSW Utkal Steel Ltd.

*Geotechnical Contractor*

Coastal Marine Construction & Engineering Ltd.

*Project*

Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.

*Drawing Title*

Sub Surface Soil Profile for Marine
MBH 04, MBH 09, MBH 24 & MBH 25

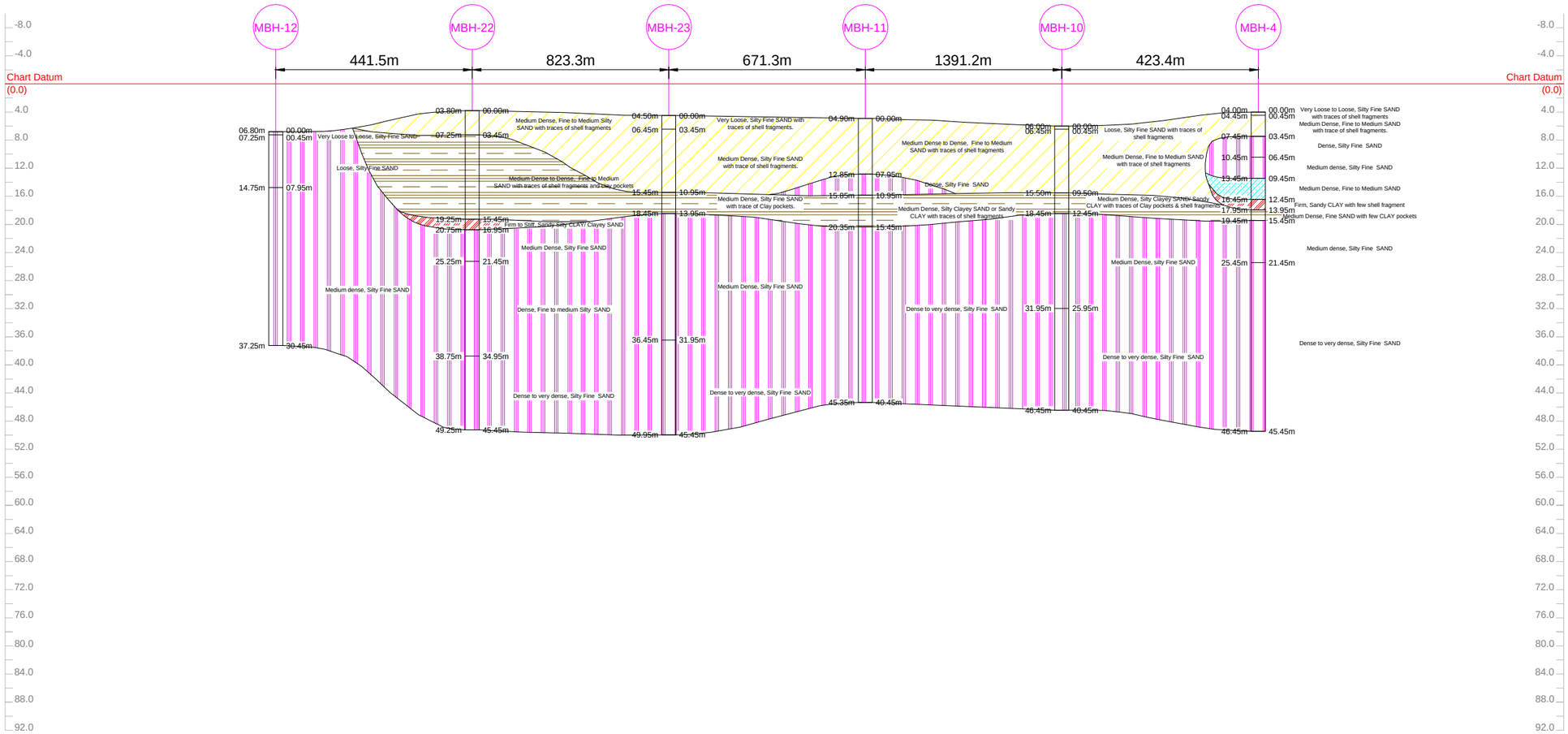
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SOUTH-WEST ◄——— SUBSURFACE SOIL PROFILE FOR MARINE BOREHOLES ——— NORTH-EAST




## NOTES :

1) All dimensions are in meters.
2) Depth mentioned are w.r.t. Chart Datum and MSL
3) The generalised sub soil profile shown in a diagrametical illustration of the information obtained from borehole logs. It is not necessarily representative of conditions at the site as a whole.

## LEGEND

- Medium dense, Silty Fine SAND/ Dense to very dense, Silty Fine SAND
- Medium Dense, Fine to Medium Silty SAND with traces of shell fragments
- Medium Dense, Silty Fine SAND with trace of Clay pockets.
- Medium Dense, Fine to Medium SAND
- Firm to Stiff, Sandy Silty CLAY/ Clayey SAND

Owner
JSW Utkal Steel Ltd.

Geotechnical Contractor
COMACOE
Coastal Marine Construction & Engineering Ltd.

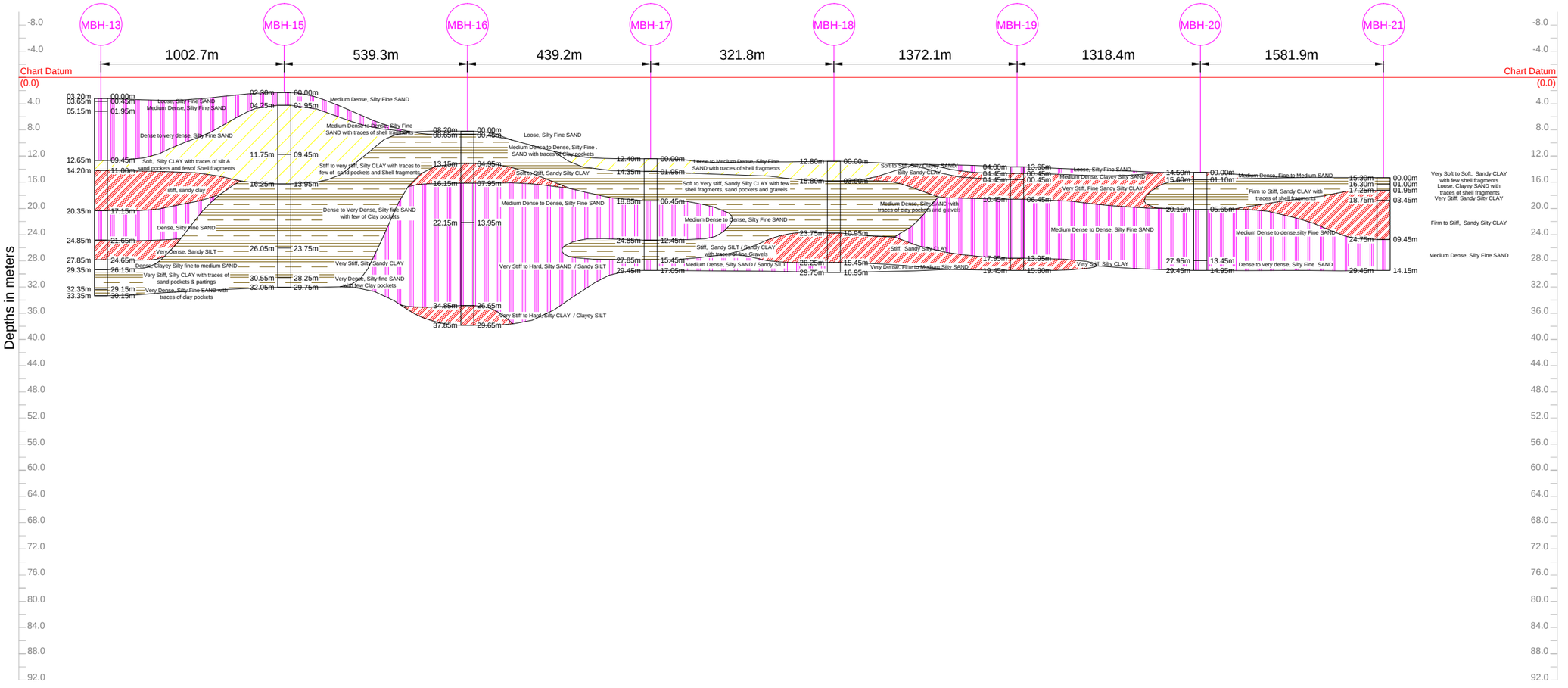
Project
Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.

Drawing Title
Sub Surface Soil Profile for Marine
MBH 12, MBH 22, MBH 23, MBH 11, MBH 10 & MBH 04

Scale
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| Drawing Number | | | | | | | | | | | | | | | | PC | DPC | DPG | A-HDP | HDQC | DATE |
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| Project Code | | | | Job Code | | | | | | Type | | Folio | | Sheet No. | | Rev. | | | | | | | |
| CM | 19 | 01 | 03 | G | T | 0 | 0 | 1 | D | R | -- | -- | 1 | OF | 2 | A | VP | JKS | ---- | ---- | HSP | 27/06/2019 |

NORTH-WEST ←——— SUBSURFACE SOIL PROFILE FOR MARINE BOREHOLES ———→ SOUTH-EAST




## NOTES :

1) All dimensions are in meters.
2) Depth mentioned are w.r.t. Chart Datum and MSL
3) The generalised sub soil profile shown in a diagrametical illustration of the information obtained from borehole logs. It is not necessarily representative of conditions at the site as a whole.

## LEGEND

- Medium dense, Silty Fine SAND/ Dense to very dense, Silty Fine SAND
- Medium Dense, Fine to Medium Silty SAND with traces of shell fragments
- Medium Dense, Silty Fine SAND with trace of Clay pockets.
- Medium Dense, Fine to Medium SAND
- Firm to Stiff, Sandy Silty CLAY/ Clayey SAND

*Owner*

JSW Utkal Steel Ltd.

*Geotechnical Contractor*

Coastal Marine Construction & Engineering Ltd.

*Project*

Geotechnical Investigation for development of Captive Jetty(ies) at Jatadharmuhan, District Jagatsinghpur, Odisha.

*Drawing Title*

Sub Surface Soil Profile for Marine
MBH 13, MBH 15, MBH 16, MBH 17, MBH 18, MBH 19, MBH 20 & MBH 21

*Scale*

Not to Scale

*Drawing Number*

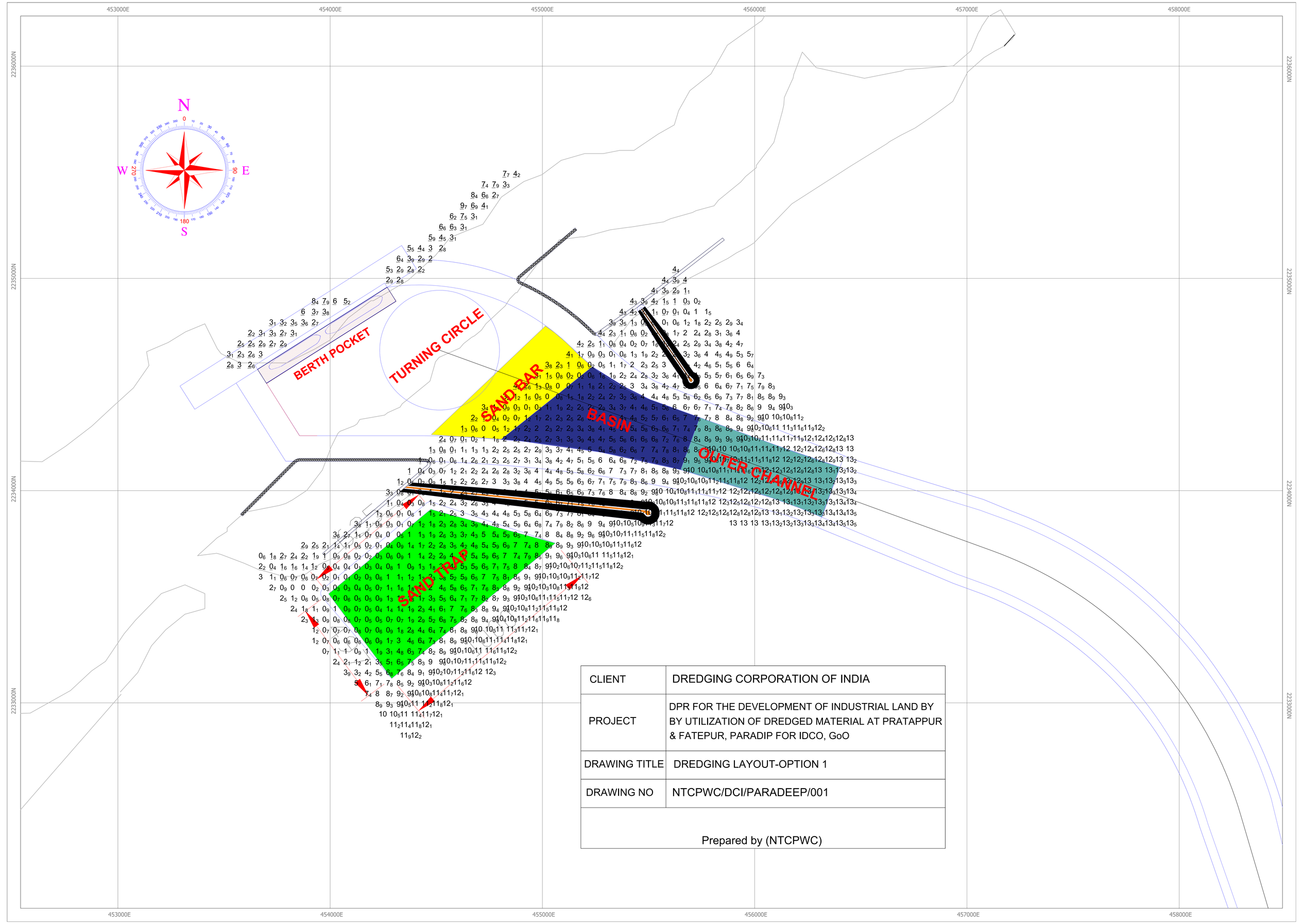
| Project Code | | | | Job Code | | | | | Type | Folio | | Sheet No. | | Rev. | PC | DPC | DPG | A-HDP | HDQC | DATE |
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| CM | 19 | 01 | 03 | G | T | 0 | 0 | 1 | D | R | -- | -- | 1 | OF | 1 | A | VP | JKS | ---- | ---- | HSP | 27/06/2019 |

# ANNEXURE V

# DREDGING AREA OPTIONS

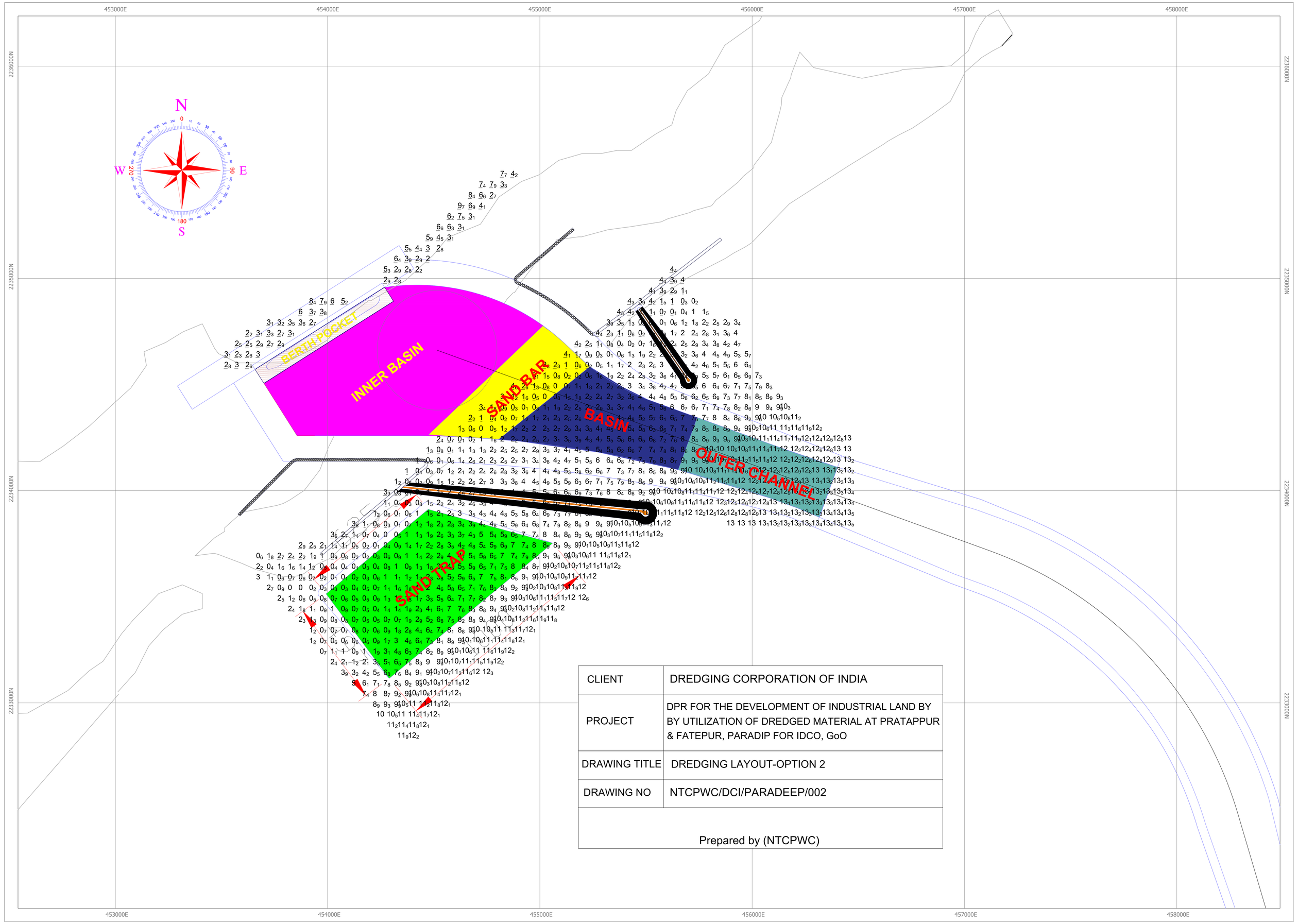
# AND

# PIPELINE ROUTING




| | |
|---|---|
| CLIENT | DREDGING CORPORATION OF INDIA |
| PROJECT | DPR FOR THE DEVELOPMENT OF INDUSTRIAL LAND BY BY UTILIZATION OF DREDGED MATERIAL AT PRATAPPUR & FATEPUR, PARADIP FOR IDCO, GoO |
| DRAWING TITLE | DREDGING LAYOUT-OPTION 1 |
| DRAWING NO | NTCPWC/DCI/PARADEEP/001 |

Prepared by (NTCPWC)




| | |
|---|---|
| CLIENT | DREDGING CORPORATION OF INDIA |
| PROJECT | DPR FOR THE DEVELOPMENT OF INDUSTRIAL LAND BY BY UTILIZATION OF DREDGED MATERIAL AT PRATAPPUR & FATEPUR, PARADIP FOR IDCO, GoO |
| DRAWING TITLE | DREDGING LAYOUT-OPTION 2 |
| DRAWING NO | NTCPWC/DCI/PARADEEP/002 |

Prepared by (NTCPWC)

E 86°32'0" E 86°34'0" E 86°36'0" E 86°38'0" E 86°40'0"

N 20°18'0" N 20°16'0" N 20°14'0" N 20°12'0" N 20°10'0" N 20°8'0" N 20°6'0"

N
W E
S

Scale 1 : 20000

250 500 1000 1500 2000 Meters

PARADIP REFINERY NORTH SIDE

RECLAMATION AREA PRATAP PURA

Return Water Collection Pit

PARADIP REFINERY SOUTH SIDE

SANTA CREEK

Paradip Port Limit Line

Elevated Projection

Pipeline route for the CSD Dredger

Pipeline route for the TSHD Dredger/Return water

Pipeline Length = 8KM

Pipeline Length = 6KM

Shoreline

Booster Station

Temporary Pipeline for TSHD

INNER BASIN

SAND BAR

BASIN

OUTER CHANNEL

SAND TRAP

CREEK

NOTE:

1.Pipeline length was calculated from the shoreline to Reclamation area.

2.Pipeline routes are shown as tentative, which may vary due to site conditions.

3.Booster pump location shown as tentative, it vary depends upon the material, site condition and pipeline distance.

| | |
|---|---|
| CLIENT | DREDGING CORPORATION OF INDIA |
| PROJECT | DPR FOR THE DEVELOPMENT OF INDUSTRIAL LAND BY UTILIZATION OF DREDGED MATERIAL AT PRATAPPUR & FATEPUR, PARADIP FOR IDCO, GoO |
| DRAWING TITLE | PIPELINE ROUTING |
| DRAWING NO | NTCPWC/DCI/PARADEEP/003 |

Prepared by (NTCPWC)

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## 1.0 Preamble

To carry out the Marine EIA study, an extensive survey was made at 21 distinct stations (3 intertidal; 18 estuary and coastal stations) from January 26th to 29th January, 2024. The survey spanned across, strategically positioned at intervals ranging from 4 to 6.5 kilometers (shortest) and 12 to 15 kilometers (longest) from the proposed project site encompassing the Mahanadi River and the coastal waters of Paradeep, Odisha. This comprehensive assessment entails analyses of various parameters such as water quality, sediment attributes, and the biodiversity of biological communities, including plankton, benthos, microbes, and other ecologically sensitive flora and fauna, if any. The latitude and longitude co-ordinates of these sampling stations are detailed in Fig. 1 and also in Table 1.




**Figure:1 Map showing the sampling stations in Estuary and Paradeep coastal waters**

**Table 1 sampling stations and their geographical coordinates**

| Station ID | Sampling Region | Latitude | Longitude |
|---|---|---|---|
| PES-1 | Mahanadi Estuary | 20°17'41.79"N | 86°41'45.45"E |
| PES-2 | | 20°17'34.69"N | 86°42'24.90"E |
| PES-3 | | 20°17'32.83"N | 86°43'13.57"E |
| PES-4 | Paradeep Port | 20°15'44.38"N | 86°41'49.00"E |
| PES-5 | | 20°15'33.97"N | 86°40'58.39"E |

| | | | |
|---|---|---|---|
| PES-6 | | 20°14'57.52"N | 86°41'01.49"E |
| PES-7 | Paradeep Offshore | 20°13'04.78"N | 86°36'14.95"E |
| PES-8 | | 20°12'16.88"N | 86°36'50.82"E |
| PES-9 | | 20°11'22.46"N | 86°37'19.78"E |
| PES-10 | | 20°10'29.83"N | 86°36'14.92"E |
| PES-11 | | 20°11'33.49"N | 86°35'31.31"E |
| PES-12 | | 20°12'18.06"N | 86°34'55.44"E |
| PES-13 | | 20°11'26.43"N | 86°33'47.89"E |
| PES-14 | | 20°10'34.64"N | 86°34'25.30"E |
| PES-15 | | 20°09'36.85"N | 86°35'13.72"E |
| PES-16 | | 20°09'05.40"N | 86°33'59.52"E |
| PES-17 | | 20°09'52.76"N | 86°33'20.67"E |
| PES-18 | | 20°10'33.75"N | 86°32'46.27"E |
| PES-19 | Intertidal Region | 20°12'09.41"N | 86°33'12.50"E |
| PES-20 | | 20°12'44.22"N | 86°34'22.94"E |
| PES-21 | | 20°08'53.12"N | 86°34'23.71"E |

(Footnote: PES-Paradeep Mahanadi Estuary Station; PPS–Paradeep Port Station; PMS–Paradeep Coastal Station; PIS-Paradeep Intertidal Station)

## RESEARCH TEAM





## 2.0 MATERIALS AND METHODS

### 2.1 Water samples

The water samples were collected from the selected stations considering tidal influences, discharge and non-discharge points. Subsurface water samples were collected at a depth 0.5 meter using Niskin water sampler. For accurate measurements of the in situ properties and composition of seawater proper sampling is of utmost importance. It is essential to ensure that the sampling is contamination free and all the samples are appropriately sub-sampled and preserved to avoid/minimize changes in the water composition during storage. After sampling, adequate care was taken for measurements of hydrographic, chemical and biological properties of sea water in coastal and near-shore waters. Adequate samples were collected for duplicate and repeat analysis.

Prior to sampling, the sampler and sampling bottles were acid washed with 1N HCl in the laboratory. Sample bottles were rinsed thoroughly with the water sample and after that samples were collected. Water samples were collected using Teflon coated Niskin samplers (avoid any form of metal contact with samples). The prioritized individual sub sampling order was planned

for the following parameters as given below: (i) for dissolved gases and pH, (ii) for nutrients and

physical parameters, (iii) trace metals, (iv) Chlorophyll and (v) bacteria.

For dissolved oxygen, the samples were fixed by employing Winkler's reagent on board vessel itself and after fixing the samples were kept in shade until analysis. Temperature and pH were measured immediately after collection. Water samples were stored in an ice box for transportation. Samples for trace metal analysis were collected in acid-washed and pre-cleaned high density polyethylene (HDPE) bottles. Disposable, clean gloves were used while sampling and handling samples for trace metals. All samples were kept in a cool condition away from light to avoid evaporation. All samples (for trace metals) were filtered immediately using 0.22 µM pore size filter paper and acidify the pH till 2 by adding SUPRAPURE NITRIC ACID and stored in metal free plastic bags till analysis, so as to avoid contamination.

## 2.2 Sediment samples

Sediment samples were stored in metal free plastic bags for trace metals analysis and in aluminium foils for analysis of organic matter. These samples were kept in a cool condition and brought in ice boxes. Further, it was dried in an electric oven at low temperatures (about 60 degrees C) in clean glass petri-dishes for the above analysis.

### 2.2.1 Collection of Sediment Samples (Grabs and Corer)

Van Veen grab with a sampling area of 0.1 m2 was employed as a standard sediment sampler, since it is (i) an efficient sampler for the range of soft surface sediments encountered in the near shore area, (ii) reliable and simple to operate and (iii) widely applied, which allows data comparison with other marine areas. Grab is equipped with hinged inspection ports. The biting depth of grabs can vary with sediment conditions. Weights coated with Teflon were added to adjust according to the sediment conditions.

## 2.3 Preservation and processing of samples

Storage and Preservation of Samples: It is understood that the concentration of dissolved constituent is bound to change with time, due to the biological activity of the microorganisms present in the seawater. Trace quantity are vulnerable to adsorption/desorption process, therefore, they were analysed immediately. Where immediate analysis is not possible, the recommended method include freezing the samples is in -80°C. A quick note for sample collection and preservation procedures is given below:

***Temperature, Salinity and pH analysis***

The physical parameters such as temperature, salinity and pH were measured in-situ in the field. The subsurface temperature was measured with a mercury thermometer (± 0.02°C accuracy) and the pH was measured by a calibrated pH pen (pH ep-3 model). Salinity was estimated using a Hand Refractometer (Atago, Japan). Water samples collected for dissolved oxygen estimation were transferred carefully to BOD bottles. The DO was immediately fixed and brought to the laboratory for further analysis.

***Preservation and Laboratory Analysis***

After collection, the water samples were immediately cooled to 4°C and then brought to the laboratory in an insulated icebox. In the laboratory, water samples were filtered through Whatman GF/C filter paper and analysed for organic matter and other nutrients. Unfiltered samples were used for the estimation of total nitrogen and total phosphorus. All the analyses were carried out by adopting standard procedures. Briefly, the methodology for each analysis is given below:

***Nitrate and Nitrite***

The nitrate and nitrite content of samples were analysed by following the methods described by Strickland and Parsons (1972). The nitrite was estimated from highly coloured azo dye formed by the addition of N (1-Napthyl) ethylene diamine di hydro-chloride and sulphanilamide into the solution was then measured at 543 nm in a spectrophotometer. The same procedure was followed for the estimation of nitrate. For this, nitrate was reduced to nitrite by passing the sample through copper coated cadmium column. The values are expressed in µmol of Nitrogen/l

***Inorganic Phosphate***

The single solution mixed reagent procedure developed by Murphy and Riley (1962) was followed for the estimation of dissolved inorganic phosphate levels in water sample. This involves the conversion of phosphate into phosphomolybdic acid, which was then reduced to molybdenum blue colour complexes and then the intensity of colour was measured at 882 nm in a spectrophotometer. The calculated values are expressed in µmol of Phosphorus/l.

***Total Phosphorus***

The Total Phosphate in samples was estimated by adopting the method described by Menzel and Corwin (1964). This procedure involves the conversion of organically bound phosphate into inorganic phosphate by wet oxidation of samples with potassium persulphate in an autoclave for 30 min at 15 lbs pressure. The converted inorganic phosphate was then estimated

by using the method described by Murphy and Riley (1962). The subtraction of original dissolved inorganic phosphate from total phosphate yielded the organic phosphate in the water sample. The calculated value is expressed in µmol of Phosphorus/l.

***Reactive Silicate***

The reactive silicate content of water was estimated by following the method of Strickland and Parsons (1972). In this method, the intensity of blue colour formed by silicomolybdate complex was measured in a spectrophotometer at 810 nm and the calculated values are expressed in µmol of Silica/l

***Total Petroleum Hydrocarbon***

The total petroleum hydrocarbon analysis of water and sediment sample was done by the methods suggested by Laboratory Analytical Work Instruction, 2011.

### 2.4 Sediment Analysis

For the analysis of textural composition and pH, the air-dried sediment samples were used as such. For all other analyses of organic matter, sediment samples were ground to fine powder and dried in an oven at 110°C to constant weight for an hour.

***Total Organic Carbon***

The estimation of total organic carbon in sediment was performed by adopting the method of El Wakeel and Riley (1956). The procedure involves chromic acid digestion and subsequent titration against ferrous ammonium sulphate solution in the presence of 1-10 Ferrous phenonthroline indicator. The values calculated are expressed in mg C/g of sediment.

***Heavy Metal Analysis in Water and Sediment Samples***

Seawater samples were collected in pre-cleaned polypropylene bottles with 10% nitric acid and Milli-Q water and acidified till pH ~1.6 using HNO3 for further metal detection by using ICP-MS (Søndergaard et al., 2015). Sediment samples were collected with the aid of cleaned and dried Teflon/stainless steel coated Peterson grab. Sediment samples were transferred from the grab to cleaned polyethylene containers using cleaned plastics scoops. The samples were stored in frozen condition for further analysis. The preserved sediment subsamples were dried at 110°C to constant weight for estimation of metals. Dry powdered sediment was gently heated and digested with Hydrofluoric acid whereby Silica volatizes as Silicon tetra-fluoride. This is followed by treatment with Nitric acid and Per-chloric acid to destroy the organic matter. The residue after evaporation of acids was dissolved in 0.1 N HCl and desired metals were determined by Atomic Absorption Spectrophotometry (AAS).

***Sediment texture***

The percentage composition of sand, silt and clay was worked out by the pipette method as proposed by Krumbein and Pettijohn (1938) and the values are plotted in soil trigon.

***Statistical analysis - Principal Component Analysis (PCA)***

PCA is a powerful tool that attempts to explain the variance of a large dataset of intercorrelated variables with a smaller set of independent variables (Simeonov et al., 2003). PCA technique extracts the eigenvalues and eigenvectors from the covariance matrix of original variables. PCA is designed to transform the original variables into new, uncorrelated variables (axes), called the principal components, which are linear combinations of the original variables (Shrestha and Kazama, 2007). It reduces the dimensionality of the data set by explaining the correlation amongst a large number of variables in terms of a smaller number of underlying factors, without losing much information (Vega et al., 1998; Alberto et al., 2001). This routine was adopted using the statistical programme PRIMER (Ver. 7.0) with a view to ascertain the relationship among the environmental entities studied in various stations of Mundra coastal waters (Clarke and Warwick, 2001).

## 2.5 Bacteriological Methods

### 2.5.1 Collection of samples

Surface water samples were collected in 30ml sterile screw capped bottles for bacteriological assessment. Enough air space was left in the bottles to allow thorough mixing. Precautionary measures were taken to avoid contamination through handling. For microbial assessment in sediment samples, a known quantity of samples was collected from the grab samples using sterilised spatula. The central portion of the collected sediment was aseptically transferred into sterile polyethylene bags. All the samples were brought to the laboratory in portable icebox soon after collection and bacteriological analyses were carried out in the laboratory immediately, with necessary dilution.

### 2.5.2 Enumeration of Total Viable Counts

TVC was enumerated by adopting the spread plate method using Zobell's Marine Agar medium (EA123, Hi-Media, Mumbai). The samples (water and sediment) were diluted using the sterile sea water and 0.1 ml of the diluted sample was pippeted into the petriplates containing Zobell's Marine Agar and it was spread using a 'L' shaped glass spreader. The plates after inoculation were incubated in an inverted position at a temperature of 28+2°C for 24to 48 h. The colonies were counted and the population density expressed as Colony Forming Unit (CFU) per ml or g of the sample. The bacterial colonies were picked up from the pertidishes and re-streaked in appropriate nutrient agar plates thrice before a pure culture was established in agar slants.

### 2.5.3 Enumeration of Total Coliforms

Macconkey agar with 0.15% bile salt, crystal violet and NaCl has been recommended in accordance with USP/Nfxi (1) for the detection, isolation and enumeration of coliforms and intestinal pathogens in water, dairy products, pharmaceutical preparations, etc. The agar weighing 51.5 g in 1000 ml distilled water was heated up to the boiling point to dissolve the medium completely and sterilized by autoclaving at 15 lbs pressure (121°C) for 15 min. suitably diluted samples were inoculated in the petriplates containing medium and were incubated for 48 h. After incubation, the colonies of E. coli appeared with pink colour. M-FC agar is employed for detection and enumeration Faecal Coliforms by the membrane filter technique at higher temperature (44.5°C). The agar weighing 52 g was suspended in 1000 ml of distilled water and heated up to the boiling point to dissolve the medium completely, 10ml of Rosolic acid (dissolved in 0.2 N NaOH) was added, heated with frequent agitation and boiled for 1 min. Then the medium was cooled to 50°C. Finally, the medium was poured into small 60mm plates. Samples filtered by Millipore apparatus using 0.45µm Whatman filter papers were impregnated in the petriplates. After 48 h of incubation, the colonies of E. coli appeared with blue colour.

### 2.6 Chlorophyll `a':

The samples were filtered through Whatman GF/C filter papers and the chlorophyll was extracted into 90% acetone. The resulting collared acetone extract was measured in a Spectrophotometer at different wavelengths and the same acetone extracts were acidified and measured for the phaeo-pigments. The detailed methodology as described in APHA manual (1989) was followed.

### 2.7 Phytoplankton

Phytoplankton samples were collected from the surface waters of the study area by towing a plankton net (mouth diameter 0.5 m) made of bolting silk (mesh size 20 micron) for half an hour. These samples were preserved in 5% neutralized formalin and used for qualitative analysis. For the quantitative analysis of phytoplankton, the settling method as described by Sukhanovo (1978) was adopted. Numerical plankton analysis was carried out using Utermohl's inverted plankton microscope.

Phytoplankton species was identified using the standard works of Hustedt (1930-1966), Venkataraman (1939), Cupp (1943), Subramanian (1946), Prescott (1954), Desikachary (1959 and 1987), Hendey (1964), Steidinger and Williams (1970) and Taylor (1976) and Anand et al. (1986).

### 2.8 Zooplankton

Zooplankton samples were collected from the surface waters of the study areas by horizontal towing of plankton net with mouth diameter of 0.35 m, made of bolting silk (No. 70 mesh size 200 μm) for half an hour. After collection, the samples were preserved in 5 - 7% neutralized formalin and used for quantitative analysis. The zooplankton collected were identified to the species level using the classical works of Dakin and Colefax (1940), Davis (1955), Kasthurirangan (1963) and Wickstead (1965) and Damodara Naidu (1981). For the quantitative analysis of zooplankton, a known quantity of water (100l) was filtered through a bag net (0.33 mm mesh size) and filtrate was made up to 1 litre in a wide mouthed bottle and then enumerated using Utermohl's inverted plankton microscope. The plankton density is expressed as number of organisms/m3.

### 2.9 Benthic Community

***Macrofauna***

Three replicate samples were collected by using van-Veen grab, which was found to take a sample covering an area of 0.1m2 and this grab is designed to take large samples from the soft bottom. The benthic sample collection was done following the standard method of Mackie (1994). After collection, the sediment samples were emptied in to a plastic tray and the larger organisms were immediately taken, remaining samples were gently sieved through 0.5mm mesh. The organisms retained by the sieve were preserved with 5-7% of formalin and stained with 0.1% Rose Bengal stain for greater visibility during sorting and species identification. After a day, the sorted macro benthic organisms were counted and identified to species level under a stereomicroscope (EISCO Stereo Binocular Microscope) by consulting the standard works of Fauvel (1953), Day (1967) for polychaetes; Lyla et al. (1999) for amphipods; Rajagopal et al. (1998) for gastropods; Shanmugam et al. (1997) & Fernando and Fernando (2002) for bivalves; Barnes (1980) and Lyla et al. (1999) for crustaceans and Subba Rao et al. (1991) and Ramakrishna (2003) for molluscs.

***Meiofauna***

Sediment subsamples (~100 g) for meiofaunal analysis were collected from each haul and placed in labeled plastic bags, immediately fixed in 4% buffered formalin in distilled water, and brought to the laboratory. The sediments were washed with tap water through a set of 0.5 mm and 0.063 mm sieves. The sediment retained on the 0.063 mm sieve was decanted to extract meiofauna following the methodology of Higgins & Thiel (1988). Sorting of metazoan meiofauna (nematodes, harpacticoids, and ostracodes) from sediment was done by flotation and

decantation using a sieve with 0.040 mm mesh size; the efficiency of this technique has been reported as 95% by various researchers (Somerfield & Warwick, 1994; Danovaro et al., 2004; Giere, 2009). The organisms retained on the sieve were placed into Petri dishes for sorting and preserved in 70% ethyl alcohol with 5% glycerol (Tolhurst et al., 2010). A few drops of Rose Bengal (1 g/l) were also added to this solution to facilitate the counting process. For the separation of foraminifera, sediment subsamples were fixed with 5% buffered formalin and stained with Rose Bengal. In the laboratory, sediment samples were washed with tap water through a 0.063 mm sieve and then dried (Walton, 1952). Subsequently, the sorted meiobenthic organisms were counted and identified to species level under a stereomicroscope (EISCO Stereo Binocular Microscope) by consulting the standard works of Loeblich & Tappan (2015), Mohan et al. (2013) and Muruganantham et al. (2017) for foraminifera; Chitwood (1958), Lambshead (2004), De Ley et al. (2005), Poinar (2008), Vovlas et al. (2011), and Ahmed et al. (2015) for nematodes; Brouwers et al. (2000), Tanaka (2008), and Yasuhara et al. (2014) for ostracods; and Huys & Boxshall (1991), Wells (2007), and Yeom & Lee (2020) for harpacticoids. The numerical abundance of the meiofauna was expressed in individuals per 10 cm2 (Fernando et al., 1983).

## 2.10 Statistical Analysis

### 2.10.1 Cluster Analysis

As done for environmental parameters, the classification method, Cluster analysis was done to find out the similarities between the samples/ stations/regions. The most commonly used clustering technique is the hierarchical agglomerative method. The results of this are represented by a tree diagram or dendrogram with the x- axis representing the full set of samples and the yaxis defining the similarity level at which the samples or groups are fused. Bray – Curtis coefficient (Bray and Curtis 1957) was used to produce the dendrogram.

### 2.10.2 MDS (non - metric Multi-Dimensional Scaling)

This method was proposed by Shepard (1962) and Kruskal (1964). To confirm the clustering pattern, this was used to find out the similarities (or dissimilarities) between each pair of entities to produce a ‘map’, which would ideally show the interrelationships of all.

### 2.10.3 BIO-ENV procedure

In the present study, to ascertain the relationship between biological and environmental variables, the BIO-ENV procedure (Clarke and Ainsworth, 1993) was employed. The basic principle behind this is to measure the agreement between the rank correlations of the biological (Bray-Curtis similarity) and environmental (Euclidean distance) matrices. A weighted

Spearman rank correlation coefficient was used to determine the harmonic rank correlation between the biological matrix and all possible combinations of the environmental variables.

## VIEWS OF SAMPLING AREA



Paradeep fishing harbor and fish landing center



Proposed M/s. JSW Utkal Steel Limited



Mangrove Zone

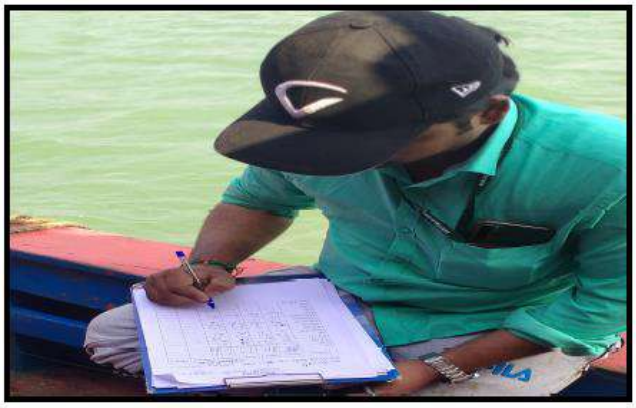


Mahanadi River mouth




Proposed Site Development for IDCO Industrial Estate at Paradeep

## RESEARCH PERSONNEL IN ACTION



Locating sampling points by using GPS



In-situ Temperature measurement by using Thermometer



Water pH measurement by using pH pen



Salinity measurement by using Refractometer



Sub-surface water sample collection by using Niskin water sampler



Sediment sample collected by using Van Veen Grab



Plankton sample collection by using Bongo net



Vertical transparency measurement by using Secchi disc



DO estimation by following Winkler's method



Sieve retains-benthic samples



Water analysis using (UV – 1900 UV – VS Spectrophotometry)



Light microscope used for identification (KL-300LED Carl Zeiss microscope)

## 3.0 OBSERVATION REPORT

### 3.1 Water Quality

#### 3.1.1 Depth

The depth in the study area varied between 3.5 and 19.5m, with maximum w a s at PMS-15 and minimum at PES-1 (Fig. 2).

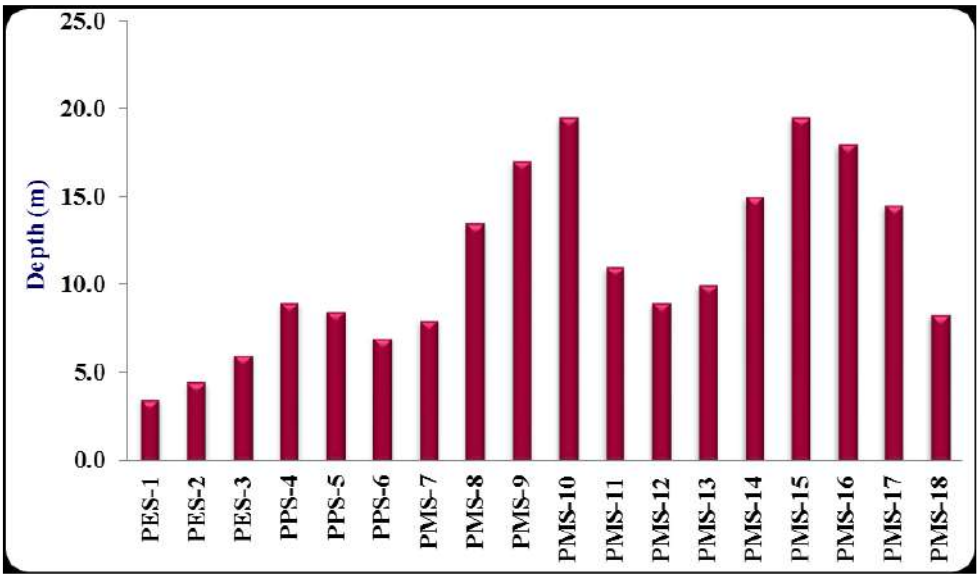



**Figure:2 Depth values recorded at various stations of Estuary and Paradeep coastal waters**

#### 3.1.2 Water Temperature

The water temperature fluctuated from 27.5 to 32.0°C. The minimum value was recorded at PES-2 and maximum was recorded at PMS-12 (Fig. 3).

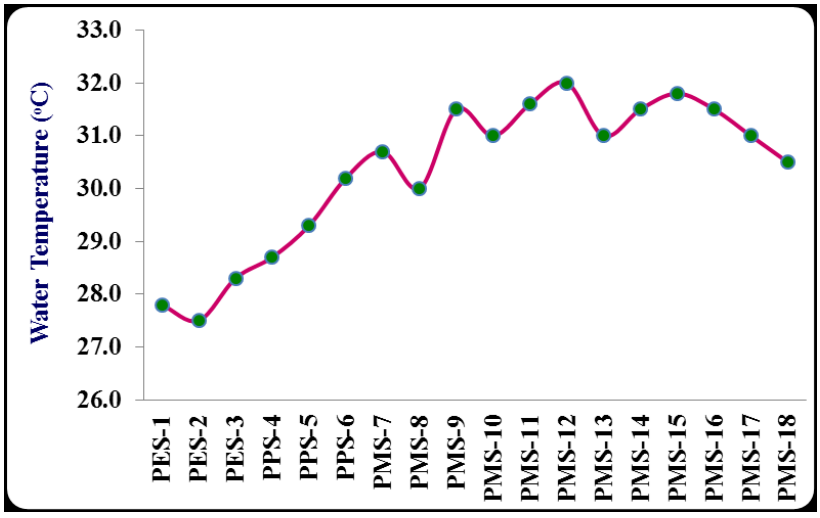



**Figure:3 Water temperature values recorded at various stations of Estuary and Paradeep coastal waters**

### 3.1.3 Salinity

The water salinity varied from 27.0 to 35.3ppt. The salinity was found to be lower at PES- 1 and higher value at PMS-15 (Fig. 4).

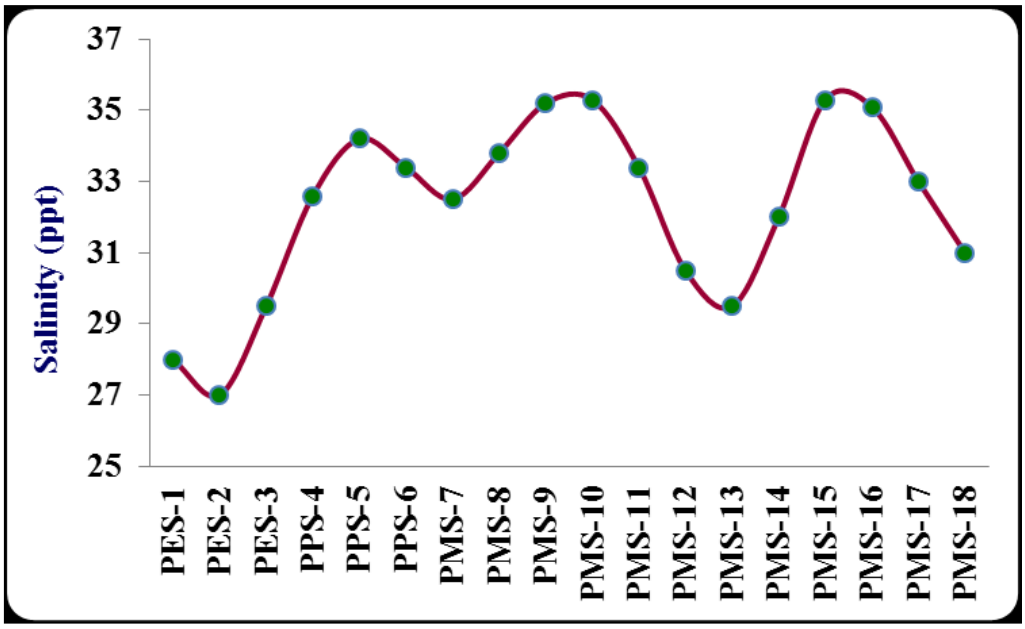



**Figure:4 Salinity level recorded at various stations in Estuary and Paradeep coastal waters**

### 3.1.4 Water pH

The water pH varied between 7.81 and 8.41 with minimum value was recorded at PES-1 and maximum value was recorded at PMS-10 (Fig. 5).

