# DETAILED PROJECT REPORT (DPR) FOR SHIP REPAIRING FACILITY AT PATNA, BIHAR

**Client**

**INLAND WATERWAYS AUTHORITY OF INDIA**

**Consultant**


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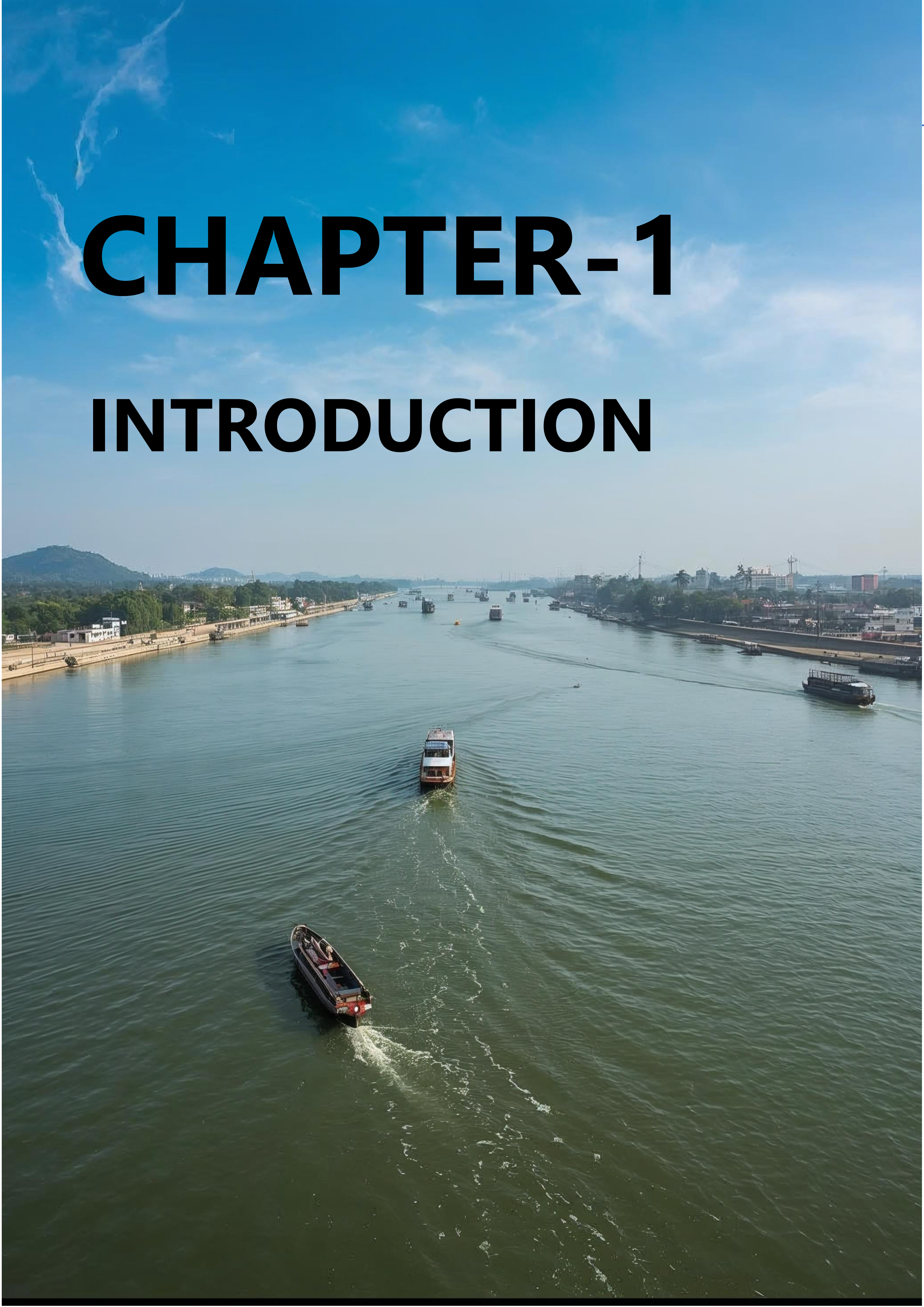
# CHAPTER-1

## INTRODUCTION



# 1 INTRODUCTION

The Inland Waterways Authority of India (IWAI), under the Ministry of Ports, Shipping & Waterways, is tasked with developing and regulating inland water transport on the nation's navigable rivers, including National Waterway-1 (NW-1), the Ganga – Bhagirathi - Hooghly system, which connects key states and cities such as Patna. Under the Jal Marg Vikas Project (JMVP), NW-1 is being enhanced with terminals, dredging, and navigation infrastructure to boost cargo and passenger movement. However, the absence of a dedicated ship repair facility along NW-1 forces vessels to travel long distances, mainly to Kolkata, for repairs, leading to high costs and downtime. Establishing a Ship Repair Facility (SRF) at Patna would enable in regional sustainability, improve vessel turnaround, support the growing inland fleet, and align with national initiatives like JMVP, Atmanirbhar Bharat, and PM Gati Shakti, while creating local employment and boosting regional economic growth.

To address this need, IWAI is undertaking major developmental activities along its waterways, including setting up dedicated ship repair facilities at various waterways across the country to minimise the operating and running expenditure of maintaining its own vessels and also the fleet of other private operators plying in the waterways. Patna, Bihar, has been identified as one of the strategic locations, where both vessels owned by IWAI and also private operators operate extensively. However, due to lack of basic infrastructure facilities for carrying out minimum repairs, the vessels plying in the route had to travel to Kolkata or other shipyards resulting in huge expenditure and time. Hence, IWAI has intended to avail the expertise of the National Technology Centre for Ports, Waterways and Coasts (NTCPWC) to carryout detailed project report inter-alia covering the need, benefits and its usefulness.

A work order bearing no IWAI/NW-1/SRF/Gazhi./2024-25(1) dated 20-05-2025 for preparation of Feasibility study and Detailed Project report (DPR) for Ship Repairing Facility at Patna, Bihar was also issued to NTCPWC. When the preliminary details were under compilation and preparatory works were initiated, IWAI had divided the original scope covered under the above mentioned work order and issued a separate work order vide IWAI work order no IWAI/NW-1/ROPatna/Patna/ShipRepairFacility dated 05.06.2025 with the scope limited to the following:

1. *Site assessment & Review of existing data*
   a. *Reconnaissance/ Site Survey: To conduct a detailed reconnaissance/ site survey of the proposed site, including geographical, environmental, and socio-economic conditions.*
   b. *Review of existing data. Collection and examination/ review of previous studies, reports, data, information, maps, charts etc. available IWAI and any other sources. Provisions of the IV Act 2021, details and type of inland vessels flying in the NW- 1.*
   c. *Identification of Location in Patna Bihar in consultation with stake holders.*

2. *Market Analysis*
   a. *Demand Assessment: Analyse the current and projected demand for ship repair services in the region. This shall include assessment at the proposed ship yard facility for repair and maintenance of IWT vessels plying in NW-1 for the time-frame 2025, 2030, 2035 and 2045 in consultation with all nodal agencies like Bihar IWT, IWAI tourist vessel operators, mechanized country boats and other relevant stakeholders / private agencies.*
   b. *Competitive Analysis: Assess the competitive landscape, identifying existing ship repair facilities and potential competitors within the region of proposed facility.*

## 1.1 Inspection Report

In line with the work order dated 05-06-2025, with the scope indicated above, a site visit and reconnaissance survey were carried out by the NTCPWC team, led by Mr. R. Srinivasakannan, Senior Project Advisor, along with IWAI officials, to assess technical feasibility, site conditions, available area, connectivity, and environmental aspects of the proposed location (Figure 1).


Figure-1 Proposed tentative location for the ship repair facility at Patna

Inspection report, inter-alia covering the physical, hydrological, and environmental conditions of the proposed site for establishing a Ship Repair Facility at Patna, was also submitted during June 2025, with the following recommendation, (Attached as Annexure – I).

> *After detailed analysis of the site environment, data shared by IWAI and various discussions & deliberations held with IWAI Authorities, the following conclusions are arrived at.*
>
> 1. *Sufficient water depth is available at the identified site, even at the lean seasons, to handle all the IWAI vessels having draft upto 2.5m. However, the water level is varying substantially and the average water level variation is around 8.4m and the maximum level variation is 9.72m. Taking into account such variation, a suitable design preferably, a boat hoisting jetty with other landside infrastructure can be designed.*

2. *If the top of the proposed Boat Hoisting jetty is fixed, with sufficient free board over and above the highest high water level, preferably around 53m or such elevation for ensuring seamless operation of Ship Repair Facilities (to be reconfirmed during the Detailed Project Report stage), the backup facilities such as repair bay, transfer bay, can be conveniently located immediately behind the boat hoisting jetty over the piles without affecting the natural water flow, while other landside infrastructure viz., workshops, substations, admin buildings, road & rail connectivity (if possible), etc., can be developed in the area identified by IWAI admeasuring 20,000 Sq.m, as shown in figure 1.*

*Considering all these aspects, particularly availability of sufficient water spread area with required water depth and land for developing the backup infrastructure facilities, it is recommended that the Ship Repair Facilities can be established at the identified location Patna, Bihar, as shown in figure 1, which will result in both direct and indirect benefits and considerable savings in cost & time, and also create substantial employment potential for the country, as a whole and Bihar/ Patna in particular.*

IWAI had agreed with the observation of NTCPWC as contained in the inspection report and advised to proceed to next stage of establishing the feasibility of the project.

## 1.2 Feasibility Report

Following the submission of the inspection report, additional operational and technical data were collected from IWAI. Using this information, two alternative layouts for the proposed Ship Repair Facility were prepared. These layouts incorporated both marine-side infrastructure (piled jetties, transfer areas, and repair bays) and landside facilities (workshops, utilities, and administrative buildings), providing two viable development options.

Subsequently, the Feasibility Report inter-alia covering the following major items was submitted in 13th August 2025.

- Finalization of development options for a two-phase implementation plan
- Market analysis and demand projections for vessel repair in the Patna stretch of NW-1
- Methodology for facility planning and design assumptions
- Preliminary block cost estimation
- Recommendations for establishing a modern Ship Repair Facility to cater to both public and private operators.

The gist of the recommendation as contained in the Feasibility Report (Attached as Annexure – II) is reproduced hereunder for ready reference.

The feasibility report has been perused by IWAI and conveyed its in-principle acceptance of the recommendation of NTCPWC. It was further advised to proceed with the detailed project report as per the scope of work as contained in the work order IWAI/NW-1/SRF/Ghazi./2024-25(1), excluding the scope of work already covered in the feasibility report

# CHAPTER-2

# PROJECT BACKGROUND

# 2 PROJECT BACKGROUND

The present Draft Detailed Project Report (DPR) has been prepared based on the findings of the inspection and feasibility studies. This DPR provides a comprehensive account of the proposed facility, including the general layout of marine and landside infrastructure, functional elements, design dimensions, and detailed cost estimates. It also outlines the phasing of development, ensuring that the project is implemented in a structured and sustainable manner.