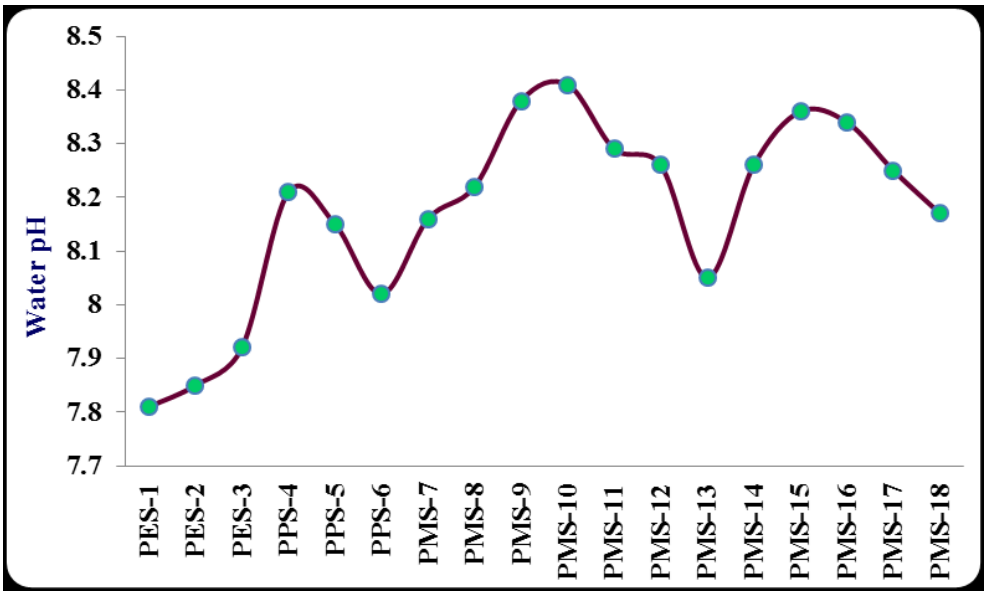



**Figure:5 Water pH level recorded at various stations of Estuary and Paradeep coastal waters**

### 3.1.5 Dissolved Oxygen

The Dissolved Oxygen level in the water varied between 3.41 and 5.69 mg/l. The lower value was recorded at PPS-5 and the higher value at PMS-13 (Fig. 6).

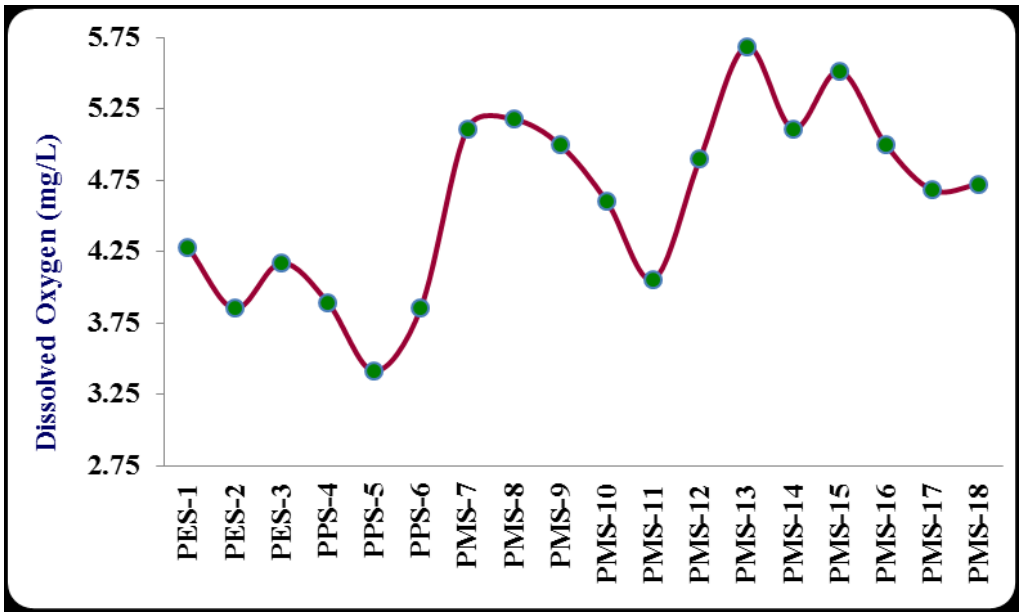



**Figure:6 Dissolved oxygen level recorded at various stations of Estuary and Paradeep coastal waters**

### 3.1.6 Biological Oxygen Demand

The BOD values varied between 1.36 and 2.51mg/l with minimum at PMS-10 and the maximum value was recorded at PPS-5 (Fig. 7).

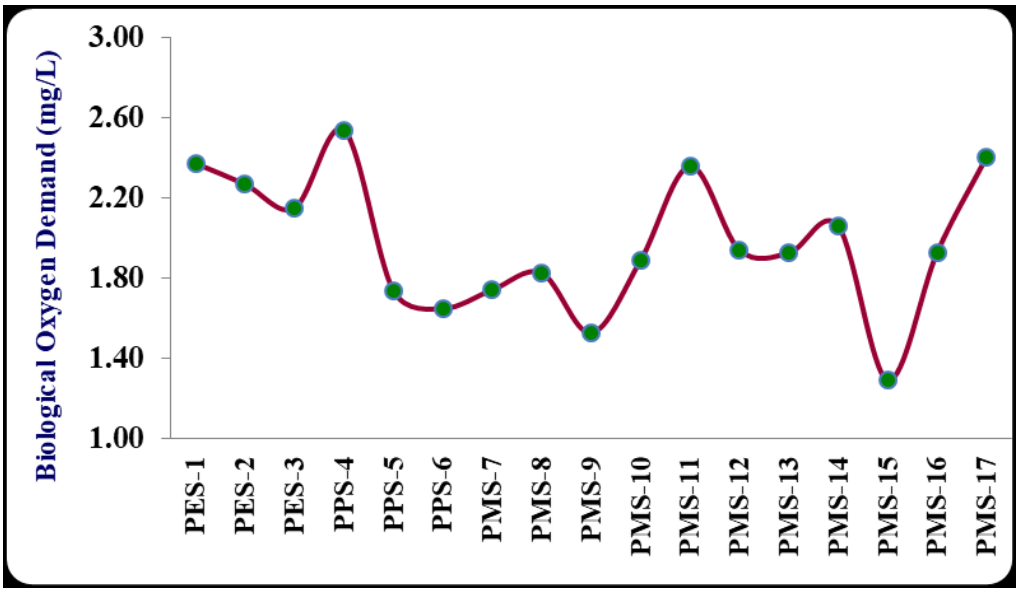



**Figure:7 Biological oxygen demand values recorded at various stations of Estuary and Paradeep coastal waters**

### 3.1.7 Total Suspended Solids (TSS)

The Total Suspended solids values ranged between 60.60 and 122.32ppm. The minimum value was recorded at PMS-11 and the maximum was recorded at PMS-5 (Fig. 8).

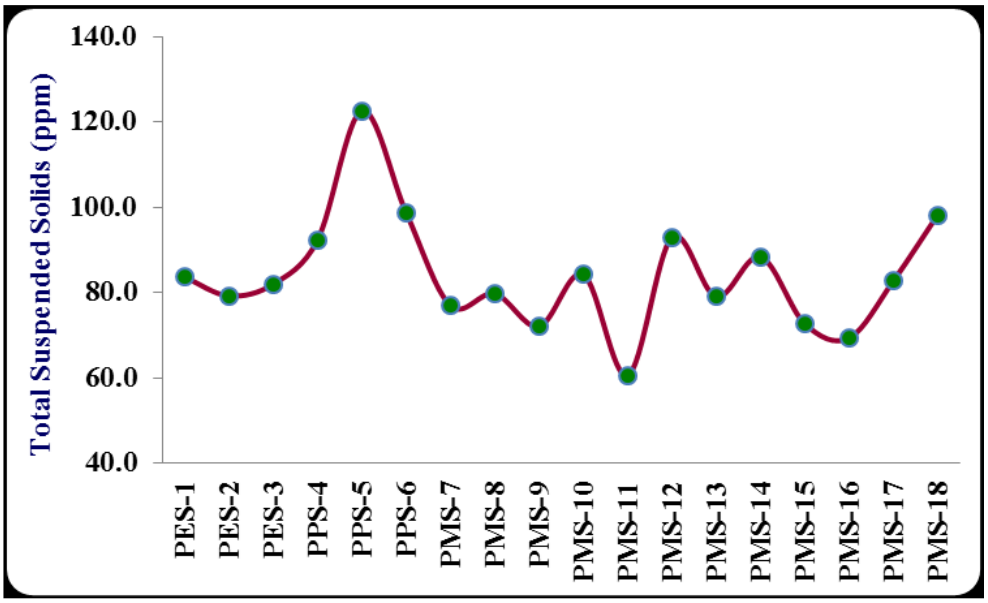



**Figure:8 Total suspended solids values recorded at various stations of Estuary and Paradeep coastal waters.**

### 3.1.8 Turbidity

The turbidity values were between 4.1 and 6.6NTU. The minimum level was recorded at PMS-10 and the maximum level at PPS-5 (Fig. 9).

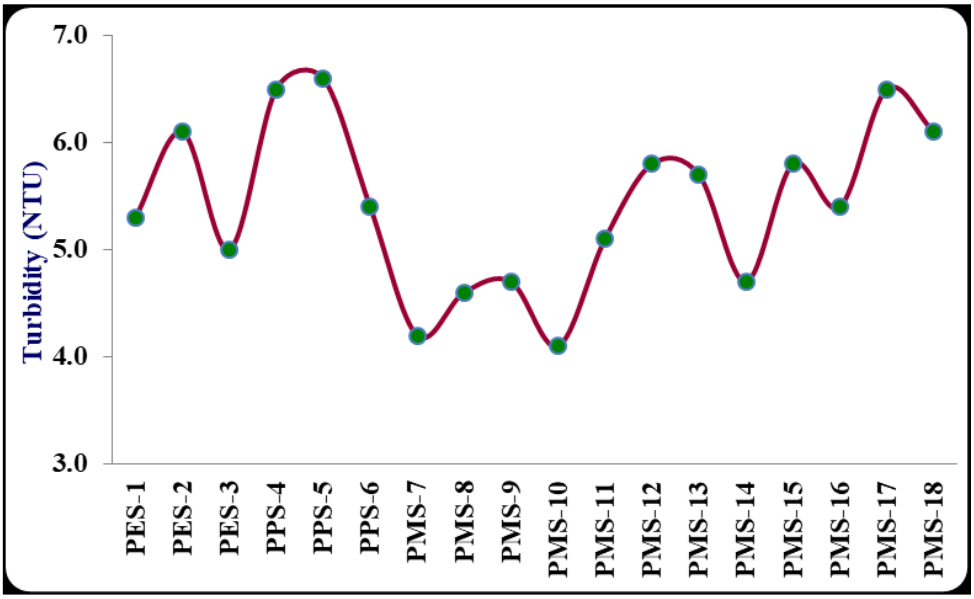



**Figure:9 Turbidity values recorded at various stations of Estuary and Paradeep coastal waters**

### 3.2 Water Nutrients

The life supporting processes in the sea requires an array of inorganic substances, of which, the role of nitrogen, phosphorus and silicon are considered to be very vital in marine ecosystem. Among the nitrogenous compounds, nitrite, nitrate and ammonia are the major constituents, which play a key role in the growth and proliferation of phytoplankton. Accordingly, the results of various parameters recorded in various stations of the study area are given below:

#### 3.2.1 Nitrite

The nitrite level varied from 0.94 to 2.17µmol/l with maximum at PES-1 and minimum at PMS-11 (Fig. 10).

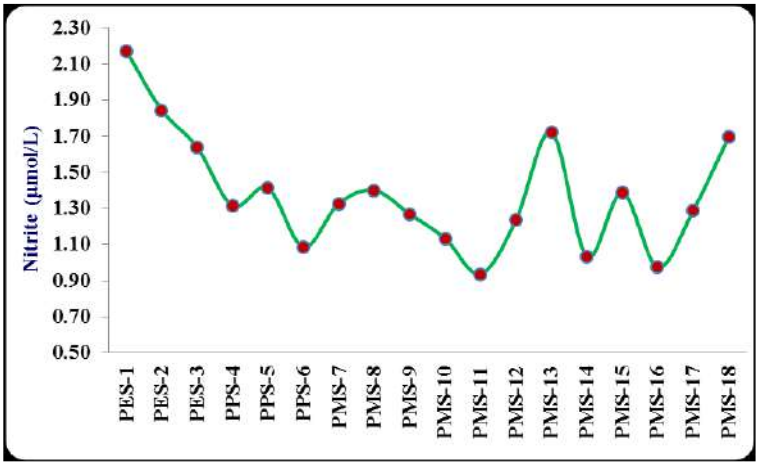



**Figure:10 Nitrite level recorded at various stations of Estuary and Paradeep coastal waters Nitrate**

Nitrate concentration ranged between 2.65 and 4.18µmol/l with minimum at PMS-10 band maximum at PES-1 (Fig. 11).

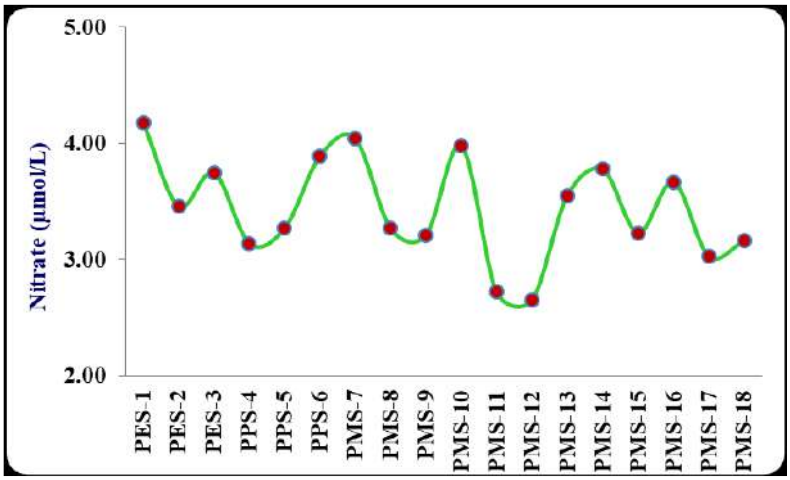



**Figure:11 Nitrate concentration recorded at various stations of Estuary and Paradeep coastal waters**

### 3.2.2 Total Nitrogen

The Total nitrogen values ranged from 13.52 to 19.42µmol/l. The minimum value was recorded at PMS-9 and the maximum value at PPS-5 (Fig. 12).

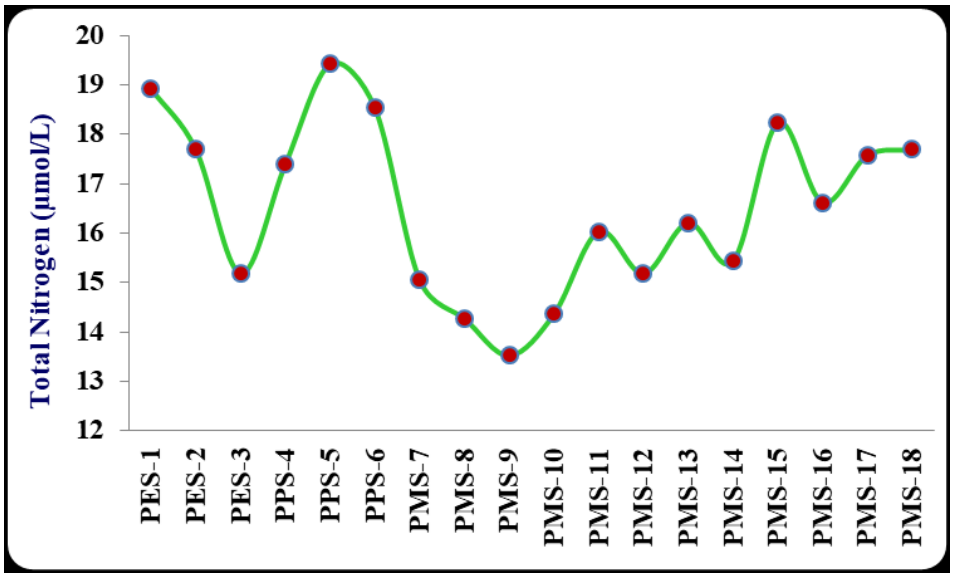



**Figure:12 Total nitrogen values recorded at various stations of Estuary and Paradeep coastal waters**

### 3.2.3 Ammonical Nitrogen

The ammonia concentration varied from 0.08 to 0.23µmol/l. The maximum concentration (0.23µmol/l) was recorded at PES-2 and minimum (0.08µmol/l) at PMS-15 (Fig. 13).

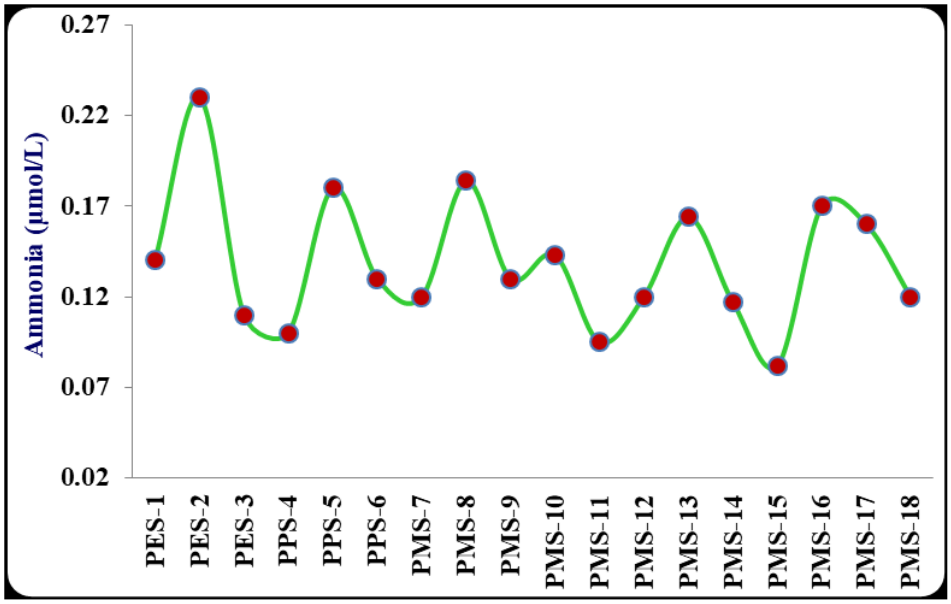



**Figure:13 Ammonical nitrogen concentration recorded at various stations of Estuary and Paradeep coastal waters**

### 3.2.4 Inorganic Phosphate

The inorganic phosphate values ranged between 0.48 and 0.99µmol/l with maximum value at PES-2 and minimum at PMS-14 (Fig. 14).

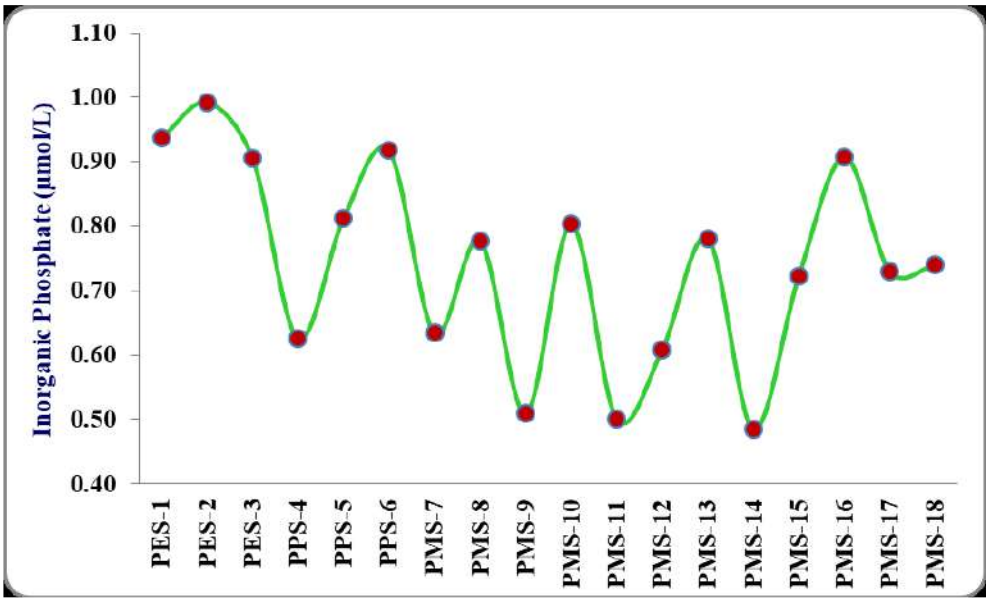



**Figure:14 Ammonical Inorganic phosphate concentration recorded at various stations of Estuary and Paradeep coastal waters**

### 3.2.5 Total Phosphorus

The Total phosphorous values ranged from 1.01 to 2.83µmol/l with minimum value were at PPS-5 and the maximum value at PMS-13 (Fig. 15).

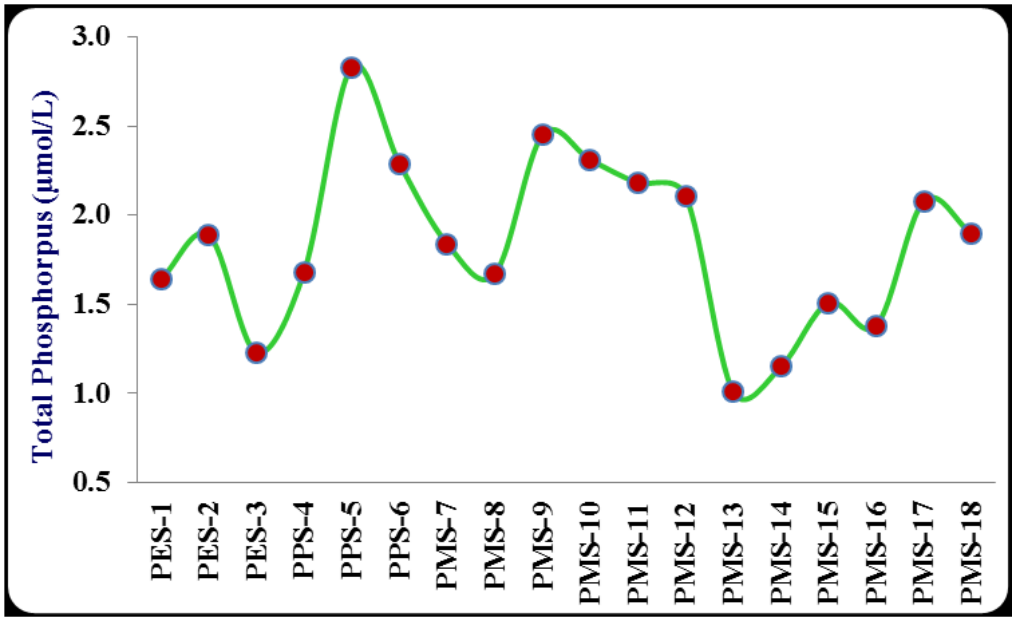



**Figure:15 Total phosphorous values recorded at various stations of Estuary and Paradeep coastal waters**

### 3.2.6 Reactive Silicate

The silicate values ranged between 25.34 and 58.25µmol/l with minimum was recoded PES-2 and the maximum values were recorded at PMS-16 (Fig. 16).

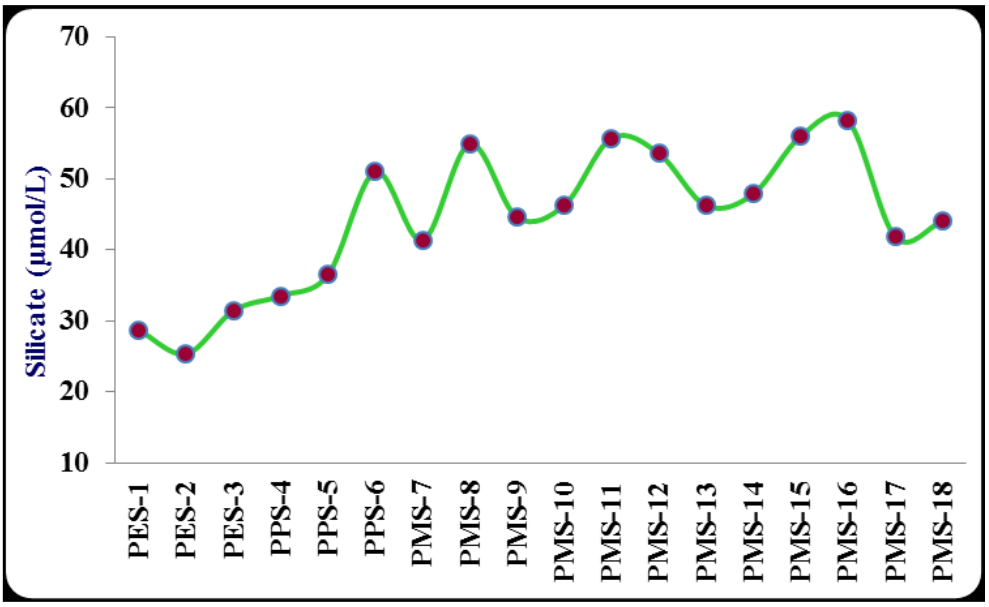



**Figure:16 Reactive silicate level recorded at various stations of Estuary and Paradeep coastal waters**

### 3.2.7 Particulate organic Carbon

The particulate organic carbon level ranged between 77.30 and 139.20µgC/l with minimum (77.30µgC/l) was at PMS-15 and maximum (139.20µgC/l) at PPS-5 (Fig. 17).

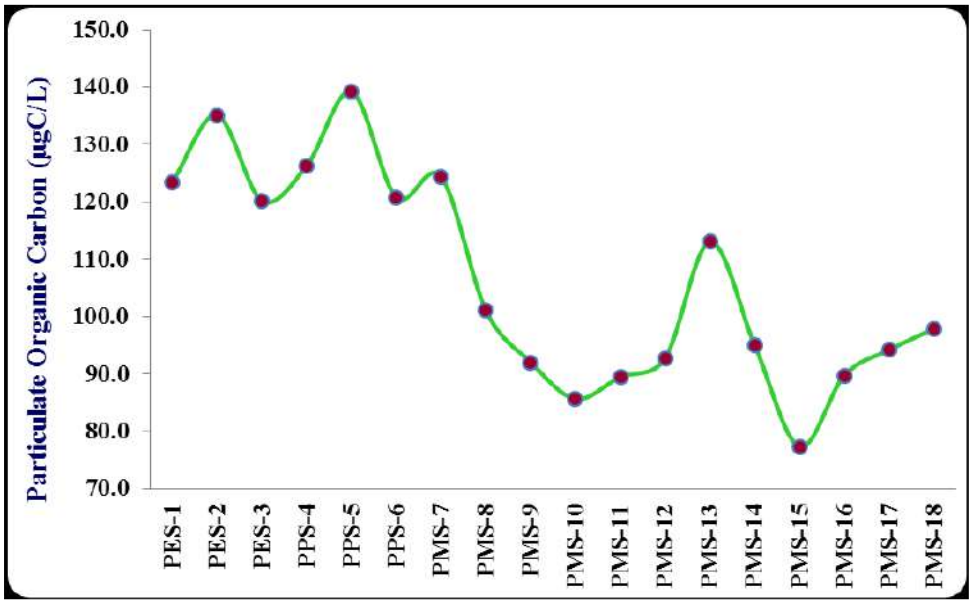



**Figure:17 Particulate organic carbon level recorded at various stations of Estuary and Paradeep coastal waters**

### 3.2.8 Petroleum hydrocarbons

PHC level in water fluctuated from 0.104 and 0.372µg/l. The maximum value was recorded at PPS-5 and the minimum was recorded at PMS-10 (Fig. 18).

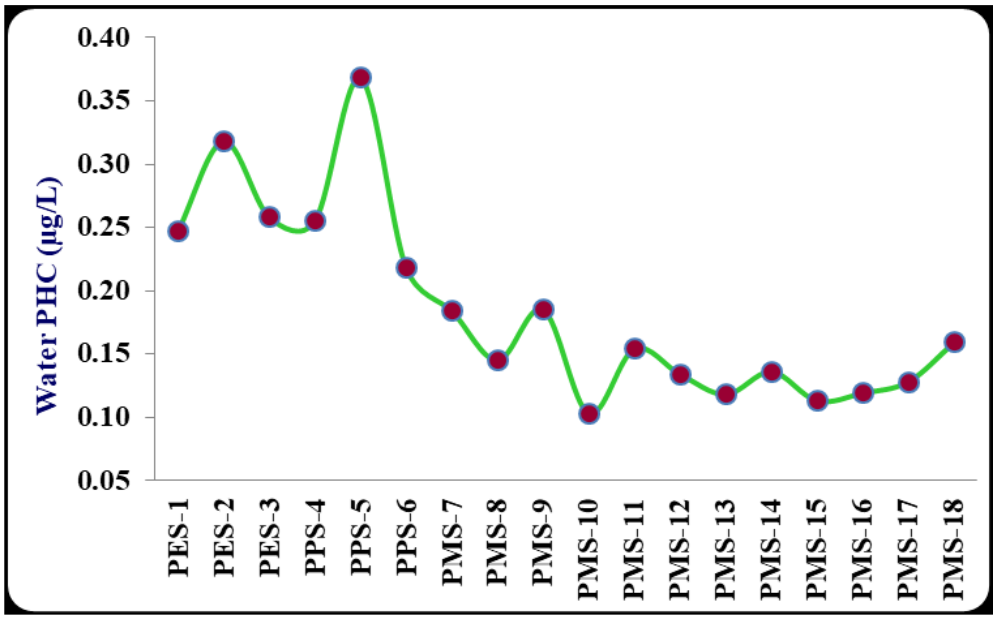



**Figure:18 Petroleum hydrocarbon concentration recorded at various stations of Estuary and Paradeep coastal waters**

### 3.3 Heavy Metals in water

### 3.3.1 Iron

The iron level varied from 11.03 to 19.31µg/L (Fig. 19). The maximum was recorded at PPS-4 and the minimum was recorded at PMS-15.

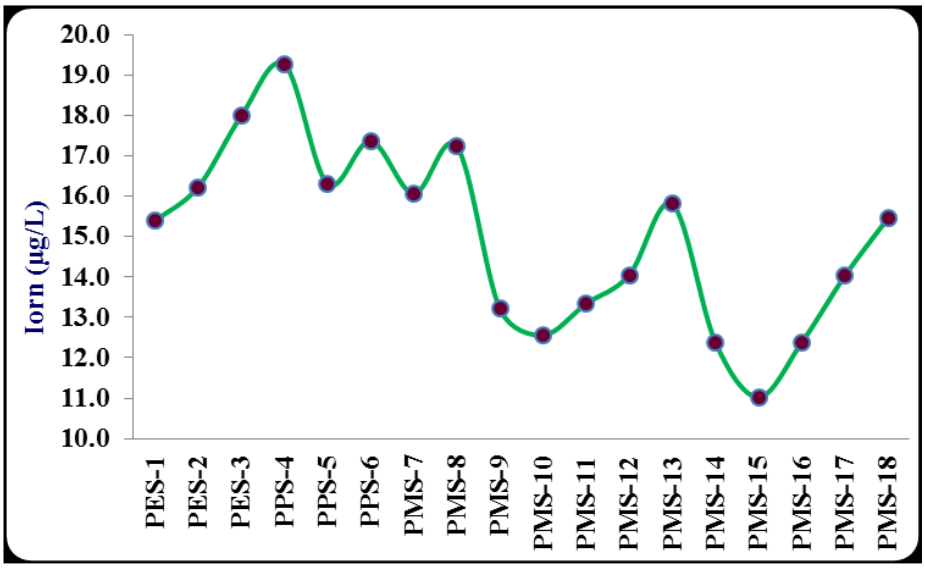



**Figure:19 Iron level recorded at various stations of estuary and Paradeep coastal waters**

### 3.3.2 Zinc

The zinc level varied from 12.97 to 25.74µg/L (Fig. 20). The maximum was recorded at PES-1 and the minimum were recorded at PMS-15.

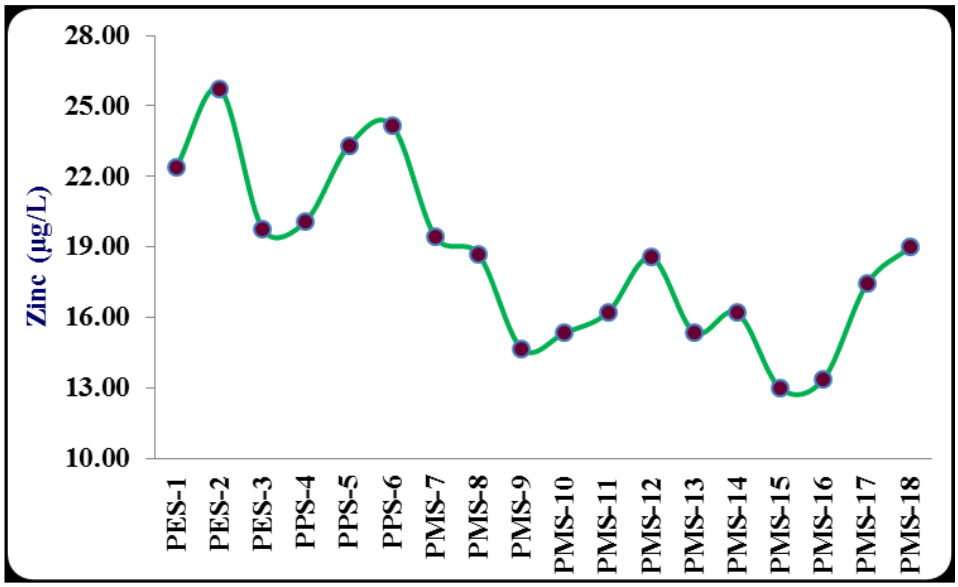



**Figure:20 Zinc level recorded at various stations of Estuary and Paradeep coastal waters**

### 3.3.3 Manganese

The Manganese concentration varied from 15.43 to 44.30µg/L (Fig. 21). The maximum was recorded PES-2 and the minimum was recorded at PMS-15.

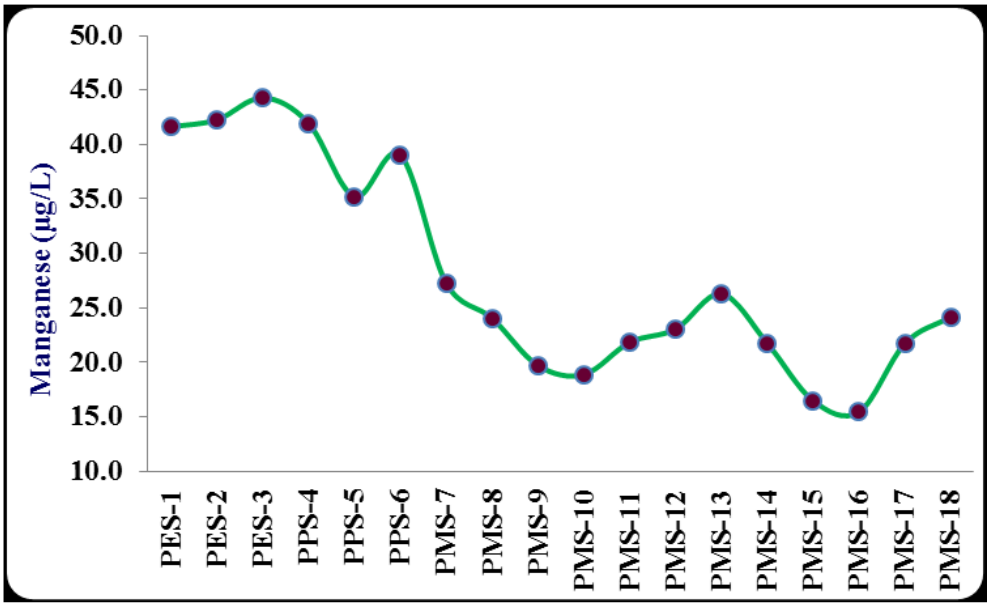



**Figure:21 Manganese concentration recorded at various stations of Estuary and Paradeep coastal waters**

### 3.3.4 Cadmium

The Cadmium concentration varied from 1.33 to 2.86µg/L (Fig. 22). The maximum was recorded at PPS-5 and the minimum was recorded at PMS-11.

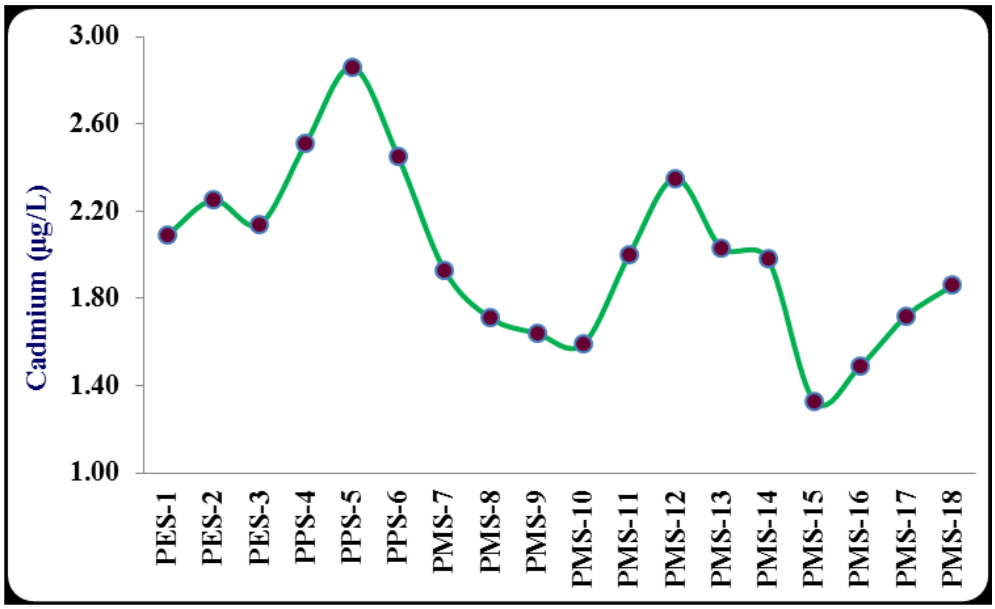



**Figure:22 Cadmium concentration recorded at various stations of Estuary and Paradeep coastal waters**

### 3.3.5 Nickel

The Nickel level varied from 1.47 to 2 . 3 4 µg/L (Fig. 23). The maximum level was recorded at PES-2 and the minimum was recorded at PMS-10.




**Figure:23 Nickel level recorded at various stations of Estuary and Paradeep coastal waters**

### 3.3.6 Chromium

The chromium level varied from 1.04 to 1.85µg/L (Fig. 24). The maximum value was recorded at PPS-5 and the minimum was recorded at PMS-10.

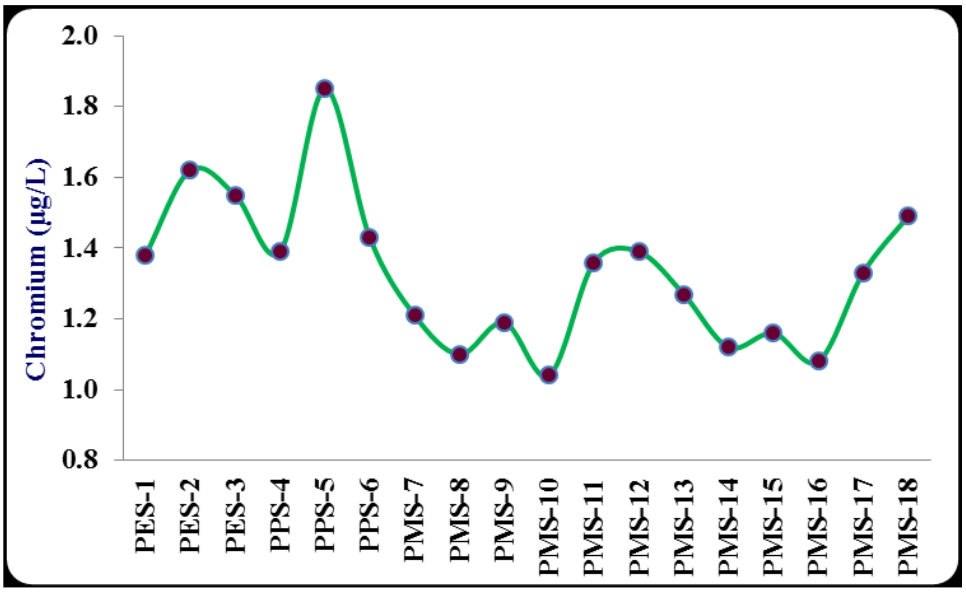



**Figure:24 Chromium level recorded at various stations at Estuary and Paradeep coastal Waters**

### 3.3.7 Lead

The Lead concentration ranged from 1.10 to 3.51µg/L (Fig. 25) with maximum value was recorded at PPS-5 and the minimum was recorded at PMS-15 during this survey.

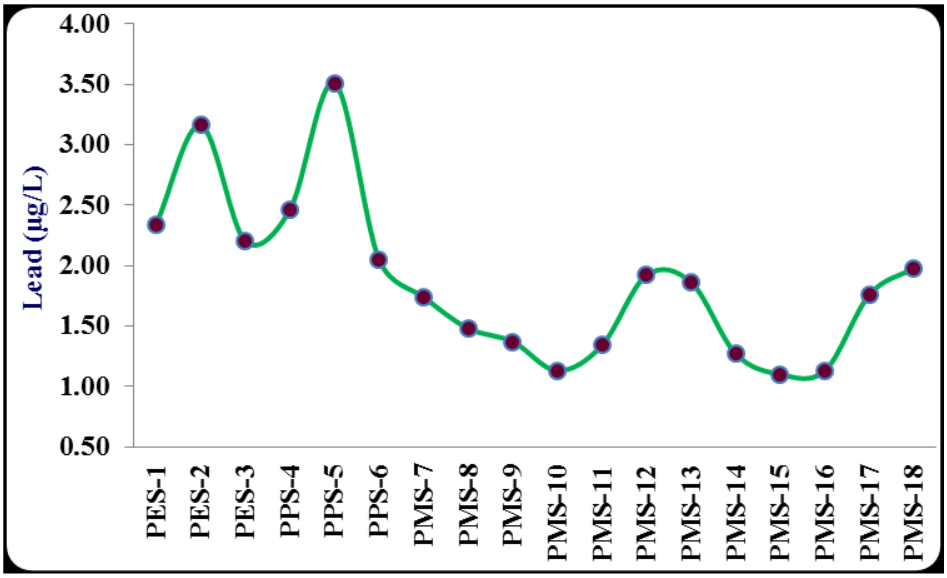



**Figure:25 Lead concentration recorded at various stations of Estuary and Paradeep coastal waters**

### 3.3.8 Copper

The copper concentration varied from 3.36 to 7.38µg/L (Fig. 26). The maximum was recorded at PPS-5 and the minimum was recorded at PMS-9 during this survey.

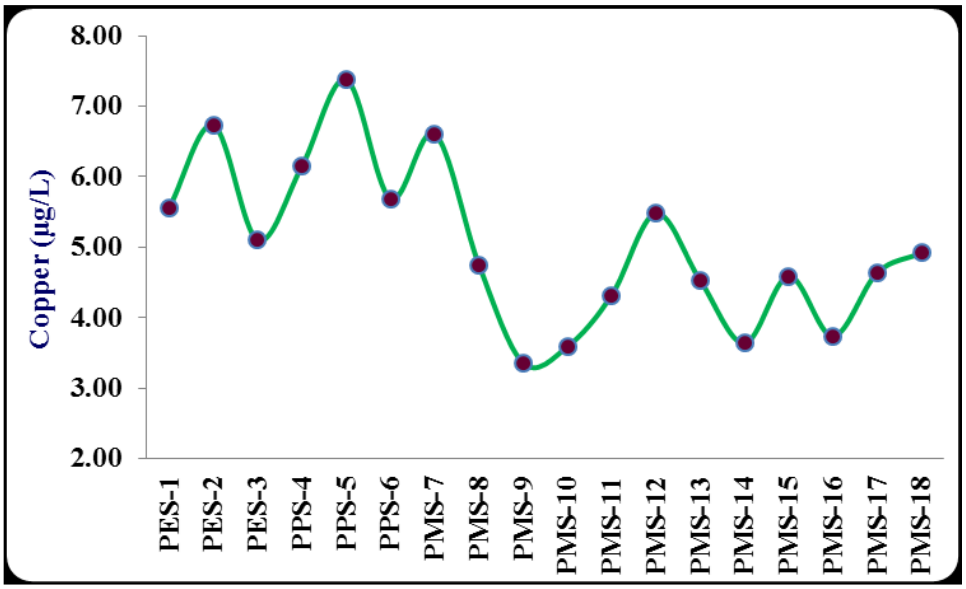



**Figure:26 Copper concentration recorded at various stations of Estuary and Paradeep coastal waters**

### 3.3.9 Mercury

The mercury level varied from 0.22 to 0.41µg/L (Fig. 27). The maximum value was recorded at PPS-5 and the minimum was recorded at PMS-15 during this survey.

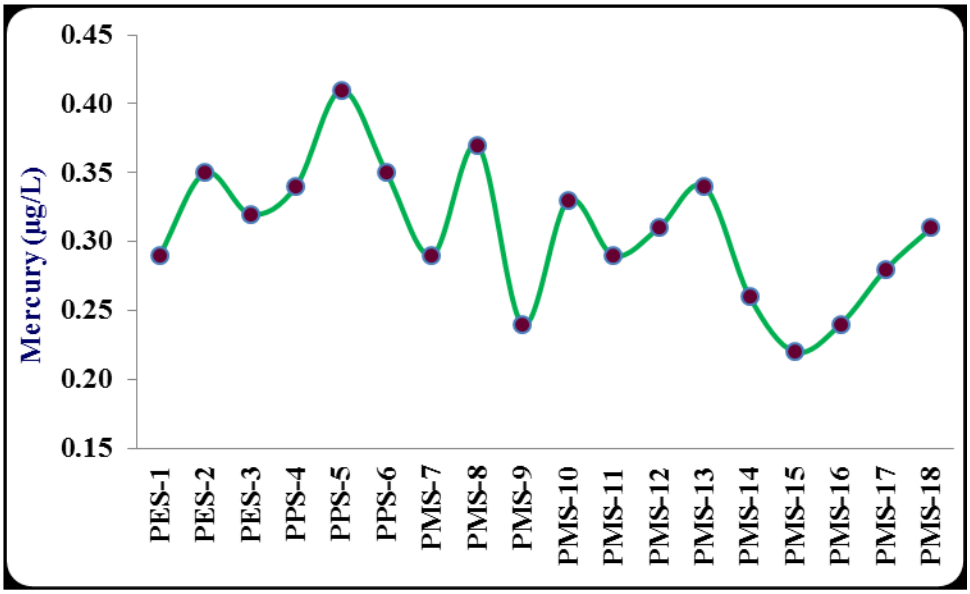



**Figure:27 Mercury level recorded at various stations at Estuary and Paradeep coastal waters**

### 3.4 Sediment Characteristics

#### 3.4.1 Sediment pH

The maximum value (8.49) of soil pH was recorded at PMS-10 and minimum of 7.93 at PES-1 (Fig. 28).

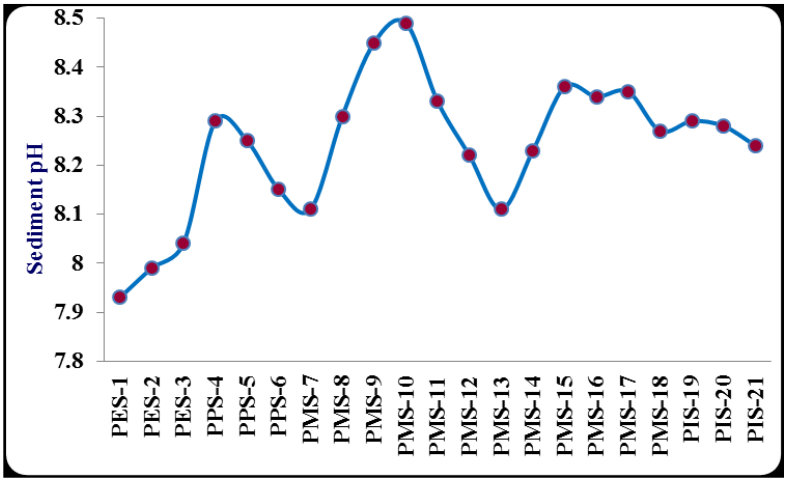



**Figure:28 Soil pH values recorded at various stations of Estuary and Paradeep coastal waters**

#### 3.4.2 Soil Texture

The sand content varied from 4.29 to 84.40 % with maximum value was at PIS-21 and the minimum at PPS-4; maximum Silt content (47.58%) was found at PES-1 and minimum (10.40%) at TIS-21 and the maximum Clay content (74.08%) was found at PES-2 and minimum (2.40%) at PIS-19 (Fig. 29).