## 2.1 Project Background Observation and assessments during the Reconnaissance / Site Survey

The proposed site, located at Latitude 25°38′23.92″ N, Longitude 85°06′49.00″ E, lies on the southern bank of the Ganges River, just north of central Patna. This National Waterway – 1 passing through Patna, Bihar is classified as Class VII Waterway, as defined in Gazette Notification CG-DL-E-17122022-241170 dated 16.12.2022. However, there is no established Ship Repair facilities in the entire stretch and all the vessels have to travel to Kolkatta for major/ minor repairs, which resulted in considerable cost and time. The location now identified for setting up of Ship Repair facilities at Patna, Bihar, offers strategic advantages for river-based operations. The proposed site is located on the southern bank of the Ganges River, just north of central Patna, offering strategic proximity to National Waterway–1 and serving as a prime location for inland vessel operations. IWAI in due consultation with other Government department, had identified about 20,000 sq.m of land parcel (200m x 100m), just outside the High water level parallel to the proposed identified location for setting up of the facility. This land parcel is most ideally suitable for setting up of the land based facilities considering its elevation, proximity to the jetty construction and adjoining roads and other areas. The area lies on flat alluvial plains, bordered by agricultural fields and a narrow strip of riparian vegetation along the riverbank. The land falls within the designated riverfront development zone under municipal jurisdiction, with significant portions already earmarked for waterway-related Infrastructure. The proposed tentative location for ship repair facility at Patna is shown in **Figure 2.1**.


Figure 2.1 Proposed location for the ship repair facility at Patna

## 2.2 Rail and road connectivity

The site is well-connected by road through local village access roads that link directly to JP Ganga Path - Patna's dedicated riverfront expressway running parallel to the Ganges. This expressway integrates with major highways such as NH-119A (the Patna–Arrah–Sasaram corridor) and other regional routes, ensuring strong inland connectivity. Rail access is equally efficient, with Patna Junction Railway Station located approximately 4 km from the site, offering both regional and national connectivity. The terrain comprises fertile, gently sloping loamy alluvium typical of the Ganges basin—highly suitable for construction and infrastructure development. Vegetation is sparse and mostly confined to the narrow riparian buffer zone along the riverbank. The site's riverfront location provides direct access to NW-1 and makes it ideal for establishing ship repair and inland vessel servicing facilities. The combination of excellent multimodal access (via river, road, and rail), suitable topography, and existing land allocation enhances its feasibility for rapid infrastructure deployment with minimal earthwork requirements.

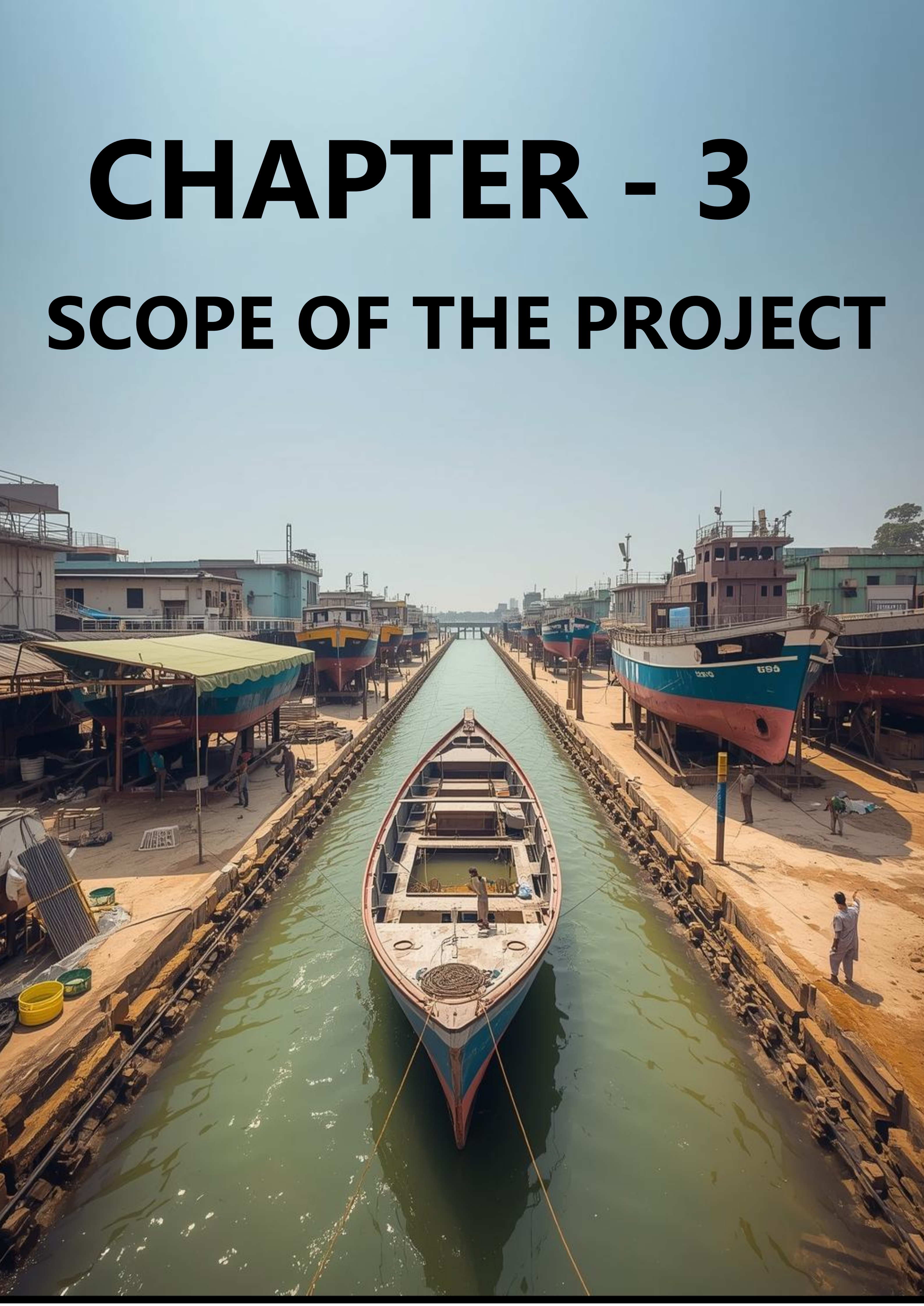
## 2.3 Organization of the Report

The report has been organized as per the following sequence.

- **Section 1: Introduction**
- **Section 2: Project Background**
- **Section 3: Objective and Scope of the work**
- **Section 4: Project Site Environment**
- **Section 5: Market Analysis**
- **Section 6: Development Plan**
- **Section 7: Proposed Ship Repair Facility**
- **Section 8: Proposed Structures Landside Development**
- **Section 9: MEP Services**
- **Section 10: Total Development Cost for Phase-1 & Phase-2**

# CHAPTER - 3

# SCOPE OF THE PROJECT



# 3 SCOPE AND OBJECTIVES OF THE WORK

**The present project is focused mainly in the following:**

1. Site assessment & Review of existing data
   d. Reconnaissance/ Site Survey: To conduct a detailed reconnaissance/ site survey of the proposed site, including geographical, environmental, and socio-economic conditions.
   e. Review of existing data. Collection and examination/ review of previous studies, reports, data, information, maps, charts etc. available IWAI and any other sources. Provisions of the IV Act 2021, details and type of inland vessels flying in the NW- 1.
   f. Identification of Location in Patna Bihar in consultation with stake holders.

2. Market Analysis
   c. Demand Assessment: Analyse the current and projected demand for ship repair services in the region. This shall include assessment at the proposed ship yard facility for repair and maintenance of IWT vessels plying in NW-1 for the time-frame 2025, 2030, 2035 and 2045 in consultation with all nodal agencies like Bihar IWT, IWAI tourist vessel operators, mechanized country boats and other relevant stakeholders / private agencies.
   d. Competitive Analysis: Assess the competitive landscape, identifying existing ship repair facilities and potential competitors within the region of proposed facility.
3. Technical Design and Engineering
   a. Facility Layout: Develop the design and layout of the ship repairing facility, including dry docks, workshops, storage areas, and other necessary infrastructure. Such facilities include but not limited to revetment / bank protection work, ship lifting facility, winches, equipment to handle ship and its parts, ship repair yard, workshop, store, hard stand, office building, internal road, water supply, firefighting, electricity etc.

b. Technical Specifications: Provide detailed technical specifications for all equipment, machinery, and materials required for the proposed ship repairing facility. Develop detailed layout plan, engineering design & drawings, preparing specifications, bill of quantities, etc.

c. Operational Plan: Outline the operational processes, including workflow, manpower requirements, and maintenance schedules.

d. Proof checking of design through a reputed agency/institution.

4. Technical Design and Engineering

   a. Cost Estimation: Prepare a detailed cost estimate for the project, including capital expenditure, operational costs, and maintenance expenses. Also provide basis for justification of such cost estimates.

      i. The consultant shall prepare a realistic construction schedule and estimated cost of development and O&M for the ship repair facility indicating the sequence of activities duly considering the river characteristics in different seasons and priority of work along with phasing of expenditure.

      ii. Further, the estimated cost of development should be realistic and based on local schedule of rates/market rate and their basis/documentary proof should be included in the DPR with necessary details.

   b. Revenue Projections: Develop revenue projections based on market analysis and operational capacity of the proposed ship repair facility.