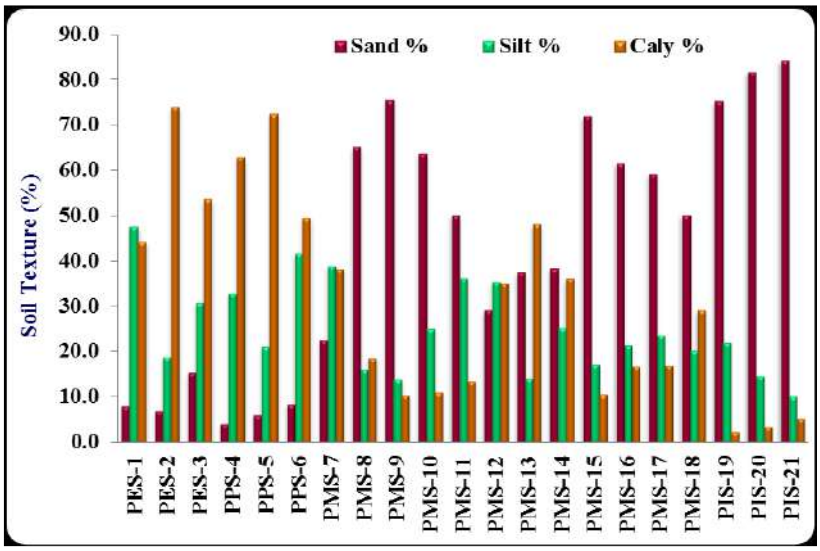



**Figure:29 Variations in soil texture recorded in various stations of Estuary and Paradeep coastal waters**

### 3.4.3 Total organic Carbon

The total organic carbon ranged between 2.24 and 10.97mgC/g. The maximum level (10.97mgC/g) was found at PES-2 and minimum (4.62mgC/g) at PIS-21 (Fig. 30).

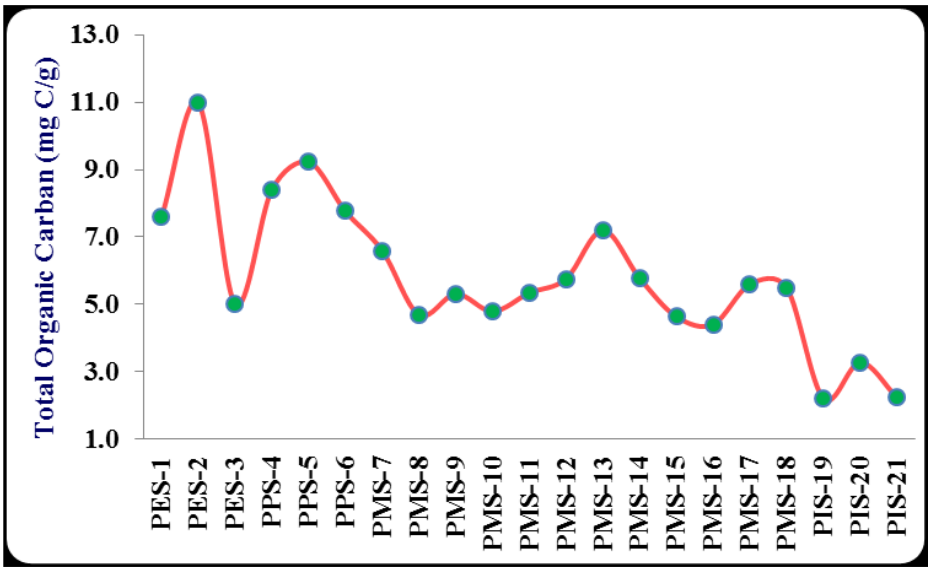



**Figure:30 Total organic carbon values recorded in various stations of Estuary and Paradeep coastal waters**

### 3.4.4 Sediment PHC

The Sediment PHC level varied from 0.065 to 0.581µg/g (Fig. 31). The maximum level was recorded at PPS-5 and the minimum was recorded at PIS-20 during this survey.

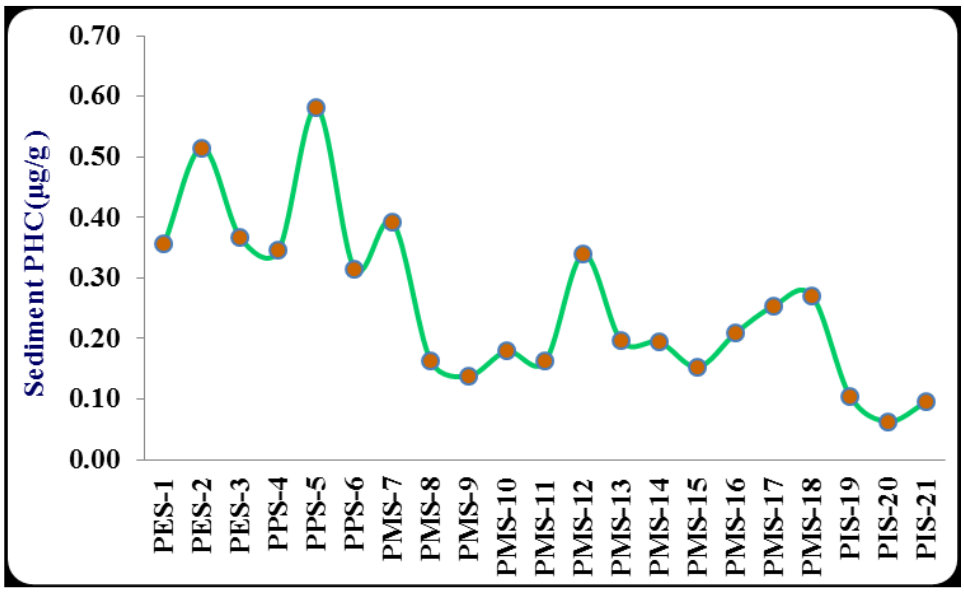



**Figure:31 Sediment PHC level recorded at various stations at Estuary and Paradeep coastal waters**

### 3.5 Heavy Metals in sediments

#### 3.5.1 Iron

The Iron level varied from 1128.90 to 1820.10µg/g (Fig. 32). The maximum was recorded at TES-2 and the minimum was recorded at PMS-9.

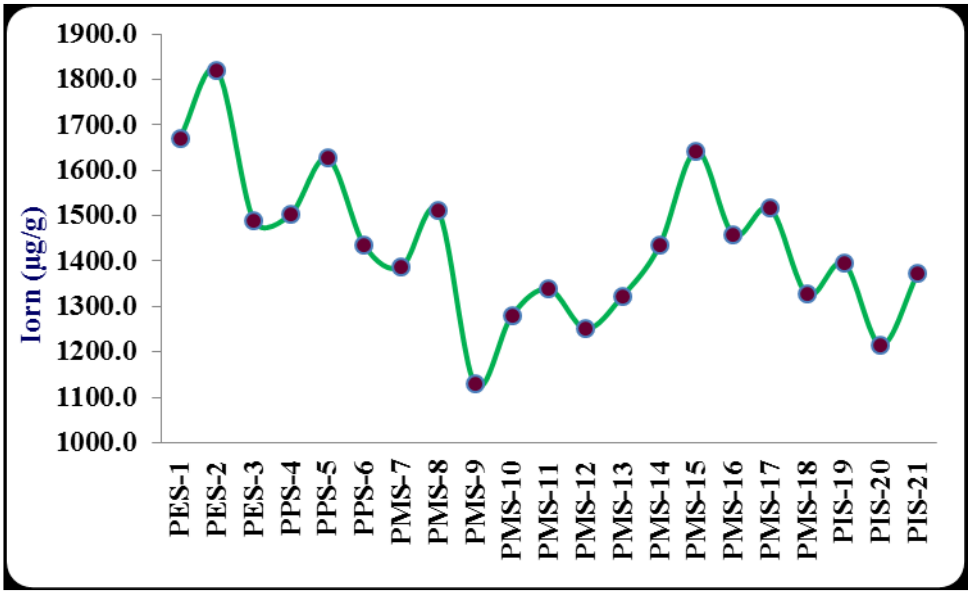



**Figure:32 Iron level recorded in various stations Estuary and Paradeep coastal waters**

#### 3.5.2 Zinc

Zinc concentration varied from 1 0 .10 to 1 8 .90µg/g (Fig. 33). The maximum level was recorded at PPS-5 and the minimum was recorded at PMS-11.

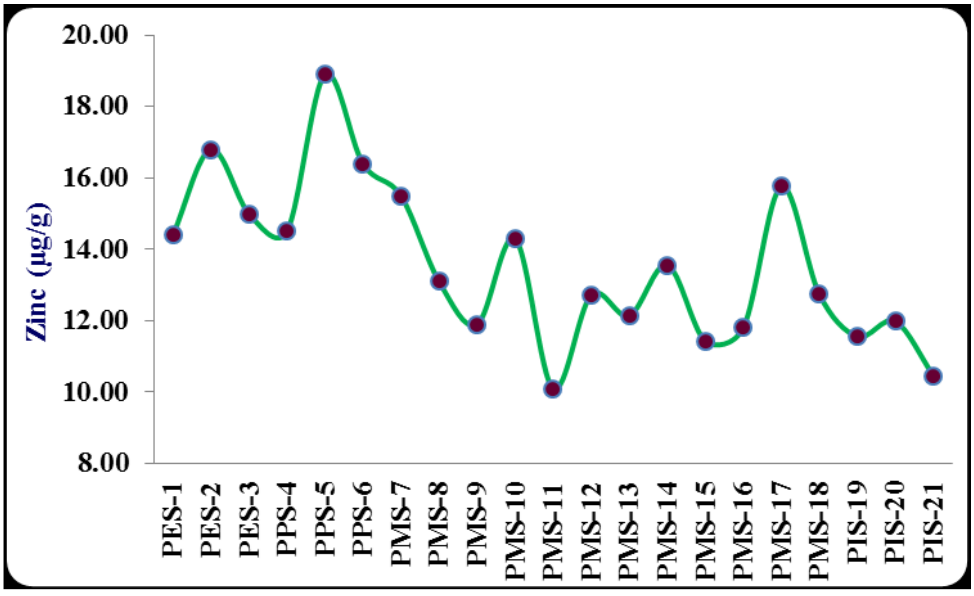



**Figure:33 Zinc concentration recorded at various stations of Estuary and Paradeep coastal waters**

### 3.5.3 Manganese

The Manganese level varied from 19.80 to 61.80µg/g (Fig. 34). The maximum level was recorded at PPS-5 and the minimum was recorded at PIS-20.

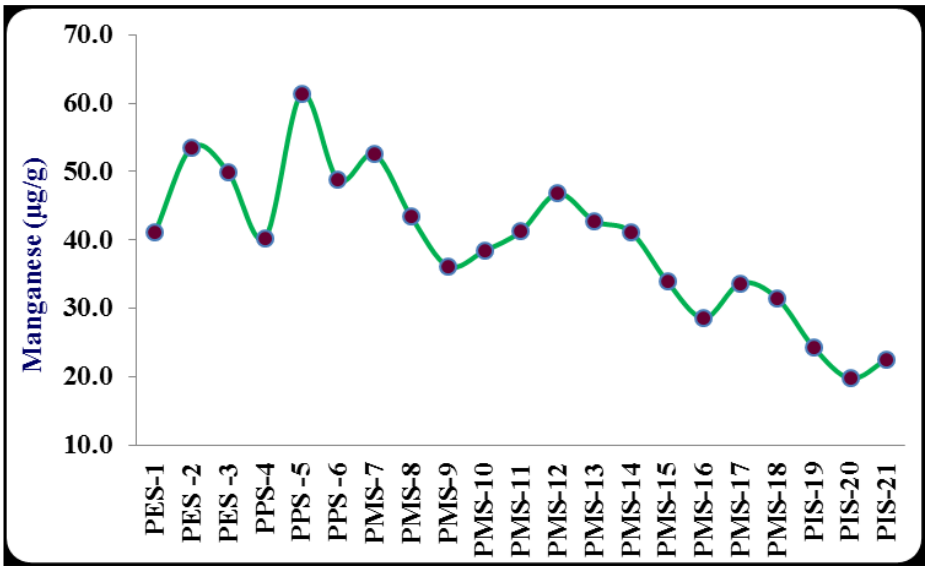



**Figure:34 Manganese level recorded at various stations of Estuary and Paradeep coastalwaters**

### 3.5.4 Cadmium

The Cadmium level varied from 1.02 to 2.36µg/g (Fig. 35). The maximum level was recorded at PPS-5 and the minimum was recorded at PMS-10.

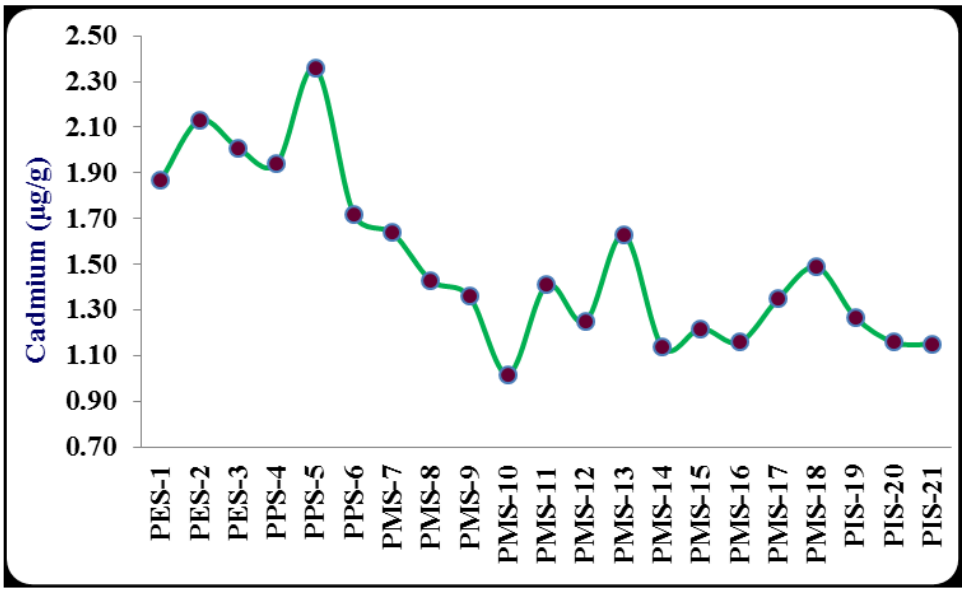



**Figure:35 Cadmium level recorded at various stations of Estuary and Paradeep coastalwaters**

### 3.5.5 Nickel

The nickel concentration varied from 1.65 to 4.54µg/g (Fig. 36). The maximum was recorded at PPS-6 and the minimum was recorded at PIS-200.

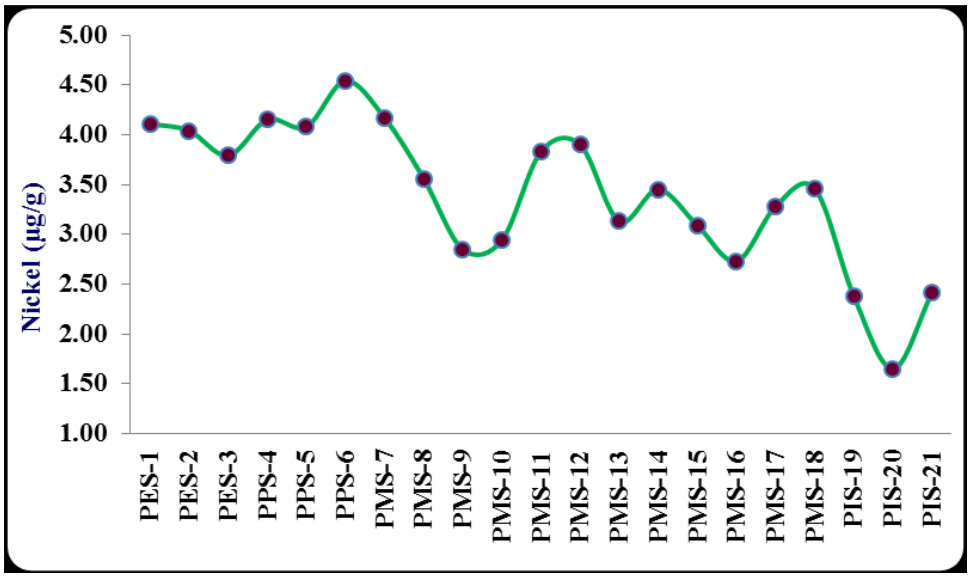



**Figure:36 Nickel concentration recorded at various stations of Estuary and Paradeep coastalwaters**

### 3.5.6 Chromium

The Chromium level varied from 4.23 to 10.37µg/g (Fig. 37) with the maximum was recorded at PES-2 and the minimum was recorded at PMS-16.

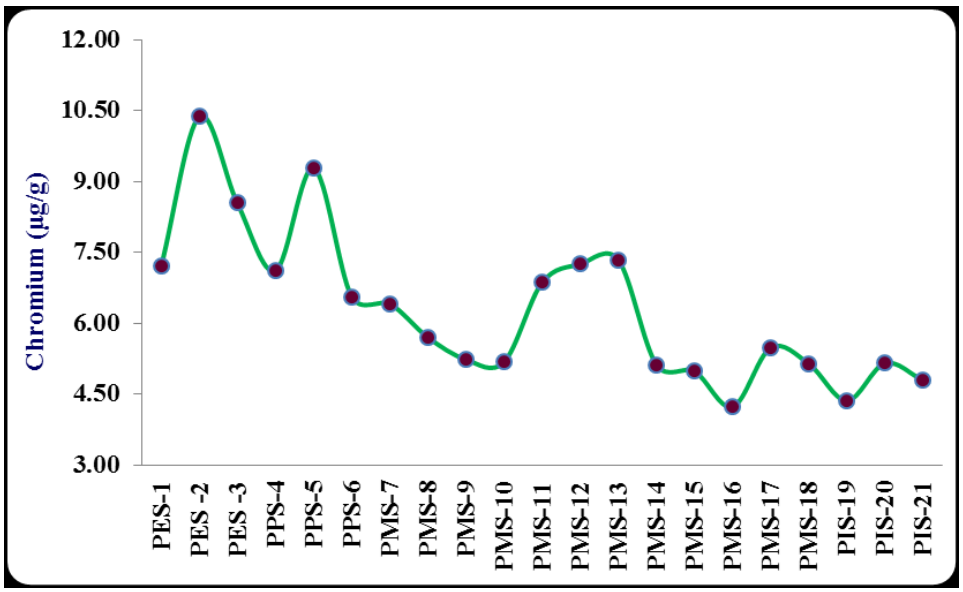



**Figure:37 Chromium level recorded at various stations of Estuary and Paradeep coastal waters**

### 3.5.7 Lead

The lead concentration varied from 3.96 to 7.04µg/g (Fig. 38). The maximum value was recorded at PES-2 and the minimum was recorded at PMS-9.

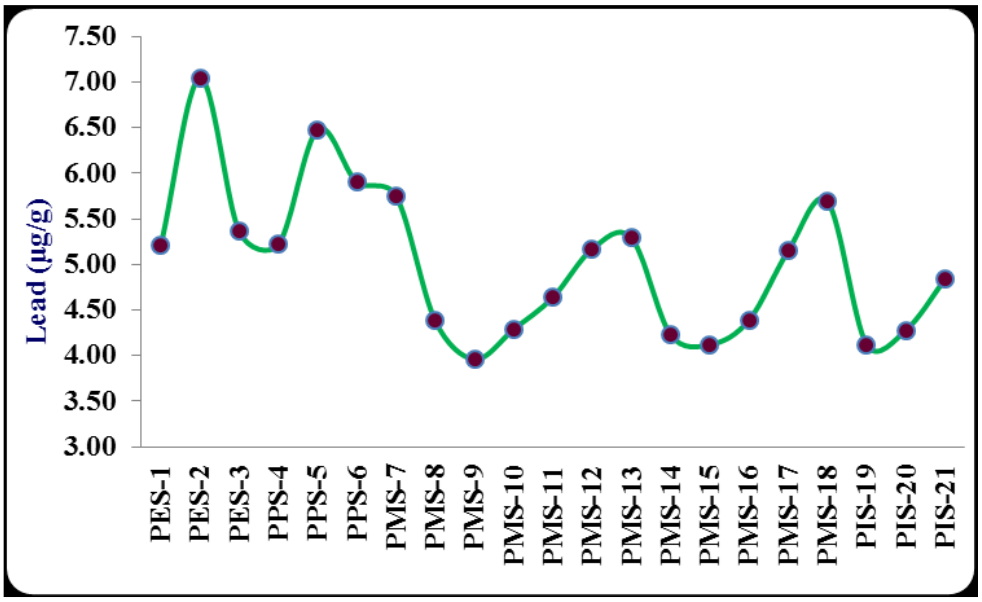



**Figure:38 Lead concentration recorded in various stations of Estuary and Paradeep coastal waters**

### 3.5.8 Copper

The copper level varied from 4 .41 to 9.17µg/g (Fig. 39). The maximum value was recorded at PES-2 and the minimum was recorded at PMS-15.

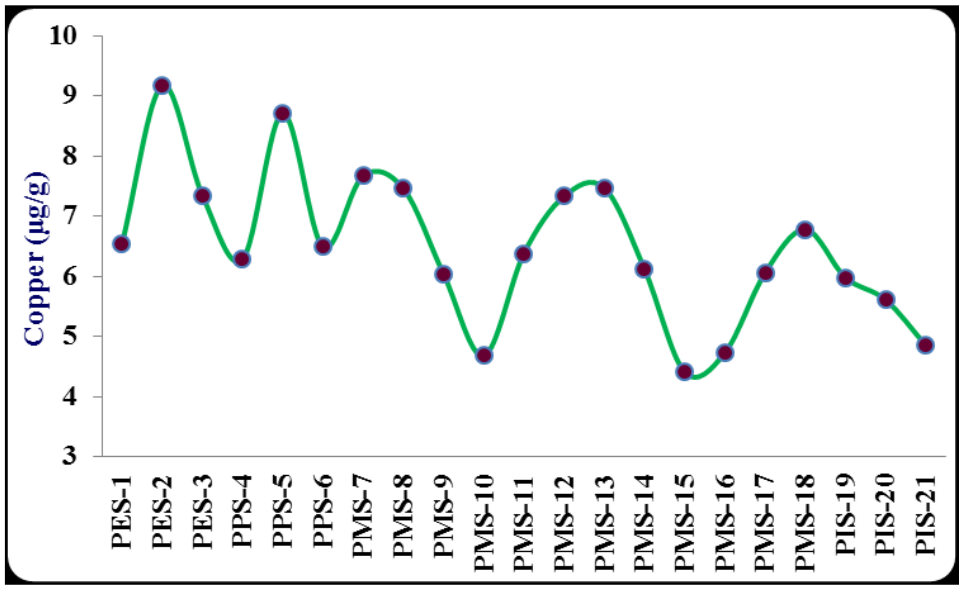



**Figure:39 Copper level recorded in various stations of Estuary and Paradeep coastal waters**

### 3.5.9 Mercury

The mercury concentration varied from 0.32 to 0.76µg/g (Fig. 40). The maximum was recorded at PPS-6 and the minimum was recorded at PMS-16.

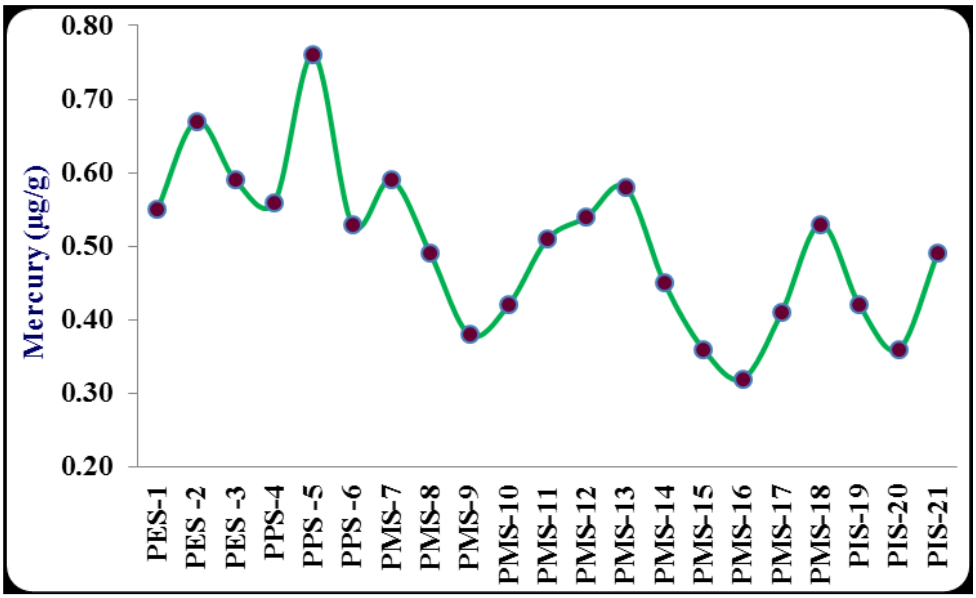



**Figure:40 Mercury concentration recorded in various stations of Estuary and Paradeep coastal waters**

### 3.5.10 Principle Component Analysis (PCA)

The data on physico-chemical parameters collected in water samples were subjected to Principle component analysis to set a well-defined relation between the environmental parameters against the surveyed stations (Fig. 41). The PCA plot drawn indicated that water parameters such as Temperature, DO, Salinity, pH, TN, TP, SiO3, POC, W.PHC, Cu, TOC, Mn, Fe, Pb sand and Cr had significant correlation with the surveyed stations. Looking at the nature of correlation, the parameters such as Temperature, DO, salinity, pH, TN, TP, SiO3, Chl-a, TOC, clay, sand, Fe and Mn got correlated with stations PMS-7, PMS-8, PMS-9, PMS-10, PMS-11, PMS-12, PMS-14, and PMS-16 while the rest of the parameters showed strong correlation with stations PMS-13, PES-1, PES-2, PES-3, PPS-4, PPS-6 and PPS-5.

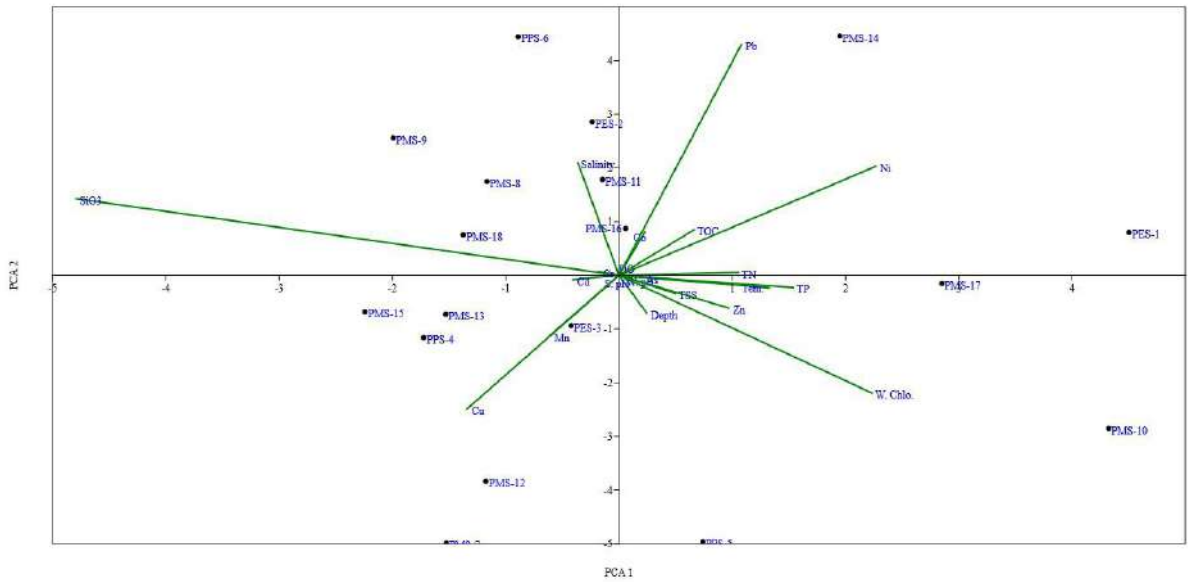



**Figure:41 Principal Component Analysis plot drawn for the correlation between various environmental variables and stations of Estuary and Paradeep coastal waters**

## 3.6 MICROBIOLOGY

### 3.6.1 Water sample

The total viable count in water samples ranged from 11 x103 to 37 x102 CFU/ml. The maximum count was found at PES-2 and the minimum count was found at PMS-15. The Total coliform count in the samples varied from 11x104 to 29x103 CFU/ml with the high colony count at PES-3 and the low count at PMS-9. The E. coli count ranged from 10x102 to 36x101 CFU/ml with a maximum value at PPS-5 and the minimum value at PMS-13. The Faecal coliform was found to vary from 11x103 to 38x104 CFU/ml with higher value at PES-2 and the lower value at PMS-15. The Pseudomonas aeurginosa count ranged from 07x102 to 17x103 CFU/ml with maximum value at PPS-5 and the minimum value at PMS-15. The Streptococcus faecalis count ranged from 06x102 to 26x101 CFU/ml. The higher values were recorded at PES-1 and the lower values were recorded at PMS-14. The Shigella count varied from 06x102 to 28x102 CFU/ml with a higher value at PES-3 and the lower value at PMS-11. The Salmonella colony count varied from 07x103 to 17x103CFU/ml with the higher value at PES-2 and the lower value at PMS-15. The Vibrio cholera colony count was found to fluctuate from 05x102 to 20x104CFU/ml. The higher colony count was observed at PES-2 and the lower count was recorded at PMS-10. Vibrio parahaemolyticus colony count varied from 09x103 to 17x104 CFU/ml with the maximum value at PPS-5 and minimum value at PMS-18 (Table 2).

**Table 2 Bacterial populations recorded in water sample at Estuary and Paradeep coastal waters**

| Station ID | FC | TVC | TC | EC | VC | VP | PA | SF | SH | SL |
|---|---|---|---|---|---|---|---|---|---|---|
| PES-1 | 37 x10$^4$ | 31 x10$^4$ | 19 x10$^4$ | 26 x10$^2$ | 12 x10$^3$ | 16 x10$^3$ | 10 x10$^4$ | 26 x10$^1$ | 11 x10$^3$ | 15 x10$^3$ |
| PES-2 | 38 x10$^4$ | 35 x10$^3$ | 23 x10$^4$ | 33 x10$^1$ | 20 x10$^4$ | 15 x10$^3$ | 17 x10$^3$ | 14 x10$^4$ | 15 x10$^3$ | 17 x10$^3$ |
| PES-3 | 36 x10$^4$ | 33 x10$^3$ | 29 x10$^4$ | 27 x10$^1$ | 14 x10$^4$ | 14 x10$^3$ | 05 x10$^3$ | 15 x10$^3$ | 28 x10$^2$ | 13 x10$^2$ |
| PPS-4 | 33 x10$^4$ | 28 x10$^3$ | 08 x10$^2$ | 28 x10$^1$ | 16 x10$^3$ | 15 x10$^4$ | 13 x10$^4$ | 12 x10$^4$ | 14 x10$^3$ | 11 x10$^3$ |
| PPS-5 | 30 x10$^3$ | 37 x10$^2$ | 21 x10$^3$ | 36 x10$^1$ | 17 x10$^3$ | 17 x10$^4$ | 12 x10$^3$ | 12 x10$^3$ | 21 x10$^2$ | 10 x10$^3$ |
| PPS-6 | 30 x10$^3$ | 24 x10$^3$ | 18 x10$^4$ | 30 x10$^1$ | 14 x10$^4$ | 16 x10$^3$ | 12 x10$^4$ | 11 x10$^4$ | 17 x10$^3$ | 16 x10$^3$ |
| PMS-7 | 31 x10$^4$ | 21 x10$^3$ | 20 x10$^4$ | 14 x10$^1$ | 18 x10$^4$ | 16 x10$^4$ | 15 x10$^4$ | 17 x10$^4$ | 23 x10$^3$ | 13 x10$^3$ |
| PMS-8 | 27 x10$^4$ | 23 x10$^2$ | 13 x10$^3$ | 20 x10$^1$ | 14 x10$^4$ | 12 x10$^4$ | 13 x10$^4$ | 10 x10$^4$ | 19 x10$^3$ | 09 x10$^3$ |
| PMS-9 | 29 x10$^4$ | 16 x10$^3$ | 10 x10$^3$ | 21 x10$^2$ | 07 x10$^2$ | 12 x10$^3$ | 10 x10$^2$ | 11 x10$^4$ | 09 x10$^2$ | 11 x10$^2$ |
| PMS-10 | 32 x10$^3$ | 11 x10$^3$ | 15 x10$^3$ | 19 x10$^1$ | 05 x10$^2$ | 12 x10$^4$ | 09 x10$^2$ | 15 x10$^4$ | 19 x10$^3$ | 13 x10$^3$ |
| PMS-11 | 14 x10$^4$ | 21 x10$^4$ | 21 x10$^3$ | 12 x10$^2$ | 16 x10$^1$ | 13 x10$^2$ | 11 x10$^4$ | 12 x10$^2$ | 06 x10$^2$ | 08 x10$^2$ |
| PMS-12 | 12 x10$^4$ | 18 x10$^4$ | 18 x10$^4$ | 13 x10$^2$ | 10 x10$^4$ | 11 x10$^2$ | 10 x10$^4$ | 10 x10$^2$ | 08 x10$^2$ | 13 x10$^2$ |
| PMS-13 | 18 x10$^4$ | 19 x10$^4$ | 21 x10$^4$ | 10 x10$^2$ | 07 x10$^3$ | 10 x10$^2$ | 11 x10$^2$ | 08 x10$^2$ | 11 x10$^2$ | 11 x10$^2$ |
| PMS-14 | 13 x10$^4$ | 15 x10$^4$ | 19 x10$^3$ | 15 x10$^2$ | 10 x10$^2$ | 10 x10$^2$ | 13 x10$^3$ | 06 x10$^2$ | 08 x10$^2$ | 09 x10$^2$ |
| PMS-15 | 11 x10$^3$ | 16 x10$^4$ | 12 x10$^3$ | 13 x10$^5$ | 06 x10$^2$ | 12 x10$^3$ | 07 x10$^2$ | 10 x10$^2$ | 09 x10$^3$ | 07 x10$^3$ |
| PMS-16 | 15 x10$^3$ | 10 x10$^4$ | 11 x10$^4$ | 16 x10$^5$ | 09 x10$^3$ | 10 x10$^3$ | 08 x10$^2$ | 09 x10$^3$ | 10 x10$^3$ | 08 x10$^3$ |
| PMS-17 | 19 x10$^3$ | 14 x10$^4$ | 15 x10$^4$ | 17 x10$^4$ | 12 x10$^2$ | 11 x10$^3$ | 09 x10$^3$ | 11 x10$^3$ | 09 x10$^3$ | 10 x10$^3$ |
| PMS-18 | 13 x10$^3$ | 12 x10$^5$ | 17 x10$^4$ | 11 x10$^3$ | 13 x10$^4$ | 09 x10$^3$ | 10 x10$^4$ | 08 x10$^3$ | 08 x10$^3$ | 09 x10$^3$ |

### 3.6.2 Sediment sample

With respect to sediment samples, the total viable count in sediment samples ranged from 16x102 to 40x104 CFU/g. The maximum was found at PES-1 and the minimum value was found at PMS-16. The Total coliform count was found to vary from 16x103 to 39x104 CFU/g with the higher value at PPS-5 and the lower value at PMS-15. The E. coli count ranged from 15x103 to 40x105CFU/g with the higher value at PES-3 and the lower value at PIS-20. The Faecal coliform count in the samples varied from 15x103 to 38x105 CFU/g with the higher colony count at PES-3 and the lower count at PMS-10. Pseudomonas aeurginosa counts ranged from 10 x104 to 18 x105 CFU/g with the maximum at PMS-17 and the minimum at TMS-15. The Streptococcus faecalis count ranged from 10x104 to 25x105 CFU/g. The higher value was recorded at PES-2 and the lower value was recorded at PMS-12. The Shigella counts varied from 12x104 to 19x104 CFU/g with the higher value at PES-1 and lower value at PMS-16. Salmonella colony counts varied from 11x102 to 26x104 CFU/g with the maximum value at PPS-5 and the minimum value at PMS-11. Vibrio parahaemolyticus colony count varied from

10x105 to 22x104 CFU/g. The higher value was found at PPS-5 and the lower value at PMS-16.

The other species Vibrio cholerae colony was found to range from 13x104 to 33x103 CFU/g with the maximum colony count at PPS-5 and the minimum count was observed at PMS-15 (Table 3).

**Table 3 Bacterial populations recorded in sediment sample at Estuary and Paradeep coastal waters**

| Station ID | FC | TVC | TC | EC | VC | VP | PA | SF | SH | SL |
|---|---|---|---|---|---|---|---|---|---|---|
| PES-1 | $32 \times 10^5$ | $40 \times 10^4$ | $31 \times 10^4$ | $32 \times 10^4$ | $25 \times 10^3$ | $19 \times 10^3$ | $14 \times 10^3$ | $24 \times 10^4$ | $19 \times 10^4$ | $24 \times 10^4$ |
| PES-2 | $45 \times 10^5$ | $36 \times 10^4$ | $32 \times 10^5$ | $35 \times 10^5$ | $27 \times 10^3$ | $19 \times 10^4$ | $16 \times 10^3$ | $25 \times 10^5$ | $18 \times 10^5$ | $22 \times 10^3$ |
| PES-3 | $38 \times 10^5$ | $23 \times 10^4$ | $36 \times 10^4$ | $40 \times 10^5$ | $23 \times 10^3$ | $21 \times 10^3$ | $17 \times 10^3$ | $21 \times 10^4$ | $15 \times 10^3$ | $25 \times 10^4$ |
| PPS-4 | $20 \times 10^5$ | $24 \times 10^4$ | $37 \times 10^4$ | $36 \times 10^5$ | $15 \times 10^3$ | $15 \times 10^3$ | $12 \times 10^3$ | $18 \times 10^4$ | $16 \times 10^3$ | $25 \times 10^3$ |
| PPS-5 | $37 \times 10^4$ | $28 \times 10^4$ | $39 \times 10^4$ | $39 \times 10^4$ | $33 \times 10^3$ | $22 \times 10^4$ | $14 \times 10^4$ | $11 \times 10^4$ | $18 \times 10^4$ | $26 \times 10^4$ |
| PPS-6 | $17 \times 10^5$ | $23 \times 10^5$ | $27 \times 10^5$ | $33 \times 10^5$ | $15 \times 10^4$ | $13 \times 10^4$ | $13 \times 10^4$ | $11 \times 10^2$ | $14 \times 10^4$ | $13 \times 10^4$ |
| PMS-7 | $18 \times 10^4$ | $27 \times 10^5$ | $22 \times 10^4$ | $34 \times 10^5$ | $18 \times 10^4$ | $15 \times 10^4$ | $12 \times 10^4$ | $13 \times 10^4$ | $12 \times 10^4$ | $16 \times 10^3$ |
| PMS-8 | $21 \times 10^4$ | $23 \times 10^4$ | $19 \times 10^5$ | $31 \times 10^3$ | $14 \times 10^4$ | $17 \times 10^4$ | $12 \times 10^4$ | $12 \times 10^4$ | $15 \times 10^4$ | $12 \times 10^3$ |
| PMS-9 | $17 \times 10^3$ | $21 \times 10^4$ | $24 \times 10^5$ | $29 \times 10^3$ | $11 \times 10^2$ | $13 \times 10^4$ | $13 \times 10^4$ | $15 \times 10^4$ | $10 \times 10^3$ | $15 \times 10^4$ |
| PMS-10 | $15 \times 10^3$ | $19 \times 10^5$ | $22 \times 10^4$ | $21 \times 10^4$ | $12 \times 10^2$ | $12 \times 10^5$ | $12 \times 10^5$ | $13 \times 10^4$ | $09 \times 10^3$ | $12 \times 10^4$ |
| PMS-11 | $18 \times 10^4$ | $33 \times 10^5$ | $22 \times 10^3$ | $19 \times 10^4$ | $13 \times 10^5$ | $11 \times 10^2$ | $12 \times 10^3$ | $12 \times 10^2$ | $14 \times 10^4$ | $11 \times 10^2$ |
| PMS-12 | $20 \times 10^4$ | $39 \times 10^3$ | $19 \times 10^3$ | $21 \times 10^3$ | $16 \times 10^2$ | $13 \times 10^2$ | $12 \times 10^3$ | $10 \times 10^4$ | $13 \times 10^3$ | $13 \times 10^2$ |
| PMS-13 | $29 \times 10^4$ | $31 \times 10^4$ | $20 \times 10^3$ | $23 \times 10^3$ | $21 \times 10^5$ | $15 \times 10^5$ | $15 \times 10^4$ | $14 \times 10^5$ | $16 \times 10^3$ | $23 \times 10^4$ |
| PMS-14 | $21 \times 10^5$ | $32 \times 10^4$ | $21 \times 10^4$ | $24 \times 10^5$ | $27 \times 10^5$ | $18 \times 10^4$ | $13 \times 10^4$ | $12 \times 10^3$ | $13 \times 10^4$ | $21 \times 10^4$ |
| PMS-15 | $19 \times 10^5$ | $18 \times 10^2$ | $16 \times 10^3$ | $20 \times 10^5$ | $13 \times 10^4$ | $16 \times 10^5$ | $10 \times 10^4$ | $11 \times 10^3$ | $14 \times 10^5$ | $12 \times 10^4$ |
| PMS-16 | $20 \times 10^5$ | $16 \times 10^2$ | $18 \times 10^3$ | $21 \times 10^5$ | $14 \times 10^4$ | $10 \times 10^5$ | $12 \times 10^5$ | $15 \times 10^3$ | $12 \times 10^4$ | $17 \times 10^4$ |
| PMS-17 | $22 \times 10^5$ | $20 \times 10^4$ | $25 \times 10^5$ | $26 \times 10^5$ | $20 \times 10^5$ | $14 \times 10^5$ | $18 \times 10^5$ | $13 \times 10^3$ | $14 \times 10^5$ | $14 \times 10^4$ |
| PMS-18 | $19 \times 10^5$ | $25 \times 10^4$ | $32 \times 10^3$ | $25 \times 10^3$ | $24 \times 10^4$ | $13 \times 10^4$ | $16 \times 10^5$ | $19 \times 10^5$ | $16 \times 10^4$ | $15 \times 10^4$ |
| PIS-19 | $21 \times 10^5$ | $26 \times 10^5$ | $26 \times 10^3$ | $18 \times 10^3$ | $20 \times 10^3$ | $15 \times 10^4$ | $16 \times 10^4$ | $16 \times 10^4$ | $14 \times 10^4$ | $12 \times 10^3$ |
| PIS-20 | $19 \times 10^4$ | $28 \times 10^5$ | $25 \times 10^3$ | $15 \times 10^3$ | $16 \times 10^5$ | $14 \times 10^5$ | $17 \times 10^5$ | $19 \times 10^4$ | $15 \times 10^5$ | $15 \times 10^3$ |
| PIS-21 | $26 \times 10^4$ | $20 \times 10^4$ | $24 \times 10^4$ | $17 \times 10^3$ | $20 \times 10^5$ | $17 \times 10^5$ | $16 \times 10^2$ | $21 \times 10^5$ | $16 \times 10^4$ | $22 \times 10^2$ |

### 3.7 Pigments concentration

#### 3.7.1 Chlorophyll –a (mg/m3), Phaeopigments (mg/m3) and Total biomass (ml/100m3).

In the present study, the chlorophyll 'a' in water sample varied from 0.886 to 1.956 mg/m3, with maximum at PMS-15 and minimum at PES-2. The Phaeopigments content varied from 0.538 to 0.971 mg/m3 with maximum was at PMS-15 and the minimum was observed at PES-2. The Total biomass values varied from 2.106 to 4.615 ml/100m3, with maximum at PMS- 9 and minimum at PPS-4 (Table 4).

**Table 4 Chlorophyll a, Phaeopigments and total biomass recorded in Mahanadi estuary and Paradeep coastal waters**

| Stations | Chlorophyll 'a' (mg/m$^3$) | Phaeopigments (mg/m$^3$) | Total biomass (ml/100m$^3$) |
|---|---|---|---|
| PES-1 | 0.976 | 0.673 | 2.845 |
| PES-2 | 0.886 | 0.538 | 2.963 |
| PES-3 | 1.168 | 0.794 | 3.236 |
| PPS-4 | 1.059 | 0.775 | 2.106 |
| PPS-5 | 1.032 | 0.652 | 3.728 |
| PPS-6 | 1.692 | 0.782 | 2.634 |
| PMS-7 | 1.863 | 0.815 | 2.587 |
| PMS-8 | 1.577 | 0.784 | 3.501 |
| PMS-9 | 1.485 | 0.769 | 4.615 |
| PMS-10 | 1.073 | 0.913 | 4.014 |
| PMS-11 | 0.951 | 0.831 | 2.845 |
| PMS-12 | 1.945 | 0.752 | 2.963 |
| PMS-13 | 1.593 | 0.868 | 3.236 |
| PMS-14 | 0.981 | 0.775 | 3.006 |
| PMS-15 | 1.956 | 0.971 | 3.728 |
| PMS-16 | 1.153 | 0.844 | 2.634 |
| PMS-17 | 1.367 | 0.884 | 2.587 |
| PMS-18 | 0.984 | 0.766 | 3.501 |

### 3.7.2 Primary productivity

The primary productivity was measured using the dark and light reaction method. The values ranged from 116.37 to 157.06mgCm-3d-1. The maximum value was recorded at PMS- 15 and minimum value at PES-2 (Fig. 42).

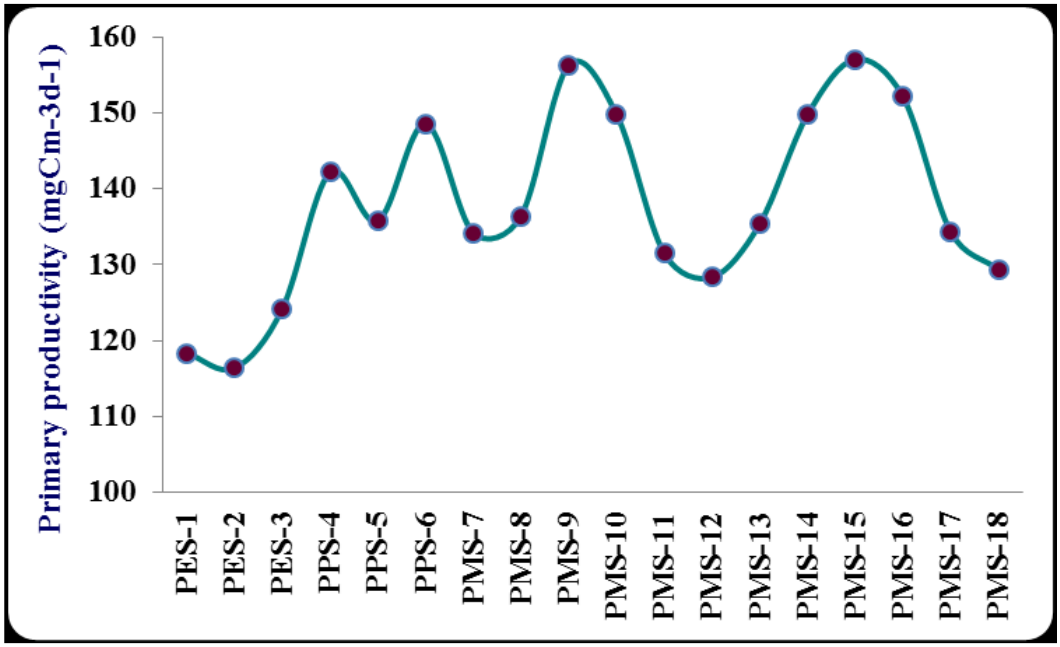



**Figure:42 Primary productivity values recorded at various stations of Estuary and Paradeep coastal waters**

## 3.8 PLANKTON

### 3.8.1 Phytoplankton

In the present study, as many as 49 phytoplankton species belonging to three major groups namely Bacillariophyceae (Diatom), Dinophyceae (Dinoflagellates) and Cyanophyceae (Cyanobacteria) were recorded in Thiruvottiyurkuppam coastal area. Of these, Bacillariophyceae were found to be the dominant group with 36 species, Dinophyceae formed next group with 10 species and Cyanophyceae with three species.