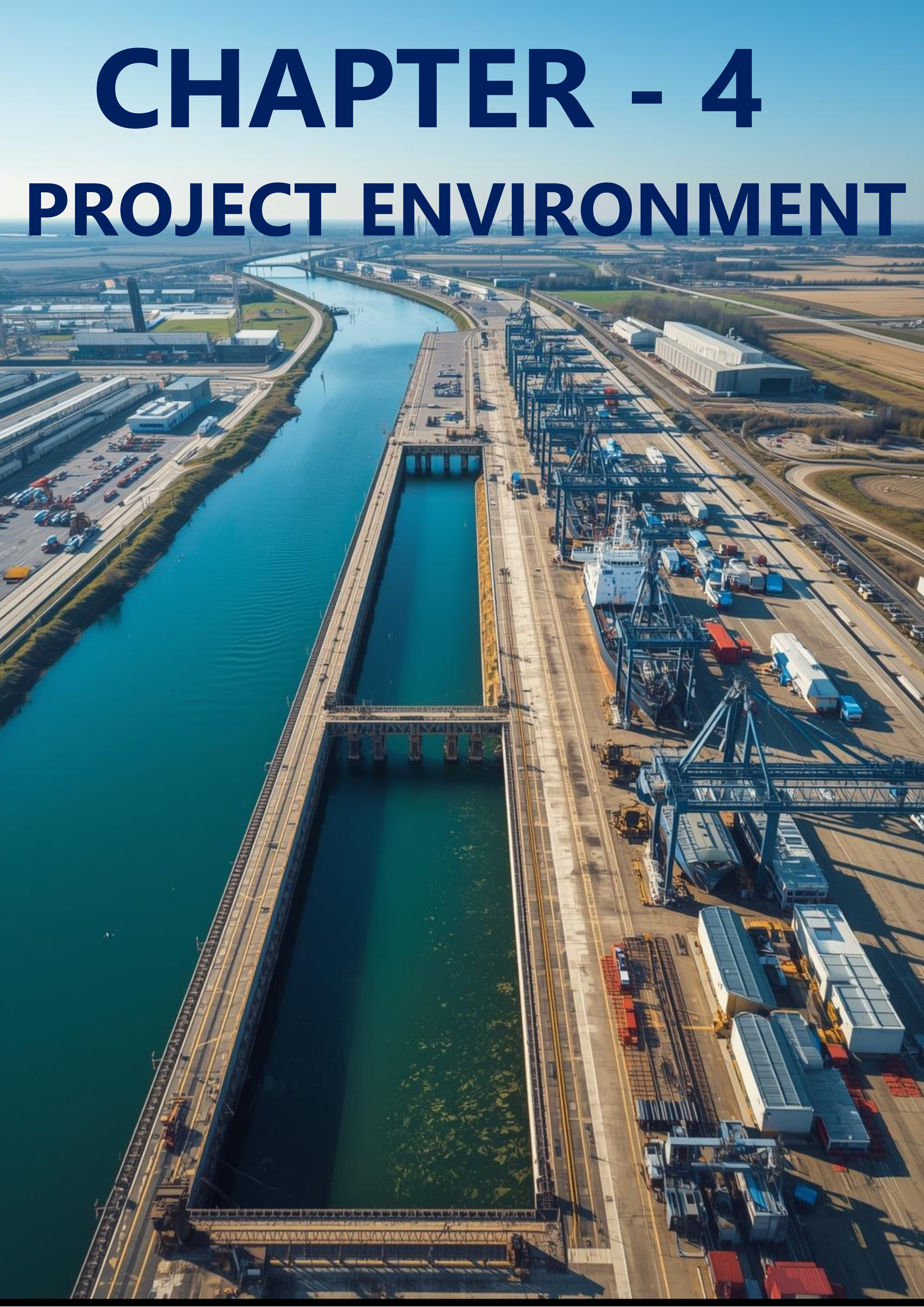
   c. Financial & Economic Viability: Workout Cost Benefit analysis, Financial Internal Rate of Return (FIRR) and Economic Internal Rate of Return (EIRR) based on current Indian /International norms, with sufficient backup calculations, basis, assumptions with their source, justification etc. The financial viability assessment should include project cash flow analysis, break-even analysis, and sensitivity analysis.

5. Environmental and Social Impact Assessment

   a. Environmental Impact Assessment (EIA): Conduct an EIA to identify and mitigate potential environmental impacts of the project.
   b. Social Impact Assessment (SIA): Assess the social impact of the project on the local community and propose mitigation measures, if necessary.
6. Risk Assessment and Management
   a. Risk Identification: Identify potential risks associated with the project, including technical, financial, and operational risks.
   b. Risk Mitigation Plan: Develop a risk mitigation plan outlining strategies to minimize or manage identified risks.
7. Implementation Plan
   a. Project Phasing: Propose a phased implementation plan, including timelines, milestones, and key deliverables.
   b. Resource Allocation: Outline the resources required for each phase of the project, including manpower, equipment, and materials.
   c. Monitoring and Evaluation: Propose a monitoring and evaluation framework to track the progress of the project during and after implementation.
8. Preparation of tender documents
   a. Tender for capital works: Prepare tender documents containing General Conditions of Contract, Special Conditions of Contract, Technical Specifications and NIT etc. all complete to facilitate implementation of project for all capital works for development of proposed ship repair facility.
   b. Tender for O&M: Prepare tender document for selecting O&M operator of ship repair facility through an open tender.

# CHAPTER - 4

# PROJECT ENVIRONMENT



# 4 PROJECT SITE ENVIRONMENT

The analysis of the prevailing environmental aspects of the project site are essential for the better understanding of the site that will help in development and modification of the ship repair facility (Slipway). Hence an overall environmental data on the location, connectivity, meteorological parameters, geotechnical aspects, and basic details of the project site are presented for better appreciation.

## 4.1 Rainfall

The annual rainfall in the catchment area varies from over 160 cm in some regions of South Bihar to less than 90 cm in the western parts. Rainfall in the region is negligible from November to March. The rainfall commences from April and reaches its peak during July and August. The average annual rainfall is about 120 cm at Patna.

## 4.2 Water level

Hydrological data from 2018 to 2025, collected at Gandhi Ghat and Digha Ghat, shows seasonal fluctuations in water level ranging from 6.6 meters to 9.7 meters annually. High Flood Levels (HFL) were recorded at 50.52 meters at Gandhi Ghat and 52.52 meters at Digha Ghat. These fluctuations are critical in planning infrastructure that must remain functional year-round.

Channel bathymetry data indicates the formation of sandbars toward the riverbank over the same period. Satellite imagery and field verification from 2018 to 2025 confirm sediment accretion trends that present navigational challenges. The development of a ship repair facility must therefore be integrated with ongoing sediment management strategies, including dredging and bank protection.

A comprehensive analysis of satellite imagery and on-site bathymetry surveys reveals the gradual formation of sandbars in the channel adjacent to the proposed site. These formations, visible in Google Earth historical imagery, demonstrate a landward shift in sediment deposition. Such conditions, if left unmanaged, may hinder navigation and pose a risk to vessel safety. The integration of sediment monitoring with real-time water level data will be essential in planning access channels, dock placement, and repair basin locations. Additionally, seasonal dredging schedules must align with hydrological forecasts to maintain a functional draft throughout the year. Minimum & Maximum Water Level of (Gandhi Ghat & (Digha Ghat)) River Ganga from 2018 to 2025 are given in Table 4.1 and Table 4.2 respectively. The channel analysis and satellite imagery for the year 2018-2025 are shown in the images depicted in Figure 4.1.

Table 4.1 Minimum & Maximum Water Level of (Gandhi Ghat) River Ganga

| Year | Min. Water Level (m) | Date | Max. Water Level (m) | Date | Water level Difference (Max-Min) (m) |
|---|---|---|---|---|---|
| 2018 | 41.01 | 25-03-2018 | 49.60 | 13-09-2018 | 8.59 |
| 2019 | 41.65 | 24-03-2019 | 49.79 | 23-09-2019 | 8.14 |
| 2020 | 42.22 | 19-02-2020 | 48.86 | 22-08-2020 | 6.64 |
| 2021 | 41.58 | 07-03-2021 | 50.45 | 15-08-2021 | 8.87 |
| 2022 | 41.94 | 16-05-2022 | 49.59 | 01-09-2022 | 7.65 |
| 2023 | 41.75 | 16-05-2023 | 48.56 | 10-08-2023 | 6.81 |
| 2024 | 41.50 | 15-05-2024 | 50.28 | 20-09-2024 | 8.78 |
| 2025 | 42.02 | 17-05-2025 | | | |
| HFL Gandhi Ghat | | | 50.52 | 21-08-2016 | |

Table 4.2 Minimum & Maximum Water Level of (Digha Ghat) River Ganga

| Year | Min. Water Level (m) | Date | Max. Water Level (m) | Date | Water level Difference (Max-Min) (m) |
|---|---|---|---|---|---|
| 2018 | 41.96 | 26-03-2018 | 50.72 | 13-09-2018 | 8.76 |
| 2019 | 42.61 | 26-03-2019 | 50.94 | 23-09-2019 | 8.33 |
| 2020 | 43.00 | 07-03-2020 | 50.05 | 22-08-2020 | 7.05 |
| 2021 | 42.26 | 08-03-2021 | 51.85 | 15-08-2021 | 9.59 |
| 2022 | 42.64 | 19-05-2022 | 50.76 | 01-09-2022 | 8.12 |
| 2023 | 42.42 | 18-05-2023 | 49.67 | 10-08-2023 | 7.25 |
| 2024 | 42.04 | 19-06-2024 | 51.76 | 20-09-2024 | 9.72 |
| 2025 | 42.58 | 14-05-2025 | | | |
| HFL Digha Ghat | | | 52.52 | 23-08-1975 | |

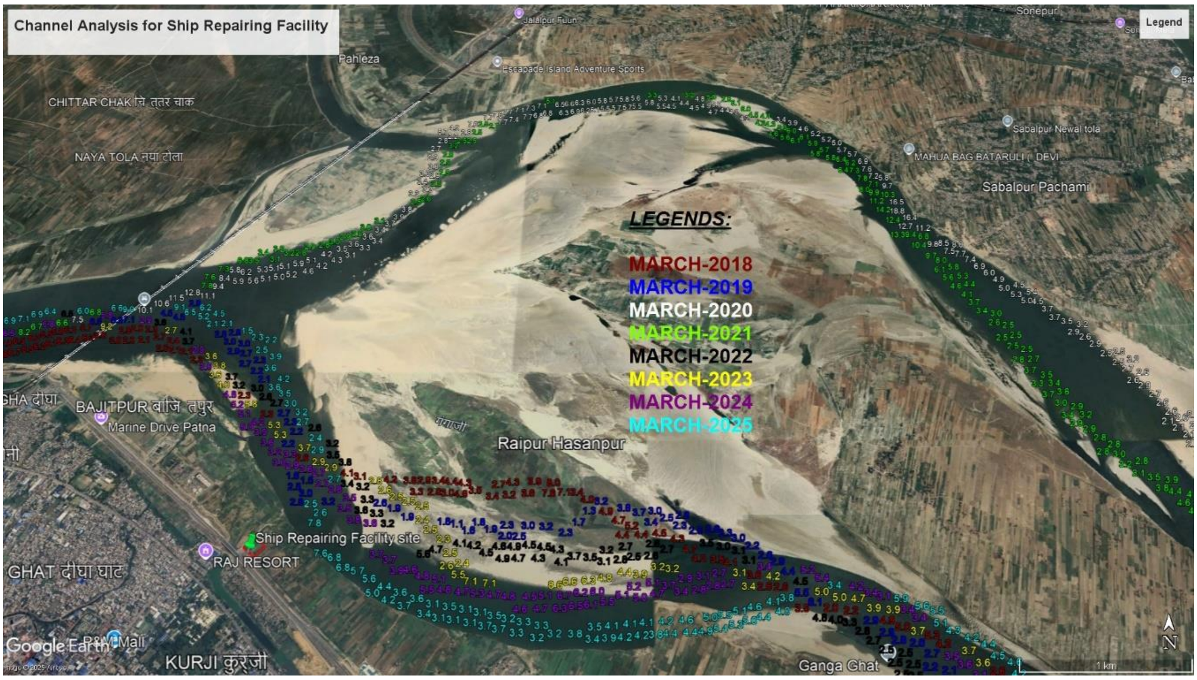



Figure 4.1 Channel Analysis of Ganga River at Patna (2018–2025)

### 4.3 Current

From the available data on river velocities at Patna, the Ganga River exhibits distinct seasonal variations. During the normal flow conditions, typically between January and May, the mean flow velocity ranges from approximately 0.8 to 1.2 m/s. In contrast, during the flood season—particularly from July to September, the velocity significantly increases, reaching values of around 3.0 to 4.5 m/s. These high velocities are generally unsuitable for safe vessel alignment along the slipway. However, even during the monsoon period, the minimum flow velocities often remain below 2.0 m/s, which is considered acceptable for slipway operations. Under such conditions, vessels can be positioned using tugboats of adequate capacity to guide them safely to the slipway and transfer them onto trolleys for hauling. To ensure operational safety and stability, additional mooring structures, such as floating buoys, will be deployed during the slipway operation phase. The maximum and minimum mean velocities (m/s) of the river ganga at Patna is shown in Table 4.3.