Among the Bacillariophyceae, Skeletonema costatum, Cylindrotheca closterium and Odentella sinensis was observed highly dominated in all the stations and followed by Asterionella glacialis Chaetoceros curvisetus, Rhizosolenia alata and Triceratium reticulatum also were found in all sampling sites except station second (PMS-10) in Mahanadi estuary and Paradeep coastal waters. The Dinophyceae, (Dinophysis caudate, Protocentrum micans and Pyrophagus stenii) and Cyanophyceae (Trichodesmium erythraeum, Merimopedia glauca) similarly were recorded in all the twelve sampling sites. Among the various species, Bacteriastrum comosum, Gramatophora marina, Gyrosigma balticum, Leptocylindrus danicus, Navicula hennedyii, Nitzschia longissima, Odentella mobilensis, Pseudonitzschia inflatula, Plonktonella sol, Rhizosolenia alata, Rhizosolenia styliformis, Thalassiosira punticera, Thalassiothrix frauenfeldii, Ceratium furca, Ceratium extensum, Ceratium macroceros, Ceratium tripos, Ditylum brightwellii, Triceratium favus, Protocentrum micans and

Pyrophagus stenii were the most abundant forms. The distribution and abundance of phytoplankton varied considerably following seasonal environmental fluctuations.

### 3.8.2 Population density

Density of phytoplankton varied from 6,915 to 11,228 Cells/l with maximum was at PMS-10 and minimum at PES-2 (Fig. 43).

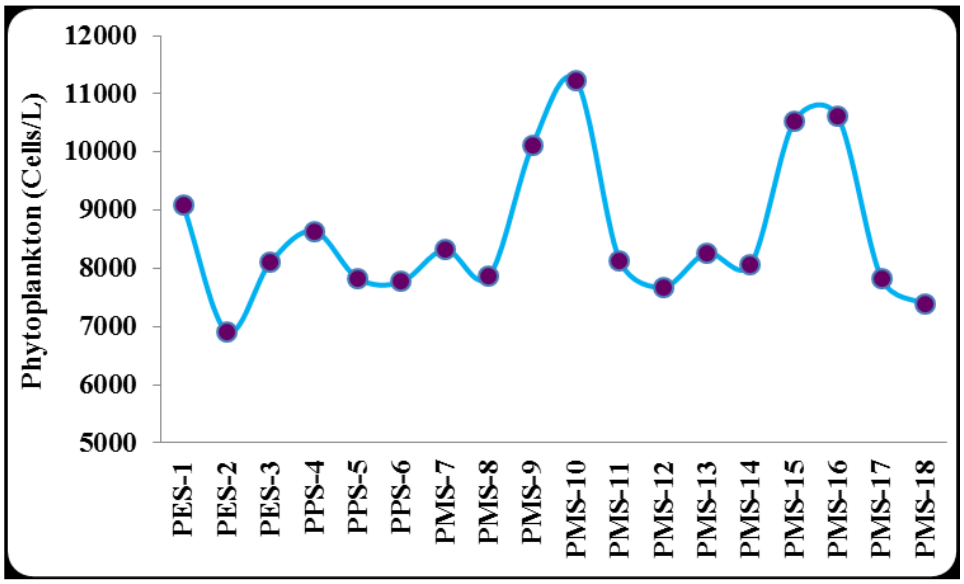



**Figure:43 Population density of Phytoplankton in various stations of Mahanadi estuary and Paradeep coastal waters**

### 3.8.3 Percentage composition

When the results of percentage composition of phytoplankton were looked at, (Bacillariophyceae) Diatoms constituted the maximum with 73% of the total followed by (Dinophyceae) Dinoflagellates with 21% and Blue Green Algae (Cyanophyceae) with 6% of the total (Fig. 44).

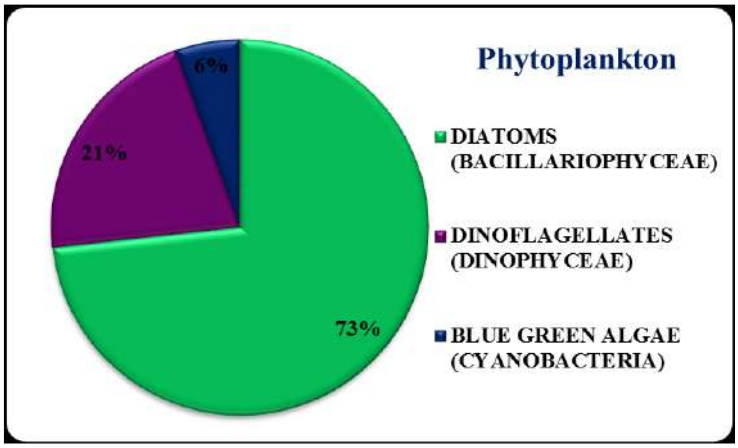



**Figure:44 Percentage composition of Phytoplankton in various stations of Mahanadi estuary and Paradeep coastal waters**

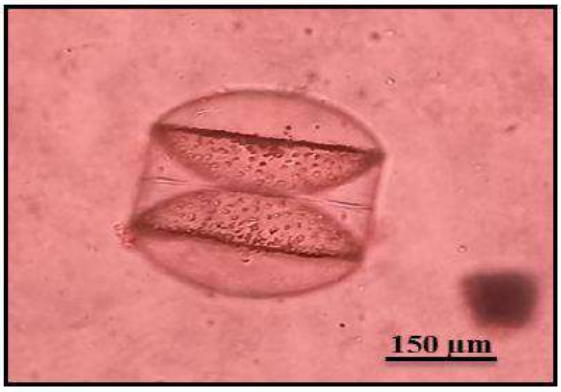
### 3.8.4 Diversity indices

The phytoplankton species diversity (H') varied from 2.365 to 3.811 with maximum value was at PMS-10 and minimum at PES-2. The species richness (d) ranged between 4.528 and 6.879 with maximum was at PPS-5 and minimum at PMS-15. The species evenness varied from 0.545 to 0.924 with maximum value was at PMS-15 and minimum at PES-2 (Table-5).

**Table 5 Diversity indices; Shannon diversity (H'); Margalef richness (d) and Pielou's evenness (J') calculated for Phytoplankton in Mahanadi estuary and Paradeep coastal waters**

| Stations | Shannon diversity (H') | Margalef richness (d) | Pielou's evenness (J') |
|---|---|---|---|
| PES-1 | 2.494 | 5.967 | 0.594 |
| PES-2 | 2.365 | 6.011 | 0.545 |
| PES-3 | 2.788 | 6.815 | 0.615 |
| PPS-4 | 2.592 | 5.916 | 0.629 |
| PPS-5 | 3.122 | 6.879 | 0.634 |
| PPS-6 | 3.193 | 5.754 | 0.74 |
| PMS-7 | 3.252 | 5.035 | 0.728 |
| PMS-8 | 2.983 | 5.634 | 0.605 |
| PMS-9 | 3.436 | 5.653 | 0.814 |
| PMS-10 | 3.811 | 4.691 | 0.623 |
| PMS-11 | 3.176 | 5.361 | 0.631 |
| PMS-12 | 2.855 | 5.848 | 0.672 |
| PMS-13 | 3.011 | 5.583 | 0.594 |
| PMS-14 | 2.988 | 6.233 | 0.77 |
| PMS-15 | 3.149 | 4.528 | 0.924 |
| PMS-16 | 3.326 | 6.824 | 0.623 |
| PMS-17 | 3.271 | 5.328 | 0.791 |
| PMS-18 | 3.388 | 5.811 | 0.734 |

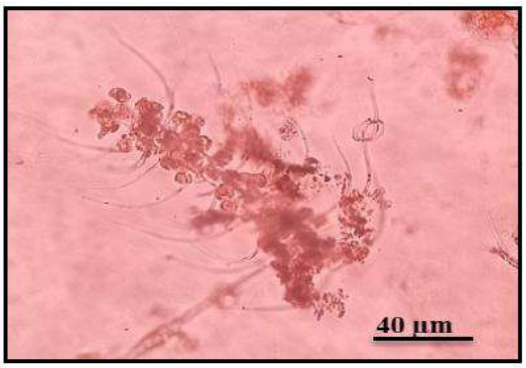
PLATE -I COMMON SPECIES OF PHYTOPLANKTON



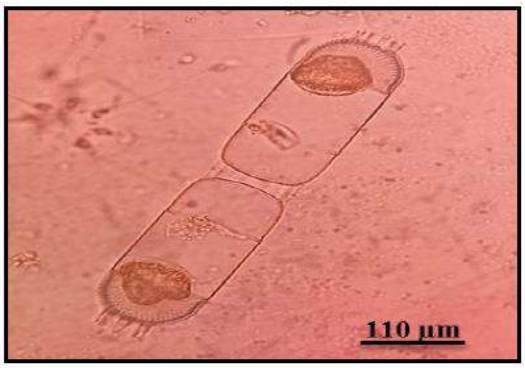

*Coscinodiscus granii*




*Odontella mobiliensis*



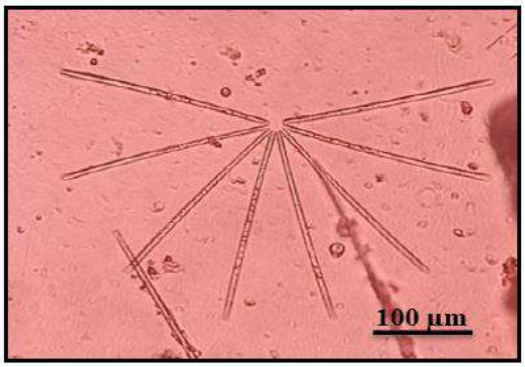

*Chaetoceros coarctatus*



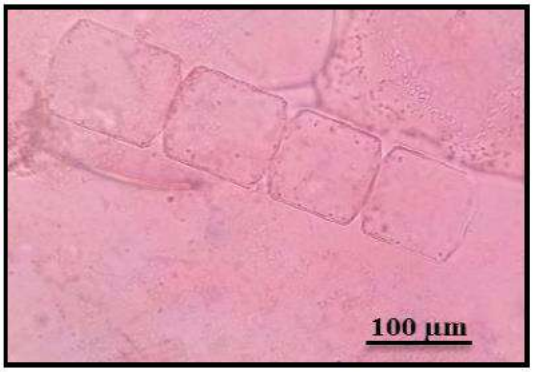

*Stephanopyxis palmeriana*




*Gyrosigma* sp.



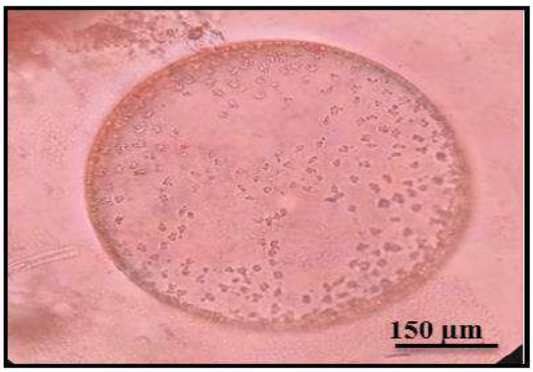

*Thalassionema nitzschioides*



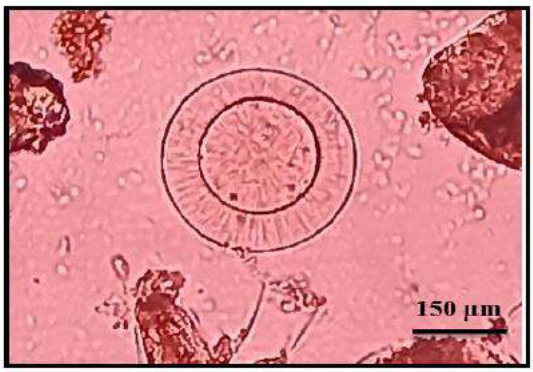

*Lauderia annulata*



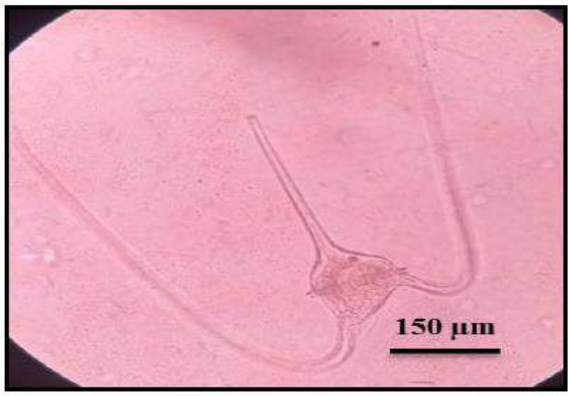

*Pleurosigma normanii*



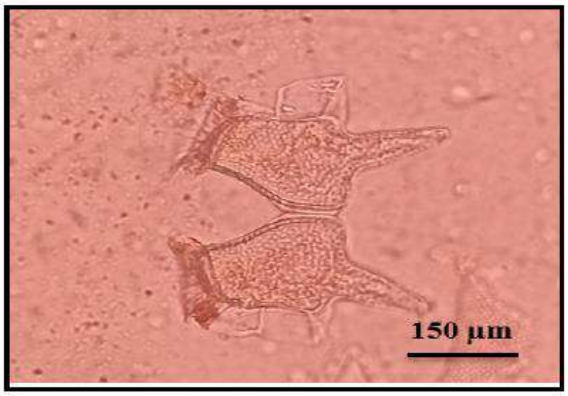

*Coscinodiscus centralis*




*Planktoniella sol*




*Ceratium macroceros*




*Dinophysis caudata*

### 3.8.5 Zooplankton

During the survey, 6 groups of macro zooplankton namely, Calanoid copepod, Cyclopoid copepod, Harpacticoid copepod, Oligotrichea, Foraminifera and Other Crustacean forms and 4 groups of micro zooplankton namely, Mollusca, Chaetognatha, Decapoda and Annelida were recorded. In them, Calanoid Copepod was found to be the dominant group with 13 species. Cyclopoid copepod and Harpacticoid copepod came as next dominant group with 6 species each. The Spirotrichea, Protozoans and Other Crustacean forms were observed with 4 species from each group, Rotatoria and Larvacean were observed with 2 species, Mollusca, Cladocera, Decapoda and Annelida were recorded 1 species from each division of total zooplankton abundance.

The common Calanoid copepod, Cyclopoid copepod, Harpacticoid copepod, Spirotricha, Foraminifera and Other Crustacean species are; Acartia danae, Acartia erythraea, Acartia spinicauda, Acrocalanus gibber, Acrocalanus gracilis, Centropages furcatus, Nannocalanus minor, Paracalanus parvus, Pseudodiaptomus serricaudatus, Temora turbinate, Clytmnestra scutellata, Euterpina acutifrons, Corycaeus danae, Corycaeus catus, Oithona rigida, Oithona similis, Oncaea venusta, Favella brevis, Favella philipiensis, Tintinnopsis tocantinensis, Globigernia bulloides and Globigernia opima were found during this survey. Mollusca, Cladocera, Decapoda and Annelida species such as Daphina sp., Lucifer hanseni, Bivalve veliger, Barnacle nauplii, Crustacean nauplii, Copepod nauplii, Gastropod veliger and Polychaete larvae showed consistency in their occurrence in the samples collected in various stations.

### 3.8.6 Population density

The zooplankton density varied from 4888 to 6680Nos/m3 with maximum at PMS-15 and minimum at PES-2 (Fig. 45).

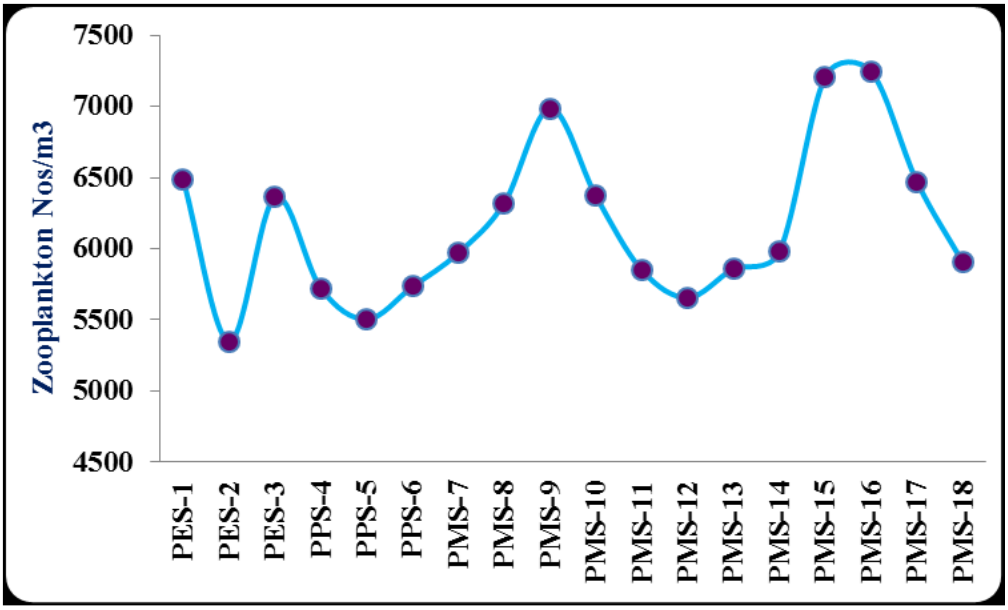



**Figure:45 Population density of zooplankton recorded in various stations of Estuary and Paradeep coastal waters**

### 3.8.7 Percentage composition

Calanoid copepod emerged as the dominant group by constituting 29% and followed by Cyclopoid copepod with 16%, Harpacticoid copepod with 12%, Protozoa with 10%, and Spirotrichea and Other Crustacean forms with 9% each and with 6%, Rotatoria with 4%, and Annelida with 3% each, Mollusca Larvacean, Decapoda and Hydroida with 2% the total percentage composition (Fig. 46).

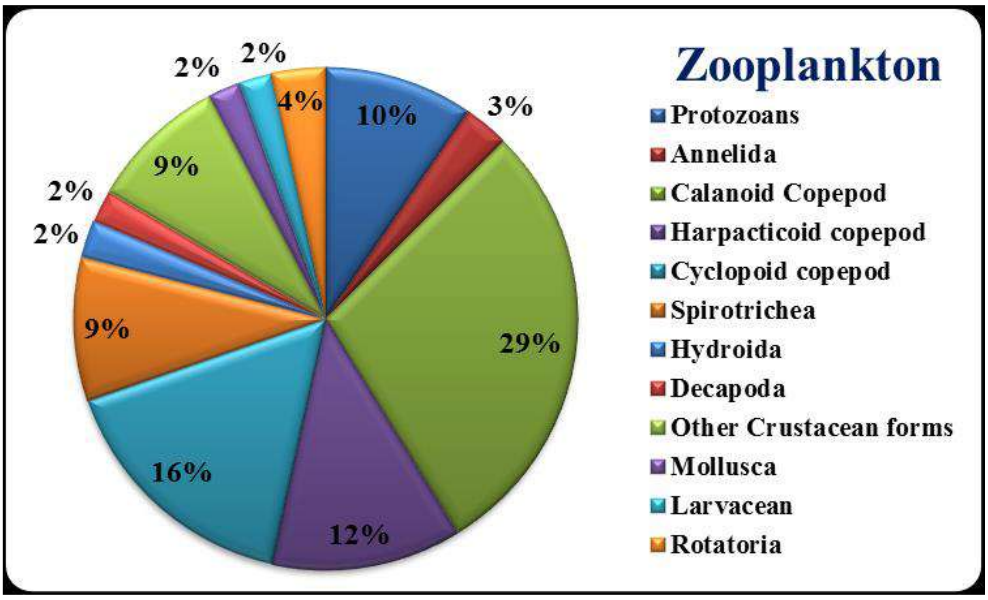



**Figure:46 Percentage composition of Zooplankton in various stations of Mahanadi estuary and Paradeep coastal waters**

### 3.8.8 Diversity Indices

As done for phytoplankton, the zooplankton species diversity (H') varied from 2.592 to 3.846 with maximum was in PMS-16 and minimum in PPS-5. The species richness (d) ranged between 4.873 and 7.186 with maximum in PES-2 and minimum in PMS-9. The species evenness varied from 0.645 to 0.941 with the maximum in PMS-10 and minimum in PES-2 (Table 6).

**Table 6 Diversity indices, Shannon diversity (H'); Margalef richness (d) and Pielou's evenness (J') calculated for zooplankton in Estuary and Paradeep coastal waters**

| Stations | Shannon diversity (H') | Margalef richness (d) | Pielou's evenness (J') |
|---|---|---|---|
| PES-1 | 2.301 | 6.296 | 0.968 |
| PES-2 | 2.492 | 6.512 | 0.645 |
| PES-3 | 2.526 | 6.615 | 0.689 |
| PPS-4 | 2.702 | 5.843 | 0.893 |
| PPS-5 | 3.136 | 5.624 | 0.792 |
| PPS-6 | 2.989 | 5.861 | 0.892 |
| PMS-7 | 3.252 | 5.690 | 0.749 |
| PMS-8 | 2.947 | 5.096 | 0.874 |
| PMS-9 | 3.423 | 4.934 | 0.939 |
| PMS-10 | 3.350 | 5.142 | 0.941 |
| PMS-11 | 2.919 | 6.265 | 0.786 |
| PMS-12 | 2.899 | 6.169 | 0.890 |
| PMS-13 | 2.626 | 5.645 | 0.697 |
| PMS-14 | 2.738 | 5.684 | 0.652 |
| PMS-15 | 2.989 | 5.596 | 0.779 |
| PMS-16 | 3.846 | 5.273 | 0.737 |
| PMS-17 | 3.763 | 5.758 | 0.759 |
| PMS-18 | 3.224 | 5.308 | 0.816 |

### 3.8.9 Cluster analysis

The abundance data of phytoplankton and zooplankton were amalgamated and subjected to classification and ordination methods. The resulting dendrogram revealed that the stations coastal regions PMS-6, PMS-7, PMS-8, PMS-9, PMS-10, PMS-11, PMS-12 PMS-13 PMS-14 PMS-15, PMS-16, PMS-17 and PMS-18 were forming a cluster based on the species

composition and abundance. Similarly, the stations within the estuarine and Port regions PES-1, PES-2, PES-3, PPS-4, PPS-5 and PPS-6 also formed separate cluster (Fig. 47). This fact was further confirmed through MDS, which was also revealed same pattern of groupings as observed in cluster analysis. The stress value (0.25), which is overlying on the top-right corner of the MDS plot, was also found to be low signifying the good ordination pattern of the samples (Fig. 48).

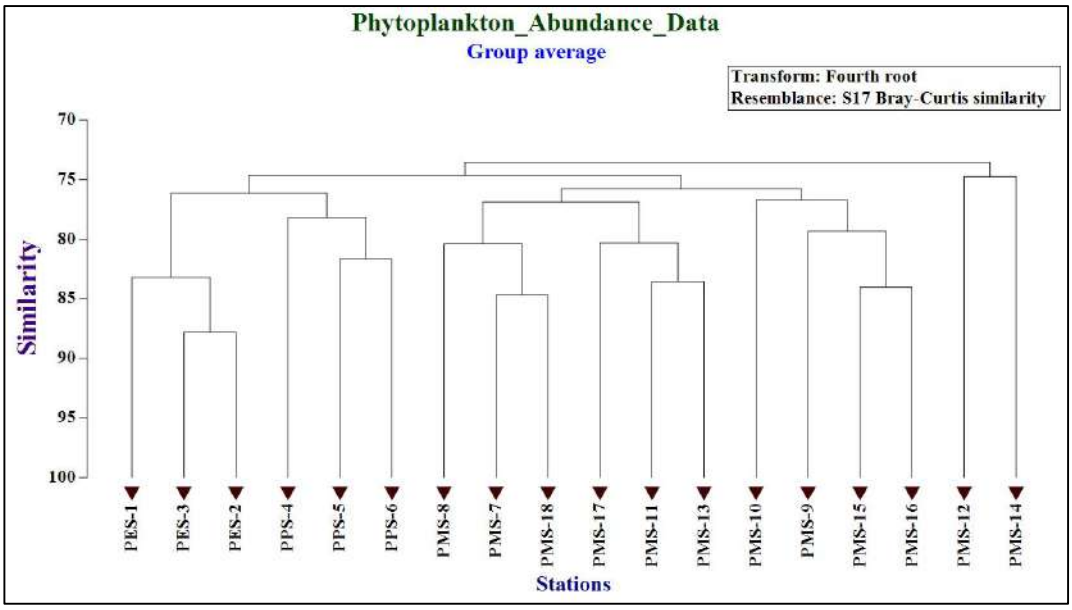



**Figure:47 Dendrogram for the Plankton abundance data collected from Estuary and Paradeep coastal waters**

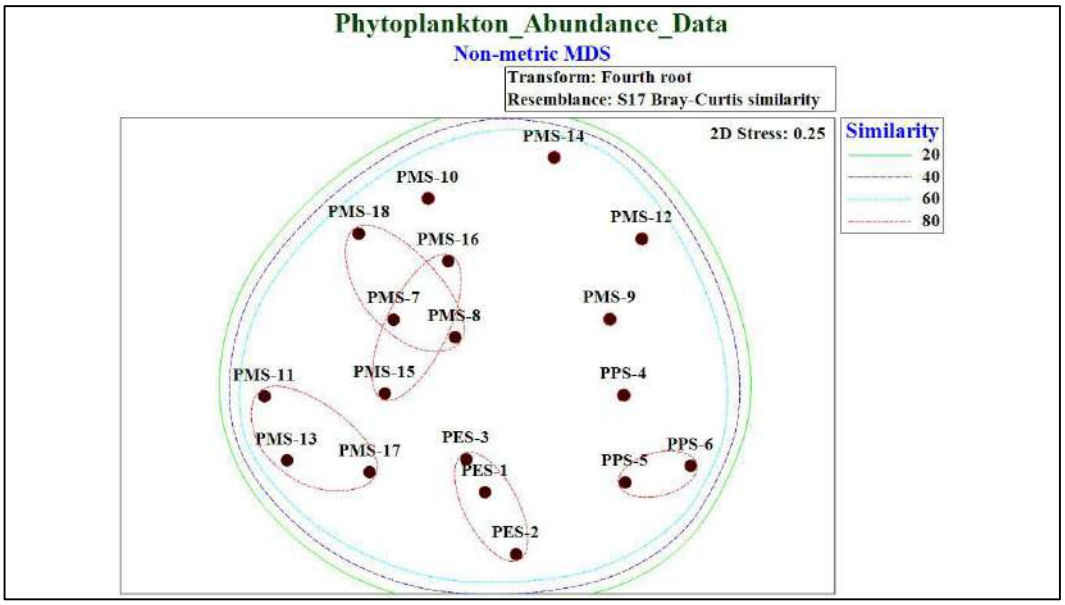



**Figure:48 MDS drawn for the Plankton abundance in various stations of Estuary and Paradeep coastal waters**

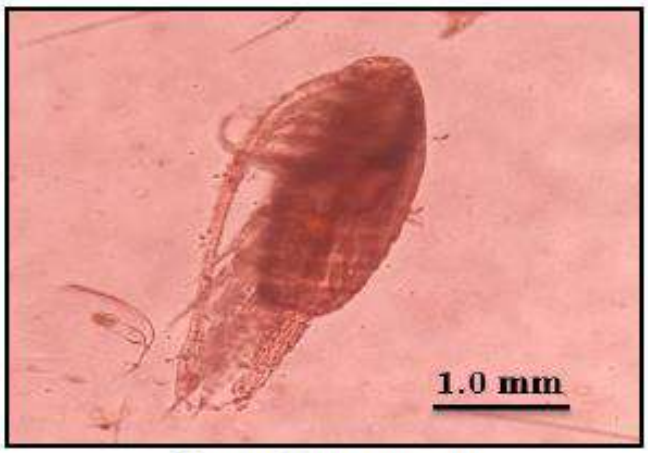
### 3.8.10 BIO-ENV (Biota-Environment matching)

The BIO-ENV procedure was adopted to measure the agreement between the rank correlations of the biological (Bray-Curtis similarity) and environmental (Euclidean distance) matrices. To achieve this, thirteen environmental variables (Primary productivity, Total nitrogen, Nitrite, Nitrate, Dissolved oxygen, Salinity, Temperature Chlorophyll 'a', Silicate, Inorganic phosphate, Total phosphate, ammonia, pH and Temperature) were allowed to match the biota. The results of best combinations are given in Table 7. In this case, the Temperature, Salinity, Dissolved Oxygen, W. pH, Total phosphate, Total Nitrogen, Chlorophyll 'a', Silicate, Primary productivity and Total biomass were featured as the major variables explaining the best match ($p\omega$= 0.915) with plankton (both phytoplankton and zooplankton) distributions. The other parameters such as W. pH, Total Nitrogen, Total phosphate, Silicate, Salinity, Chlorophyll 'a', Dissolved Oxygen and Primary productivity ($p\omega$ = 894) which also got manifested in the next best variable combinations in determining the plankton distribution in Mahanadi estuary and Paradeep coastal waters

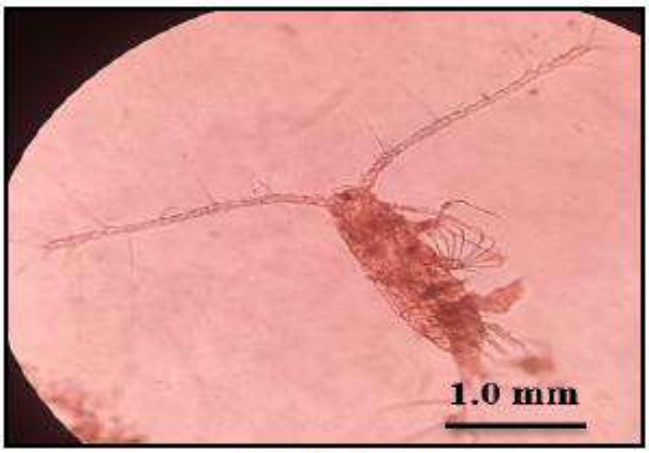
**Table 7 Harmonic rank correlations ($p\omega$) between plankton (both phytoplankton and zooplankton) abundance against environmental variables in Estuary and Paradeep coastal waters**

| No. of variables | Best variable combinations | Correlation ($p\omega$) |
|---|---|---|
| 10 | Temperature – Salinity – Dissolved Oxygen – W. pH – Total phosphate – Total Nitrogen –Chlorophyll 'a' – Silicate – Primary productivity –Totalbiomass | 0.938 |
| 8 | W. pH – Total Nitrogen – Total phosphate – Silicate – Salinity – Chlorophyll 'a' –Dissolved Oxygen – Primary productivity | 0.894 |
| 8 | Salinity – Dissolvedoxygen– Total Nitrogen – Chlorophyll 'a'– Total phosphate – Silicate – Total biomass – Primary productivity | 0.853 |
| 6 | Primary productivity – Chlorophyll 'a' – Total Nitrogen –Total Phosphate – Silicate – Dissolved Oxygen – Total Biomass | 0.811 |
| 6 | Dissolved Oxygen – Total Nitrogen – Primary productivity – Chlorophyll 'a' – Total biomass - Salinity | 0.775 |

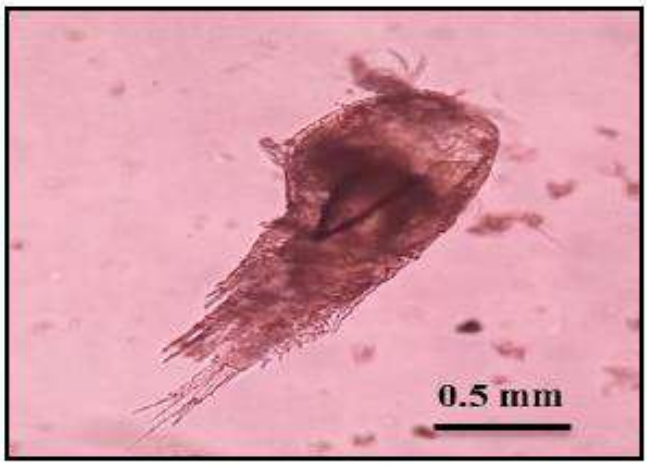
PLATE-II COMMON SPECIES OF ZOOPLANKTON



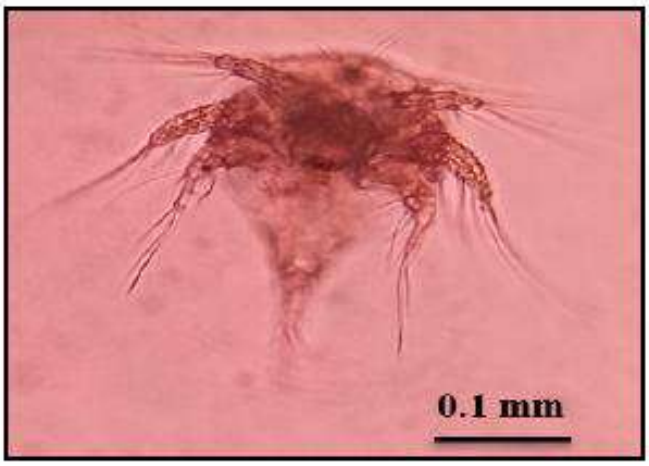

*Paracalanus parvus*



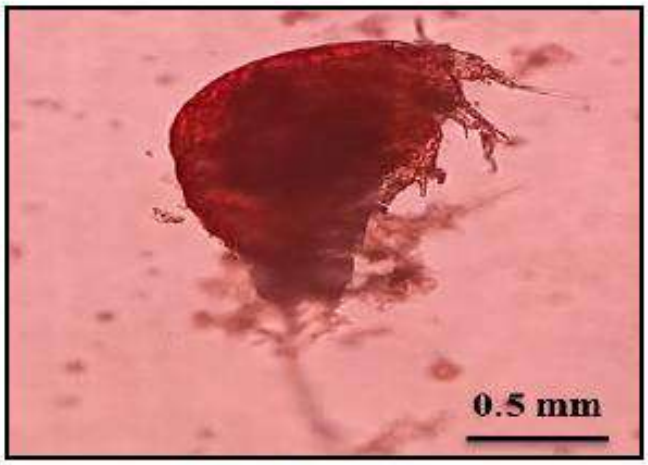

*Acartia danae*



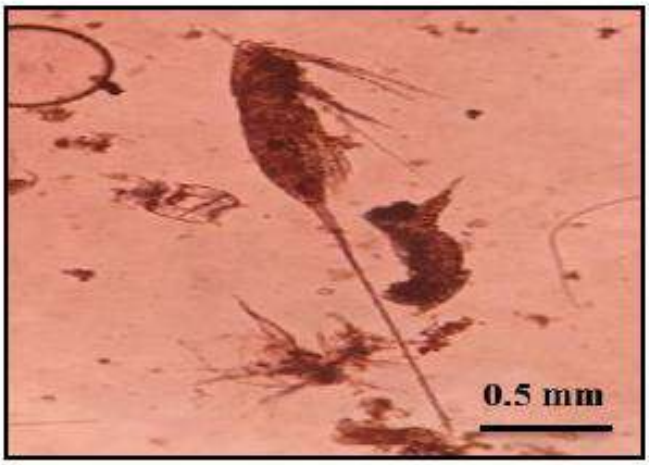

*Corycaeus catus*



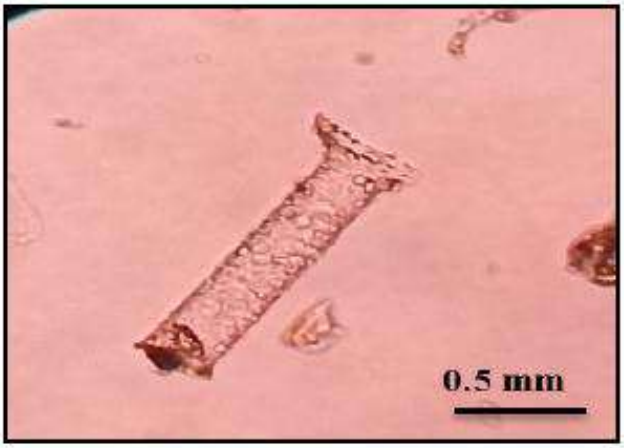

*Copepod nauplii*




*Metis jousseaumei*



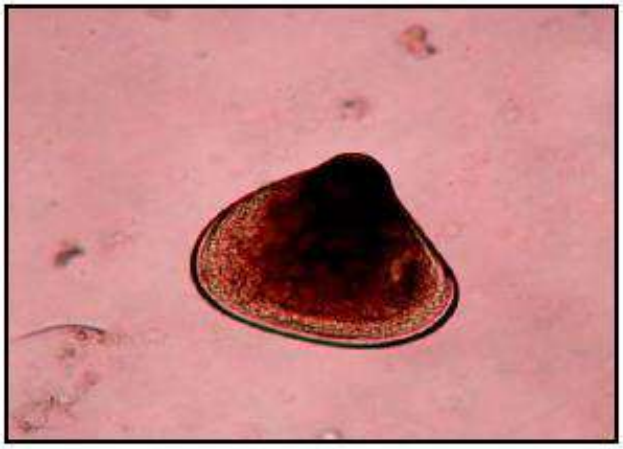

*Microsetella* sp



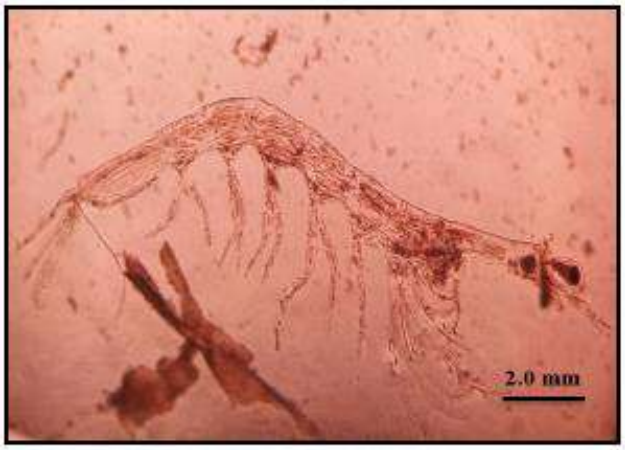

*Tintinnopsis tubulosa*




*Oithona rigida*



*Bivalve veliger*




*Lucifer hanseni*



*Globigerina rubescense*



*Globigerina rubescense*

## 3.9 Benthos

### 3.9.1 Macro-benthos

During the present investigation, four groups of benthic organisms namely Polychaetes, Bivalves, Gastropods and Crustaceans were recorded in various stations in Mahanadi estuary and Paradeep coastal waters. Among them, polychaetes constituted the dominant group followedby bivalves, gastropods and Crustaceans. Altogether, 45 species of macro fauna were recorded from the surveyed stations. Of these, polychaetes topped the list with 26 species. Bivalves were found to be the next dominant group in the order of abundance with 8 species. Gastropods and Crustaceans came next in the order with 8 and 4 species respectively of the total benthic organisms collected during the present study.

Among the polychaetes, Aramantia intermedia, Ancistrolysis robusta, Capitella capitella, Cossura coasta, Etone siphodonta, Eunice siciliensis, Glycera unicornis, Goniada emerita, Minuspio cirriferra, Nephtys dibranchis, Notomastus aberans, Pista brevibranchiata, Poecilochaetes serpens, Polydontes melanonlus, Prionospio cirrifera, Prionospio cirrobranchiata, Prionospio japonica, Prionospio pinnata, Scoloplos johnstoneri and Terebelides stroemi were found to be the most commonly occurring species in the samples collected in Mahanadi estuary and Paradeep coastal waters.. Coming to bivalves Anadara rhombea, Bivalve veliger, Donax incarnatus, Gafrarium tumidum, Meretrix meretrix, Siliqua radiata, Sunettta meroe, and in Gastropods, Cerithedia cingulata, Drillia sacra, Gastropods veliger, Turritella dublicata, Turritella attenuata and Umbonium vestiarium and in Crustaceans, Amphithoe romondi and Crab larvae were found to be the common species in the collection.

### 3.9.2 Population density

The population density varied from 875 to 2575 No m-2 with maximum was at PMS-10 and minimum was PIS-21 (Fig. 49).

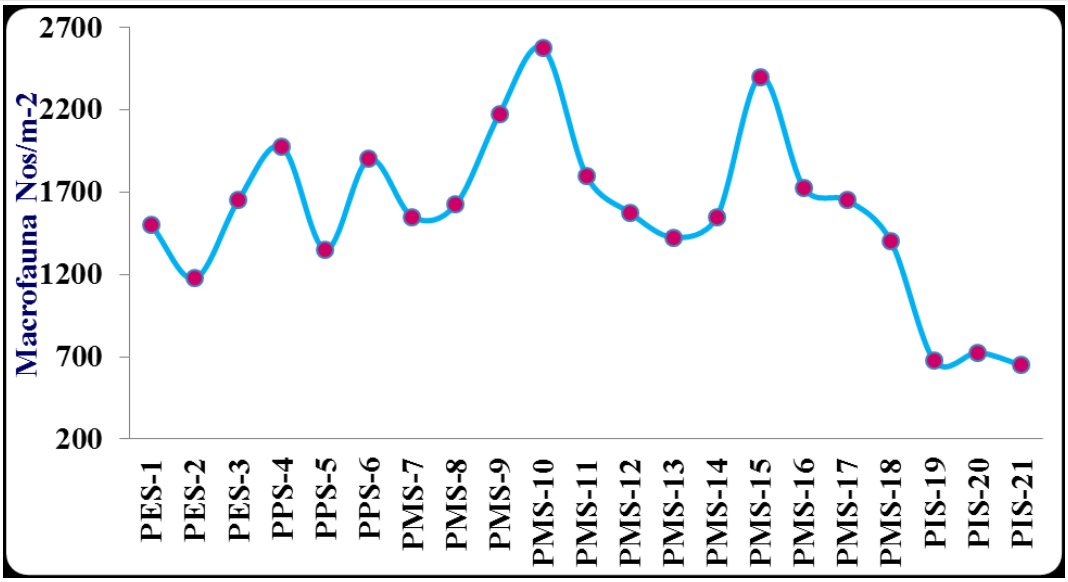



**Figure:49 Population density of Macro benthos in various stations of Estuary and Paradeep coastal waters**

### 3.9.3 Percentage composition

When the results of percentage composition of benthic fauna were viewed, polychaetes constituted the maximum with 63% to the total benthic organisms. Bivalves, Gastropods and Crustaceans contributed to 17%, 10% and 10% respectively to the total benthic faunal community (Fig. 50).

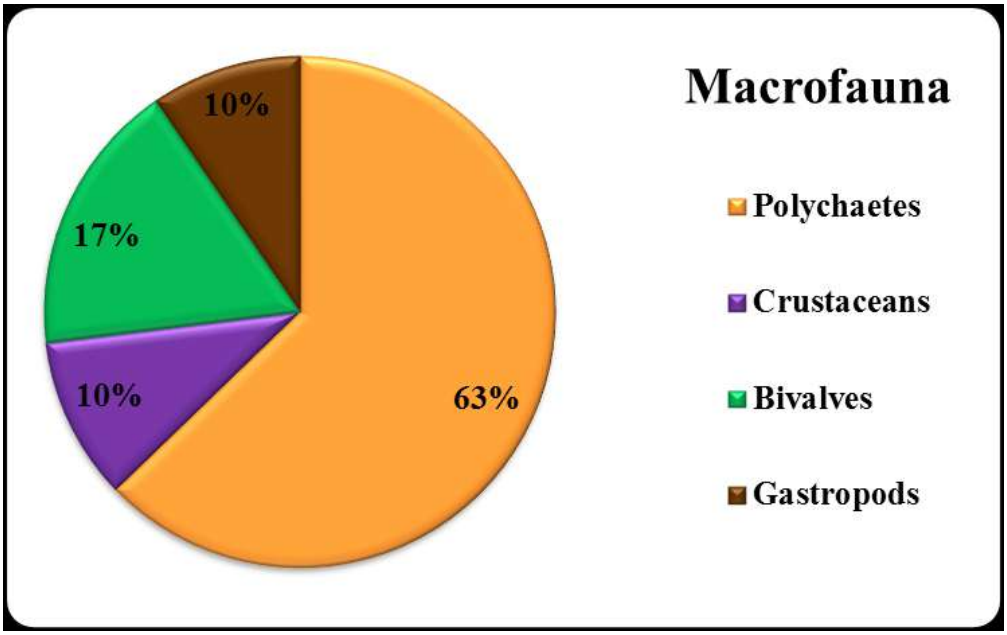



**Figure:50 Percentage composition of macro benthos in various stations of Mahanadi estuary and Paradeep coastal waters**

### 3.9.4 Diversity Indices:

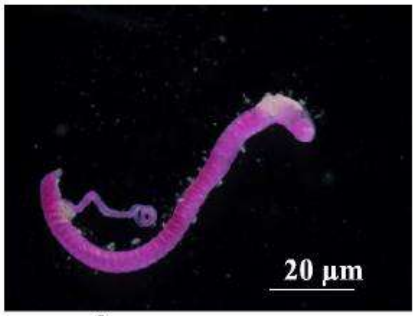
The macro-benthic species diversity (H') varied from 2.355 to 3.627 with maximum was in PMS-10 and minimum in PIS-20. The species richness (d) ranged between 4.223 and 7.845 with maximum in PES-2 and minimum in PMS-16. The species evenness varied from 0.521 to 0.973 with the maximum in PMS-10 and minimum in PES-2 (Table 8).

**Table 8 Diversity indices Shannon diversity (H'); Margalef richness (d) and Pielou's evenness (J') calculated for macro benthos in Mahanadi estuary and Paradeep coastal waters**

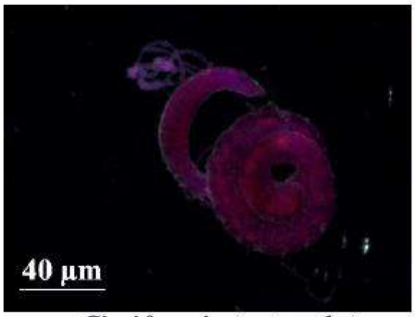
| Stations | Shannon diversity (H') | Margalef richness (d) | Pielou's evenness (J') |
|---|---|---|---|
| PES-1 | 2.461 | 6.248 | 0.544 |
| PES-2 | 2.529 | 7.845 | 0.521 |
| PES-3 | 2.416 | 6.771 | 0.54 |
| PPS-4 | 2.385 | 6.689 | 0.522 |
| PPS-5 | 3.004 | 5.68 | 0.672 |
| PPS-6 | 3.048 | 6.264 | 0.659 |
| PMS-7 | 3.12 | 6.537 | 0.758 |
| PMS-8 | 3.164 | 5.725 | 0.885 |
| PMS-9 | 3.581 | 4.856 | 0.964 |
| PMS-10 | 3.627 | 4.697 | 0.973 |
| PMS-11 | 3.055 | 5.284 | 0.661 |
| PMS-12 | 2.923 | 5.737 | 0.64 |
| PMS-13 | 3.268 | 4.613 | 0.66 |
| PMS-14 | 2.943 | 5.639 | 0.868 |
| PMS-15 | 2.868 | 4.759 | 0.851 |
| PMS-16 | 2.549 | 4.223 | 0.662 |
| PMS-17 | 2.713 | 4.719 | 0.85 |
| PMS-18 | 2.675 | 5.683 | 0.648 |
| PIS-19 | 2.402 | 5.035 | 0.721 |
| PIS-20 | 2.355 | 5.475 | 0.735 |
| PIS-21 | 2.541 | 4.605 | 0.767 |

## PLATE-III MACRO BENTHOS

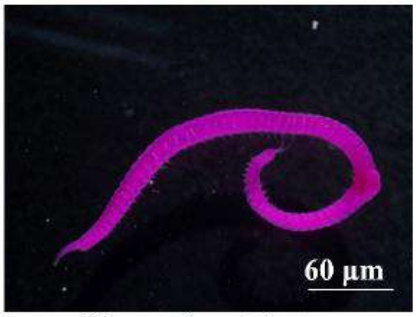
## POLYCHAETES



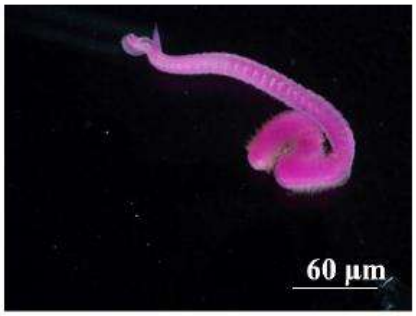

*Cossura* sp.



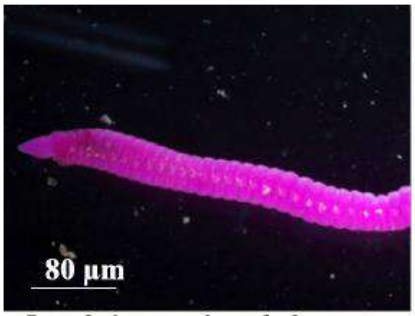

*Cirriformia tentaculata*



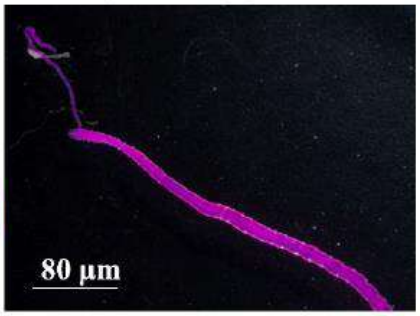

*Glycera longipinnis*




*Goniada* sp.



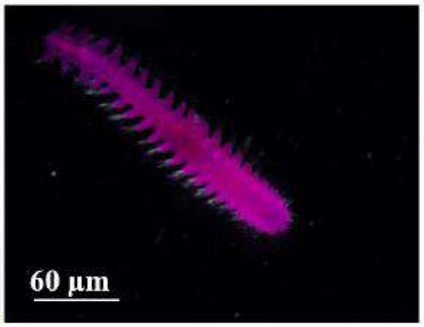

*Lumbriconereis polydesma*



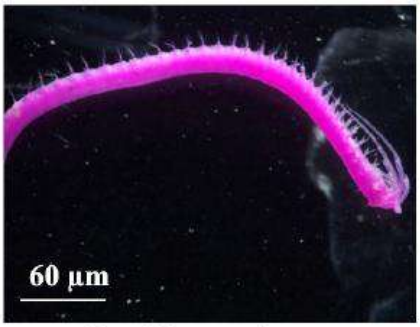

*Magelona* sp.



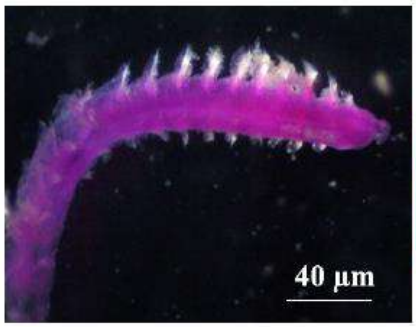

*Eunice* sp.



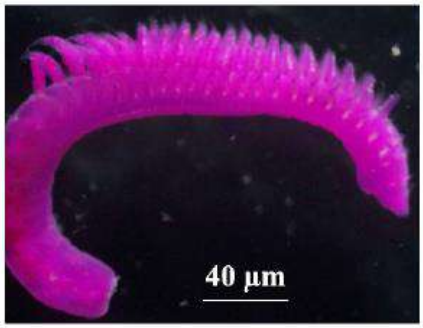

*Nephthys polybranchia*



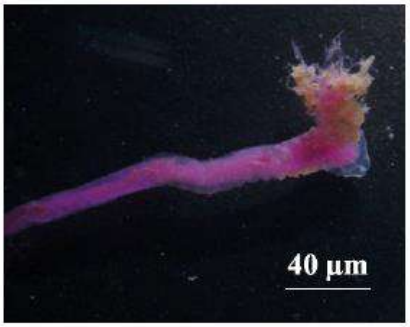

*Onuphis eremita*




*Prionospio pinnata*




*Scoloplos* sp.

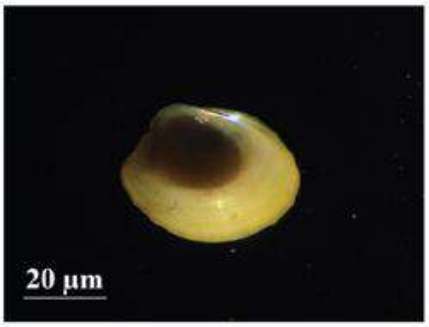



*Terebellides stroemii*

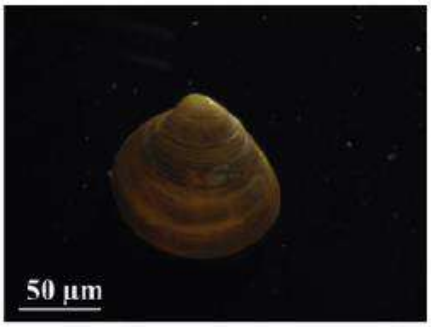
## BIVALVES



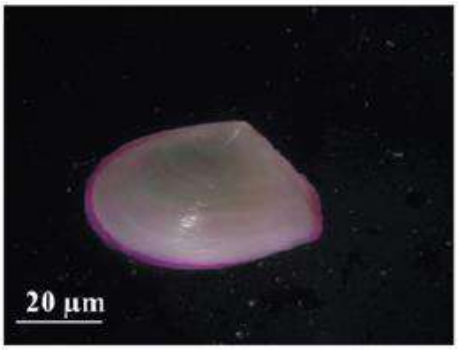

*Donax scortum*




*Meretrix casta*




*Meretrix meretrix*

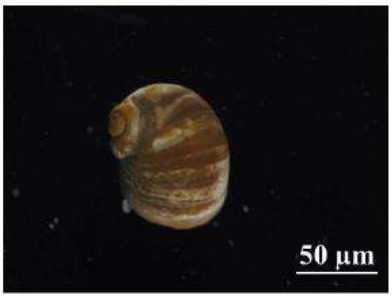



*Tellina angulata*

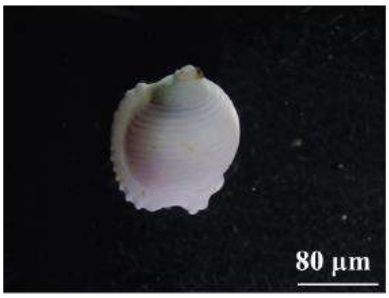
## GASTROPODS




*Nassarius stolatus*



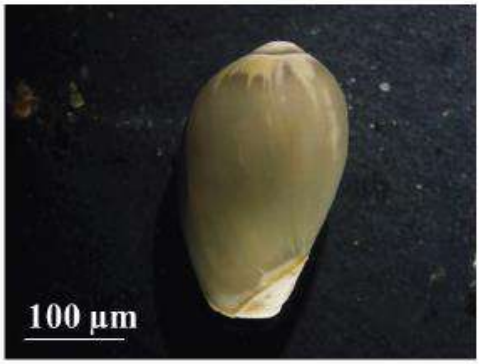

*Neverita didyma*




*Tonna sulcosa*




*Umbonium vestiarium*




*Volvarina angustata*

### 3.9.5 Meio-benthos:

In the present study, as many as 40 species belonging to four groups of Meio-benthic organisms namely Foraminiferans, Nematodes, Ostracodes and Harpacticoids were recorded. Among them, Foraminiferans topped the list with 22 species. Nematodes were found to be the next dominant group in the order of abundance with 8 species and Ostracodes and Harpacticoids came next with 6 and 4 species.

Among the foraminiferans, Ammonia beccarii, Ammonia tepida, Ammodiscus intermedius, Bolivina limbata, Cornuspira foliacea, Discorbinella montereyensis, Elphidium texanum, Globorotalia hirsute, Lagena lacunata, Lagena semistriata, Neouvigerina hispida, Nonion grateloupi, Orbulina universa, Orbitolites adunca, Pararotalia ozawai, Pseudononion japonicum, Quinqueloculina granulocostata, Rosalina globularis, Rosalina orbicularis, Spirillina lateseptata, Spiroloculina excavata, Sorites marginalis, Triloculina tricarinata and Trochammina adaperta were found commonly in various stations. With respect to nematodes, Astomonema jenneri, Daptonema conicum, Draconema cephalatum, Neochromadora craspedota, Halalaimus filum, Theristus acer and Oxystomina clavicauda were found to be the common species in the samples collected in various stations. The Ostracodes species such as Basslerites liebaui, Bairdoppilata scaura, Keijella reticulate, Neocytherideis senescens, Candona candida, Eucythere argus and Stenocypris major and in Harpacticoids, Paramesochra dubia, Canuella perplexa, Euterpina acutifrons, Cylindropsyllus laevis and Laophonte thoracica were found to be common species in the surveyed stations.

### 3.9.6 Population density

The population density of Meio-benthic fauna varied from 108 to 310 Nos.10cm-2 with maximum was recorded at PMS-10 and minimum at PIS-20 (Fig. 51).

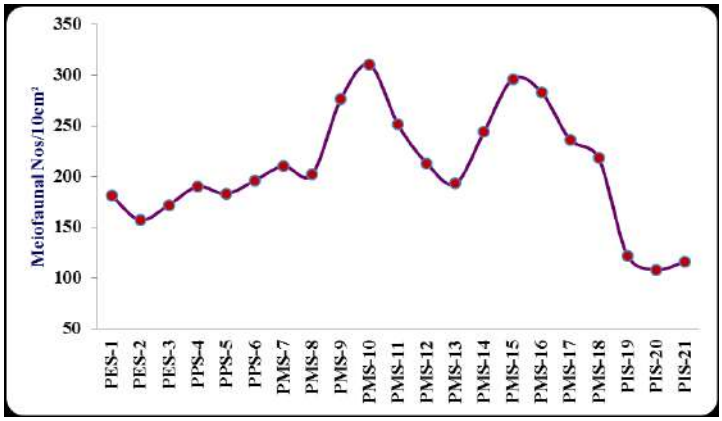



**Figure:51 Population density of Meio-fauna recorded in various stations of Mahanadi estuary and Paradeep coastal waters**

### 3.9.7 Percentage composition:

The results of percentage composition of Meio-fauna revealed that Foraminiferans constituted maximum with 62% of the total Meio-benthic organisms. Nematodes, Ostracodes and Harpacticoids contributed with 16%, 15% and 7% respectively to the total Meio-benthic samples collected (Fig. 52).

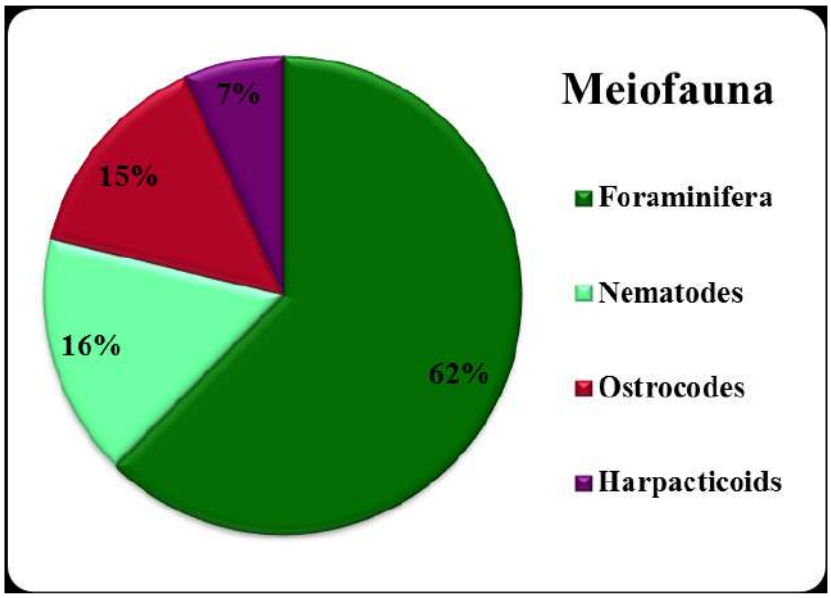



**Figure:52 Percentage composition of Meio-benthos in various stations of Mahanadi estuary and Paradeep coastal waters**

### 3.9.8 Diversity Indices

The Meio-benthic species diversity (H') varied from 2.327 to 3.628 with maximum was in PMS-10 and minimum in PES-2 and similarly the species richness (d) ranged between 4.392 and 7.975 with maximum in PPS-5 and minimum in PIS-21. The species evenness varied from 0.579 to 0.914 with the maximum in PMS-14 and minimum in PES-2 (Table 9).

**Table 9 Diversity indices Shannon diversity (H'); Margalef richness (d) and Pielou's evenness (J') calculated for Meio-benthos in Mahanadi estuary and Paradeep coastal waters**

| Stations | Shannon diversity (H') | Margalef richness (d) | Pielou's evenness (J') |
|---|---|---|---|
| PES-1 | 2.52 | 6.415 | 0.586 |
| PES-2 | 2.327 | 6.634 | 0.579 |
| PES-3 | 2.575 | 7.172 | 0.583 |
| PPS-4 | 2.471 | 7.765 | 0.591 |
| PPS-5 | 2.972 | 7.975 | 0.685 |
| PPS-6 | 3.064 | 6.695 | 0.65 |
| PMS-7 | 3.112 | 6.71 | 0.677 |

| | | | |
|---|---|---|---|
| **PMS-8** | 3.304 | 5.719 | 0.612 |
| **PMS-9** | 3.537 | 4.849 | 0.746 |
| **PMS-10** | 3.628 | 4.943 | 0.766 |
| **PMS-11** | 2.873 | 6.196 | 0.695 |
| **PMS-12** | 2.694 | 6.304 | 0.853 |
| **PMS-13** | 2.982 | 5.872 | 0.865 |
| **PMS-14** | 2.863 | 6.153 | 0.914 |
| **PMS-15** | 3.011 | 5.057 | 0.726 |
| **PMS-16** | 2.928 | 4.895 | 0.805 |
| **PMS-17** | 2.941 | 4.829 | 0.718 |
| **PMS-18** | 3.279 | 5.679 | 0.874 |
| **PIS-19** | 3.265 | 4.567 | 0.583 |
| **PIS-20** | 3.398 | 4.723 | 0.715 |
| **PIS-21** | 3.478 | 4.392 | 0.744 |

### 3.9.9 Cluster analysis

To find out the similarity/dissimilarity between stations, as done for plankton data, the benthic faunal abundance data (macrofauna and meiofauna) were amalgamated and subjected to classification and ordination methods. The resulting dendrogram revealed that the stations stations coastal regions PMS-6, PMS-7, PMS-8, PMS-9, PMS-10, PMS-11, PMS-12 PMS-13 PMS-14 PMS-15, PMS-16, PMS-17 and PMS-18 were forming cluster separately based on the species composition and abundance. Similarly, the stations estuarine, Intertidal and Port regions PES-1, PES-2, PES-3, PPS-4, PPS-5, PPS-6, PIS-19, PIS-20 and PIS-21 also formed separate cluster (Fig. 53). This fact was further confirmed through MDS, which was also revealed the same pattern of groupings as observed in cluster analysis. The stress value (0.19), which is overlying on the top-right corner of the MDS plot, was also found to be low signifying the good ordination pattern of the samples (Fig. 54).

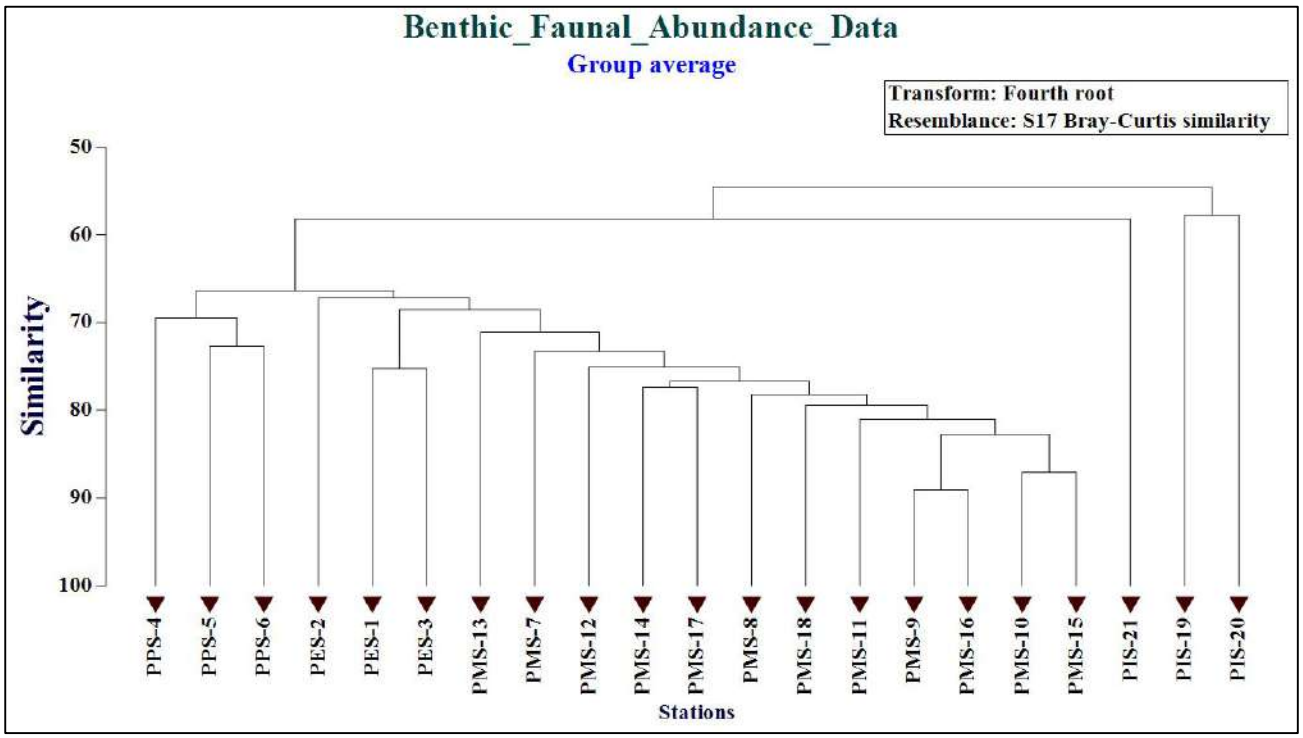



**Figure:53 Dendrogram for the benthic faunal abundance data collected in Mahanadi estuary and Paradeep coastal waters**

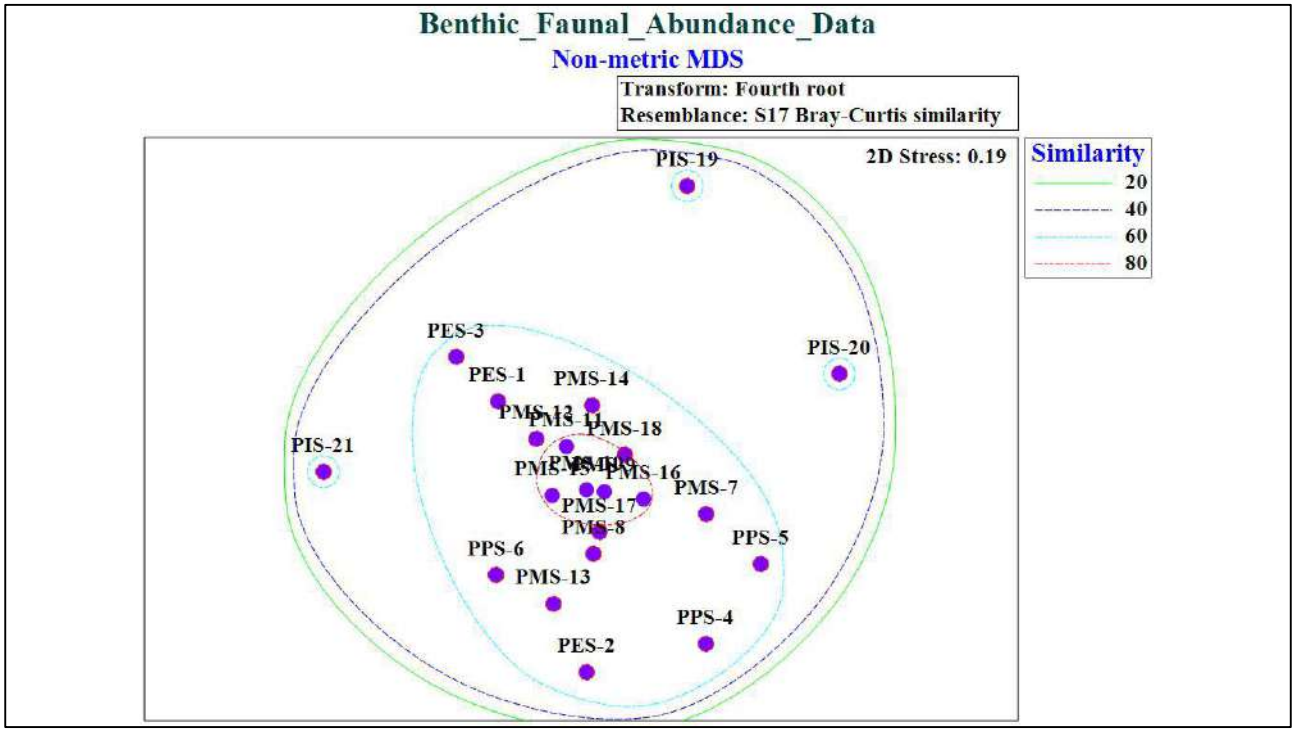



**Figure:54 MDS drawn for the benthic faunal abundance in various Mahanadi estuary and Paradeep coastal waters**

### 3.9.10 BIO-ENV (Biota-Environment matching)

As done for plankton data, the BIO-ENV matching was employed to measure the rank correlations of the benthic faunal abundance (Bray-Curtis similarity) and environmental (Euclidean distance) matrices as well. For this, eleven environmental variables (Temperature, Salinity, W. pH, Silt, Sand, Clay, DO, TOC, S. pH, Evenness, Richness and Diversity) were allowed to match the biota. The results revealed that, a combination of eight environmental parameters ($p\omega = 0.948$) namely Salinity, Dissolved Oxygen, S. pH, Sand, Diversity, Evenness, Clay and TOC got manifested as best match in determining benthic faunal distribution followed by Salinity, S. pH, Dissolved Oxygen, Clay, TOC, Sand, Diversity and Evenness ($p\omega = 0.891$) which also got manifested as second best variable combinations, in determining the faunal distribution in the Mahanadi estuary and Paradeep coastal waters (Table 10).

**Table 10 Harmonic rank correlations (pω) between benthic faunal (both Macro-benthos and Meio-benthos) abundance against environmental variables in Mahanadi estuary and Paradeep coastal waters**

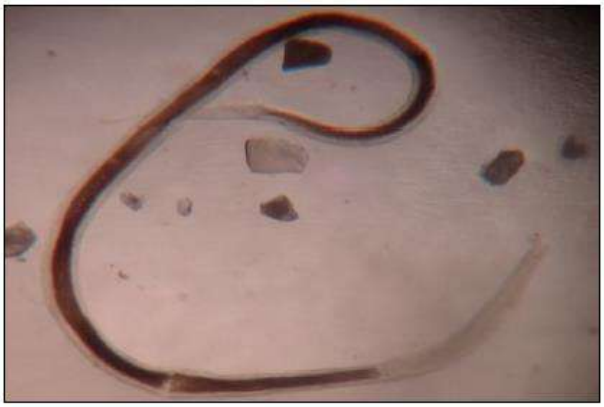
| No. of variables | Best variable combinations | Correlation (pω) |
|---|---|---|
| 8 | Salinity – Dissolved Oxygen – S. pH – Sand – Diversity – Evenness – Clay – TOC | 0.948 |
| 8 | Salinity – S. pH – Dissolved Oxygen – Clay – TOC – Sand – Diversity – Evenness | 0.891 |
| 7 | Dissolved Oxygen – W. pH – Salinity – Sand – TOC – Diversity – Evenness | 0.825 |
| 7 | Salinity – W. pH – Dissolved Oxygen – Clay – TOC – Sand – S. pH | 0.794 |
| 6 | Salinity – Dissolved Oxygen – Clay – TOC – Evenness – Diversity | 0.768 |

## PLATE-IV MEIO-BENTHOS

## NEMATODES



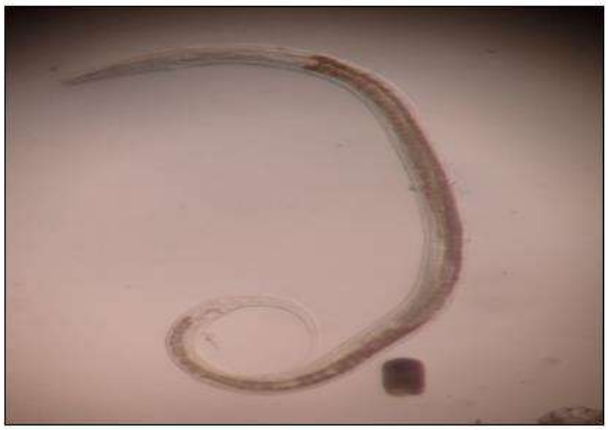
*Halalaimus filum*



*Oxystomina clavicauda*



*Neochromadora craspedota*



*Daptonema conicum*



*Epsilonema steiner*

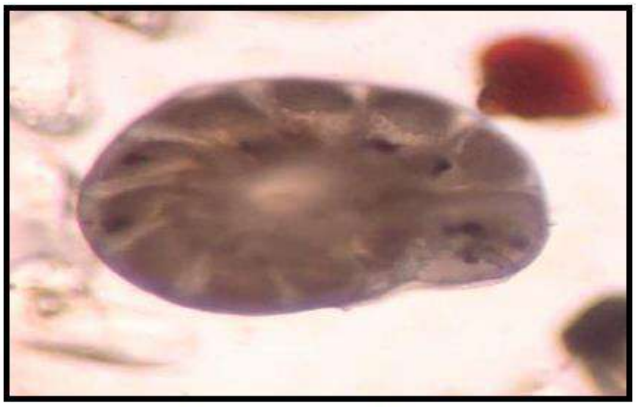


*Desmodora cambelli*

## FORAMINIFERANS



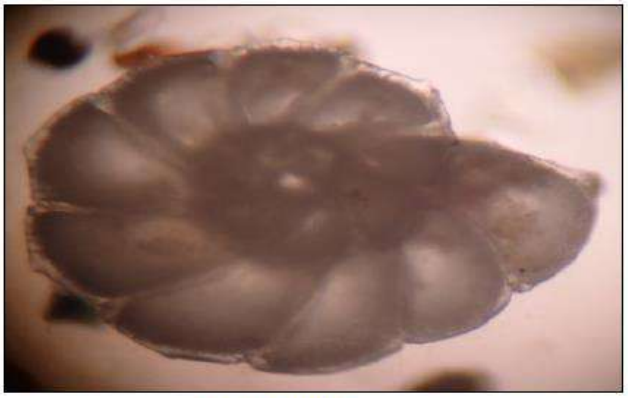
*Spiroloculina excavata*



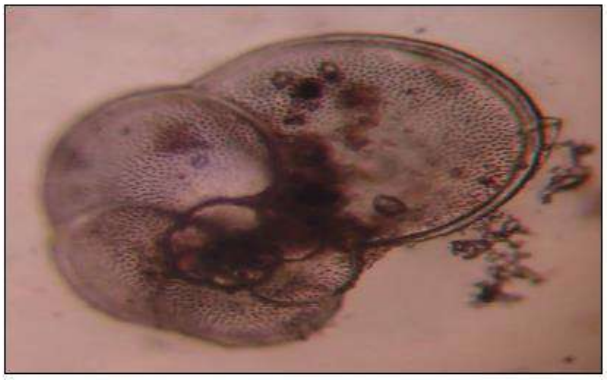
*Ammonia tepida*



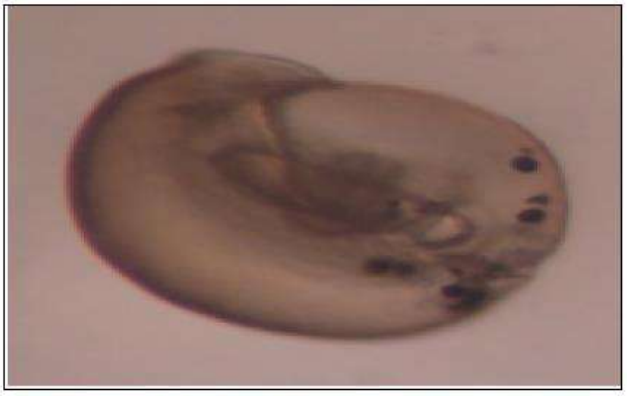
*Nonion depressulus*



*A. beccarii*



*Rosalina globularis*



*Miliolinella subrotunda*

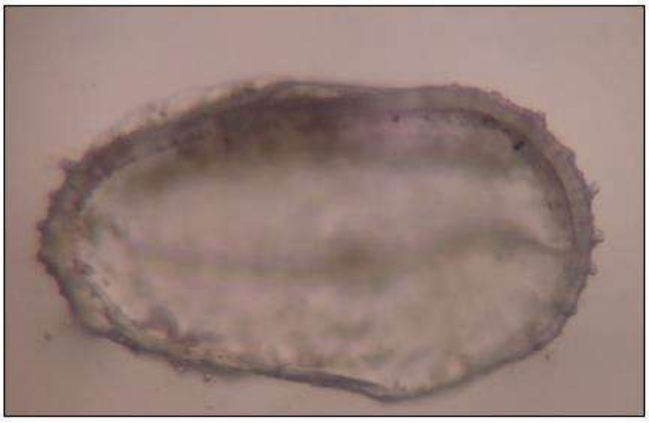
## OSTRACODES



*Parastenocypris canaliculata*



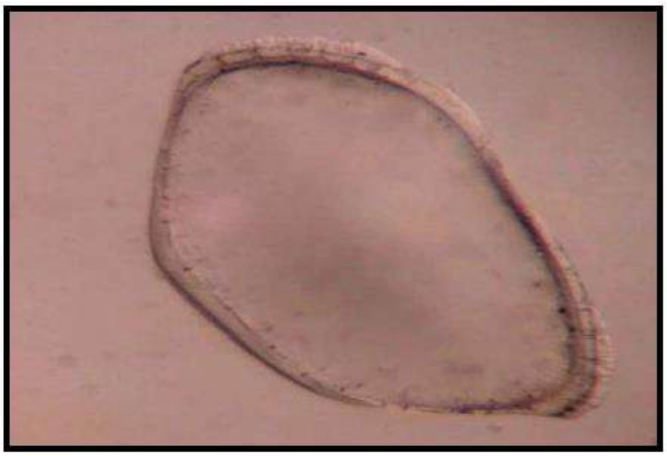
*Stigmatocythere indica*



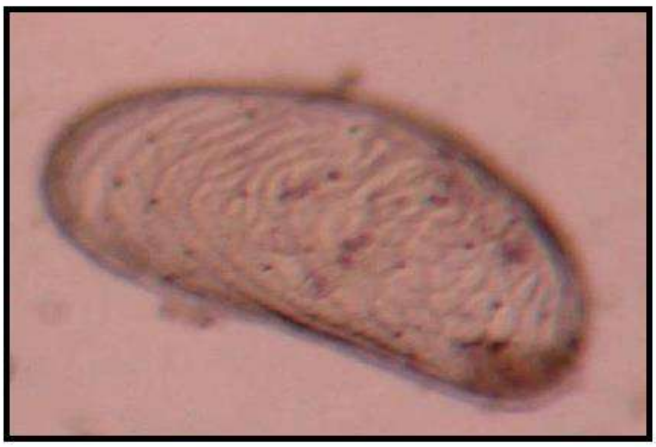
*Echinocythereis* sp.



*Keijella reticulata*

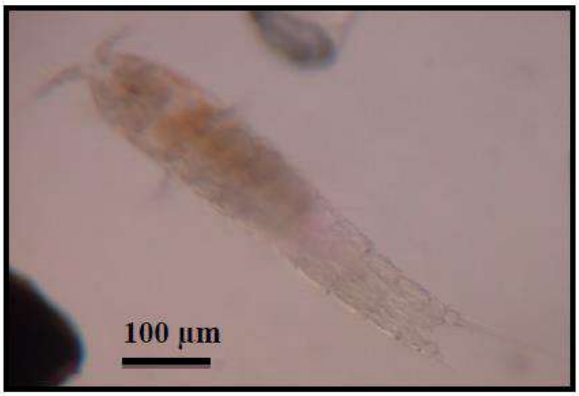


*Microcytherura nigrescens*



*Cytheronorph fuscata*

**HARPACTICOIDS**




*Laophonte thoracica*




*Harpacticus chelifer*

### 3.10 Other Ecologically Sensitive Fauna and Flora

#### 3.10.1 Mangroves

In Paradeep, the mangroves are best tidal forest and fall in arid regions and semi-arid regions where evapo-transpiration and mean annual rainfall decide quality of the vegetation. Climatic conditions in this region are not very favorable for the development of the tidal forests of outstanding quality, hence only few species of mangroves grow this coast. A patchy occurrence of mangroves species such as Avicennia marina, Rhizophora stylosa, Rhizophora mucronata, were observed, that is away from the project site.

#### 3.10.2 Corals

No coral or any associated reef has been reported along the surveyed stations of the project region.

#### 3.10.3 Turtles

The Odisha coast sustains the largest congregation of olive ridley turtles, and is among the only three mass nesting grounds of the world; this phenomenon of mass nesting is called the

Arribada-a Spanish term for mass arrival. Turtles, such as Chelonia mydas, Eretmochelys imbricata and Dermochelys coriacea have also been sighted off the shores of Odisha. However, only olive ridley has been reported to nest in the Paradeep coast, Odisha (Kar and Bhaskar, 1982; Kar, 1988, Dash and Kar, 1990; Pandav et al. 1997). During this survey, no organized nesting Laophonte thoracica Harpacticus chelifer 100 µm 100 µm area was observed but the local residents advocated that Olive Ridley Sea turtles (Lepidochelys olivacea) nests are observed oddly between December-March. The lesser incidence of turtle nesting in the

surveyed area may be due to the fact that the inter-tidal area is dominated bymuddy substratum besides scanty occurrence of mangroves.

### 3.10.4 Other Endangered Species

The other endangered species like Sea horse, Indian otter, Salt water crocodile and etc., were not sighted during the survey.

### 3.10.5 Avifauna

In the project region, a few common bird species were recorded. They are Black-headed Ibis, Black-necked Stork, Lesser Sand Plover and Indian Roller.

### 3.10.6 Seaweeds and sea grass

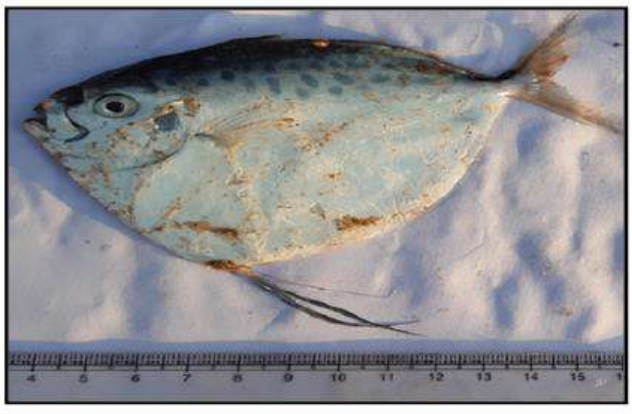
A patchy occurrence of the following seaweed and seagrass species found near the surveyed stations: Gracilaria verrucosa, Cladophora sericea and Gelidium divaricatum.

### 3.10.7 Fisheries

*Dasyatis zugei, Arius arius, Plicofollis tenuispinis, Caranx para, Decapterus russelli, Scomberoides lysan, Scomberoides tala, Lepturacanthus savala, Nemipterus bipunctatus, Secutor insidiator, Sillago sihama, Leiognathus equulus and Rastrelliger kanagurta. The other common species were Liza macrolepis, Mugil cephalus, Polynemus tetradactylus, Thryssa hamiltonii, Lepturacanthus savala, Parapenaeopsis stylifera, Penaeus monodon, P. merguiensis, Metapenaeus monoceros, M. brevicorins, Portunus pelagicus, Portunus sanguinolentus, Charybdis sp., Podophthalmus sp. and Charybdis cruciate were the commonly recorded fishes.*

Crustacean resources like prawns, lobsters & crabs formed an important commercial catch for the local fishing community.

**COMMERCIALLY IMPORTANT FISHES**



*Mene maculate*



*Platax orbicularis*



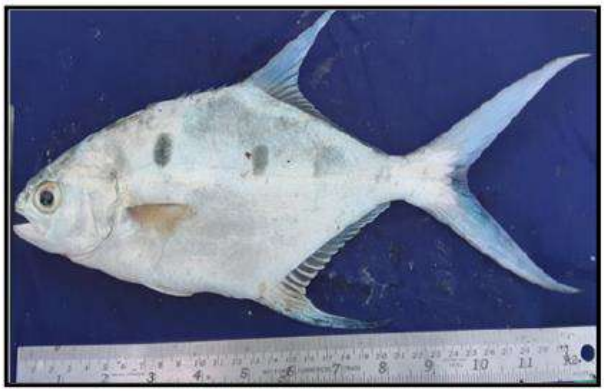
*Rhabdosargus sarba*



*Xanthichthys ringens*



*Lates calcarifer*



*Trachinotus blochii*

## 4.0 SUMMARY AND CONCLUSION

In the present survey, which lasted for four days, the physico-chemical and biological parameters were analyzed both in the water and sediment samples from predetermined (3 intertidal and 18 coastal stations) locations of Mahanadi estuary and Paradeep coastal waters. As such, the physico-chemical parameters did not show much variation barring a few parameters which showed only marginal variations. The results of various parameters are summarized below:

The surface water temperature varied from 27.5 to 32.0°C. The salinity varied from 27.0 to 35.3PPT. Hydrogen ion concentrations in surface waters remained alkaline and the maximum value of 8.41 was recorded at PMS-10. The observations made on the key physical factors such as TSS and turbidity was within the safe level. The turbidity ranged between 4.1 and 6.6NTU. The TSS values fluctuated from 60.60 and 122.60ppm. The maximum TSS and turbidity values were at PPS-5 and minimum at PMS-11. The variation noticed between the stations is only marginal, which might be due to seasonal, geographical location and tidal influence.

The range of ecologically sensitive chemical parameters such as Dissolved Oxygen, BOD, nutrients were also at the optimal concentration conforming to the seasonal trend. The oxygen level fluctuated from 3.41 and 5.69mg/l, with the maximum DO level was recorded at PMS-13 and the minimum was recorded at PPS-5. The DO concentration remained fairly well within the prescribed limit of water quality. The BOD level was found to be ranged from 1.37 and 2.50mg/l with the maximum BOD was observed at PPS-5 during this survey.

In the present investigation, the ammonical nitrogen concentration ranged between 0.08 and 0.23µmol/l. The concentration of nitrite fluctuated from 0.94 to 2.17 µmol/l. The nitrate values ranged from 2.65 to 4.18µmol/l and the total nitrogen varied between 13.52 to 19.42µmol/l. The inorganic phosphate ranged from 0.48 and 0.99µmol/l. The observed total phosphorus values ranged between 1.01 to 2.83µmol/l. The silicate concentration ranged from 25.34 and 58.25µmol/l. The particulate organic carbon values ranged from 77.30 and 139.21µgC/l respectively.

In the present survey, Petroleum Hydrocarbons in water varied between 0.16 and 0.37µg/l. with higher concentration was at station PPS-5. The total organic carbon content varied from 2.14 and 10.97mgC/g with the maximum was at PES-2 and minimum at PIS-21. The present survey showed that the Petroleum hydrocarbon relatively higher in sediment than the water and the values ranged from 0.113 to 0.584µg/g. The maximum was recorded at PPS-5 and the minimum was recorded at PIS-20 during this survey.

The level of metal concentrations recorded in the present study is comparatively lesser than the earlier reports from the study area except for Iron. The sediment Iron concentration was found to be higher (1128.90 to 1820.10µg/g) compared to iron concentration in water (11.07 to 19.30µg/L). The maximum was recorded at PES-2 and the minimum was recorded at PMS-15. In general, areas experiencing high shipping and boating operations are usually to record higher Iron concentration. The concentration in coastal sediment samples indicates that it is well within the ERM (Effective Range Median) which mean there are no possibilities of Heavy metal contamination in the region.

The sand, silt and clay fraction at each station along with their textural classification indicated that the Sand and Clay percentage was higher during this survey. Principal Component Analysis (PCA) is considered to be effective as they can reveal information from data sets containing larger amounts of variance, simultaneously considering the inter-relationships of several influential variables. Further, this method also allows us to analyse patterns in biotic data and to relate biotic patterns to spatio-temporal environmental variables

(Field et al., 1987). It is understood that environmental factors can modify, support or augment each other by acting independently or in tandem as has been stated by Kinne (1964).

The PCA plot drawn for the physico-chemical parameters collected in water samples were subjected to Principle component analysis to set a well-defined relation between the environmental parameters against the surveyed stations. The PCA plot drawn indicated that water parameters such as Temperature, DO, Salinity, pH, TN, TP, SiO3, POC, W.PHC, Cu, TOC, Mn, Fe, Pb sand and Cr had significant correlation with the surveyed stations. Looking at the nature of correlation, the parameters such as Temperature, DO, salinity, pH, TN, TP, SiO3, Chl-a, TOC, clay, sand, Fe and Mn got correlated with stations PMS-7, PMS-8, PMS-9, PMS- 10, PMS-11, PMS-12, PMS-14, and PMS-16 while the rest of the parameters showed strong correlation with stations PMS-13, PES-1, PES-2, PES-3, PPS-4, PPS-6 and PPS-5 significantly correlated with other parameters. Similar combinations of parameters with stations were also obtained earlier from Chennai coast by Mohanty et al. (2014).

The microbial population showed typical seasonal trend in water and sediment samples during this survey. The maximum colony count was observed in sediment when compared to the water samples.

In the present study, the chlorophyll ‘a’ in water sample varied from 0.886 to 1.956 mg/m3, with maximum at PMS-15 and minimum at PES-2. The Phaeopigments content varied from 0.538 to 0.971 mg/m3 with maximum was at PMS-15 and the minimum was observed at PES-2. The Total biomass values varied from 2.106 to 4.615 ml/100m3, with maximum at PMS- 9 and minimum at PPS-4. The primary productivity was measured using the dark and light reaction method. The values ranged from 116.37 to 157.06mgCm-3d-1. The maximum value was recorded at PMS-15 and minimum value at PES-2.

Density of phytoplankton varied from 6,915 to 11,228 Cells/l with maximum was at PMS-10 and minimum at PES-2. In the present study, as many as 49 phytoplankton species belonging to three major groups namely Bacillariophyceae (Diatom), Dinophyceae (Dinoflagellates) and Cyanophyceae (Cyanobacteria) were recorded in Thiruvottiyurkuppam coastal area. Of these, Bacillariophyceae were found to be the dominant group with 36 species, Dinophyceae formed next group with 10 species and Cyanophyceae with three species.

The phytoplankton species diversity (H’) varied from 2.365 to 3.811 with maximum at PMS-10 and minimum at PES-2. The species richness (d) ranged between 4.528 and 6.879 with maximum at PPS-5 and minimum at PMS-15. The species evenness varied from 0.545 to 0.924 with the maximum at PMS-15 and minimum at PES-2.

The zooplankton density varied from 4888 to 6680Nos/m3 with maximum at PMS-15 and minimum at PES-2. During the survey, 6 groups of macro zooplankton namely, Calanoid copepod, Cyclopoid copepod, Harpacticoid copepod, Oligotrichea, Foraminifera and Other Crustacean forms and 4 groups of micro zooplankton namely, Mollusca, Chaetognatha, Decapoda and Annelida were recorded. In them, Calanoid Copepod was found to be the dominant group with 13 species. Cyclopoid copepod and Harpacticoid copepod came as next dominant group with 6 species each. The Spirotrichea, Protozoans and Other Crustacean forms were observed with 4 species from each group, Rotatoria and Larvacean were observed with 2 species, Mollusca, Cladocera, Decapoda and Annelida were recorded 1 species from each division of total zooplankton abundance.

As done for phytoplankton, the zooplankton species diversity (H') varied from 2.592 to 3.846 with maximum in PMS-16 and minimum in PPS-5. The species richness (d) ranged between 4.873 and 7.186 with maximum in PES-2 and minimum in PMS-9. The species evenness varied from 0.645 to 0.941 with the maximum in PMS-10 and minimum in PES-2.

The abundance data of phytoplankton and zooplankton were amalgamated and subjected to classification and ordination methods. The resulting dendrogram revealed that the stations coastal regions PMS-6, PMS-7, PMS-8, PMS-9, PMS-10, PMS-11, PMS-12 PMS-13 PMS-14 PMS-15, PMS-16, PMS-17 and PMS-18 were forming a cluster based on the species composition and abundance. Similarly, the stations within the estuarine and Port regions PES-1, PES-2, PES-3, PPS-4, PPS-5 and PPS-6 also formed separate cluster. This fact was further confirmed through MDS, which was also revealed same pattern of groupings as observed in cluster analysis. The grouping of stations might be based on the variation in species composition in nearshore and off-shore besides fluctuations in environmental variables between the stations as evidenced by Sahu et al. (2010); Robin et al. (2013) from Chennai coastal waters; Janakiraman et al. (2013); Baliarsingh et al. (2014) and Srichandan et al. (2015) from east coast of India.

The BIO-ENV results indicated that the parameters such as Temperature, Salinity, Dissolved Oxygen, W. pH, Total phosphate, Total Nitrogen, Chlorophyll 'a', Silicate, Primary productivity and Total biomass were featured as the major variables explaining the best match ($p\omega$= 0.915) with plankton (both phytoplankton and zooplankton) distributions. The other parameters such as W. pH, Total Nitrogen, Total phosphate, Silicate, Salinity, Chlorophyll 'a', Dissolved Oxygen and Primary productivity ($p\omega$ = 894) which also got manifested in the next

best variable combinations in determining the plankton distribution in Mahanadi estuary and Paradeep coastal waters. This view point agrees well with the earlier works as they have pointed out that these parameters are the most important factor in determining the distribution of phytoplankton and zooplankton abundance in estuarine environments (Juggins, 1992; Hassan et al., 2007).

With respect to benthos, the population density varied from 875 to 2575 No m-2 with maximum was at PMS-10 and minimum at PIS-21. During the present investigation, four groups of benthic organisms namely Polychaetes, Bivalves, Gastropods and Crustaceans of organisms were recorded in various stations in Mahanadi estuary and Paradeep coastal waters. Among them, polychaetes constituted the dominant group followed by bivalves, gastropods and Crustaceans. Altogether, 45 species of macro fauna were recorded from the surveyed stations. Of these, polychaetes topped the list with 26 species. Bivalves were found to be the next dominant group in the order of abundance with 8 species. Gastropods and Crustaceans came next in the order with 8 and 4 species of the total benthic organisms collected during the present study.

The macro-benthic species diversity (H') varied from 2.355 to 3.627 with maximum was in PMS-10 and minimum in PIS-20. The species richness (d) ranged between 4.223 and 7.845 with maximum in PES-2 and minimum in PMS-16. The species evenness varied from 0.521 to 0.973 with the maximum in PMS-10 and minimum in PES-2.

Regarding meiobenthic organisms, the population density of Meio-benthic fauna varied from 108 to 310 Nos.10cm-2 with maximum was recorded at PMS-10 and minimum at PIS-20. In the present study, as many as 40 species belonging to four groups of Meio-benthic organisms namely Foraminiferans, Nematodes, Ostracodes and Harpacticoids were recorded. Among them, Foraminiferans topped the list with 22 species. Nematodes were found to be the next dominant group in the order of abundance with 8 species and Ostracodes and Harpacticoids came next with 6 and 4 species.