Table 4.3 Maximum & Minimum Mean Velocities (m/s) of the River Ganga at Patna

| Month | Minimum Velocity (m/s) | Maximum Velocity (m/s) |
|---|---|---|
| January | 0.8 | 1.0 |
| February | 0.8 | 1.0 |
| March | 0.9 | 1.2 |
| April | 1.0 | 1.5 |
| May | 1.2 | 2.0 |
| June | 1.5 | 3.5 |
| July | 1.8 | 4.5 |
| August | 1.7 | 4.3 |
| September | 1.5 | 4.0 |
| October | 1.2 | 2.5 |
| November | 1.0 | 1.5 |
| December | 0.8 | 1.0 |

## 4.4 Temperature

Patna experiences a humid subtropical climate with hot summers, a pronounced monsoon season, and mild to cool winters. The average high temperature is around 32°C, while the average minimum is about 18°C. During the summer months (April to June), maximum temperatures can soar up to 42°C, especially in May. In contrast, the winter season (December to February) sees minimum temperatures dropping to around 5°C, with January typically being the coldest month.

## 4.5 Geotechnical Data

The geotechnical investigation details are shared by IWAI (Attached as Annexure-III) and extract of which is reproduecd hereunder.

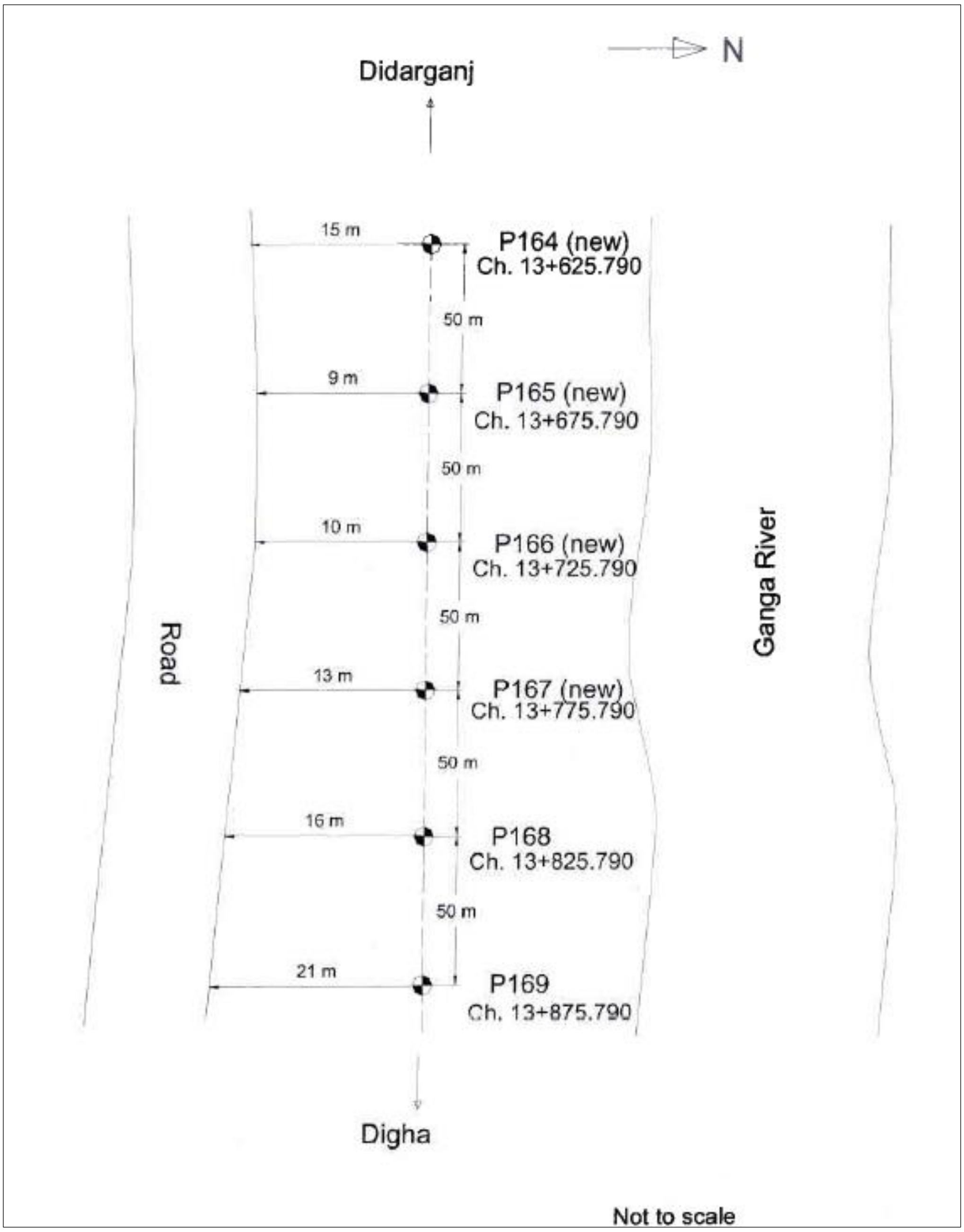



Figure 4.2 Locations of Borehole

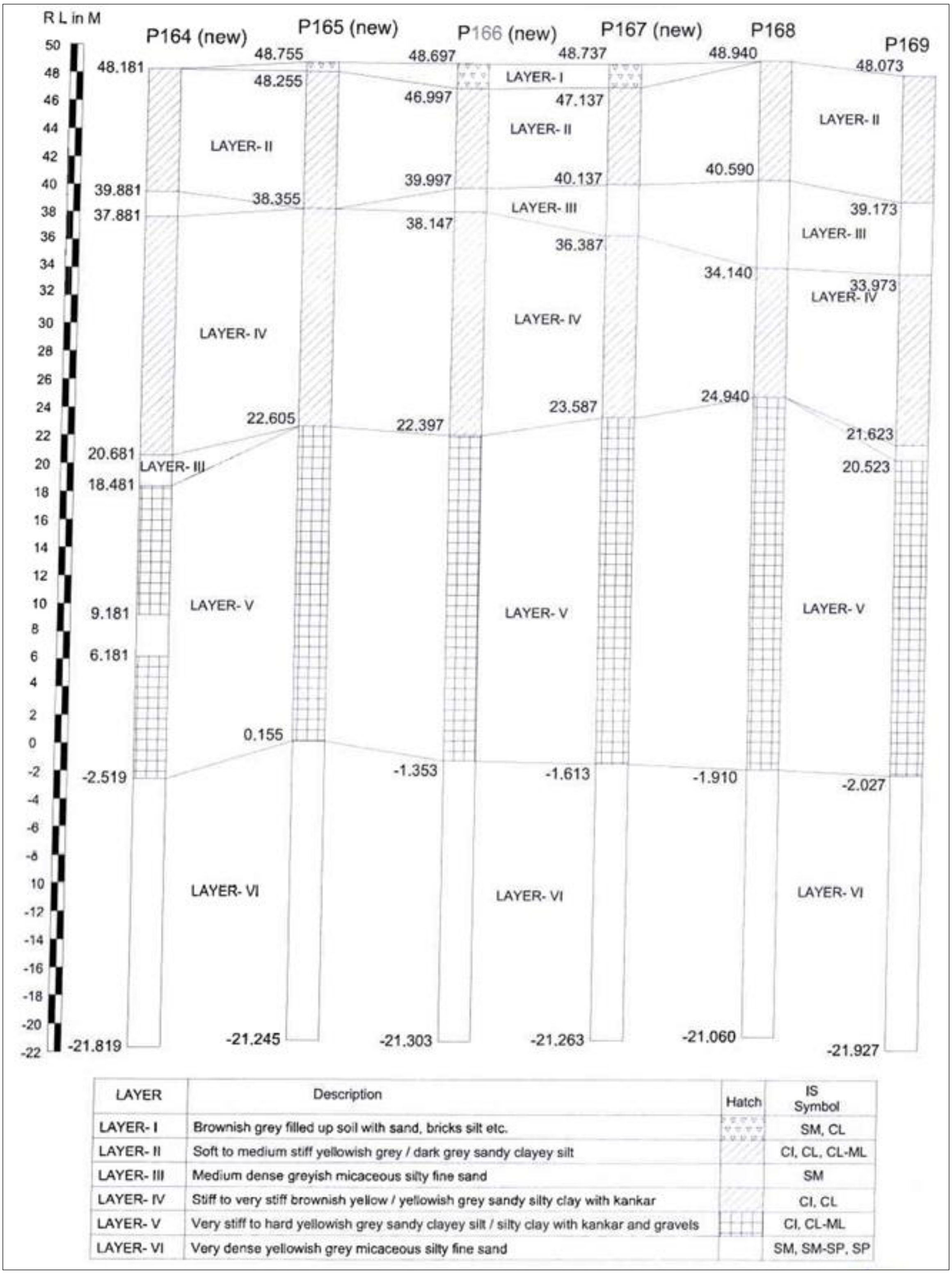



Figure 4.3 Sub soil Profile

**Note:**

The Geotechnical investigations carried out in connection with the "Construction of Four lane Elevated Road as part of under construction Ganga Path (Digha to

Deedargani) from Duli ghat to Nuruddin Ghat, from Dharmashala Ghat to Old NH-30 along with connectivity to Ashok Rajpath at Kangan Ghat and Patna Ghat with allied facilities at Patna", which is about 10.7 kms away from the proposed site, as shared by IWAI has been relied upon for the preliminary assessment/ design. However, since it is proposed to execute the work in EPC mode, the contractor shall be conduct the additional geotechnical investigations, both at water and land side, and accordingly redesign the structure.

### 4.6 Topographic and Bathymetry survey data

The IWAI Survey Department provided the topographic and bathymetric survey charts for the proposed Ship Repair Facility site at NW-1, Kurjighat, Patna. The landside ground elevations range between 43.283 m and 50.860 m above Mean Sea Level (MSL), while the riverbed levels vary between 36.80 m and 41.00 m above MSL.

The survey locations, Topographic and bathymetry chart are Shown in Figure 4.4 to Figure 4.6.