The Meio-benthic species diversity (H') varied from 2.327 to 3.628 with maximum was in PMS-10 and minimum in PES-2 and similarly the species richness (d) ranged between 4.392 and 7.975 with maximum in PPS-5 and minimum in PIS-21. The species evenness varied from 0.579 to 0.914 with the maximum in PMS-14 and minimum in PES-2.

The resulting dendrogram revealed that the stations coastal regions PMS-6, PMS-7, PMS-8, PMS-9, PMS-10, PMS-11, PMS-12 PMS-13 PMS-14 PMS-15, PMS-16, PMS-17 and

PMS-18 were forming cluster separately based on the species composition and abundance. Similarly, the stations estuarine, Intertidal and Port regions PES-1, PES-2, PES-3, PPS-4, PPS-5, PPS-6, PIS-19, PIS-20 and PIS-21 also formed separate cluster. This fact was further confirmed through MDS, which was also revealed the same pattern of groupings as observed in cluster analysis. The stress value (0.19), which is overlying on the top-right corner of the MDS plot, was also found to be low signifying the good ordination pattern of the samples. Similar groupings in intertidal and inshore waters were reported earlier by various researchers (Ajmal Khan et al. 2005; Tolhurst and Chapman, 2007 and Martins et al., 2016).

The BIO-ENV matching indicated that the combination of eight environmental parameters ($p\omega = 0.948$) namely Salinity, Dissolved Oxygen, S. pH, Sand, Diversity, Evenness, Clay and TOC got manifested as best match in determining benthic faunal distribution followed by Salinity, S. pH, Dissolved Oxygen, Clay, TOC, Sand, Diversity and Evenness ($p\omega = 0.891$) which also got manifested as second best variable combinations, in determining the faunal distribution in the Mahanadi estuary and Paradeep coastal waters. True to its sense, in a study made by Murugesan (2002), Muthuvelu (2013) and Sivaraj (2014) reported the similar combinations of environmental variables influencing the macro-benthic and meio-benthic faunal distribution.

With respect to ecologically sensitive groups, the presence of patchy stunted mangrove, Avicennia marina, Avicennia alba Rhizophora mucronata, were observed in the nearby regions. No coral or any associated reef has been reported along the surveyed stations of the project region. During this survey, no organized nesting area was observed but the local residents advocated that Olive Ridley Sea turtles (Lepidochelys olivacea) nests are observed oddly between December-March. The lesser incidence of turtle nesting in the surveyed area may be due to the fact that the inter-tidal area is dominated by muddy substratum besides scanty occurrence of mangroves.

In the project region, a few common bird species were recorded. They are Black-headed Ibis, Blue Rock Pigeon, Lesser Sand Plover and Indian Roller.

The proposed area was found to have very poor coastal floral growth, as the sandy/muddy substratum is associated with relatively high turbidity which does not support the species. The survey conducted indicated the presence of Seaweed species such as Gracilaria verrucosa, Cladophora sericea and Gelidium divaricatum. Observations made on fish landing center, revelaed 44 species of fin fishes, prawns, Squilla, crab, other crustaceans, and cephalopods. Dasyatis zugei, Arius arius, Plicofollis tenuispinis, Caranx para, Decapterus

russelli, Scomberoides lysan, Scomberoides tala, Lepturacanthus savala, Nemipterus bipunctatus, Secutor insidiator, Sillago sihama, Carcharhinus macloti, Stolephorus commersonii, Cynoglossus arel, Synaptura albomaculata, Pseudorhombus elevatus, Himantura uarnak, Lagocephalus lunaris, Triacanthus biaculeatus, Leiognathus equulus and Rastrelliger kanagurta. The other common species were Liza macrolepis, Mugil cephalus, Polynemus tetradactylus, Thryssa hamiltonii, Lepturacanthus savala, Parapenaeopsis stylifera, Penaeus monodon, P. merguiensis, Metapenaeus monoceros, M. brevicorins, Portunus pelagicus, Portunus sanguinolentus, Charybdis sp., Podophthalmus sp. and Charybdis cruciate were the commonly recorded fishes.

Further, the diversity indices calculated for the plankton and benthic data in the present study showed undisturbed nature of the environment since diversity values of plankton and benthos were more than 2.5 as has been stated by the Marine ecologist Sanders (1968). The macro benthic conservative species Armandia sp., Glycera longipinnis, Goniada emerita, Spiochaetopterus costarum, Nereis sp. were predominantly occurred in the Mahanadi river Paradeep coastal waters which reflect the stable nature of the ecosystem.

Further, the results of physico-chemical and biological parameters indicated that the water is well oxygenated and nutrients are adequate supporting fairly good plankton population, the base in the food chain. Not only is that, the metal concentration in coastal water and sediment samples indicates that it is well within the ERM (Effective Range Median) values (Long et al., 1995) which means there is no possibilities of heavy metal contamination in the region.

In short, the results of marine ecological survey made during 26th to 29th January 2024 Mahanadi estuary and Paradeep coastal waters and careful perusal of the available information suggested that the water quality parameters are within the safe level and did not indicate any alarming impact on the existing biological components. The analysis on other ecologically sensitive organisms reflected the patchy occurrence of a few groups especially seaweeds from the nearby regions. The discharges occurring from the proposed facility will result in only marginal impacts on biota but such impacts are confined to a limited period since most of the marine organisms are capable of recouping themselves quickly to its original form and thus there will not be any pronounced change to the biotic community. Further, the present marine survey was done only short period, continuous monitoring is also needed even after commissioning of this proposed facility with a view to ascertain the temporal variations in the physico – chemical and biological components of this environment, if any.

# ANNEXURE VII

# MODELING REPORT

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## EXECUTIVE SUMMARY

Dredging Corporation of India Ltd. had entrusted the task of preparation of detailed project report (DPR) for reclamation work for the development of land for industrial activities at Paradip. Modeling report addresses two cases for the consequence assessment of the dredging and reclamation activities. These cases delve into hydrodynamic modelling and siltation assessment for the reclamation project aimed at industrial land development in Paradip. Modeling report consists of five sections with complete details of mathematical studies on hydrodynamics and morphodynamics along with advection dispersion study. In order to provide a credible analysis of tidal hydrodynamics, advection dispersion and siltation in the study area, 2D hydrodynamic, morphodynmaic and advection dispersion model studies were carried out. The numerical model study covers the areas of the proposed borrow area including portion of outer channel, sand trap, sand bar, harbour basin and inner basin area as per JSW layout. It is noteworthy that the breakwater is excluded from this study due to its extended timeline for breakwater construction, whereas dredging and reclamation project is scheduled for completion within a shorter time frame. The following aspects were derived.

- Details of impact on hydrodynamics in the proposed borrow area considered in this study for two different cases considered.
- Credible analysis of siltation phenomenon for two cases.
- Advection dispersion study was conducted to assess the implications of return slurry during the reclamation process

Based on modeling results, dredging activities within the study domain has not significantly altered current conditions, suggesting that the natural flow patterns remain largely unaffected. Across two cases examined, the analysis reveals consistent siltation rates with minimal variation observed after deepening the designated borrow area mentioned in this study for reclamation purposes. Siltation study suggests that the dredging activities for land reclamation are not anticipated to substantially alter the siltation rates in the area. The findings of this advection dispersion study provide valuable insights into the behavior of dispersion of sediments under various conditions. As per dispersion study, dumping at proposed location alone does not cause any impact on the adjacent creek area and proposed harbour area. Overall, the study suggests that dredging activities and the disposal of return slurry have no noticeable impact on study area, as evidenced by the minimal changes in current and siltation pattern observed across different

scenarios. The detailed analysis and outcomes outlined in thus report contribute essential insights necessary for informed decision making and project planning moving forward.

## 1.0 BACKGROUND

A "Detailed Project Report" (DPR) needs to be prepared after the site investigations to obtain statutory clearances, if any, NOC from the concerned departments of the State Government of Odisha and the Government of India. Considering the expertise available with National Technology Centre for Ports, Waterways, and Coasts (NTCPWC) of the Indian Institute of Technology Madras (IITM) for carrying out similar type of studies and preparation of the detailed project reports (DPR), DCIL had awarded the work of Preparation of DPR for Reclamation work for the development of land for Industrial Activities at Paradip vide work order no DCl/IWD/NTCPWC/2023/02 dated 15.12.2023.



**Figure:1 Aerial view of the Paradip**

## 2.0 HYDRODYNAMIC AND MORPHODYNAMIC STUDY

Mathematical models are used to predict the bed level change based on the hydrodynamic parameters that exist over the region of inspection. In order to pursue the mathematical model studies of hydrodynamics and siltation, the in-house developed hydrodynamic model used is Ocirc employed, the details of which are discussed in **Annexure A**. The model predicts the tide induced flow near the borrow area. The model domain can be discretized with triangular elements to obtain numerical solutions to the hydrodynamic equations and computes the changes in the bed levels due to the tidal flow using sediment load balance in the water column.

## 2.1 Methodology

Demarcation of the study domain is done to set up the extent of the model domain. Hydrodynamic modelling is executed using Ocirc circulation model. Modeling the bed evolution is performed using the morphodynamics routine of Ocirc. Both hydrodynamics and morphodynamics model is simulated for a neap-to-neap condition, which covers all the astronomical aspects of tidal forcing. Estimation of the dredge quantity based on the siltation simulation is carried out. Calibration for the present case has been carried out by comparing the present results with that of MIKE-21 with alternate wetting/drying capabilities.

## 2.2 Modeling the study area

The solution for the present problem is carried out for the Paradip. Since an unstructured approach is being used in the present model, no hybrid meshing scheme is needed for capturing small features in geometry and flow. The domain of the study is represented by a number of bodies representing exterior coastal lines. This is basically the geometric configuration of the Paradip. The computational mesh used for simulation for Case I and II is shown in **Figure 2** and bathymetry used for simulation is shown in **Figure 4.** Region of interest in the study domain is shown in **Figure 3**. The bathymetry used is the measured bathymetry interpolated with the GEBCO 30 arc second gridded bathymetry. The final mesh has fine elements near the coastlines and shallower water depths. The size of mesh in the creek and borrow area ranges from 20 to 50 m. The average mesh size is found to be about 30-300m which is very fine for a simulation such as the present problem. The mesh is coarser near the offshore boundaries, where the water depths are greater. The interpolated bathymetry on the mesh shows contours at regular intervals. The typical representation of the bed profile along with the computational mesh used in model is shown in **Figure 5**. The interpolated bathymetry on the mesh represents the contours at regular intervals. Detailed numerical model studies have been carried out to investigate the hydrodynamics of tides. It is to be noted that, considering such a time series for the 15 days' period covers the neap-neap variations of the astronomical tide and addresses all variations in the astronomical tides. The time series plot for the domain at the open boundary conditions are shown in **Figure 6** and **Figure 7.**

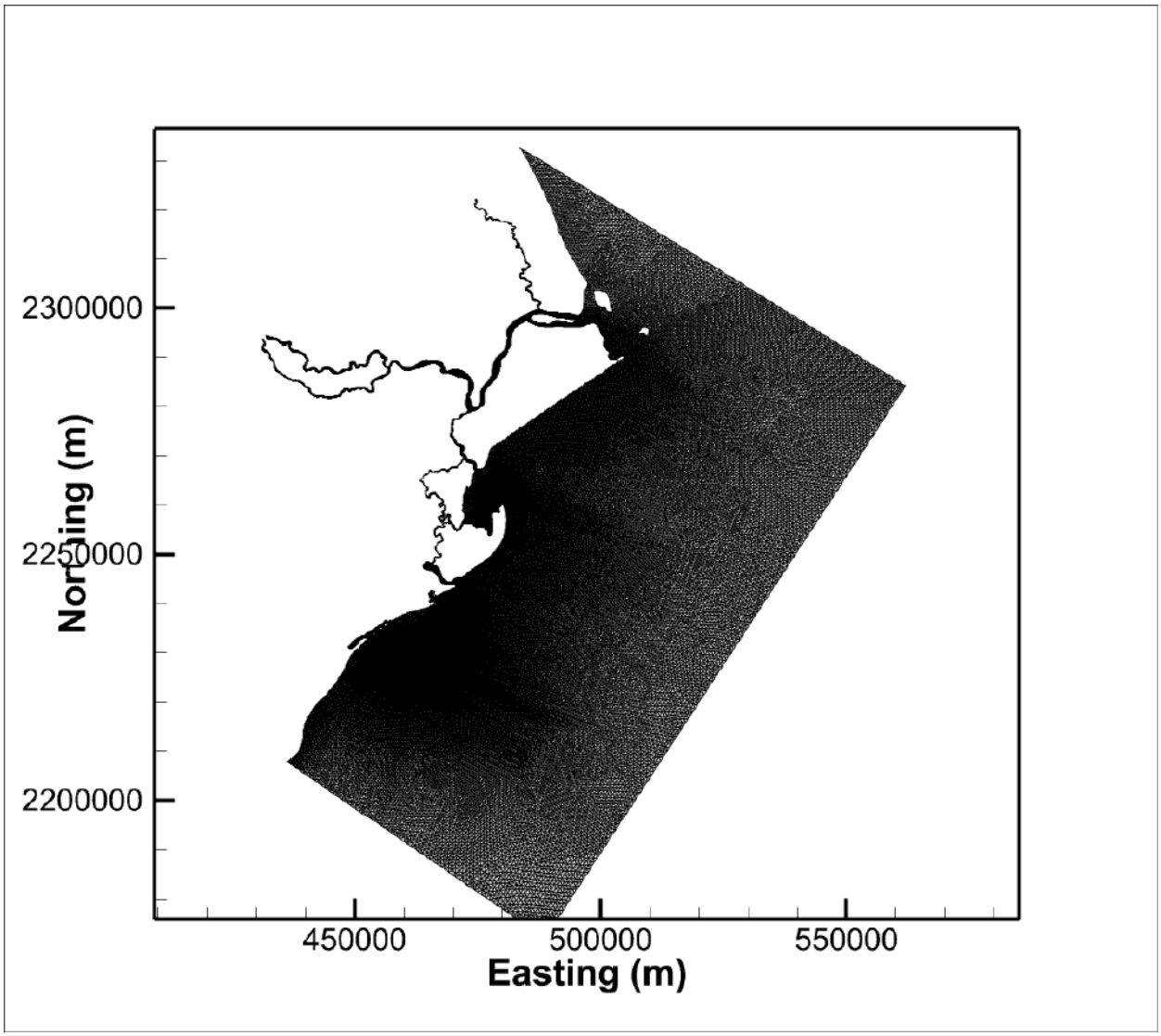



**Figure 2 Typical meshing of the domain considered for simulation for Case I and II in Paradip**

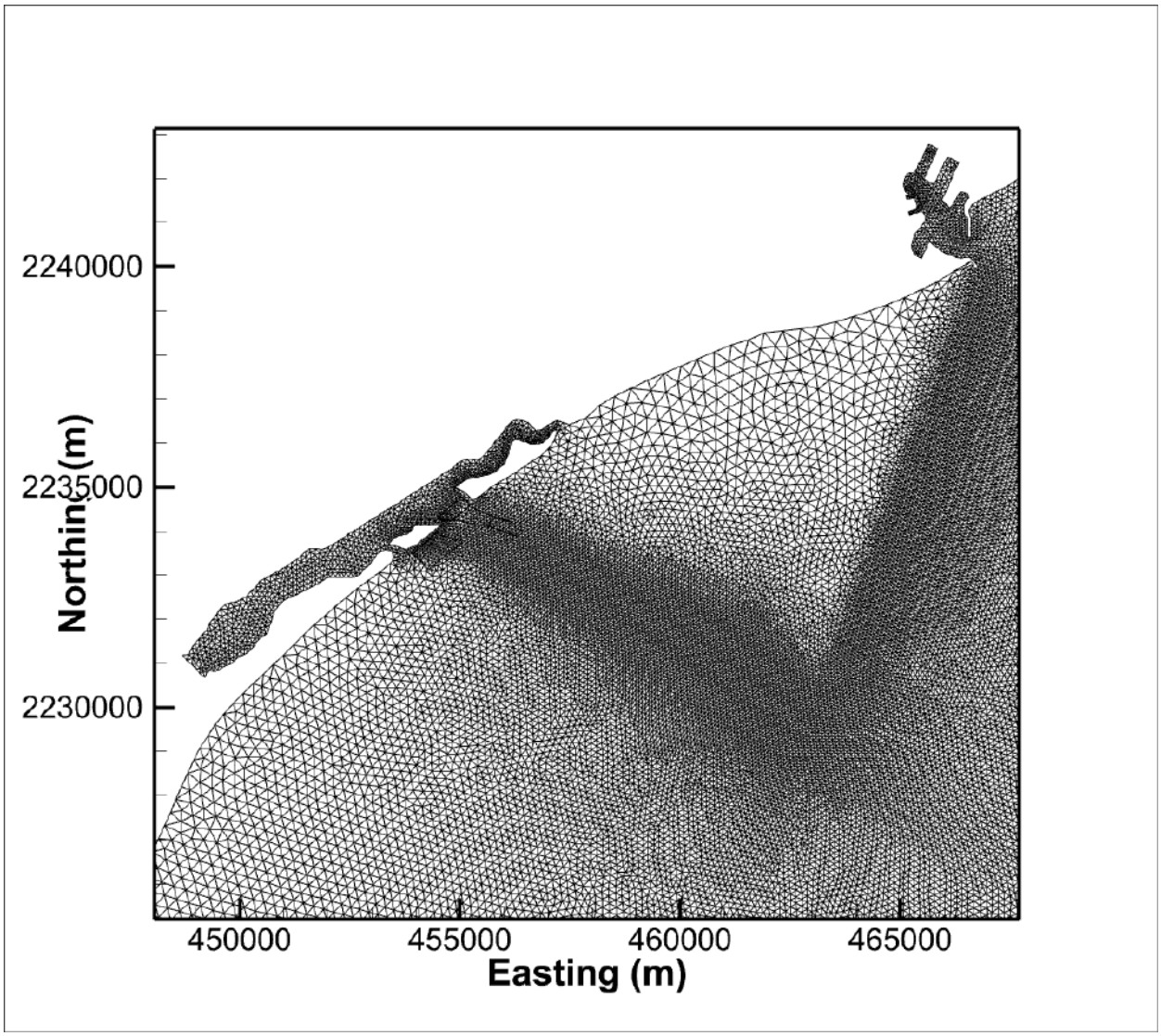



**Figure 3 Region of interest in the study domain for Case I and II in Paradip**

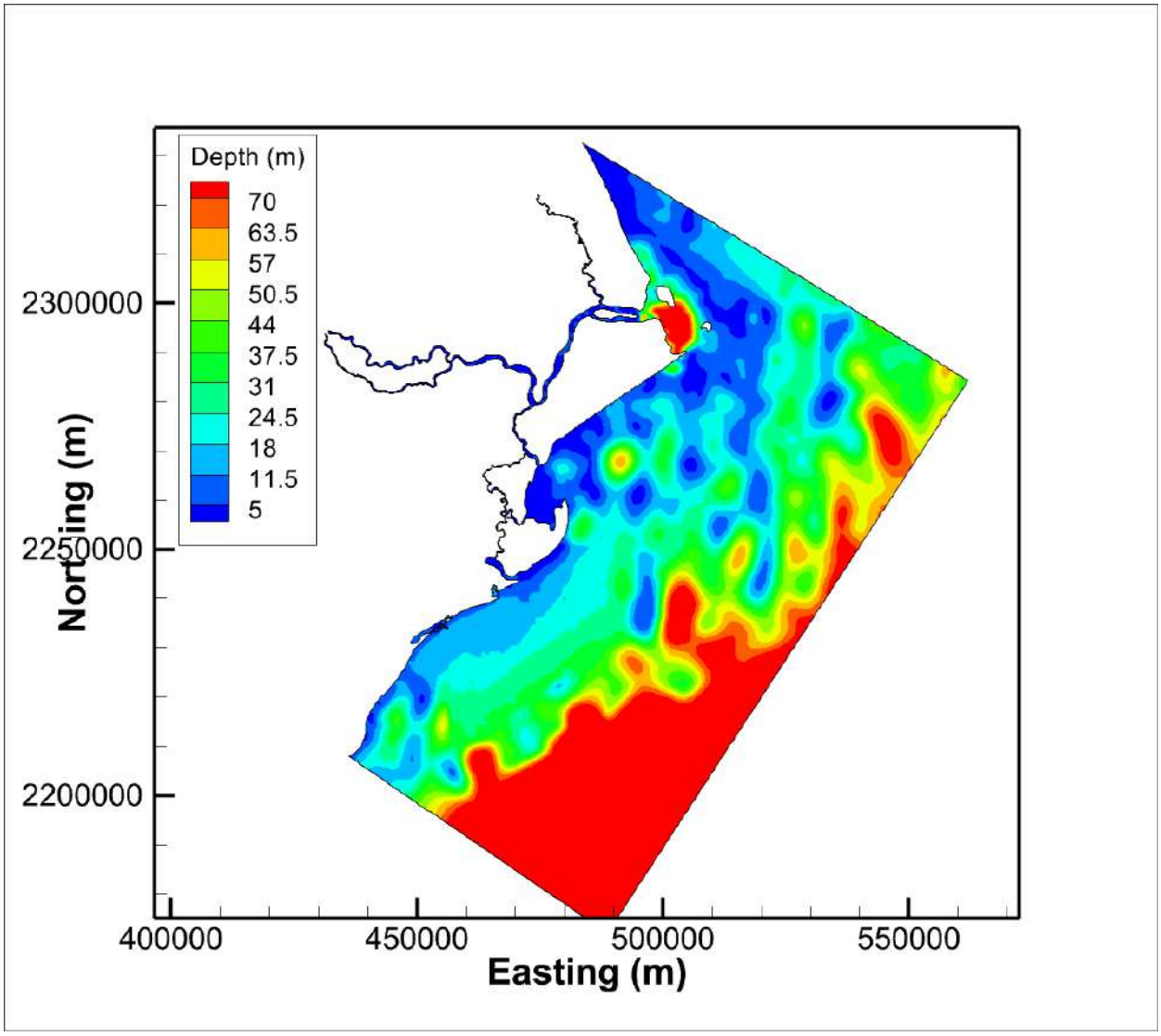



**Figure 4 Existing bathymetry used in computational mesh for simulation in Paradip**

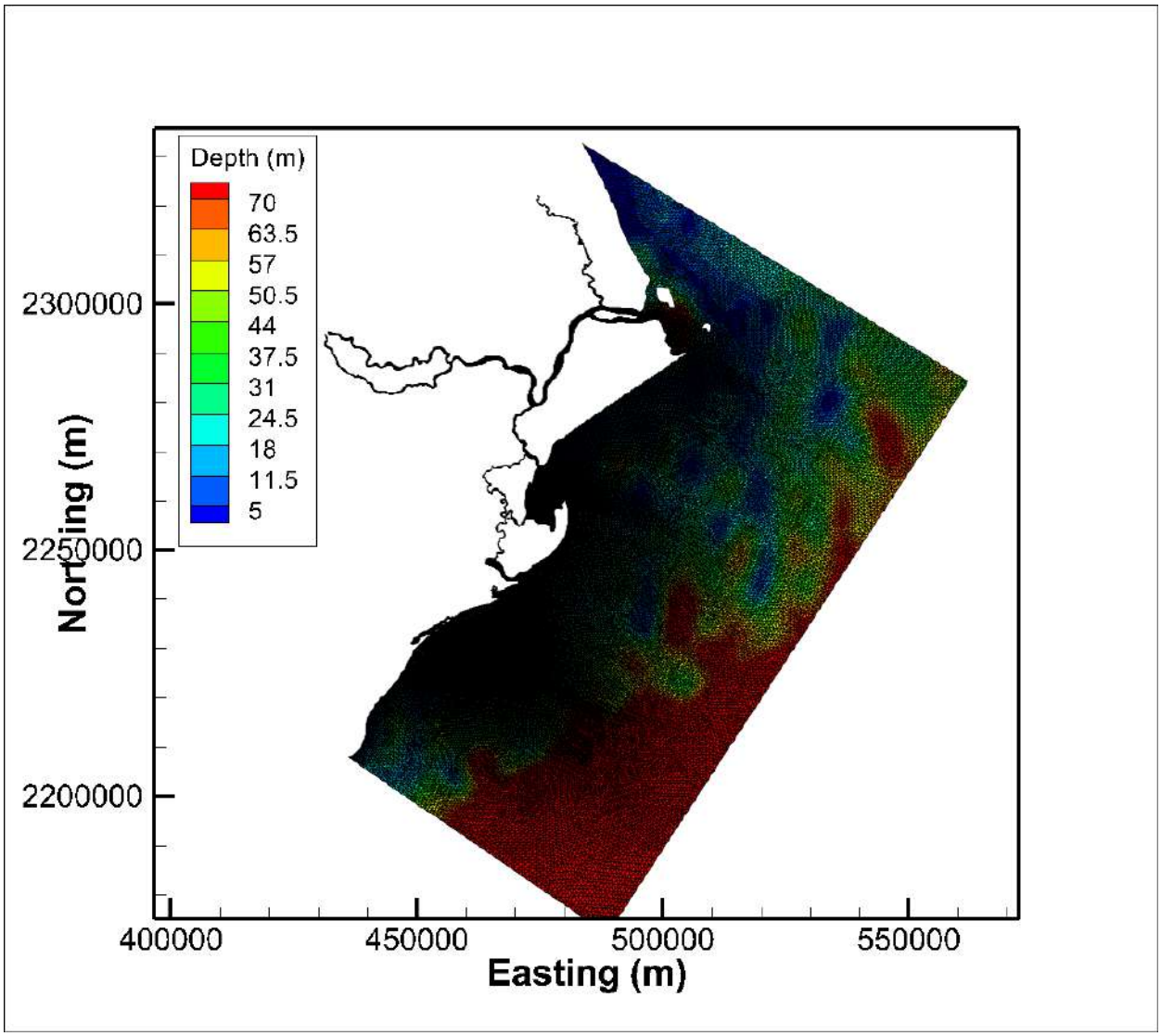



**Figure 5 Computation mesh and bathymetry used for the simulation in Paradip**

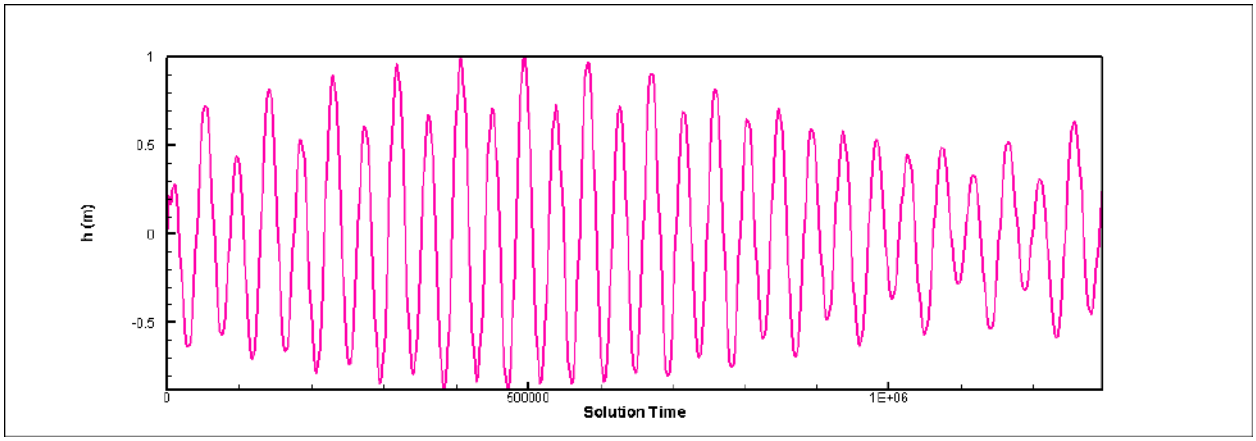



**Figure 6 Times series plot of surface elevation at Southern offshore open boundary in Bay of Bengal**

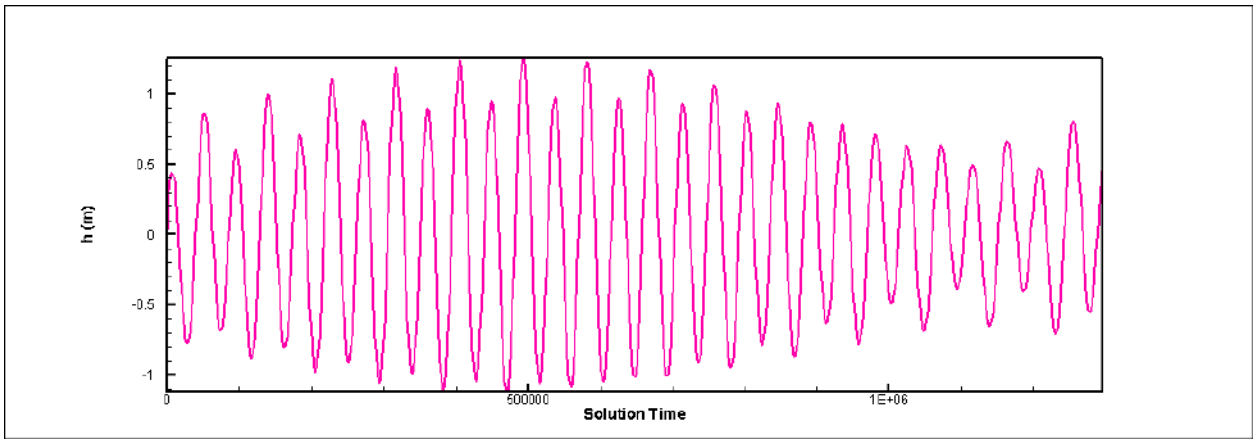



**Figure 7 Times series plot of surface elevation at Northern offshore open boundary in Bay of Bengal**

Along with the tidal elevation current speed components u and v are also provided in the open boundary for driving the tidal currents in this tide dominated domain. The model is capable of capturing the details of the bathymetry significantly closer to reality. For the consequence assessment of the dredging and reclamation work for development of land for industrial activities at Paradip, two different cases were envisaged. In Case I, the model is updated with the latest bathymetry data to simulate the dredged condition of the study domain, resulting in a volume of 10.9 million cubic meters for reclamation purposes. For Case I, the areas demarcated in **Figure 8** are dredged to the following depths: outer channel to 12 m, sand bar to 10.5 m, sand trap to 5.5 m, and harbour basin to 10.5 m. In Case II, in addition to the aforementioned areas, the inner basin is also dredged to a depth of 10.5 m. These variations in scenarios allow for a comprehensive assessment of the potential consequences of the dredging and reclamation efforts, considering different borrow areas and depth alterations. Bathymetry considered for simulation for Case I and II are represented in **Figure 9**. Different cases considered for the study is shown in **Table 1.**

**Table 1 Details of cases considered for the study**

| Cases | Area considered for the proposed borrow area | Area (m2) | Dredged depth considered |
|---|---|---|---|
| Case I | Sand Trap | 4,03,424 | 5.5 |
| | Sand Bar | 1,71,557 | 10.5 |
| | Harbour Basin | 2,31,646 | 10.5 |
| | Outer channel | 1,74,417 | 12 |
| Case II | Sand Trap | 4,03,424 | 5.5 |
| | Sand Bar | 1,71,557 | 10.5 |
| | Harbour Basin | 2,31,646 | 10.5 |
| | Outer channel | 1,74,417 | 12 |
| | Inner basin | 5,74,491 | 10.5 |

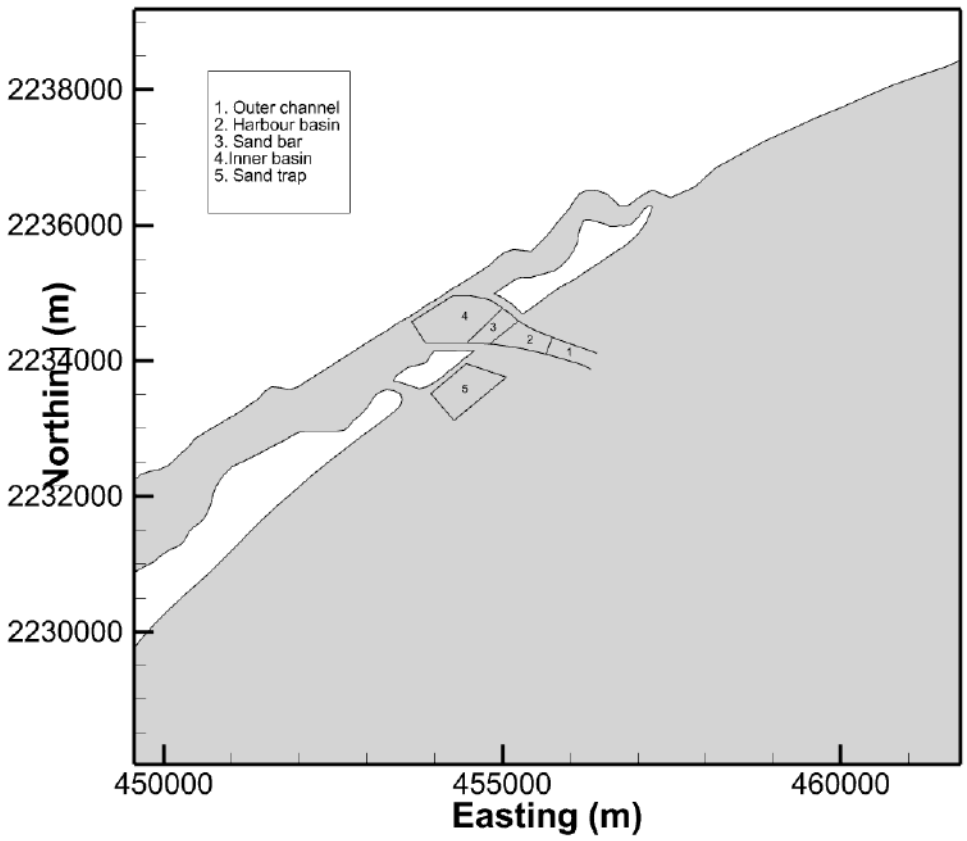



**Figure 8 Area demarcated in the proposed borrow area at Paradip**

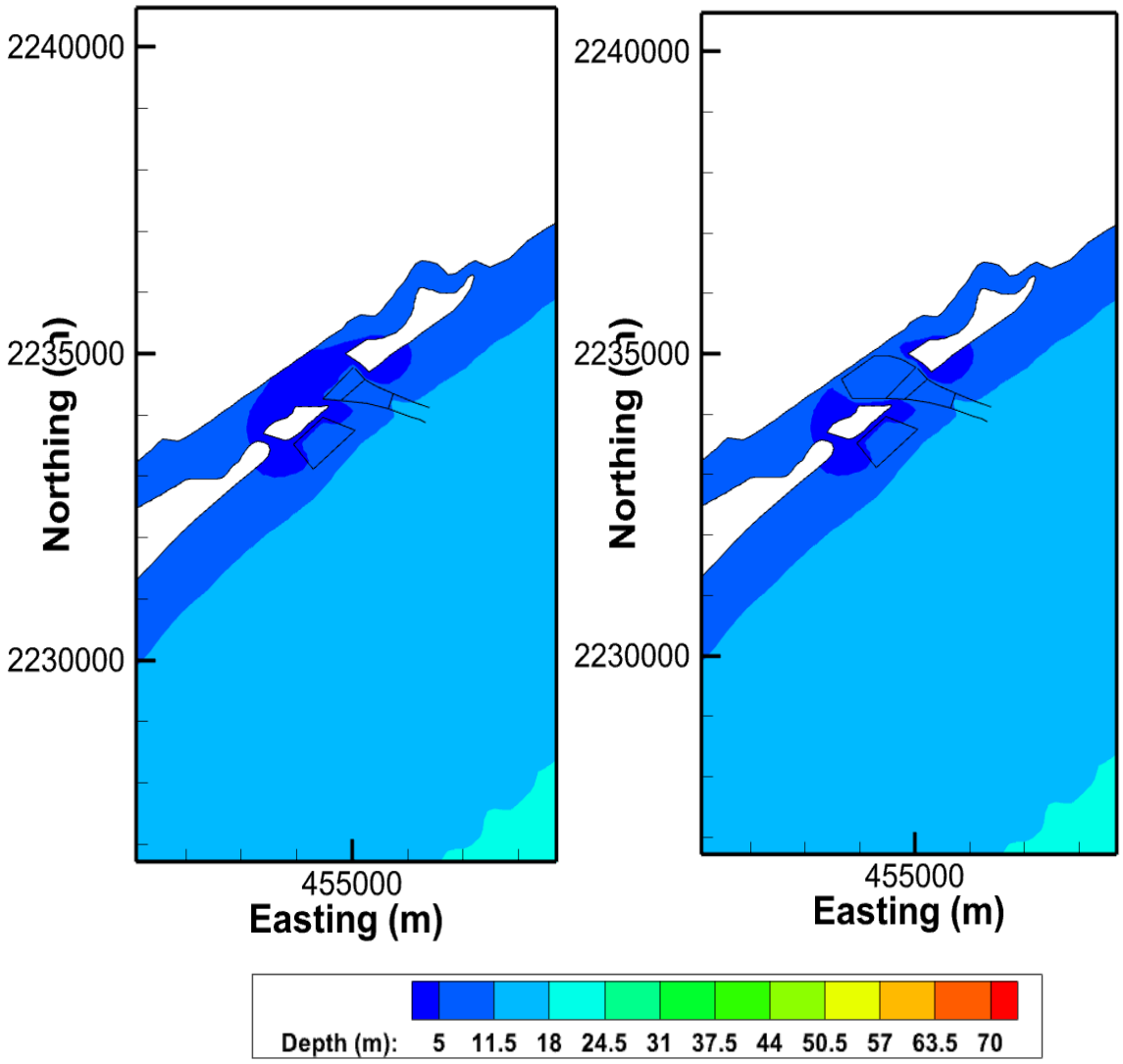



**Figure 9 Bathymetry considered for simulation for Case I and II in the proposed borrow area at Paradip**

## 2.3 Results and discussion

### 2.3.1 General

Accurate simulation of the tidal hydrodynamics at Paradip, depends on the kind of computational mesh generated for the simulations. An unstructured meshing scheme was selected in order to accurately capture the adjoining shoreline. The unstructured meshing scheme is capable of resolving all the boundary and bathymetry details in the study area. This typical computational mesh depicts the ability of the meshing algorithm to exactly discretize the study area.

### 2.3.2 Simulated Tidal conditions

The present tidal hydrodynamic conditions at the site are mainly characterized by alternating northerly and southerly flow in the open sea. The directions of flow are northerly during flooding and the vice versa during ebbing near the proposed borrow area along the coast line. For the purpose of easy referencing of the hydrodynamics with the tide levels, typical time instances at which flow patterns have been extracted, are shown in **Figure 10**. The origin is at mean sea level.

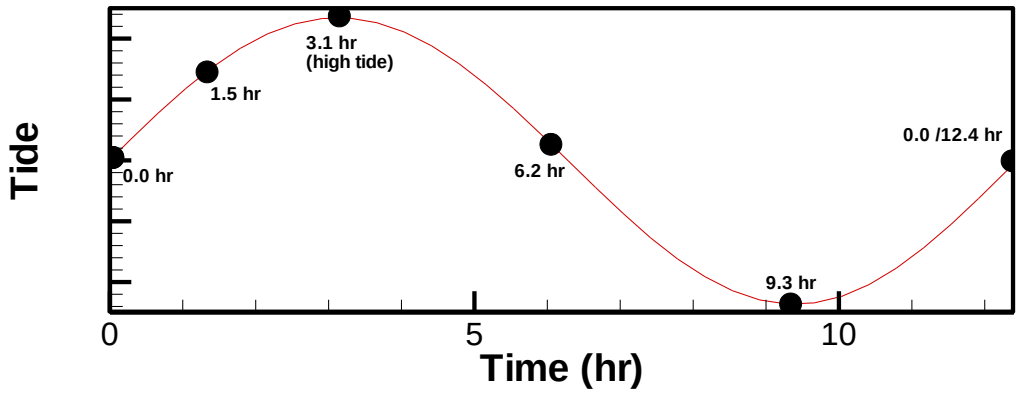



**Figure 10 Times of tide at which results are plotted**

### 2.3.3 Hydrodynamic study for Case I

**Flooding**

Flow patterns during flooding condition in the Paradip, shown in **Figure 11** & **Figure 12**. The figures show a typical flow situation during the rising tide (at about 0 hr) from which, the magnitudes of current at various locations of the study area can be deduced.

The flooding phase of the tide is characterized with flow in the north easterly direction in the Paradip. The range of flow velocity around the region near the outer channel area is about 0.02-0.19m/s, sand bar is about 0.03-0.26m/s, harbour basin area is about 0.09-0.25m/s and sand trap is about 0.03-0.18m/s. During the highest flooding event, the velocities around the location are about 0.30 m/s, shown in **Figure 12**. The above currents are disappearing during the high tide event as shown in **Figure 13**, during which the velocities near the creek is about 0.08 m/s. The steep velocity gradient may lead to siltation. Reversal of currents is observed to be prominent inside the proposed borrow areas and this may lead to bed level changes.

## Ebbing

During the ebbing phase of the tide, which is followed by the occurrence of high tide, the tide starts to recede from the inlet and reversal of flow start to occur towards the sea as can be seen in **Figure 14.** As the tide start to recede, the velocities immediately raises to 0.1-0.19 m/s during the ebbing event. During the peak ebbing event, the flow picks up to 0.28 m/s without changing the directional features as described earlier. During the low tide, the entire area become devoid of currents with some prominent reversal currents at the confluence regions in the domain and at locations near the mouth of the creek. The velocity is about 0.06 m/s as shown in **Figure 15** during low tide. During high and low tides some strong eddies are observed in several parts of the study area which induces the potential for shoaling.

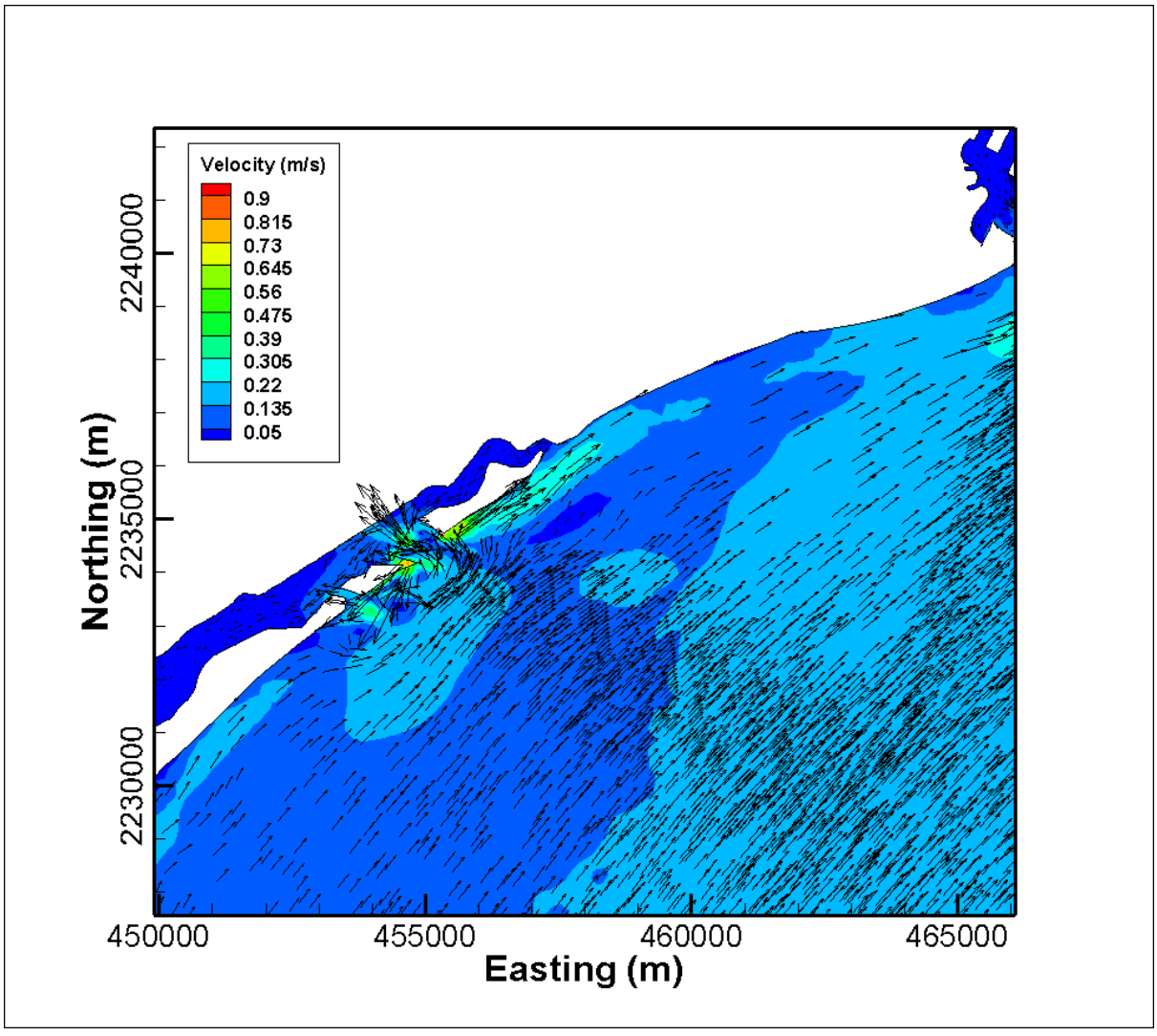



**Figure 11 Velocity vectors and contour plots during flooding tide at 0 hours for Case I**

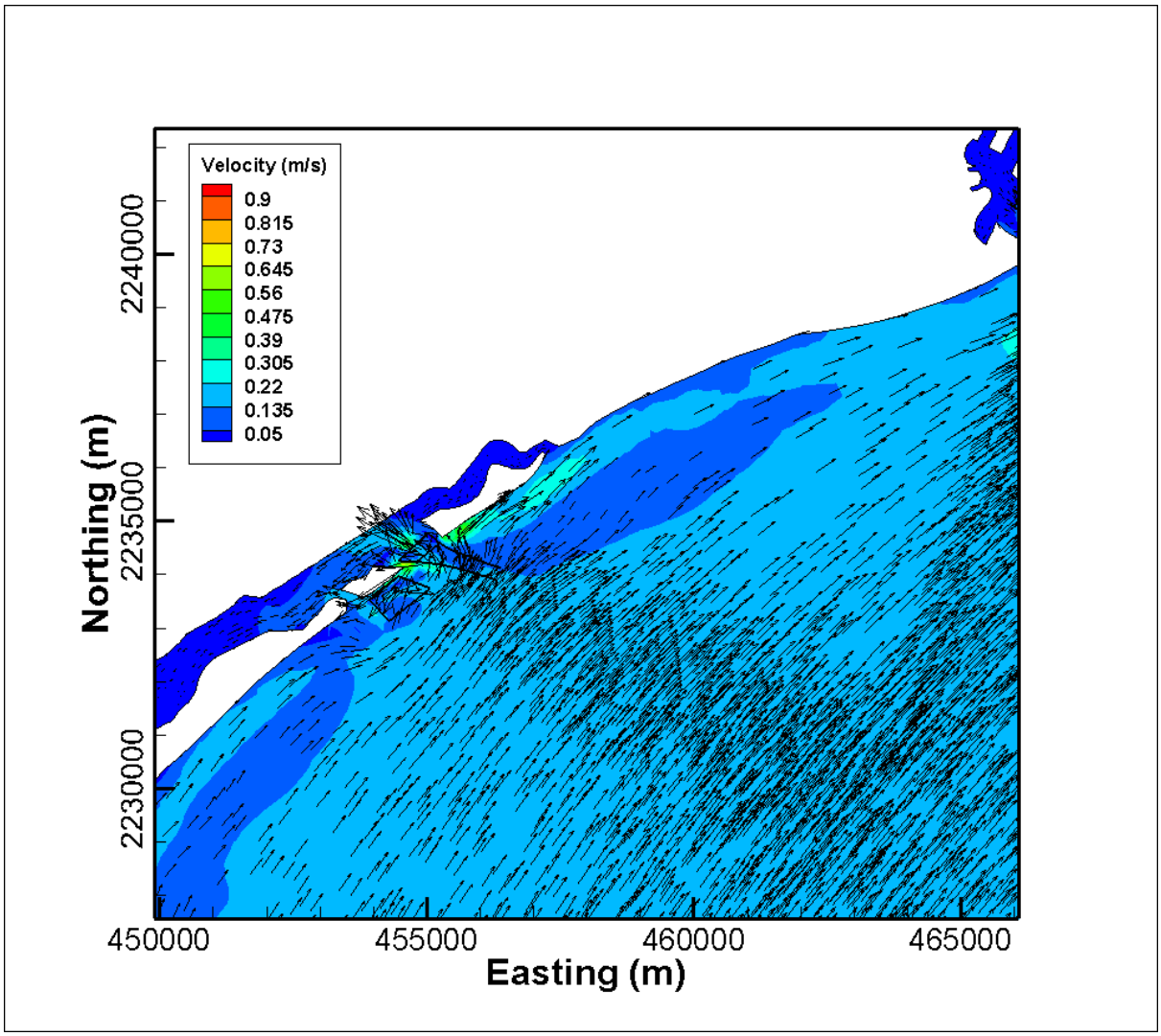



**Figure 12 Velocity vectors and contour plots during maximum flooding tide at 1.5 hours for Case I**

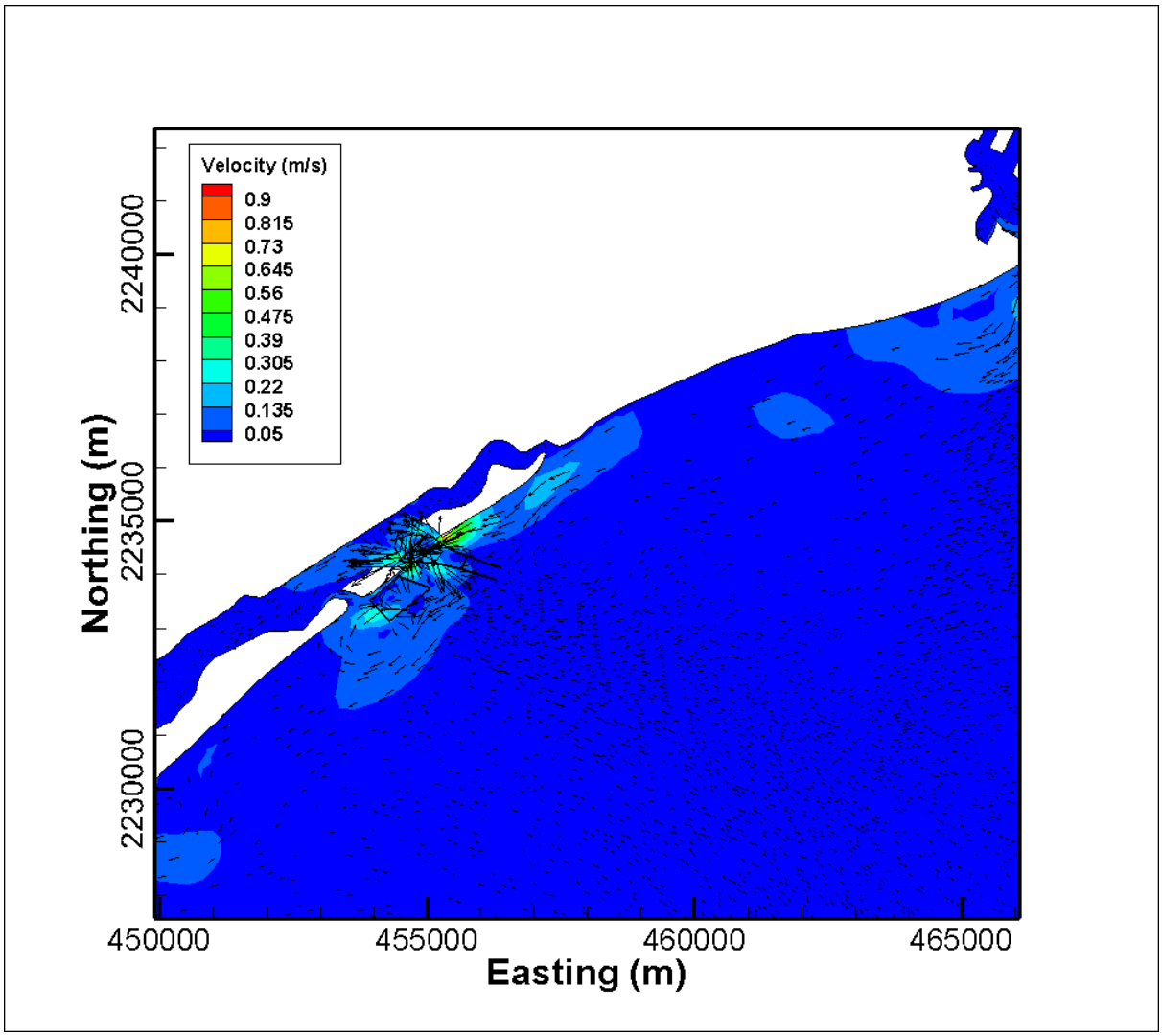



**Figure 13 Velocity vectors and contour plots during high tide at 3.1 hours for Case I**

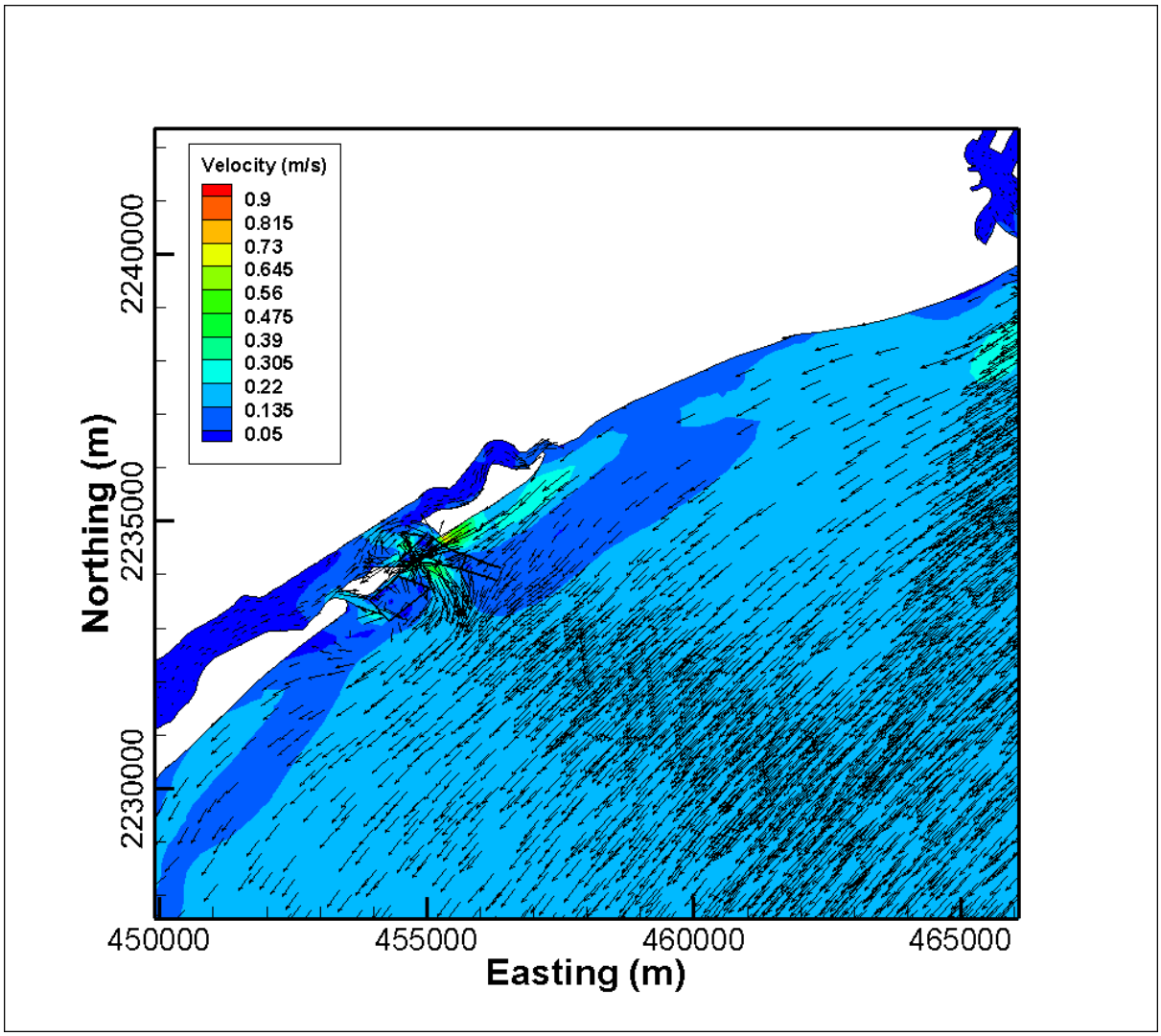



**Figure 14 Velocity vectors and contour plots during ebbing tide at 6.2 hours for Case I**

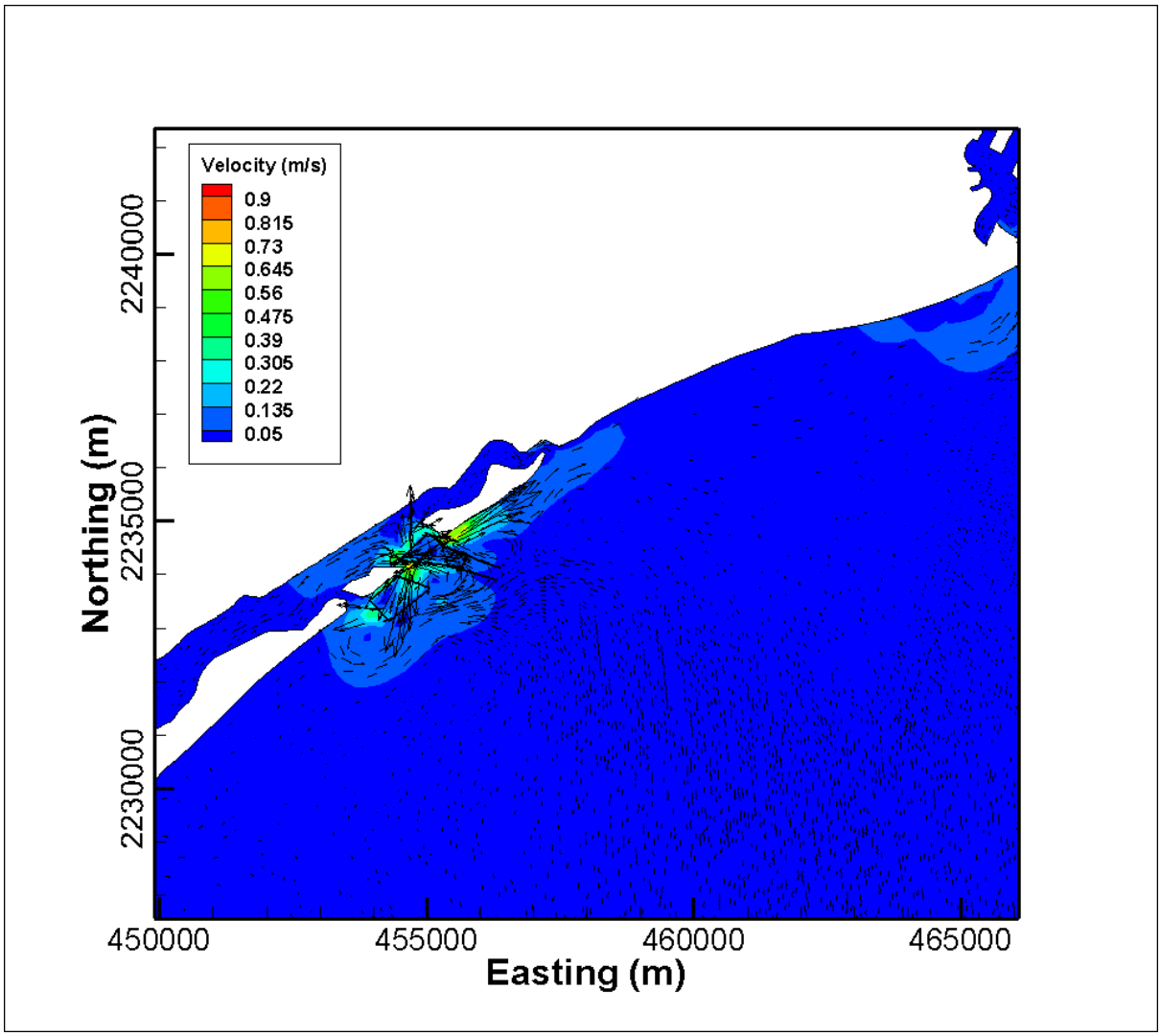



**Figure 15 Velocity vectors and contour plots during low tide at 9.3 hours for Case I**

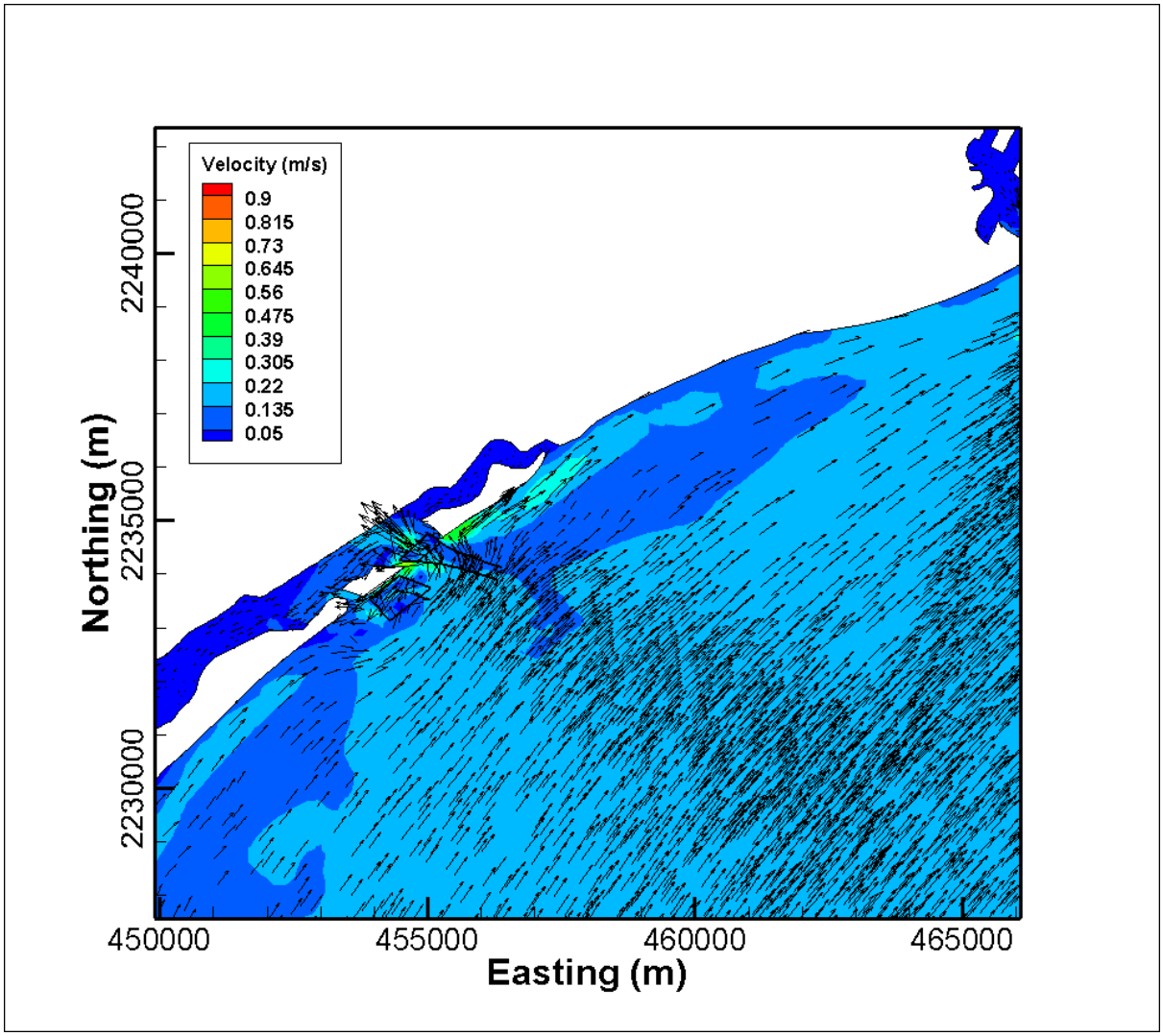



**Figure 16 Velocity vectors and contour plots during flooding tide at 12.4 hours for Case I**

### 2.3.4 Hydrodynamic study for Case II

**Flooding**

Flow patterns during flooding condition in the Paradip, shown in **Figure 17** & **Figure 18**. The figures show a typical flow situation during the rising tide (at about 0 hr) from which, the magnitudes of current at various locations of the study area can be deduced.

The flooding phase of the tide is characterized with flow in the north easterly direction in the Paradip. The range of flow velocity around the region near the outer channel area is about 0.02-0.19m/s, sand bar is about 0.03-0.26m/s, harbour basin area is about 0.09-0.25m/s,inner basin area is 0.03 – 0.18 m/s and sand trap is about 0.03-0.18m/s. During the highest flooding event,

the velocities around the location are about 0.30 m/s, shown in **Figure 18**. The above currents are disappearing during the high tide event in the area as shown in **Figure 19**, during which the velocities is about 0.08 m/s. The steep velocity gradient may lead to siltation. Reversal of currents is observed to be prominent inside the borrow area and this may lead to bed level changes.

**Ebbing**

During the ebbing phase of the tide, which is followed by the occurrence of high tide, the tide starts to recede from the inlet and reversal of flow start to occur towards the sea as can be seen in **Figure 20.** As the tide start to recede, the velocities immediately raises to 0.1-0.19 m/s during the ebbing event. During the peak ebbing event, the flow picks up to 0.28 m/s without changing the directional features as described earlier. During the low tide, the entire area become devoid of currents with some prominent reversal currents at the confluence regions in the domain and at locations near the mouth of the creek. The velocity is about 0.06 m/s as shown in **Figure 21** during low tide. During high and low tides some strong eddies are observed in several parts of the study area which induces the potential for shoaling.

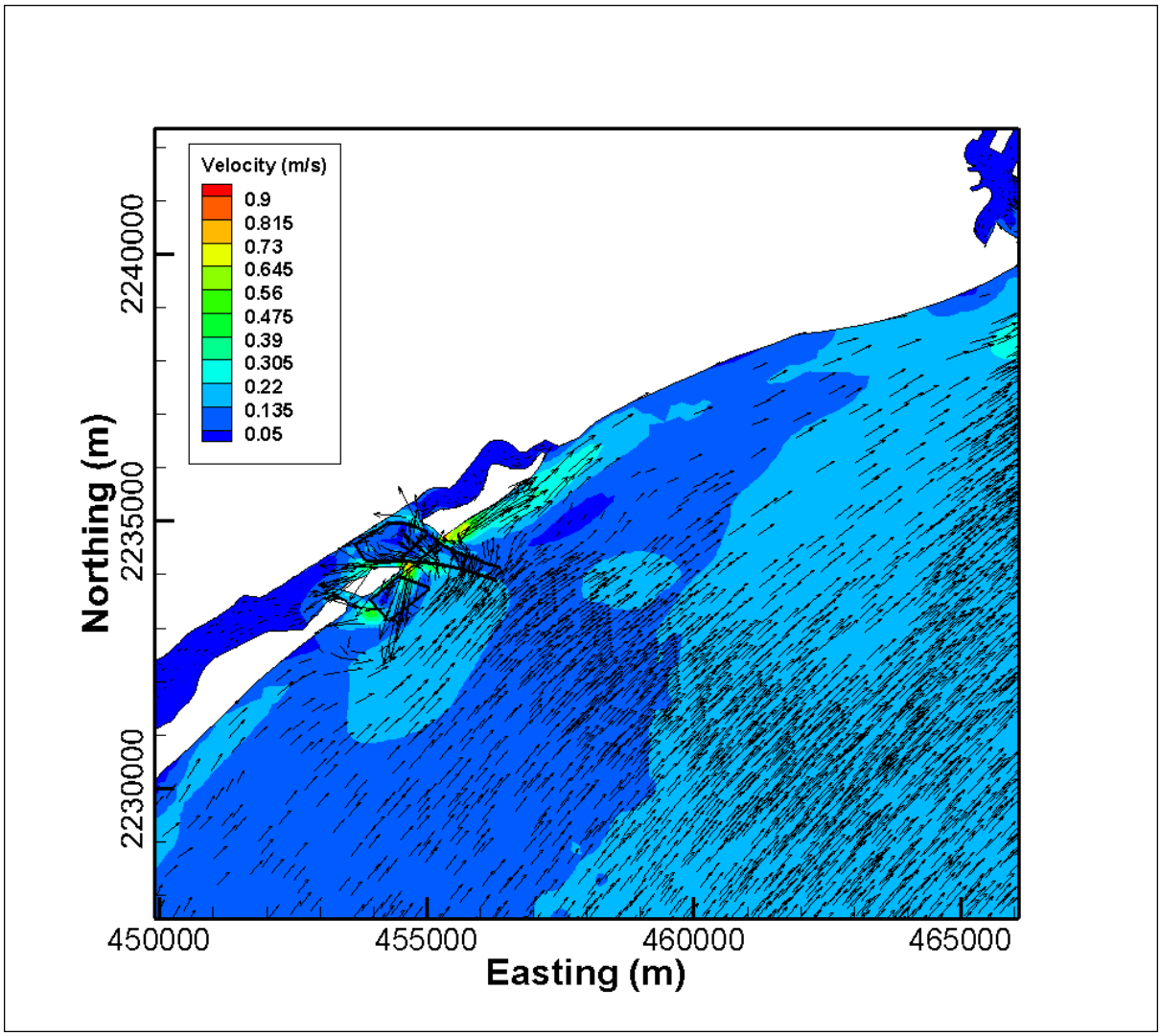



**Figure 17 Velocity vectors and contour plots during flooding tide at 0 hours for Case II**

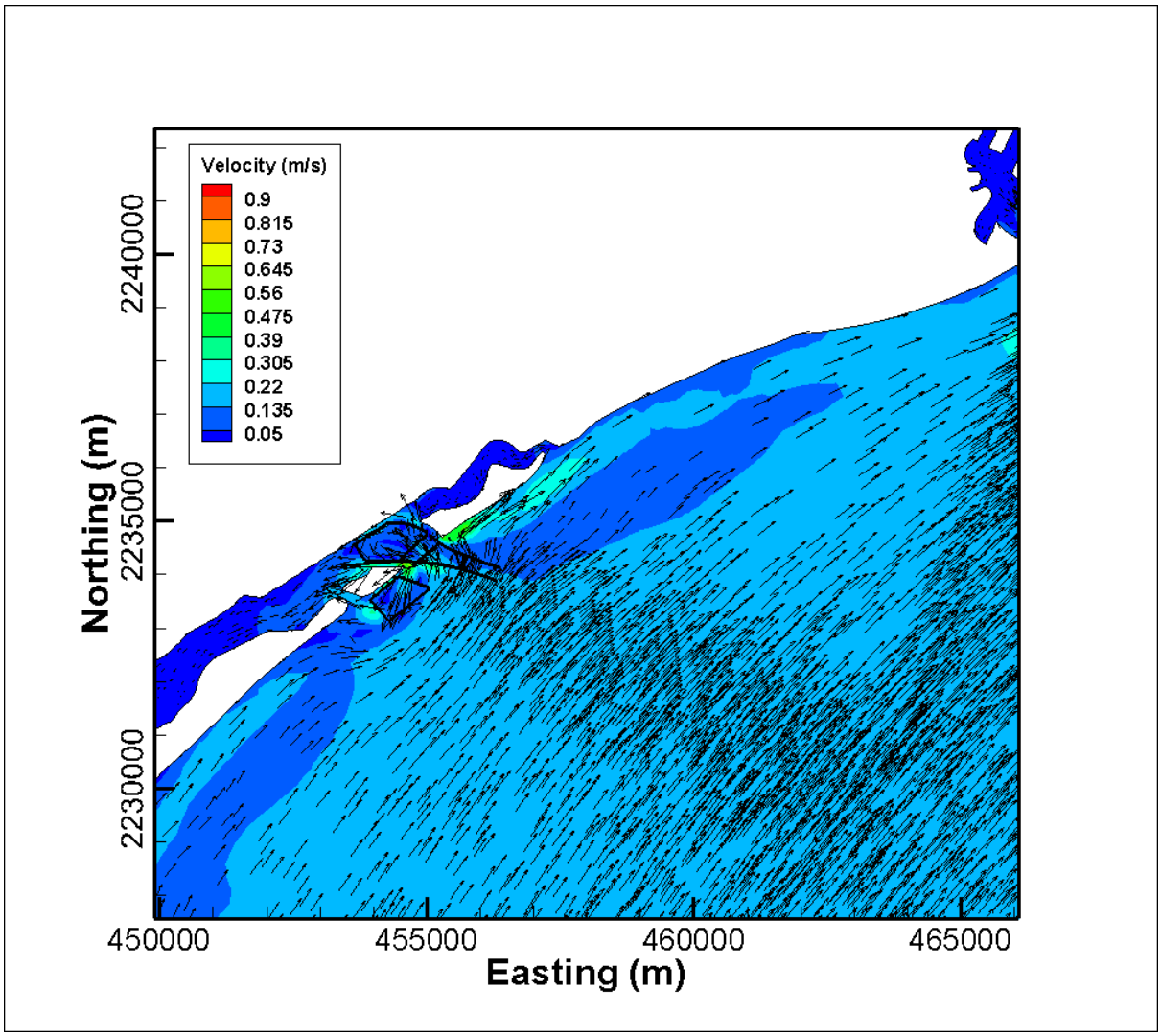



**Figure 18 Velocity vectors and contour plots during maximum flooding tide at 1.5 hours for Case II**

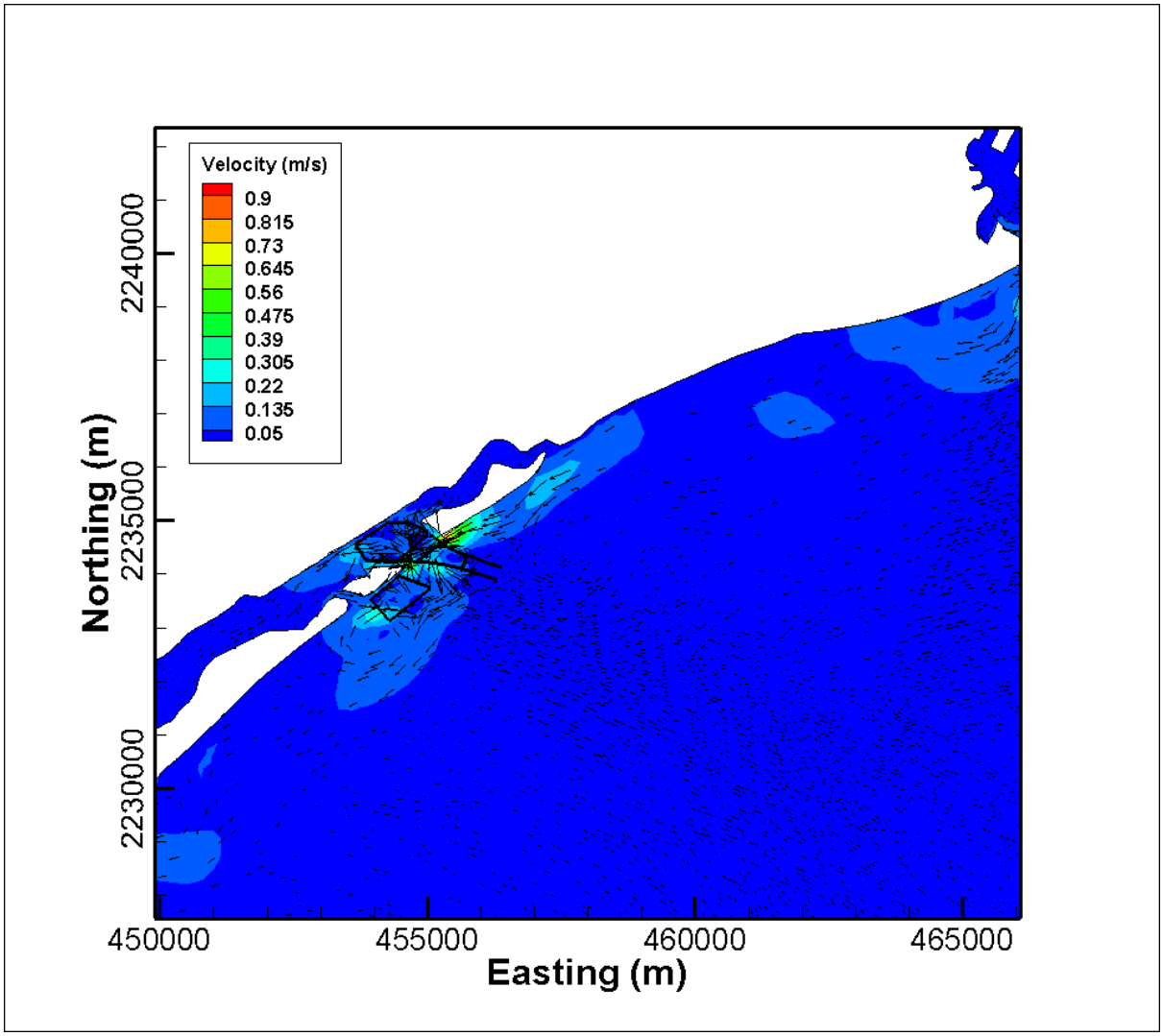



**Figure 19 Velocity vectors and contour plots during high tide at 3.1 hours for Case II**

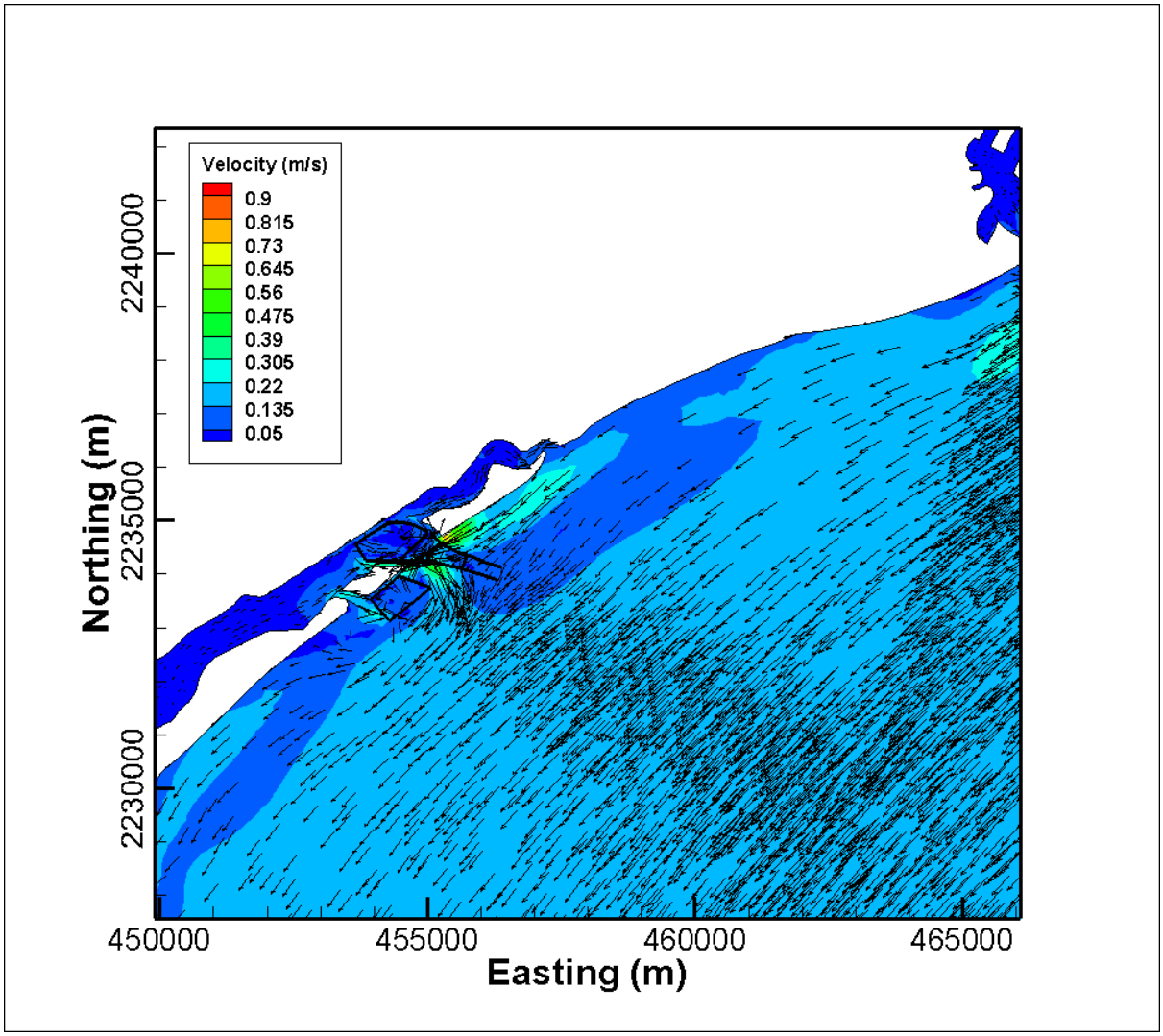



**Figure 20 Velocity vectors and contour plots during ebbing tide at 6.2 hours for Case II**

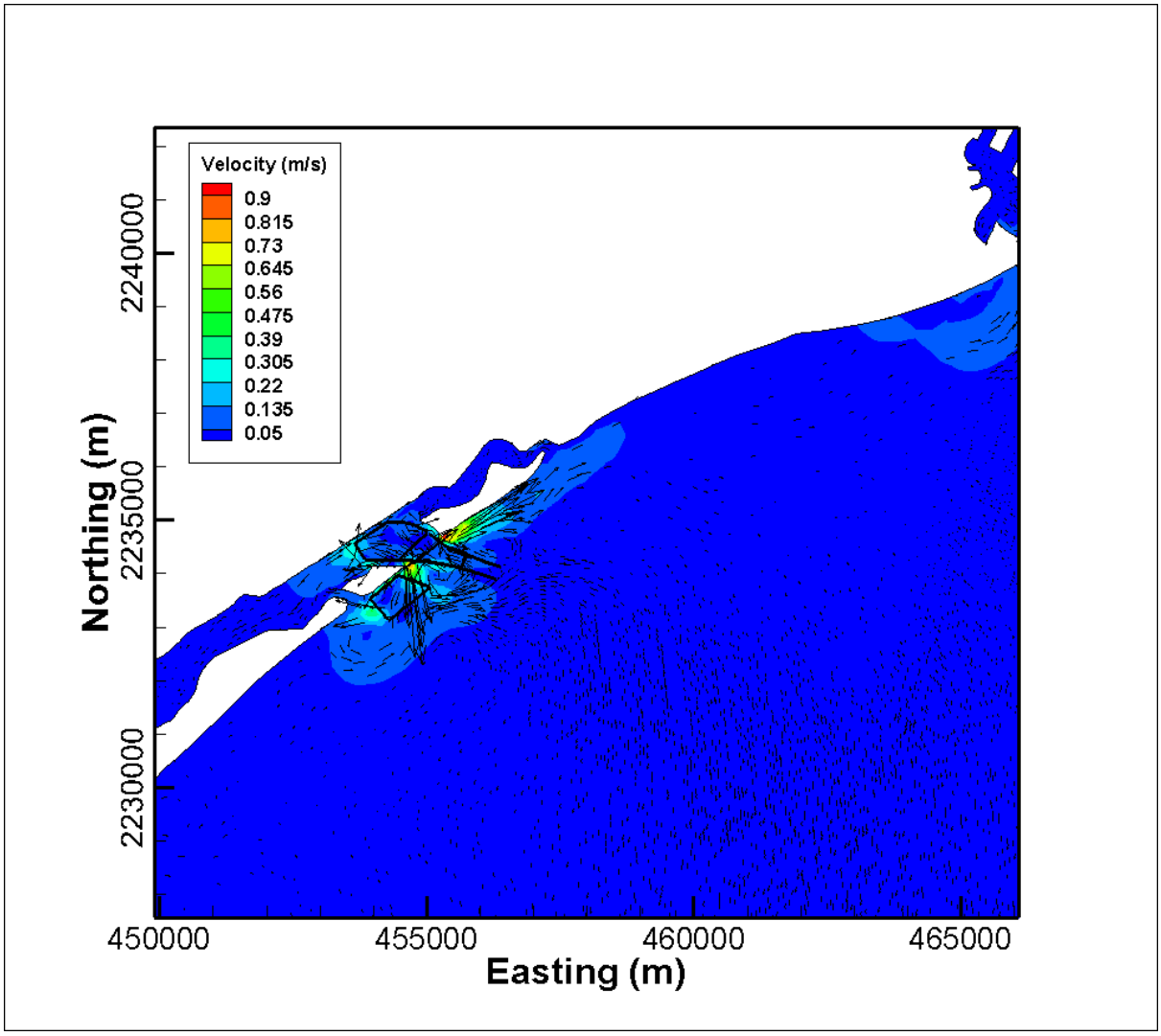



**Figure 21 Velocity vectors and contour plots during low tide at 9.3 hours for Case II**

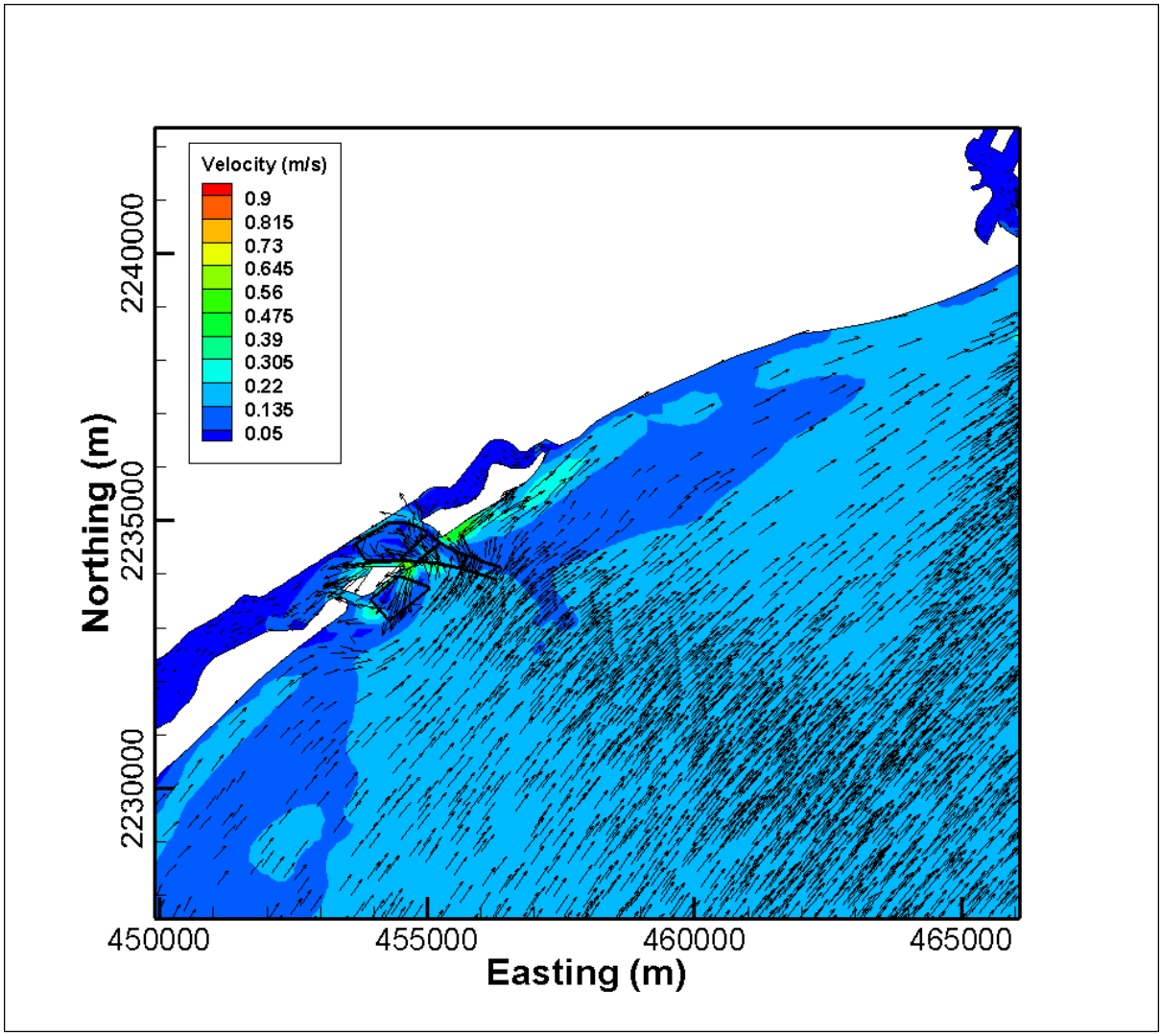



**Figure 22 Velocity vectors and contour plots during flooding tide at 12.4 hours for Case II**

## 3.0 MORPHODYNAMIC MODELING

### 3.1 General

The solution for the present problem, is to find the annual rate of siltation based on morphological changes for the two cases considered and consequence assessment of the dredging and reclamation work for development of land for industrial activities at Paradip. Since an unstructured approach is being used in the present model, no hybrid-meshing scheme is needed for capturing small features in geometry and flow. The domain of the study is

represented by a number of bodies representing outer domain and interior islands. The bathymetry used is the measured bathymetry interpolated with the GEBCO 30 arc second gridded bathymetry. The final mesh has fine elements near the coastlines and shallower water depths. The average mesh size is found to be about 30-300m which is very fine for a simulation such as the present problem. The mesh is coarser near the outer boundaries, where the water depths are greater. The interpolated bathymetry on the mesh shows contours at regular intervals. Detailed numerical model studies have been carried out to investigate the hydrodynamics as explained in the previous section. With flow pattern and current velocity, the sediment transport model is simulated and the silt that gets settled in patches all over the domain is predicted. The inputs are given based on field data available with NTCPWC, IIT Madras.

### 3.2 Results and discussion

Based on the siltation study, the average siltation rate in the proposed borrow area and proposed harbour basin are estimated. Siltation occurs during the low and high tide time, when the current magnitudes are relatively low. Across the two cases examined, the average siltation inside the proposed outer channel area area ranges from 0.03m/N-N -0.7m/N-N cycle, proposed sand trap ranges from 0.02m/N-N - 0.08m/N-N cycle, proposed harbour basin area ranges from 0.01m/N-N – 0.07m/N-N cycle and proposed sand bar area ranges from 0.02m/N-N -0.06m/N-N cycle for Case I and in case –II additionaly inner basin area is also considered in which the average siltation ranges from 0.04m/N-N -0.08 m/N-N cycle.The analysis reveals consistent siltation rates with minimal variation observed after deepening the borrow area for reclamation purposes. This study suggests that the dredging activities for land reclamation are not anticipated to substantially alter the siltation rates in the area. Typical bed level change for Case I and II is shown in

Figure 23.

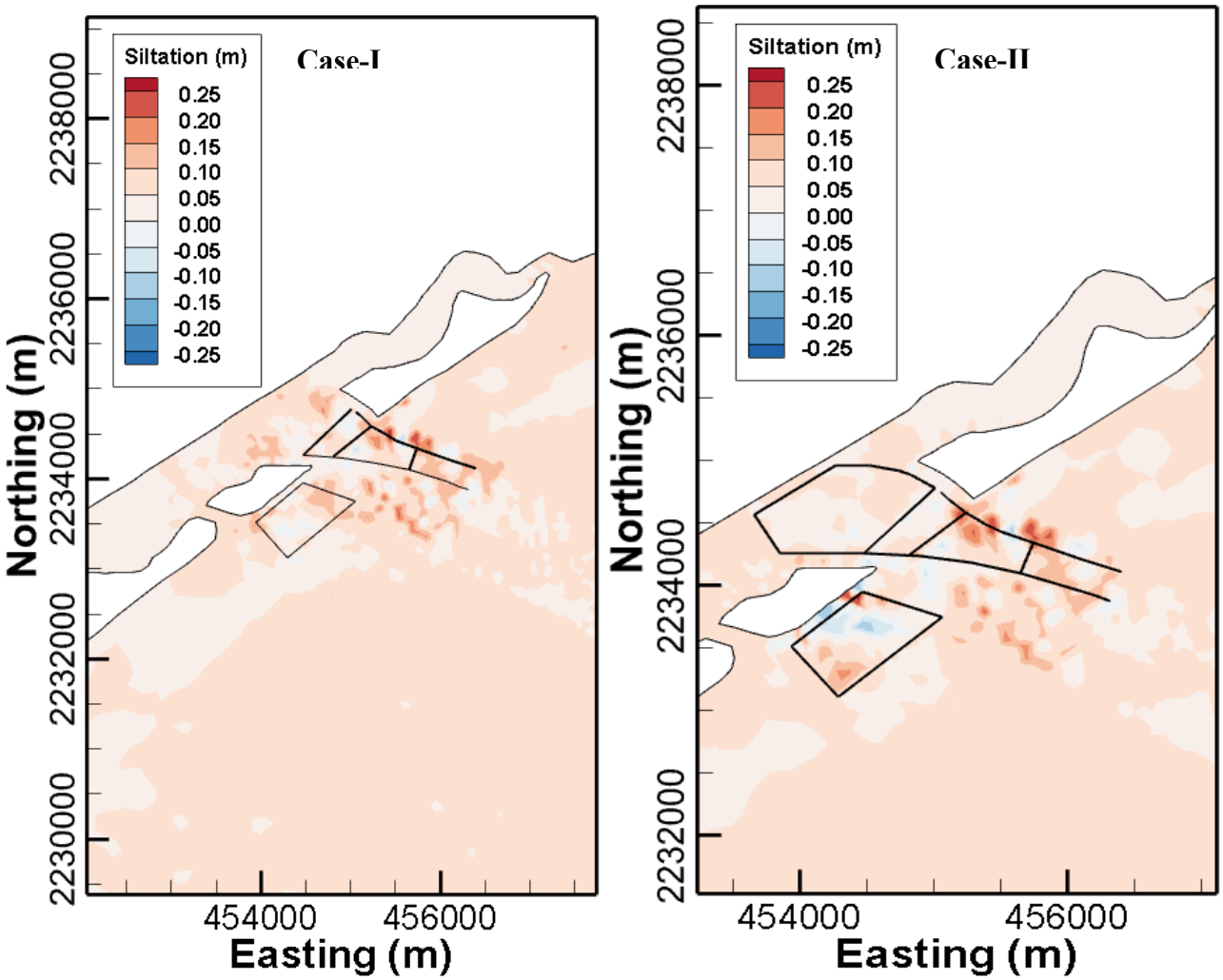



**Figure 23 Typical bed level change for Case I and II in the proposed borrow area at Paradip**

### 3.2.1 Estimation of annual siltation

The dredge quantity estimate for Case-I for one year in sand trap area is 0.29 $Mm^3$/year, sand bar is 0.16 $Mm^3$/ year, harbour basin is 0.28 $Mm^3$/ year and outer channel is 0.21 $Mm^3$/ year. For Case-II the dredge quantity estimate for one year in sand trap area is 0.19 $Mm^3$/year, sand bar is 0.21 $Mm^3$/ year, harbour basin is 0.31 $Mm^3$/ year, outer channel is 0.25 $Mm^3$/ year and inner basin is 0.55 $Mm^3$/ year. The total dredge quantity estimate for a year for Case-I and Case-II are 0.94 $Mm^3$ and 1.51 $Mm^3$. Total estimated dredge quantity for one year is shown in **Table 2**.