Figure 4.4 Survey Area for Proposed Ship Repair facility

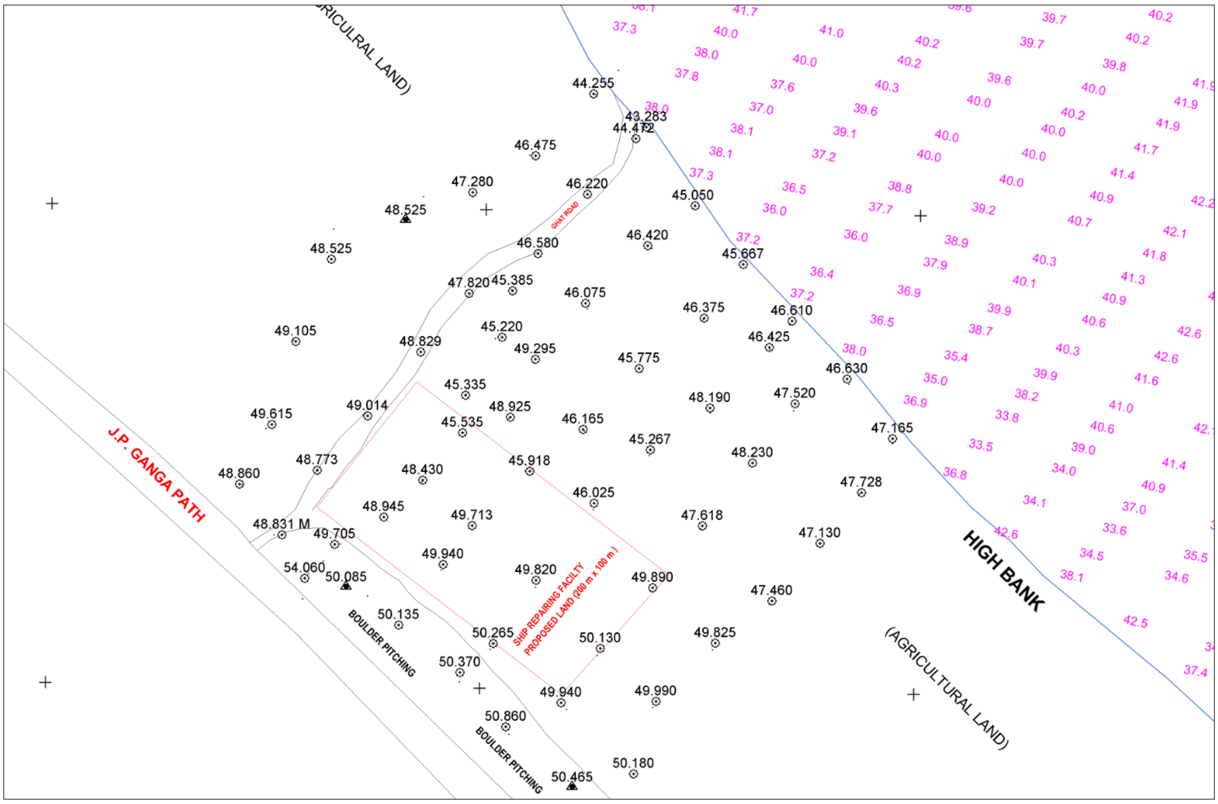



Figure 4.5 Topographic chart

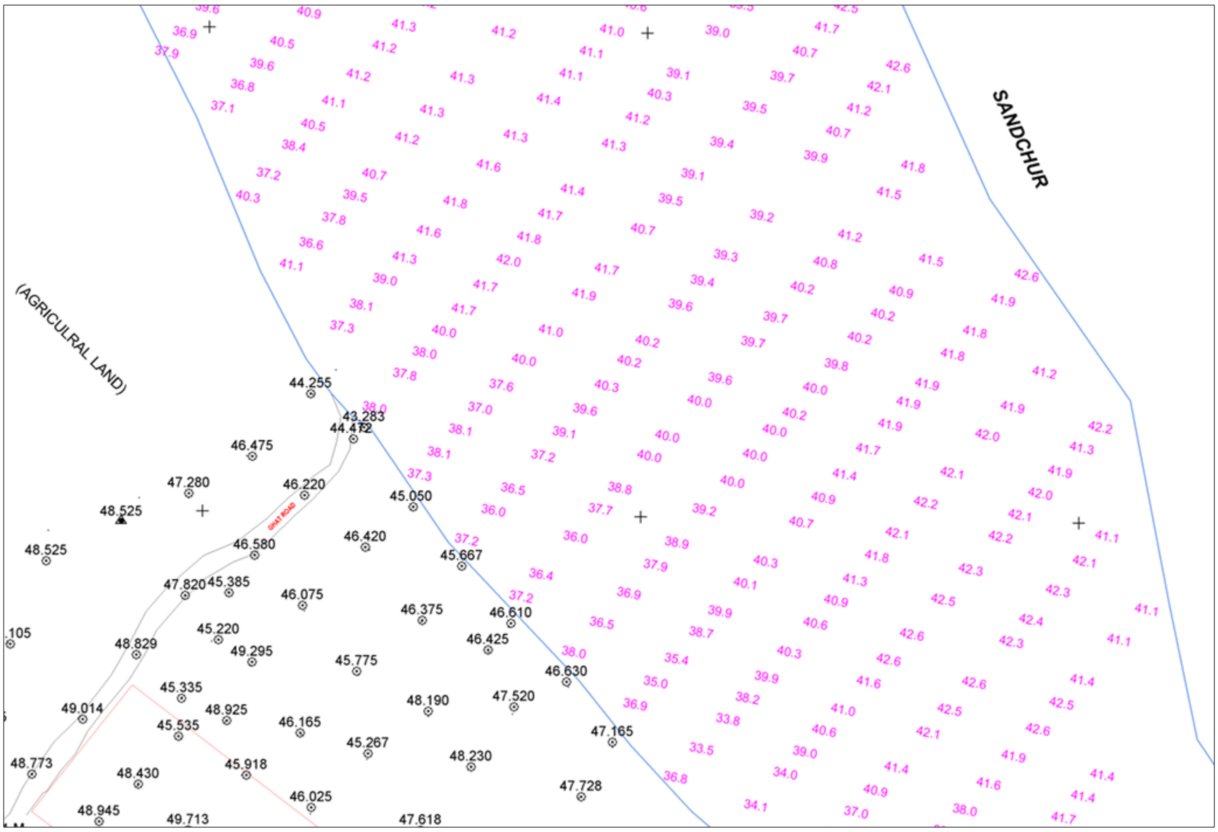



Figure 4.6 Bathymetry Chart

## 4.7 SEISMICITY

Patna is in Zone IV of Indian Map of Seismic zones (IS-1893 Part-1 2016) which is a severe risk seismic intensity zone (Figure 4.7).

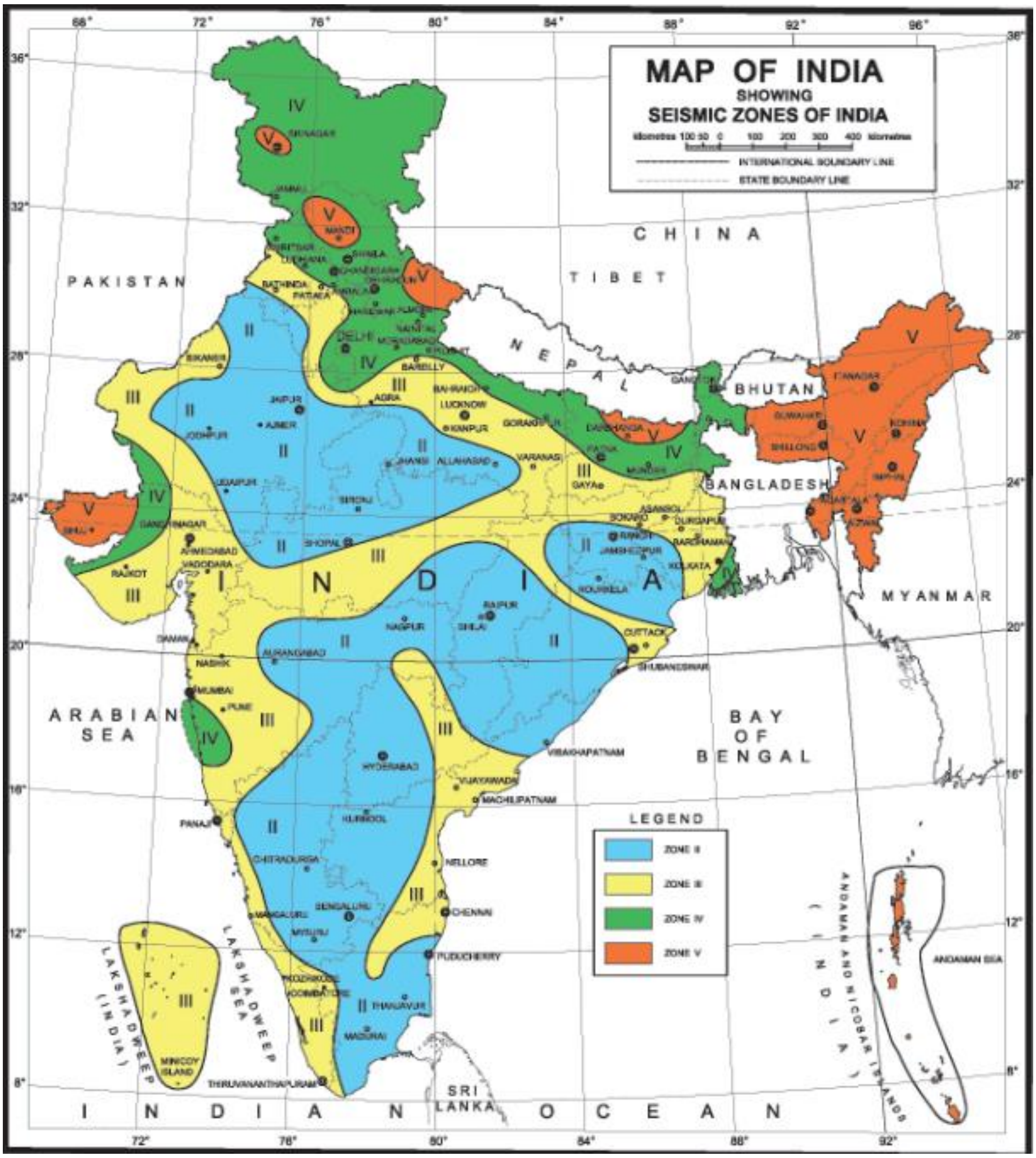
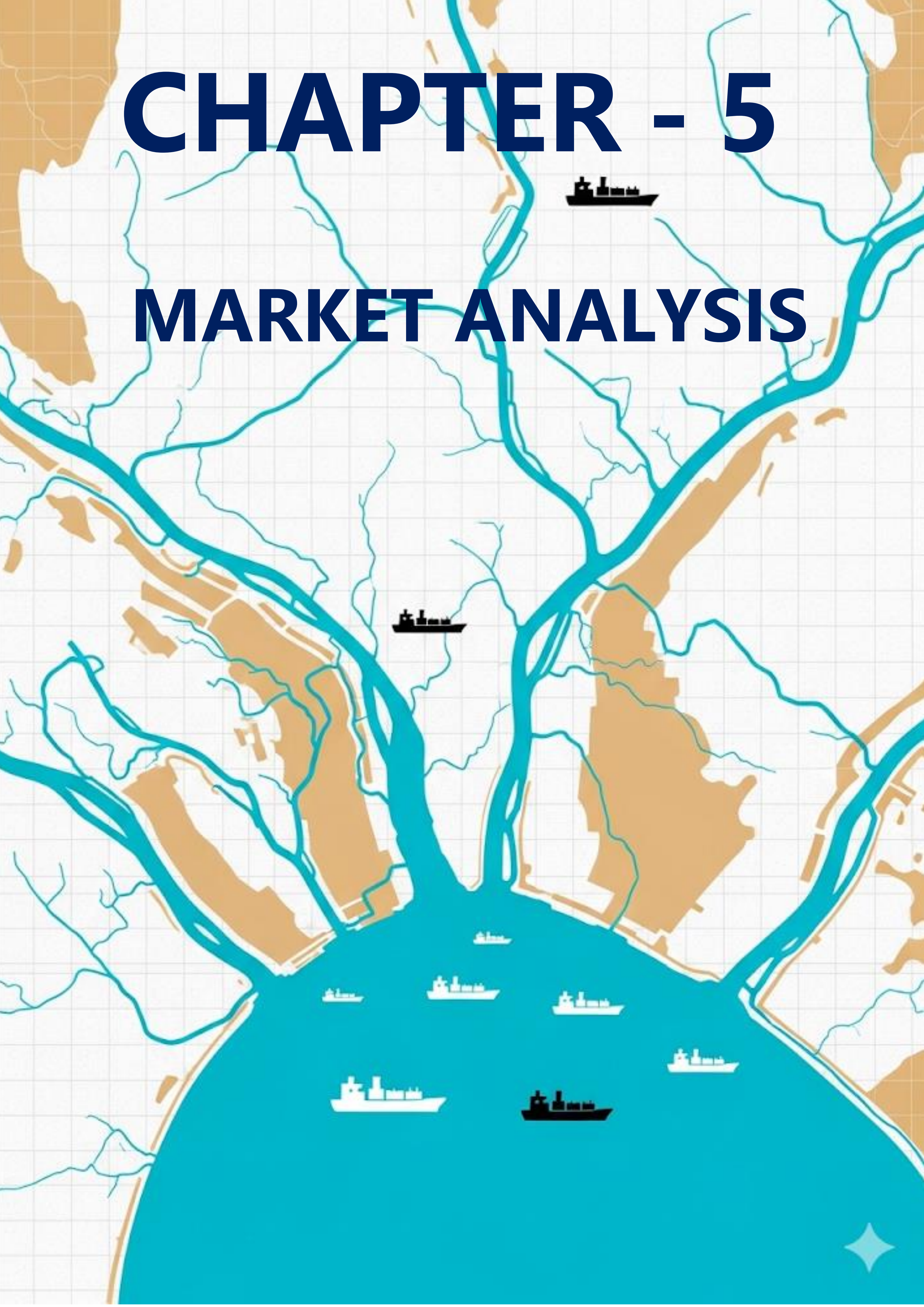