**Table 2 Estimated total dredge quantity for Case-I and Case-II in Paradip**

| Location | Dredging area ($m^2$) for prevailing condition | Siltation rate (m/N-N days) | | Estimated dredge quantity ($Mm^3$)/year | |
|---|---|---|---|---|---|
| | | Case-I | Case-II | Case-I | Case-II |
| **Sand Trap** | 4,03,424 | 0.03 | 0.02 | 0.29 | 0.19 |
| **Sand Bar** | 1,71,557 | 0.04 | 0.05 | 0.16 | 0.21 |
| **Harbour Basin** | 2,31,646 | 0.05 | 0.055 | 0.28 | 0.31 |
| **Outer channel** | 1,74,417 | 0.05 | 0.06 | 0.21 | 0.25 |
| **Inner basin** | 5,74,491 | - | 0.04 | - | 0.55 |
| **Total** | | | | **0.94** | **1.51** |

## 4.0 Advection- Dispersion Study

In the process of understanding the impact of disposal of return slurry during reclamation work, it is proposed to carry out dredge dispersion study along the study domain. Advection - Dispersion studies are conducted using the modelling approach as discussed in **Annexure-B**. As the CFD model is more accurate and computes dredge dispersion very well, the model is extended to encompass the area of Paradip as projected**.** The physical settings and domain considered for the advection-dispersion model with the mesh therein. For the present disposal of return slurry during reclamation at proposed disposal location is analysed.

### 4.1 Modelling the study area

For the advection dispersion model, the lean period is considered with a nominal current of 0.1-0.9 m/s occurring in open sea. In other periods, the ocean is more turbulent and advection - dispersion takes place much faster. Hence, the scenario considered in the present studies may be said to be critical one for predicting highest concentrations of sediment near slurry disposal sites. Detailed numerical model studies have been carried out to investigate the hydrodynamics of tides. The final mesh has fine elements near the coastlines and shallower water depths. The average mesh size varies from 30-500 m, which is very fine for a simulation such as the present problem. The mesh is coarser near the offshore boundaries, where the water depths are greater. **Figure 24** shows the computational mesh generated from the boundary curve. The bathymetry used is the measured bathymetry interpolated with the GEBCO 30 arc second gridded bathymetry, which is shown in **Figure 25.** The

location of the dumping site for this study is also shown in **Figure 26.** It is to be noted that, considering such a time series for the 15 days period covers the neap-neap variations of the astronomical tide and addresses all variations in the astronomical tides.

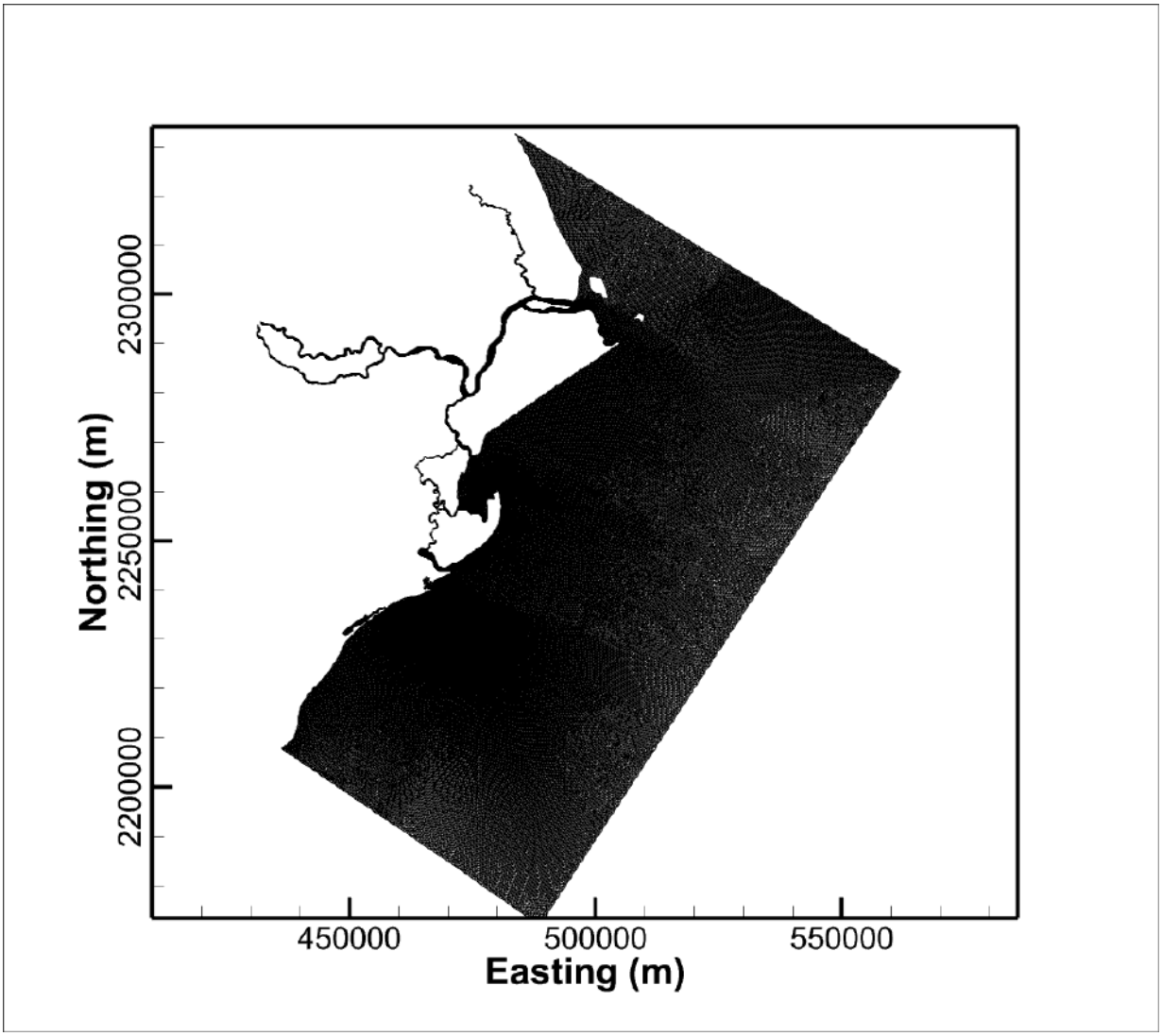



**Figure 24Typical meshing of the domain used for simulation**

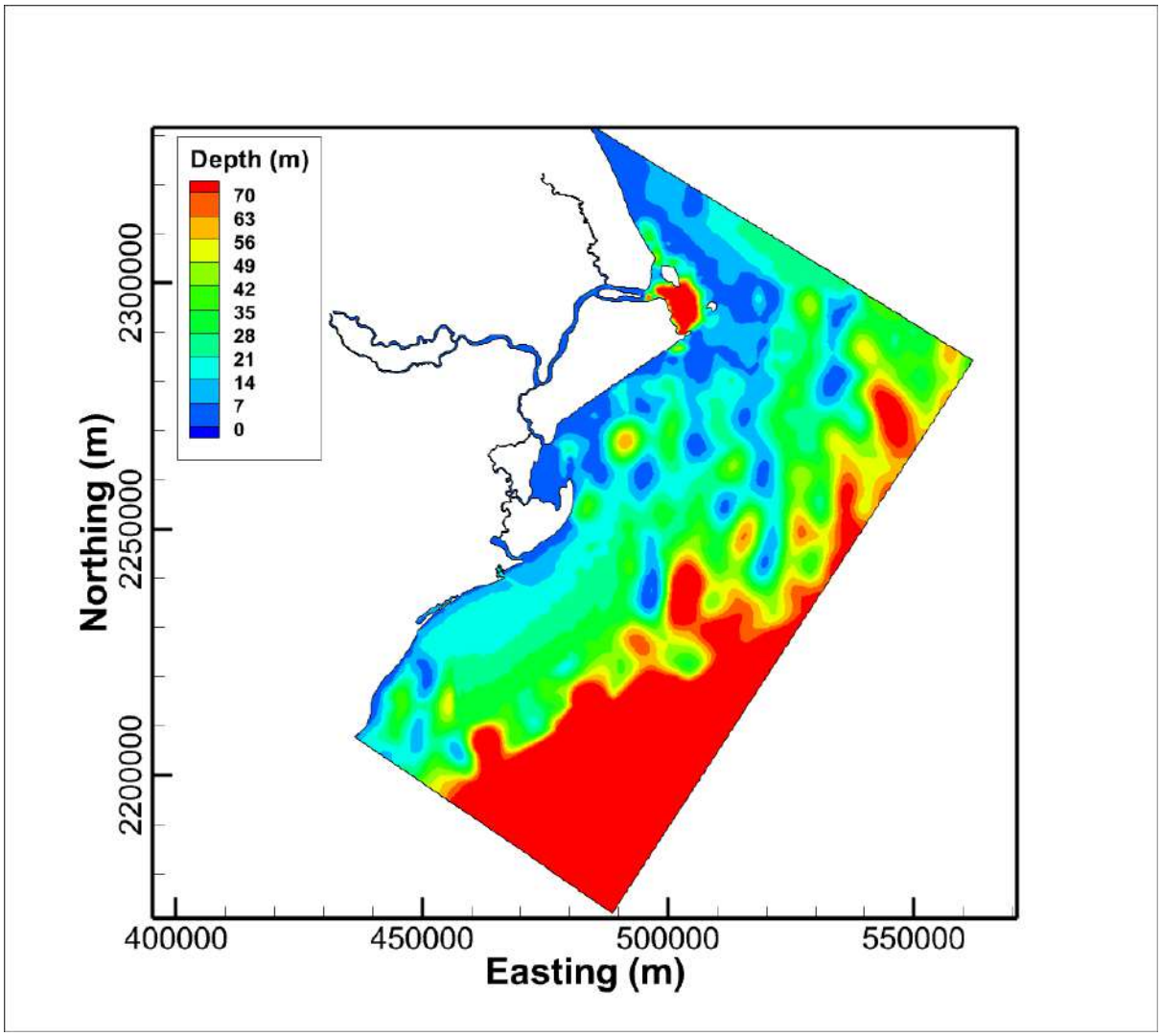



**Figure 25Seabed levels represented in the computational mesh**

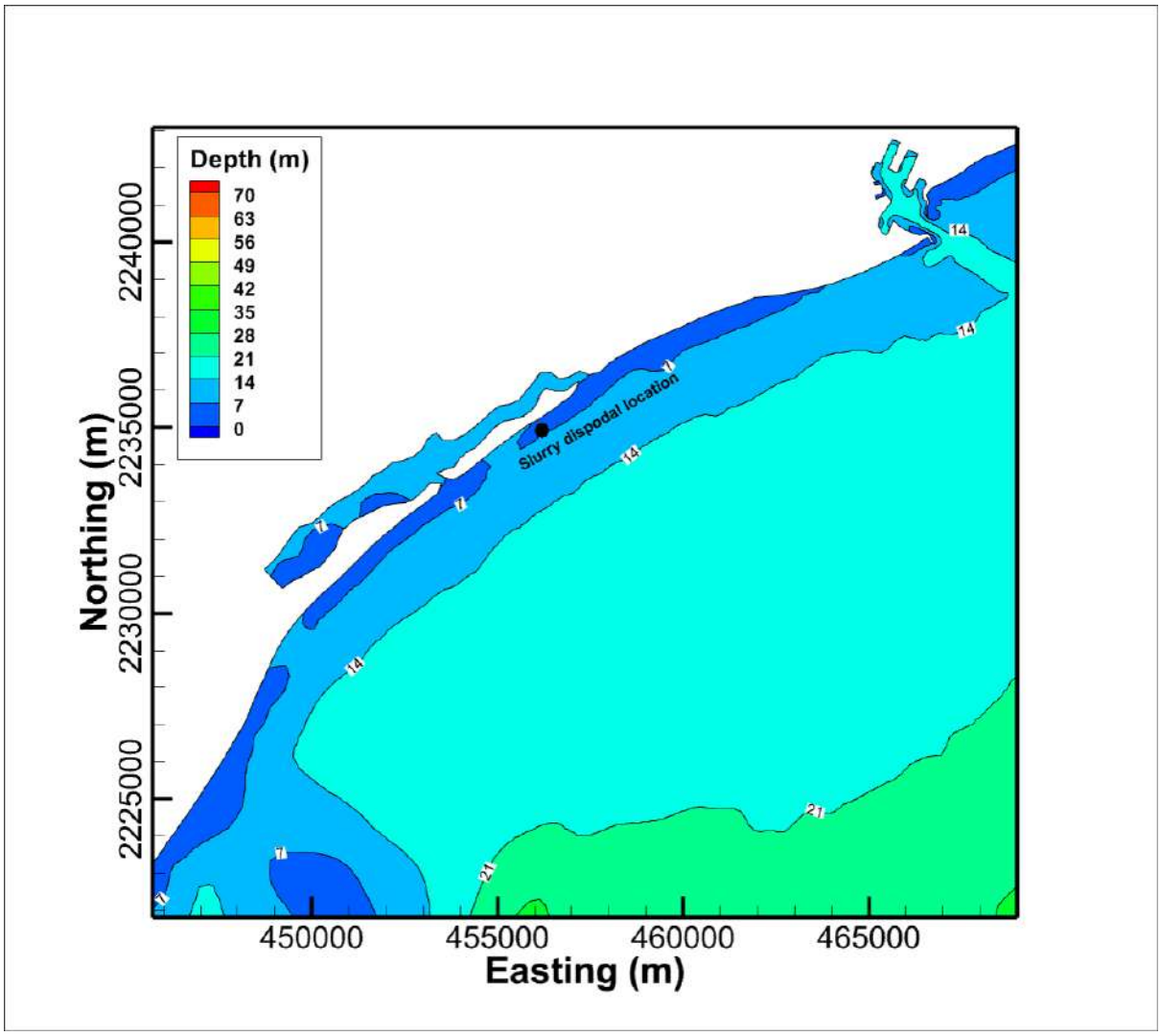



**Figure 26 Locations of Dumping sites**

## 4.2 Results and Discussion

### 4.2.1 Disposal of return slurry at proposed disposal location

The disposal site for slurry disposal location is at 20°12'40.86"N, 86°34'50.19"E. For the considered slurry disposal location, the initial sediment concentration is considered as 0.05g/l. In order to obtain the sediment concentration, range at the disposal locations, a pipe size of 500mm diameter is considered to dispose the slurry in 5m depth contour area at regular intervals at proposed location. As a result this disposed slurry,will raise the sediment concentration from considered ambient value of 0.05 to 106g/l at the instant of disposal at the proposed dumping site. From 106 g/l to 0.5 g/l i.e., 25000 dilutions takes place within 200 m. The results are plotted once the concentration reaches a steady condition. Based on the model study, for the sediment concentration to reach in a steady state,

it takes a distance of 3700m from dumping location towards east, 2300 m towards west and 2160 m towards south. This high dilution is possible as the disposal quantity is very less and the magnitude of current is in range of 0.1-0.9 m/s. Distance to dillution of sediment concentration dispersion at steady condition is given in **Table 3** . The results have been plotted once the concentration reaches a steady condition after initial dispersion as shown in **Figure 27.**

**Table 3 Distance to dilution of sediment concentration dispersion at steady condition**

| **Sediment concentration dilution (g/l)** | **Number of dilutions** | **Distance (m)** | | | |
|---|---|---|---|---|---|
| | | Maximum distance towards North | Maximum distance towards South | Maximum distance towards East | Maximum distance towards west |
| 106-0.5 | 25000 | 330 | 250 | 500 | 560 |
| 0.5-0.25 | 50000 | 400 | 450 | 850 | 1500 |
| 0.25-0.05 | >50000 | - | 2160 | 3700 | 2300 |

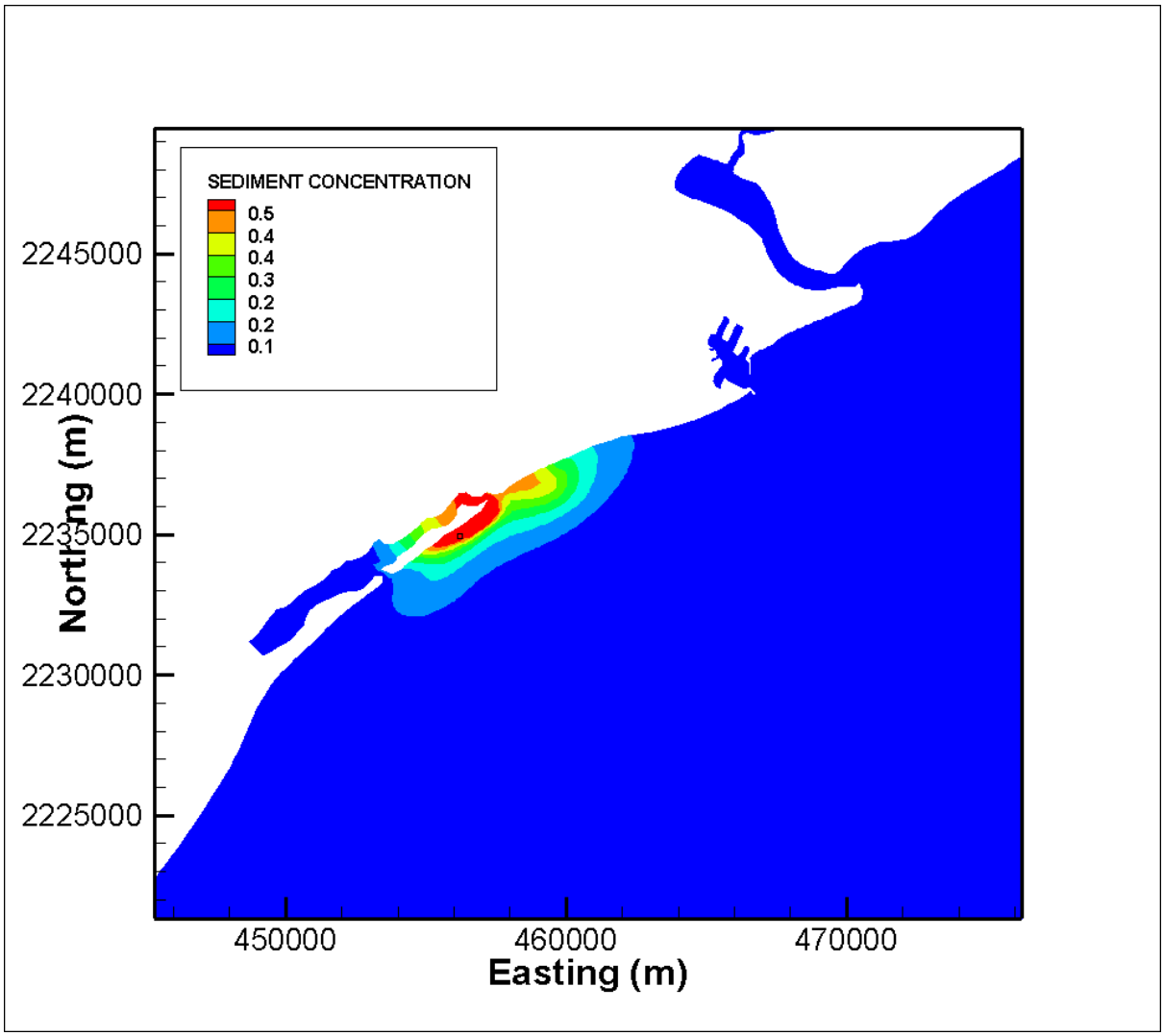



**Figure 27 TSS pattern at proposed dumping location once the concentration reaches a steady condition**

### 4.3 Conclusive Remarks

Numerical Advection- Dispersion study is carried out at Paradips' return slurry disposal sites. The results are plotted once the concentration reaches steady condition. The entire study has been carried out under critical scenario, for predicting highest concentrations of sediment near slurry disposal sites. As per dispersion study, dumping at proposed location alone does not cause any impact on the adjacent creek area and proposed harbour area.

## 5.0 CONCLUSION

1. Based on hydrodynamic modeling results, the dredging activities within the study domain has not significantly altered current conditions, suggesting that the natural flow patterns remain largely unaffected.
2. Case I involves updating the model with the latest bathymetry data to simulate the dredged condition of the study domain, resulting in a volume of 10.9 million cubic meters for reclamation purposes.
3. In Case-I outer channel is dredged to 12 m, sand bar to 10.5 m, sand trap to 5.5 m, and harbour basin to 10.5 m. In Case II, in addition to the aforementioned areas, the inner basin is also dredged to a depth of 10.5 m.
4. Across two cases examined, the average siltation inside the proposed borrow area ranges from 0.02-0.08 m/N-N per cycle which is more or less consistent with the existing scenario described in the first modeling report.
5. The dredge quantity estimate for Case-I for one year in sand trap area is 0.29 $Mm^3$/year, sand bar is 0.16 $Mm^3$/ year, harbour basin is 0.28 $Mm^3$/ year and outer channel is 0.21 $Mm^3$/ year. For Case-II the dredge quantity estimate for one year in sand trap area is 0.19 $Mm^3$/year, sand bar is 0.21 $Mm^3$/ year, harbour basin is 0.31 $Mm^3$/ year, outer channel is 0.25 $Mm^3$/ year and inner basin is 0.55 $Mm^3$/ year. The total dredge quantity estimate for a year for Case-I and Case-II are 0.94 $Mm^3$ and 1.51 $Mm^3$.
6. The analysis reveals that there are no significant variations in siltation rates after deepening the borrow area for reclamation purposes. This study suggests that dredging activities for land reclamation are not expected to substantially alter the siltation rates in the area.
7. As per dispersion study, dumping at proposed location alone does not cause any impact on the adjacent creek area and proposed harbour area.
8. As has been ascertained from the mathematical model studies there is no impact on adjacent creek area and proposed harbor areas.
9. Overall, the study suggests that dredging activities and the disposal of return slurry have no noticeable impact on study area, as evidenced by the minimal changes in current and siltation pattern observed across different scenarios.

## Annexure -A

### Details of Hydrodynamic and Morphodynamic model (Ocirc)

The hydrodynamic and morphological modeling is to be carried out using Ocirc (Ocean circulation model). In this model the hydrodynamic equations governing the ocean flow field are the vertically integrated form of Shallow Water Equations (SWE) (Chitra et al., 1996). Finite Volume Method (FVM) is used to discretize the SWE. The FVM is chosen for the SWE as it will better conserve the mass and momentum in the truncated solution domain. Rigorous validation of the model Ocirc 1.0 has been performed in the past (Murali et al., 2002). Accurate simulation of the tidal hydrodynamics at Hooghly estuary depends on the kind of computational mesh generated for the simulations. An unstructured meshing scheme was selected in order to accurately capture the shoreline. The unstructured meshing scheme is capable of resolving all the boundary and bathymetry details in the study area. This typical computational mesh depicts the ability of the meshing algorithm to exactly discretize the study area. The hydrodynamic model has to be calibrated for the purpose of ascertaining that the model parameters chosen are valid for the present estuary. The main model parameters in the present formulation are Horizontal Eddy Viscosity coefficient (ε) and Bottom friction coefficient $K_b$. Several simulations were conducted to determine the proper range of these parameters. Usually, where bed is smooth with alluvial sediments, the value of $K_b$ could be of the order of $10^{-3.}$ In the present case, the value of $K_b$ and the value of ε is made spatially and temporally varying.

### A1. Governing Equations

### A1.1 Model formulation

Navier-Stokes equations (N-S equations) are the fundamental mathematical framework for any fluid dynamics process. In the context of tides, the N-S equations simplify to the well-known "vertically integrated shallow water equations (SWE)" that govern the ocean flow field with main momentum transport occurring in the horizontal directions only. The SWE in a Cartesian co-ordinate frame fixed to the rotating earth and without lateral turbulent diffusion are,

$$q_{x,t} + \frac{q_x}{H} q_{x,x} + \frac{q_y}{H} q_{x,y} - f q_y = -\rho^{-1} H p_{a,x} - gH\eta_{,x} + \rho^{-1}\left(\tau_{ax} - \tau_{bx}\right)$$

$$q_{y,t} + \frac{q_y}{H} q_{y,z} + \frac{q_y}{H} q_{y,y} + f q_x = -\rho^{-1} H p_{a,y} - gH\eta_{,y} + \rho^{-1}\left(\tau_{ay} - \tau_{by}\right)$$

Here, the origin of the co-ordinate system is chosen at the undisturbed sea surface with 'z' measured positive upwards. *(qx, qy)* is the volume transport vector in the *(x, y)* plane and t is the time. The suffixes preceded by ',' indicate partial derivatives. $H = h+\eta$ is the total depth of water, h is the undisturbed depth of water at *z=0,* $\eta$ is the sea surface elevation measured from the undisturbed sea surface, f is the Coriolis parameter, ρ is the density of water and g is the acceleration due to gravity. *(τax, τay) and (τbx, τby)* are the stresses at air-water interface and bottom surface respectively. They are evaluated using the conventional quadratic law as follows:

$$\tau_a = K_a \rho_a |W| W, \qquad \tau_b = K_b \rho \, H^{-2} |q| q$$

where *Ka* and *Kb* are the wind and bottom stress coefficients respectively, *ρa* is the air density, *W* is the wind velocity measured 10m above the sea level and the volume transport $q \equiv (qx, qy)$. The effects of lateral eddy viscosity are added to the model for the purpose accounts for energy dissipation in lateral direction through standard eddy diffusivity term and using an Eddy viscosity formulation. Appropriate water levels and wind velocities have to be specified for this equation for simulation of tides. It has been observed (Chitra, 1998) that in long wave simulation studies, the initial conditions do not affect the numerical solution. Hence, the usual practice in tide simulation studies, is to assume the ocean to be initially at rest, before the introduction of the free surface perturbation or wind stress at the ocean free surface, i.e. $\eta, qx, qy = 0 \quad for \quad t \leq 0$. The conventional impermeable vertical side wall assumption may be made along the coastal boundary.

**A2. Ocirc 1.0**

IIT Madras has developed an in-house computer code to implement the above equations. ***Ocirc 1.0*** has been used in several projects in the past for investigating tidal hydrodynamics and siltation, specifically to Cochin, Kandla, and Paradeep ports and to study Storm surge and Tsunami hydrodynamics for DoAE, MES, and DRDO etc. The model has also been applied in high tidal range basins such as Gulf of Kutch and Gulf of Khambat. The model uses an unstructured mesh generation technique and solves the shallow water equations using a Finite Volume – Finite Element based method. The convective fluxes are estimated using Godunov's approach.

**A2.1 Finite Volume Discretization**

The FVM is chosen for the SWE as it will better conserve the mass and momentum in the truncated solution domain. To obtain a basic idea of the FVM, the reader is referred to Roache (1998). And for a detailed description of the method one should read Ashford (1996). The FVM involves partitioning the domain into a set of non-overlapping control volumes. On each control

volume, the integral form of the equations is required to hold. The solution unknowns are taken to be the cell-average quantities that interact through fluxes at the boundaries of the control volumes. Using the integral form of the equations guarantees that any discontinuities that arise in the solution will have the proper strengths (and speeds in an unsteady calculation). Several possible choices exist for the control volumes on an unstructured mesh. In this work, a cell-vertex method is used in which the unknowns are associated with the mesh vertices and the control volumes are taken to be the cells of the median dual mesh. The fluxes through the boundaries of the control volumes are computed using an upwind procedure based on Godunov's (Godonov, 1959) method.

**A2.2 Time Stepping**

With the spatial discretisation complete, the PDE reduce to a coupled system of ordinary differential equations that can be written as

$$\frac{dU}{dt} = R(U)$$

$U(0) = U_0$

Where U is the global conserved state vector containing all the unknowns, R (U) is an operator representing the spatial discretisation and $U_0$ is the initial condition. A widely used explicit method for the above equations is the multistage scheme, where m is the stage, is

$$U^{(0)} = U^n$$

$$U^{(k)} = U^n + \alpha_k dt R\left(U^{(k-1)}\right), k = 1,2,\dots,m$$

$$U^{(n+1)} = U^{(m)}$$

Where (n) and (n+1) refer to recent and new time levels respectively and $\alpha_k$ are the stage coefficients. We have implemented a 1 and a 2 stage scheme with $\alpha_0 = 1.0$ for the 1 stage scheme and $\alpha_0 = 0.5$ and $\alpha_1 = 1.0$ for the 2 stage scheme.

**A2.3 Initial condition**

Generally, in coastal hydrodynamic modeling, the initial conditions do not play any crucial role. Hence the usual practice is to assume the ocean to be initially at rest, before the introduction of boundary conditions on lateral boundaries and on the sea surface, i.e., $\zeta$, $qx$, $qy = 0$; $t \leq 0$.

**A2.4 Boundary conditions**

The current solver could work with tide elevation boundary conditions alone. When elevation is provided at boundaries, velocity Somerfield radiation condition is satisfied at these

boundaries. In cases, where velocity boundary condition shall be used, the solver would use the Somerfield condition to estimate the elevation at the boundary. It is also possible to run the model with Elevation and Velocity boundary conditions in case measurements are available.

**A2.5 Mesh Generation**

An unstructured mesh generation technique has been incorporated in the present model to produce high quality meshes suitable for shallow water equations. The mesh generation process begins with the construction of the boundary mesh. In this process, the domain boundaries are discretized considering a courant number criteria (C-criteria). The discretisation mainly aims at keeping the overall mesh courant number, required by the user, constant while it will also try to model the geometry as close as possible. This will produce high quality meshes in the estuary.

**A2.6 Morphodynamics Model**

The mass balance of sediments at a given control volume and resulting change in volume of sediments is used to estimate change in bed level. This is same as MIKE21 ST module of MIKE 21 software. The bed level ($h$) equation as provided below is used to compute the siltation rates.

$$\frac{\partial h}{\partial t} + \frac{1}{1-n}\nabla_h \bullet (q_x, q_y) = 0$$

In the above, n is the porosity and q is the total sediment transport rate. The above approximation assumes that, under a balanced condition, the sediment entrainment and deposition rates are at equilibrium (Tambroni et al., 2010). In order to smooth out the bed level changes, a diffusion term could be added to the above equation. However, quantifying the diffusion coefficient will require lot of data. Hence, a laplacian smoothing of the bed levels is carried out, with 3 cycles, for the purpose of mimicking the location specific diffusion of bed levels.

In order to compute the sediment fluxes, Ocirc employs the following approaches.

**Ackers and White formula**: This formula is the most suitable one for the present situation as it directly computes the total load of sediment transport. It works very well when the flow conditions mostly shallow water, as that of the present case. It is applicable for a wide range of sediment size and water depths. Hence, this formula is expected to give more appropriate estimate of the sediment load.

**Van Rijn formula:** This formula is another favoured formula in field by many engineers for total load estimates. However, the limitations of this approach (flow depth, h>1.0 m and $D_{50}$>0.5 mm) is making this formula unusable for the present application.

**Bed & Suspended load estimates:** Traditionally, the sediment transport has been considered to be of mainly 2 forms: Bed load and Suspended load. In this approach the load estimates will be combined to give the total load. It is usually observed that *(Coastal Engineering, 2004)* this formula will give the lower bounds of the total load.

**A2.7 Estimation of Total Load**

According to Ackers and White formula, the sediment transport is related to,

$$G_{gr} = \frac{q_t}{UD}\left[\frac{u_*}{U}\right]^n$$

$$G_{gr} = C\left[\left(\frac{F_{gr}}{A_{gr}}\right)-1\right]^m$$

The above relationship is used to estimate $q_t$ ($m^3/m/s$) from U (Mean flow), D (D35), u* (friction velocity), C (Chezy coefficient) and parameters n, m, Agr and Fgr. More information can be found in *Coastal Engineering (*2004*)*. The transport equation governing the

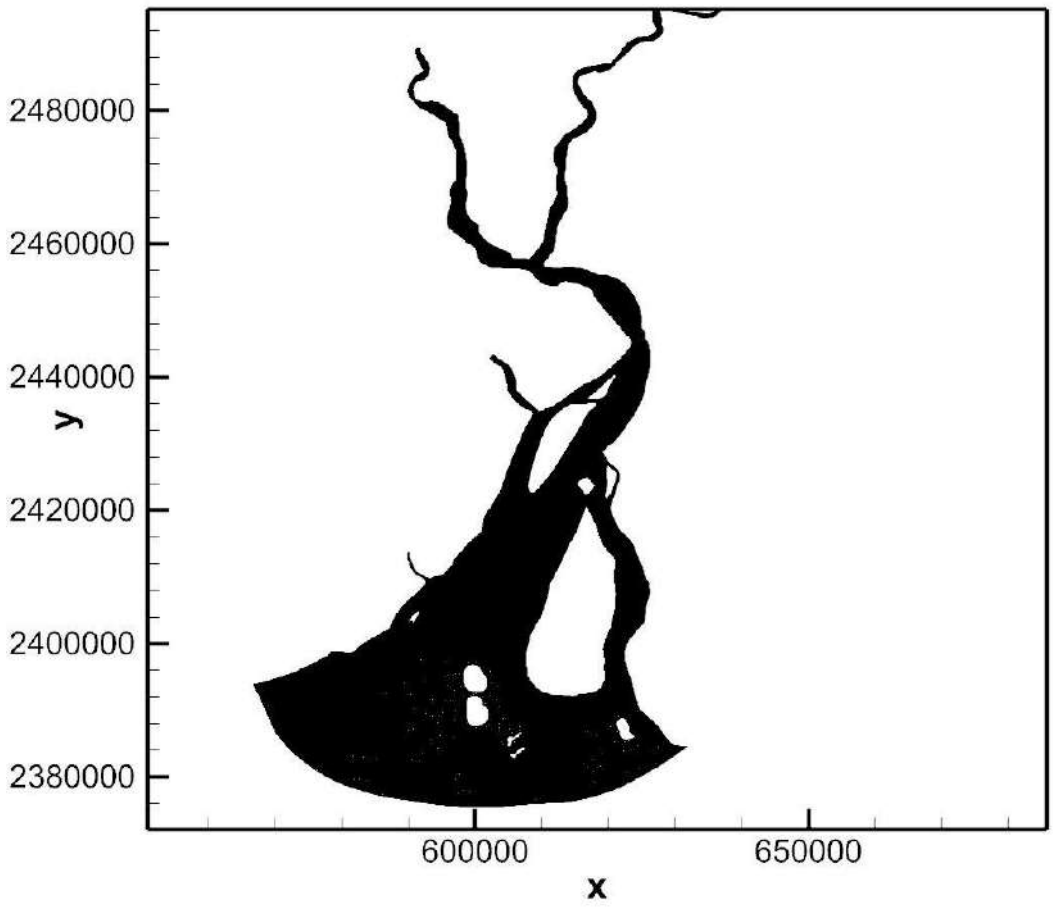
bed level change is coupled with the hydrodynamic equation to estimate the rate of sedimentation in the estuary.

In the present study, the hydrodynamics and morphodynamics modules are coupled in time domain to provide the most sophisticated estimates of bed level change. After each hydrodynamic solution, the sediment rates are resolved in each cell and converted into siltation. The computed siltation is added to the bathymetry to provide a direct feedback of bed change to velocity computation. Thus the balance between sediment mobilizing and stabilizing stresses are continuously maintained during the computations.

**A3 Modeling the study area**

The Hooghly estuary is a complex dynamic estuary facing dredging maintenance and navigation related problems due to the high rate of sediment load brought in by the Hooghly River. Based on the similar studies carried out for the Hooghly domain in order to investigate the stability of navigation channel (Haldia Dock Complex (HDC)), this study can be channelized to find solutions to the objective of this study. The domain of the study will be represented by a number of bodies representing exterior coastal lines and interior islands. This is basically the geometric configuration of the coastal boundaries in Hooghly estuary. The computational mesh and bathymetry used for simulation are shown in **Fig.A-3.1 and Fig.A-3.2** respectively. The final mesh has fine elements near the coastlines and shallower water

depths. The average mesh size is about 20-100m which is very fine for a simulation such as the present problem. The mesh is coarser near the offshore boundaries, where the water depths are greater. The interpolated bathymetry on the mesh represent the contours at regular intervals. Detailed numerical model studies have been carried out earlier to investigate the hydrodynamics of tide induced flow features and the tidal boundary conditions employed is shown in **Fig.A-3.3**. It is to be noted that, considering such a time series for the 15 days period covers the spring-neap variations of the astronomical tide and addresses all variations in the astronomical tides. Along with the tidal elevation current speed components u and v are also provided in the open boundary for driving the tidal currents in this tide dominated domain. The typical time series validation of the model extracted from previous studies are projected in **Figs.A-3.4.**




**A-3.1 Typical meshing of the domain considered for simulation**

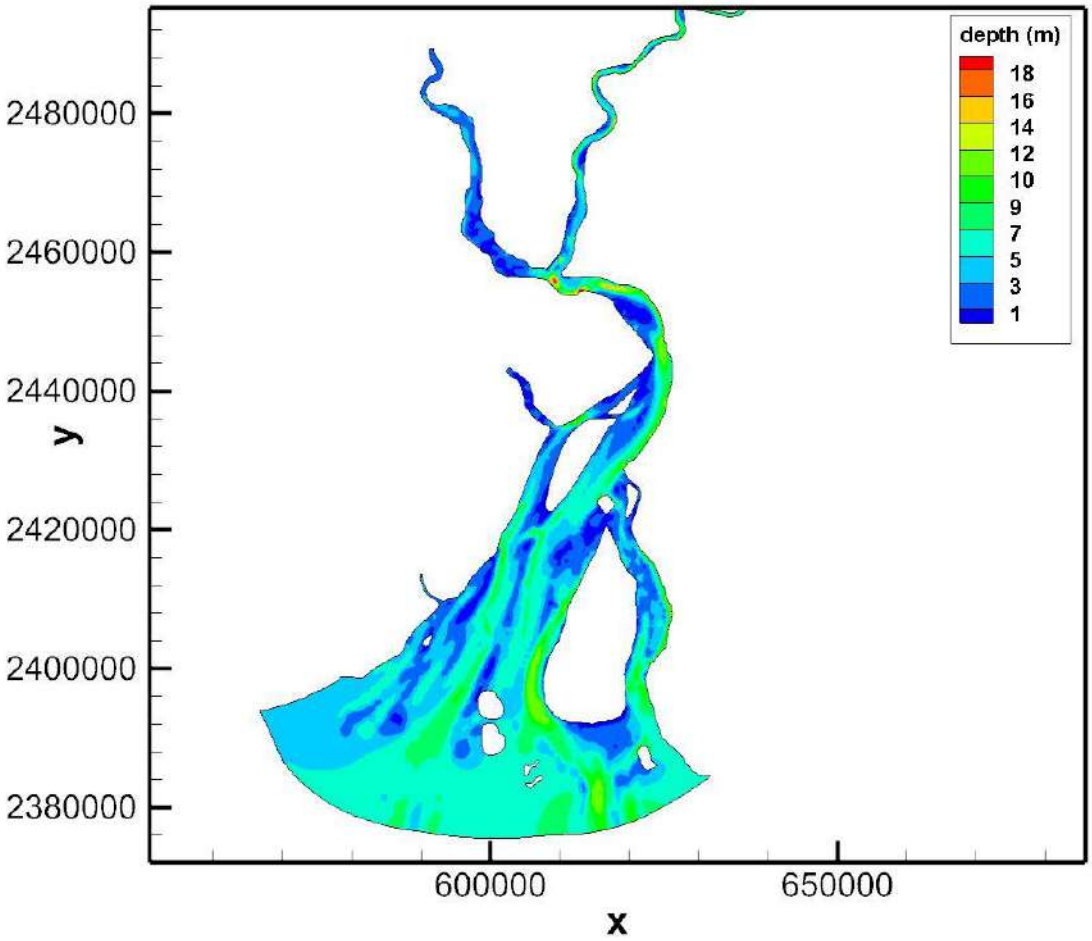



**Fig.A-3.2 Bathymetry of the domain used for simulation**

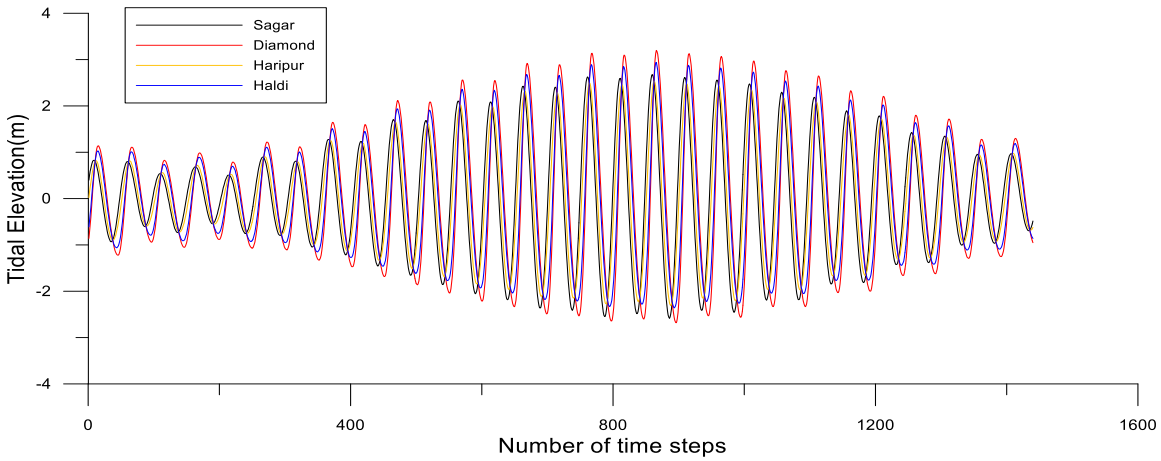



**Fig.A-3.3 Open boundary conditions used for the study**

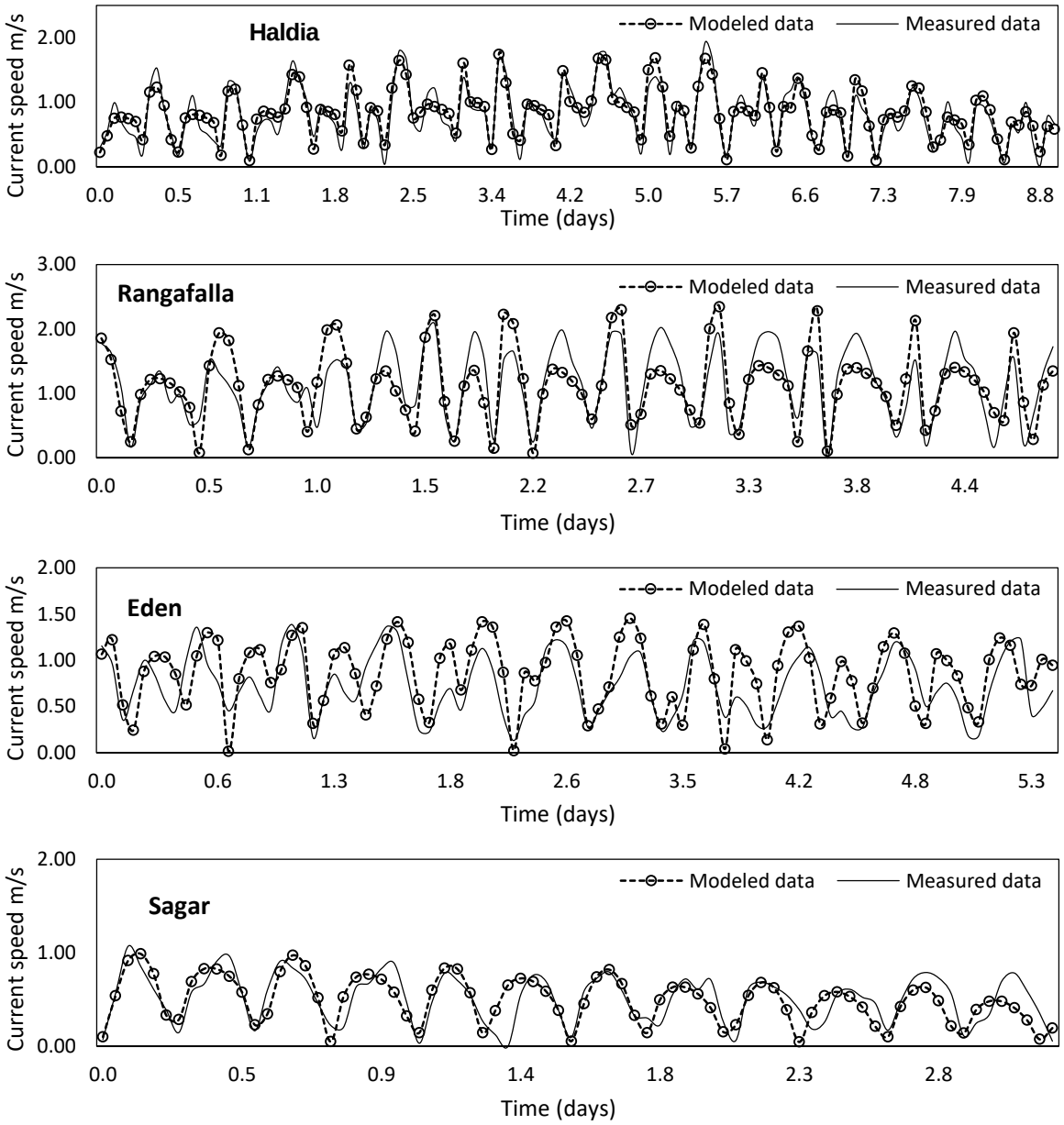



**Fig.A-3.4 Time series plots of measured current speed at different locations compared with modeled results of Hooghly domain**

## Annexure-B

### B.B.1 Computational Model for Advection-Dispersion studies

The computational model is based on a three-dimensional Navier-Stokes equation that solves the mass and momentum conservation of the fluid flow.

Mass conservation: $\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{v}) = S_m$ (1)

where $S_m$ = mass source term.

Momentum conservation: $\frac{\partial}{\partial t}(\rho \vec{v}) + \nabla \cdot (\rho \vec{v}\vec{v}) = -\nabla p + \nabla \cdot (\bar{\bar{\tau}}) + \rho \vec{g} + \vec{F}$ (2)

Where, $\tau_{ij}$ = stress tensor = $\mu\left[\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) - \frac{2}{3}\frac{\partial u_l}{\partial x_l}\delta_{ij}\right]$, $p$ = static pressure,

$g_i$ = gravitational acceleration in the i[th] direction, and $F_i$= external body forces. Some of the important aspects of the model are described as follows.

### B.B.2 *Standard* $\kappa$-$\varepsilon$ Model

For the turbulent flow, additional conservation equations for κ (kinetic turbulence energy) and ε (turbulence energy dissipation) are solved. In the present project, a standard κ-ε model was adopted in the calculation. The standard κ-ε model is a semi-empirical model, which is valid for fully developed turbulent flows. It is derived from the Reynolds-Averaged Navier-Stokes equations based on the assumption that the flow is fully developed. The model has been found to work well for a wide range of wall-bounded and free shear flows. The equations of the standard κ-ε model are given below.

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_i}(\rho k u_i) = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right] + G_k + G_b - \rho\varepsilon - Y_M + S_k \quad (3)$$

and

$$\frac{\partial}{\partial t}(\rho \varepsilon) + \frac{\partial}{\partial x_i}(\rho \varepsilon u_i) = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right] + C_{1\varepsilon}\frac{\varepsilon}{k}(G_k + C_{3\varepsilon}G_b) - C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} + S_\varepsilon \quad (4)$$

where $G_k$ is the generation of $k$ due to the turbulent stress, and $G_b$ is the generation of $k$ due to buoyancy.

The model constants have the following default values:

$C_{1\varepsilon} = 1.44\ C_{2\varepsilon} = 1.92\ C_{\mu} = 0.09\ \sigma_k = 1.0,\ \sigma_{\varepsilon} = 1.3$

These default values have been determined from experiments with air and water for fundamental turbulent shear flows. They have been found to work fairly well for a wide range of wall-bounded and free shear flows.

**B.B.3 Boundary Conditions and Initial Condition**

***B.B.3.1 Wall boundary conditions - Shoreline***

Non-slip boundary condition is used at walls. The modified law-of-the-wall was evaluated using the applied roughness height to calculate the shear stresses at walls. A roughness constant of 0.5 as the default value was used for the simulation.

***B.B.3.2 Velocity boundary conditions - for tidal flow inlet***

The intake and diffuser ports are assigned with known discharges. The velocity inlet boundary condition was applied. The inflow is assumed to be fully open to allow the flow ramp up to the maximum flow rate from start of simulations with the specified pressure head corresponding to the water depth. Velocities obtained in the tidal hydrodynamics study are used for this purpose

***B.B.3.3 Pressure boundary condition - outlet***

Atmosphere pressure was applied at the free surface boundary. Slip condition has been used for velocities tangential to the boundary.

***B.B.3.4 Initial condition***

The model simulation starts from rest. This is a suitable condition as the dispersion process is governed predominantly by advection and diffusion.

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