Figure 4.7 Seismic Zone of India – IS 1893 (Part 1): 2016

# CHAPTER - 5

# MARKET ANALYSIS



# 5 MARKET ANALYSIS

## 5.1 Overview

The development of a Ship Repair Facility (SRF) at Patna, Bihar, along the National Waterway-1 (NW-1), is a strategic initiative by the Inland Waterways Authority of India (IWAI). NW-1 connects Haldia to Allahabad via the Ganga-Bhagirathi-Hooghly river system, making Patna a critical midpoint. A robust market analysis is vital to ensure the viability and long-term sustainability of the SRF, considering demand, competition, and stakeholder interest.

## 5.2 Demand Assessment

### 5.2.1 Present Demand

Currently, a substantial number of Inland Water Transport (IWT) vessels, including cargo barges, passenger boats, and mechanized country crafts, operate on NW-1. IWAI Patna, had also shared the details of the vessels plying in this route. With the Government's thrust on increasing IWT share in freight movement, a consistent demand for periodic maintenance and repair of vessels is expected.

Stakeholders such as:

- Uttar Pradesh Inland Waterways Authority
- IWAI
- Private logistic operators
- Tourist operators
- Government and defence vessels

All contribute to the growing need for localized, reliable ship repair facilities. Presently, vessels require travel to Kolkata or Haldia for repairs, leading to increased downtime and costs.

### 5.2.2 Projected Demand (2025 – 2045)

According to traffic projections and published data from the Inland Waterways Authority of India (IWAI), the operational capacity and vessel traffic on National Waterway-1 (NW-1) is expected to increase significantly over the next two decades due to continuous investment under the Jal Marg Vikas Project (JMVP).

In FY 2022–23, NW-1 handled over 10.9 million tonnes of cargo with more than 2,500 vessel trips reported between Haldia and Varanasi (Source: IWAI Annual Report 2022–23). Considering the Government of India's objective to increase modal share of inland waterways and the multimodal connectivity initiatives, the vessel movement along NW-1 is projected to grow at a compound annual growth rate (CAGR) of 6–8% over the next 20 years.

Based on this growth trajectory, the number of active vessels in the Patna region is expected to rise from approximately 320 in 2025 to over 1,000 by 2045. With maintenance needs arising from mechanical wear, riverine navigation issues, and compliance with safety standards, it is estimated that 25–35% of these vessels will require routine or emergency repair annually.

Table 5.1 Estimated Ship Repair Demand (2025–2045)

| Year | Active Vessels (est.) | % Requiring Repairs | Repair Demand (Vessels/Year) |
|---|---|---|---|
| 2025 | 320 | 25% | 80 |
| 2030 | 520 | 30% | 156 |
| 2035 | 700 | 32% | 224 |
| 2040 | 850 | 33% | 281 |
| 2045 | 1000 | 35% | 350 |

## 5.3 Competitive Analysis

### 5.3.1 Existing Ship Repair Facilities in the Region

A review of existing ship repair facilities along the National Waterway-1 (NW-1) corridor reveals a significant gap between Varanasi and Kolkata, where the availability of dedicated ship repair infrastructure is limited. Below is an analysis of existing facilities operating within or adjacent to this stretch:

Table 5.2 Major Facilities Beyond Patna Corridor

| Facility | Location | Capacity / Specialization | Status |
|---|---|---|---|
| Syama Prasad Mookerjee Port | Kolkata | Multiple dry docks (up to 160 m), engine and structural workshops | Fully operational |
| Rajabagan Dockyard (GRSE) | Hooghly River | Three dry docks, jetties; handles small to medium IWT vessels | Operational |
| Hooghly Cochin Shipyard Ltd. | Howrah | Dry docks, repair workshops for 15,000 DWT vessels | Operational |
| Kolkata Inland Port (IWAI) | Garden Reach | RCC jetty (70 m), pontoon jetties, container/barge handling | Operational |

### 5.3.2 Facility Gaps in and around Patna, Bihar

- No dedicated, full-service ship repair yards exist between Kolkata (West Bengal), where, the ship repair facilities are exists at the identified ship yard mentioned in Table 5.2 and Patna (Bihar). In the Varanasi region, MM Terminal (IWT port, depth ~2.2 m) offers cargo transhipment but no ship infrastructure exists.
- Facilities in eastern Odisha/Northeast are primarily tourist jetties or cargo terminals, not repair yards.
- The inland repair capacity in the region relies heavily on Kolkata and Howrah/GRSE facilities, which involve significant downtime and navigating delays.

### 5.3.3 Facility Gaps Between Varanasi and Patna

1. Location Gap: Patna is positioned nearly 600–700 km upstream of Kolkata/Haldia docks. In absence of repair infrastructure between Varanasi and Kolkata, operators face prolonged downtime.
2. Capacity Gap: Existing facilities mainly serve large vessels and maritime cargo. Repairs for small-to-medium IWT vessels on NW-1 (e.g., barges, tugs, dredgers) are not prioritized.
3. Accessibility Gap: Transporting vessels from central Bihar to Kolkata involves additional logistics and high costs, whereas a local facility would significantly reduce travel and turnaround time.
4. Strategic Value: As per IWAI's strategic initiatives announced in June 2025, the authority has prioritized setting up regional ship repair facilities along NW-1 to support increased traffic and improve service readiness.

### 5.3.4 Existing Ship Repair Facilities in the Region

The absence of repair facilities between Varanasi and Kolkata provides a clear competitive advantage for developing an SRF at Patna. With growing IWT traffic on this corridor and IWAI's policy directives to enhance service infrastructure, a Ship Repair Facility at Patna would fill a critical operational void, reduce vessel turnaround time, and align with national inland waterways development objectives.

## 5.4 Stakeholder Interest

The development of a Ship Repair Facility (SRF) at Patna has garnered interest from multiple stakeholders across the inland water transport ecosystem. The stakeholders include government agencies, vessel operators, cargo logistics firms, terminal operators, local industries, and technical institutions. Each has a vested interest in ensuring that repair and maintenance infrastructure is accessible, reliable, and cost-effective.

1. Inland Waterways Authority of India (IWAI): As the primary agency responsible for the development and regulation of inland waterways, IWAI has expressed support for enhancing support infrastructure like SRFs to improve the reliability of NW-1 operations. The proposed SRF aligns with their vision under the Jal Marg Vikas Project (JMVP).
2. Private Vessel Operators and Logistics Companies: Companies operating cargo barges, dredgers, tugs, and support vessels require timely repair services to reduce downtime. Stakeholder consultations indicate a willingness to use a Patna-based SRF if pricing is competitive and turnaround is efficient.
3. Terminal Operators: Facilities at Patna, Varanasi, and Sahibganj handle multi-modal cargo and rely on support from towing vessels and cargo barges. The absence of nearby repair infrastructure disrupts operational continuity.
4. Local Industries and Shipbuilders: Local mechanical workshops and fabrication units see the SRF as an opportunity to participate as vendors or sub-contractors. The facility will contribute to the local economy and employment.
5. Academic and Research Institutions: Institutions like NIT Patna and other regional polytechnics may contribute through skill training, internships, and R&D collaboration related to ship maintenance technologies.

Overall, there is a strong convergence of interest among stakeholders who view the SRF as a critical enabler of sustainable waterway logistics in Bihar and eastern India.

# CHAPTER - 6

# DEVELOPMENT PLAN

# 6 DEVELOPMENT PLAN

## 6.1 Review of the existing data

As part of the feasibility assessment for the proposed Ship Repair Facility at Patna, a review of available information and field observations has been undertaken. The objective of this review was to evaluate the suitability of the site based on its geographical setting, environmental conditions, land availability, technical feasibility, and connectivity. Both primary data (from reconnaissance/site surveys) and secondary data (from IWAI records and previous studies) were examined in detail. The outcome of this review provides a baseline understanding for developing the facility layout and planning its implementation.

The key aspects of the review are summarized below:

1. A detailed reconnaissance/site survey of the proposed site, including geographical, environmental, and socio-economic conditions, has been conducted.
2. The details received from IWAI for the previous studies, reports, data, information, maps, charts etc., have been viewed and the details available at the Patna site office is taken into cognizance.
3. The identified site by IWAI has been inspected after consultation with the stake holders.

## 6.2 Inland Vessel movement in the NW-1

Data from IWAI R.O. Patna indicates substantial vessel movement in the area, with a cumulative total of 451 vessels operating in the Patna sector from 2020 to 2025. Of these, 83 are IWAI vessels and 368 are privately operated. Vessel sizes range up to 77.37 meters in length and 15 meters in width (MV AAI), underscoring the need for adequate repair infrastructure.

Currently, there are no major ship repair facilities in or around the Patna stretch of NW-1. In the absence of such facilities, inland vessels must travel long distances to receive routine maintenance and emergency services. This not only increases fuel consumption and crew deployment times but also reduces overall fleet efficiency. The establishment of a dedicated ship repair unit in Patna would drastically improve operational turnaround, especially during peak navigation seasons.

### 6.2.1 Details of Vessels plying in NW -1

At present, the vessels operating on NW-1 belong to the IWAI and various other private operators. A summary of the broad range of these vessels is presented in Table 6.1. The vessel data were collected from IWAI.

Table 6.1 Summary of Vessels Operating on NW-1

| Sl. No | Category | Name of Vessel | Dimension in mts | Capacity | Unit | Built Year | Builder |
|---|---|---|---|---|---|---|---|
| 1 | Accommodation boats/house Boats | H.B.Vindhyas | 26.5x9.0x2.2 | 20 | Person | 2002 | A.C.Roy & Co |
| 2 | Accommodation boats/house Boats | H.B.Himgiri | 26.5x9.0x2.2 | 20 | Person | 2002 | A.C.Roy & Co |
| 3 | Accommodation boats/house Boats | H.B.Kalsubai | 26.5x9.0x2.2 | 20 | Person | 2008 | A.C.Roy & Co |
| 4 | Accommodation boats/house Boats | H.B.Vishwakarma | 30.5x7.6x2.5 | 30 | Person | 1986 | |
| 5 | Accommodation boats/house Boats | H.B.Dhawalgiri | 26.5x9.0x2.2 | 20 | Person | 2004 | Neptune Marine Pvt.Ltd. |
| 6 | Accommodation boats/house Boats | H.B.Chandradinga | 26.5x9.0x2.2 | 20 | Person | 2005 | Neptune Marine Pvt.Ltd. |
| 7 | Accommodation boats/house Boats | H.B.Kailash | 26.5x9.0x2.2 | 20 | Person | 2008 | A.C.Roy & Co |
| 8 | Accommodation boats/house Boats | H.B.Kedarnath | 26.5x9.0x2.2 | 20 | Person | 2008 | A.C.Roy & Co |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 9 | Accommodation boats/house Boats | H.B.Nandadevi | 26.5x9.0x2.2 | 20 | Person | 2002 | A.C.Roy & Co |
| 10 | Accommodation boats/house Boats | H.B.Nilgiri | 26.5x9.0x2.2 | 20 | Person | 2008 | A.C.Roy & Co |
| 11 | Accommodation boats/house Boats | H.B.Rajrambha | 26.5x9.0x2.2 | 20 | Person | 2008 | A.C.Roy & Co |
| 12 | Accommodation boats/house Boats | H.B.Devprayag | 26.5x9.0x2.2 | 20 | Person | 2008 | A.C.Roy & Co |
| 13 | Accommodation boats/house Boats | H.B.Sivalik | 26.5x9.0x2.2 | 20 | Person | 2004 | Neptune Marine Pvt.Ltd. |
| 14 | Cargo | M.V. Homi Bhabha | 54.6x9.0x2.4 | 300 | T | 2004 | HDPEL |
| 15 | Cargo | M.V. Lal Bahadur Shastri | 54.6x9.0x2.4 | 300 | T | 2004 | HDPEL |
| 16 | Cargo | M.V.Vishveswarya (POL Tanker) | 54.6x9.0x2.4 | 300 | T | 2006 | HDPEL |
| 17 | Cargo | M.V.Rabindra Nath tagore (Container vessel) | 54.6x9.0x2.4 | 16 | TEU | 2006 | HDPEL |
| 18 | Cargo | M.V.Zakir Hussian | 54.6x11.0x2.1 | 300 | T | 2009 | HDPEL |
| 19 | Cargo | M.V. Rajagopalachari | 62.8x10.6x2.1 | 600 | T | 1988 | Damen Shipyard |
| 20 | Cargo | M.V.V.V.Giri(Under Construction) | 54.6x11.0x2.1 | 300 | T | 2012 | HDPEL |
| 21 | Classic watermaster III | AD Manimala | 10.10x3.2x 1.05 | 80 | cu.m. | 2011 | Aquamec Limited |
| 22 | Classic watermaster IV | AD Falgu | 10.10 x 3.2 x 1.05 | 80 | cu.m. | 2012 | Aquamec Limited |
| 23 | Classic watermaster IV | AD Narmada | 10.10 x 3.2 x 1.05 | 80 | cu.m. | 2014 | Aquamec Limited |
| 24 | Container cranes | One Container crane | | 20 | T | 2005 | TIL Kolkata |
| 25 | Crane Pontoons | CP Ganga-III | 35.0x8.0x1.6 | 4 | T | 2003 | HDPEL |
| 26 | Crane Pontoons | CP Brahmaputra-V | 35.0x8.0x1.6 | 4 | T | 2004 | A.C.Roy & Co |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 27 | Crane Pontoons | CP Brahmaputra-IV | 35.0x8.0x1.6 | 4 | T | 2004 | A.C.Roy & Co |
| 28 | Crane Pontoons | CP Brahmaputra-III | 35.0x8.0x1.6 | 4 | T | 2004 | A.C.Roy & Co |
| 29 | Crane Pontoons | CP Brahmaputra-II | 35.0x8.0x1.6 | 4 | T | 2004 | A.C.Roy & Co |
| 30 | Crane Pontoons | CP Ganga-IV | 35.0x8.0x1.6 | 4 | T | 2003 | HDPEL |
| 31 | Crane Pontoons | CP Ganga-II | 35.0x8.0x1.6 | 4 | T | 2003 | HDPEL |
| 32 | Crane Pontoons | CP Ganga-I | 35.0x8.0x1.6 | 4 | T | 2003 | HDPEL |
| 33 | Crane Pontoons | CP Brahmaputra-I | 35.0x8.0x1.6 | 4 | T | 2004 | A.C.Roy & Co |
| 34 | Cutter suction dredgers | ID-I | 18.3x6.1x1.5 | 120 | | 1984 | Old dredger transferred from DCI |
| 35 | Cutter suction dredgers | CSD Yamuna | 40.0x9.5x2.3 | 500 | | 1988 | Delta Shipyards |
| 36 | Cutter suction dredgers | CSD Mahananda | 34.0x7x1.8 | 500 | | 2004 | Mazagon Dock Ltd |
| 37 | Cutter suction dredgers | CSD Jalangi | 34.0x7x1.8 | 500 | | 2004 | Mazagon Shipyards |
| 38 | Cutter suction dredgers | CSD Tapi | 40.0x9.5x2.3 | 500 | | 2009-10 | Tebma Shipyard Ltd. |
| 39 | Cutter suction dredgers | CSD Alkananada | 40.0x9.5x2.3 | 500 | | 2009-10 | Tebma Shipyard Ltd. |
| 40 | Cutter suction dredgers | CSD Tizu | 34.0x7x1.8 | 500 | | 2004 | Mazagon Dock Ltd |
| 41 | Cutter suction dredgers | CSD Sweta | 40.0x9.5x2.3 | 500 | | 2010-11 | Tebma Shipyard Ltd. |
| 42 | Cutter suction dredgers | ID-IV | 29.0x7.0x1.85 | 300 | | 1991 | Old dredger transferred from DCI |
| 43 | Cutter suction dredgers | CSD Kalada | 18.0x4.0x1.25 | 180 | | 2010 | Startek Shipyards Pvt.Ltd. |
| 44 | Cutter suction dredgers | CSD Champakkara | 18.0x4.0x1.25 | 180 | | 2010 | Startek Shipyards Pvt.Ltd. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 45 | Cutter suction dredgers | CSD Shipra | 40.0x9.5x2.3 | 500 | | 2010 -11 | Tebma Shipyard Ltd. |
| 46 | Hydraulic surface Dredger | HSD Jia Bhorali | 23.5 x 10 x 2.8 | 260 | BHP | 2012 | HDPEL |
| 47 | Hydraulic Surface Dredgers | HSD Sone | 27.5x10.0x2.8 | | | 2001 | HDPEL |
| 48 | Hydraulic Surface Dredgers | HSD Dhansiri | 27.5x10.0x2.8 | | | 2002 | HDPEL |
| 49 | One Container Crane | 20 | T | | | 2005 | TIL Kolkata |
| 50 | Patrol Boats/Inspection Boats | Robin-I | 7.9x2.4x0.9 | | | 1990 | Reinplast |
| 51 | Patrol Boats/Inspection Boats | Falcon-I | 7.6x1.9x0.9 | | | 2005 | KSINC |
| 52 | Patrol Boats/Inspection Boats | Falcon-II | 7.6x1.9x0.9 | | | 2005 | KSINC |
| 53 | Patrol Boats/Inspection Boats | Robin-II | 7.9x2.4x0.9 | | | 1990 | Reinplast |
| 54 | Patrol Boats/Inspection Boats | Kingfisher-I | 7.6x1.9x0.9 | | | 2005 | KSINC |
| 55 | Patrol Boats/Inspection Boats | Hawk-II | 7.6x1.9x0.9 | | | 2005 | KSINC |
| 56 | Patrol Boats/Inspection Boats | Hawk-I | 7.6x1.9x0.9 | | | 2005 | KSINC |
| 57 | Ro-Ro cargo | MV VV Giri | 54.6 x 11 x 2.10 | 300 | T | 2012 | HDPEL |
| 58 | Survey vessels | S.L.Dihang | 25.0x5.8x2.8 | | | 2001 | HDPEl |
| 59 | Survey vessels | S.L.Anupallav | 19x4.8x1.75 | | | 1987 | Rajbagan Dock Yard |
| 60 | Survey vessels | S.L.Koel | 25.0x5.8x2.8 | | | 2008 | A.C.Roy & Co |
| 61 | Survey vessels | S.L.Meghna | 25.0x5.8x2.8 | | | 2008 | A.C.Roy & Co |
| 62 | Survey vessels | S.L.Dwarkeshwar | 25.0x5.8x2.8 | | | 2008 | A.C.Roy & Co |
| 63 | Survey vessels | S.L.Kosi | 21.5x5.8x1.7 | | | 1988 | Delta Shipyard |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 64 | Survey vessels | S.L.Kamla | 25.0x5.8x2.8 | | | 2003 | Tebma |
| 65 | Survey vessels | S.L.Mandakini | 25.0x5.8x2.8 | | | 2003 | Tebma |
| 66 | Survey vessels | S.L.Ghaghra | 25.0x5.8x2.8 | | | 2008 | A.C.Roy & Co |
| 67 | Survey vessels | S.L.Gandak | 25.0x5.8x2.8 | | | 2007 | A.C.Roy & Co |
| 68 | Survey vessels | S.L.Punpun | 25.0x5.8x2.8 | | | 2008 | A.C.Roy & Co |
| 69 | Survey vessels | S.L.Rihand | 25.0x5.8x2.8 | | | 2008 | A.C.Roy & Co |
| 70 | Survey vessels | S.L.Subansiri | 25.0x5.8x2.8 | | | 2003 | Tebma |
| 71 | Survey vessels | S.L.Dibang | 25.0x5.8x2.8 | | | 2008 | A.C.Roy & Co |
| 72 | Survey vessels | S.L.Burhi Dihing | 25.0x5.8x2.8 | | | 2008 | A.C.Roy & Co |
| 73 | Survey vessels | S.L.lohit | 25.0x5.8x2.8 | | | 2003 | Tebma |
| 74 | Survey vessels | S.L.Barak | 25.0x5.8x2.8 | | | 2003 | Tebma |
| 75 | Survey vessels | S.L. Pamba | | | | 2003 | Western Marine Engg. |
| 76 | Terminal barges | F.J.Ganga XXI | 35.0x8.0x1.6 | | | 2009 | A.C.Roy & Co |
| 77 | Terminal barges | F.J.Ganga XIV | 35.0x8.0x1.6 | | | 2009 | A.C.Roy & Co |
| 78 | Terminal barges | F.J Brahmaputra-VI | 35.0x8.0x1.6 | | | 2003-04 | HDPEL |
| 79 | Terminal barges | F.J Brahmaputra-V | 35.0x8.0x1.6 | | | 2003-04 | HDPEL |
| 80 | Terminal barges | F.J Brahmaputra-IV | 35.0x8.0x1.6 | | | 2003-04 | HDPEL |
| 81 | Terminal barges | F.J Brahmaputra-III | 35.0x8.0x1.6 | | | 2003-04 | HDPEL |
| 82 | Terminal barges | F.J Brahmaputra-VIII | 35.0x8.0x1.6 | | | 2008-09 | Techno Steel |
| 83 | Terminal barges | F.J Brahmaputra-I | 35.0x8.0x1.6 | | | 2003-04 | Techno Steel |
| 84 | Terminal barges | F.J Brahmaputra-IX | 35.0x8.0x1.6 | | | 2010-11 | Techno Steel |
| 85 | Terminal barges | F.J.Ganga XX | 35.0x8.0x1.6 | | | 2009 | A.C.Roy & Co |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 86 | Terminal barges | F.J.Ganga XIX | 35.0x8.0x1.6 | | | 2009 | A.C.Roy & Co |
| 87 | Terminal barges | F.J.Ganga XVIII | 35.0x8.0x1.6 | | | 2009 | A.C.Roy & Co |
| 88 | Terminal barges | F.J.Ganga XVII | 35.0x8.0x1.6 | | | 2009 | A.C.Roy & Co |
| 89 | Terminal barges | F.J.Ganga XVI | 35.0x8.0x1.6 | | | 2009 | A.C.Roy & Co |
| 90 | Terminal barges | F.J Brahmaputra-II | 35.0x8.0x1.6 | | | 2003 -04 | Techno Steel |
| 91 | Terminal barges | F.J Brahmaputra-VII | 35.0x8.0x1.6 | | | 2003 -04 | HDPEL |
| 92 | Terminal barges | F.J.Ganga XIII | 35.0x8.0x1.6 | | | 2008 | A.C.Roy & Co |
| 93 | Terminal barges | F.J Brahmaputra-XIII | 35.0x8.0x1.6 | | | 2010 -11 | Techno Steel |
| 94 | Terminal barges | F.J Brahmaputra-XII | 35.0x8.0x1.6 | | | 2010 -11 | Techno Steel |
| 95 | Terminal barges | F.J Brahmaputra-XI | 35.0x8.0x1.6 | | | 2010 -11 | Techno Steel |
| 96 | Terminal barges | F.J Brahmaputra-X | 35.0x8.0x1.6 | | | 2010 -11 | Techno Steel |
| 97 | Terminal barges | F.J.Ganga XV | 35.0x8.0x1.6 | | | 2009 | A.C.Roy & Co |
| 98 | Terminal barges | F.J.Ganga V | 35.0x8.0x1.6 | | | | Tebma |
| 99 | Terminal barges | F.J.Ganga XII | 35.0x8.0x1.6 | | | 2008 | A.C.Roy & Co |
| 100 | Terminal barges | F.J.Ganga XI | 35.0x8.0x1.6 | | | 2009 | A.C.Roy & Co |
| 101 | Terminal barges | F.J.Ganga X | 35.0x8.0x1.6 | | | 2008 | A.C.Roy & Co |
| 102 | Terminal barges | F.J.Ganga IX | 35.0x8.0x1.6 | | | | A.C.Roy & Co |
| 103 | Terminal barges | F.J.Ganga VIII | 35.0x8.0x1.6 | | | | Tebma |
| 104 | Terminal barges | F.J.Ganga VI | 35.0x8.0x1.6 | | | | Tebma |
| 105 | Terminal barges | F.J.Ganga IV | 35.0x8.0x1.6 | | | | Tebma |
| 106 | Terminal barges | F.J.Ganga II | 35.0x8.0x1.6 | | | | HDPEL |
| 107 | Terminal barges | F.J.Ganga I | 35.0x8.0x1.6 | | | | HDPEL |
| 108 | Terminal barges | F.J.Ganga VII | 35.0x8.0x1.6 | | | | Tebma |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 109 | Terminal barges | F.J.Ganga III | 35.0x8.0x1.6 | | | | Tebma |
| 110 | Tug | WB Mogra | 23.5 x 8 x2.2 | 540 | BHP | 2011 | A.C Roy & Co. |
| 111 | Tug | HPT BR Ambedkar | 23.28 x 7.2 x2.6 | 12 | T | 2013 | A.C Roy & Co. |
| 112 | Tug | MPT Mangal Pandey | 28 x 7.2 x 2.6 | 6 | T | 2013 | A.C Roy & Co. |
| 113 | Tug | HPT Rani Lakshmi bai | 23.28 x 7.2 x2.6 | 12 | T | 2013 | A.C Roy & Co. |
| 114 | Tug | MPT Lala Lajpat Rai | 28 x 7.2 x 2.6 | 6 | T | 2013 | A.C Roy & Co. |
| 115 | Work Boats/Tugs | Tug Bhagat Singh | 25x7x2.5 | 5 | T | 2003 | A.C.Roy & Co |
| 116 | Work Boats/Tugs | MPT Khudiram Bose | 28x7.5x2.6 | 5 | T | 2010 | A.C.Roy & Co |
| 117 | Work Boats/Tugs | W.B.Lily | 25.5x6.56x2 | 5 | T | 1988 | delta Shipyards |
| 118 | Work Boats/Tugs | P.T.Tilak | 20.0x7.0x2.0 | 6 | T | 1988 | chowgule & Co Ltd |
| 119 | Work Boats/Tugs | Tug Birsa Munda | 25.0x7.0x2.5 | 5 | T | 2003 | A.C.Roy & Co |
| 120 | Work Boats/Tugs | Tug S.C.Bose | 25.0x7.0x2.5 | 5 | T | 2003 | A.C.Roy & Co |
| 121 | Work Boats/Tugs | Tug Birsa Munda | 28.0X7.5X2.6 | 5 | T | 2003 | A.C.Roy & Co |
| 122 | M.V.V.V.Giri | Cargo | 54.6x11.0x2.1 | 300 | T | | HDPEL |
| 123 | HSD | Hydraulic Surface Dredger | 27.5x10.0x2.8 | - | | | HDPEL |
| 124 | W.B.Mogro(Partly Finished | Work Boats/Tug | 23.5x8.0x2.2 | 5 | T | | Neptune Marine Pvt.Ltd. |
| 125 | Work Boat | Work Boats/Tug | 23.5x8.0x2.2 | 5 | T | | Neptune Marine Pvt.Ltd. |
| 126 | Work Boat | Work Boats/Tug | 24.5x8.5x2.2 | 5 | T | | HDPEL |
| 127 | W.B.Jamanthy | Work Boats/Tug | 15.0x5.0x2.0 | 2 | T | | Startek Shipyards Pvt.Ltd. |
| 128 | W.B.Chempakumy | Work Boats/Tug | 15.0x5.0x2.0 | 2 | T | | Startek Shipyards Pvt.Ltd. |
| 129 | Work Boat | Work Boats/Tug | 24.5x8.5x2.0 | 5 | T | | HDPEL |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 130 | CSD Brahman | Under Construction | 40.0x9.5x2.3 | 500 | | | Temba Shipyards Ltd. |
| 131 | CSD Mandovi | Under Construction | 40.0x9.5x2.3 | 500 | | | Temba Shipyards Ltd. |
| 132 | Pusher RSP-SB-113 | | 21 x 8.2 x 1.20 | | | | |
| 133 | Pusher SCH-2414 | | 16.5 x 8.15 x 1.60 | | | | |
| 134 | Pusher RSP-SB-151 | | 21 x 8.2 x 1.20 | | | | |
| 135 | Pusher RSB-SB-118 | | 21 x 8.2 x 1.20 | | | | |
| 136 | Barge S2 | | 32.5 x 9.5 x 2.17 | 530 | T | | |
| 137 | Barge S2 | | 32.5 x 9.5 x 2.17 | 530 | T | | |
| 138 | Barge S2 | | 32.5 x 9.5 x 2.17 | 530 | T | | |
| 139 | Barge L1 | | 65 x 8.2 x 2.16 | 530 | T | | |

### 6.2.2 Details of Vessel movement under IWAI, R.O. Patna

Details of Vessel movement under IWAI, R.O. Patna is given in Table 6.2

Table 6.2 Details of Vessel movement under IWAI, R.O. Patna

| Sl. No. | Particulars | Year (FY) | Vessels (Nos) | Total |
|---|---|---|---|---|
| 1 | IWAI Vessel in Patna Sector | | 83 | 83 |
| 2 | Private Vessel in Patna Sector | 2020-21 | 132 | 368 |
| 3 | | 2021-22 | 58 | |
| 4 | | 2022-23 | 54 | |
| 5 | | 2023-24 | 68 | |
| 6 | | 2024-25 | 56 | |
| | | | **Grand Total** | **451** |
| Note: - | Maximum Length of Vessel - 77.37m (MV AAI) | | | |
| | Maximum Width of Vessel - 15m (MV AAI) | | | |

## 6.3 Infrastructure Gaps and Facility Needs

Currently, there are no major ship repair facilities in or around the Patna stretch of NW-1. In the absence of such facilities, inland vessels must travel long distances to receive routine maintenance and emergency services. This not only increases fuel consumption and crew deployment times but also reduces overall fleet efficiency. The establishment of a dedicated ship repair unit in Patna would drastically improve operational turnaround, especially during peak navigation seasons.

Repair facilities must be tailored to the needs of the inland vessel fleet operating in this region. Based on IWAI data and projected traffic, the proposed site should include both afloat repair infrastructure and dry-docking capabilities. A typical layout should accommodate:

- One or more dry docks to handle vessels of up to 80 meters in length
- Slipways for mid-size barge and tug maintenance
- Floating jetties for emergency afloat repair
- Covered workshops for mechanical, electrical, and hull repairs
- Equipment for bilge water treatment and hazardous waste handling

The selection of technologies and design criteria must take into account flood-level variations, riverbank stability, and environmental compliance. Environmental impact mitigation measures such as erosion-resistant structures, stormwater drainage, and sediment control systems should be embedded into the project layout. In addition, adequate firefighting systems, lighting, and navigation aids must be planned to ensure safe round-the-clock operations.

A major gap observed in the current waterway infrastructure is the unavailability of rapid-response repair units. The proposed facility at Patna can bridge this by including mobile repair teams and floating workshops that can travel upstream or downstream for on-site diagnostics and minor interventions. Prioritization will be given to areas with high vessel density and significant repair needs but lack adequate facilities. It is also necessary to determine the type of facilities needed depending on the nature of repair to be carried out, either afloat repair or dry docking repairs.

## 6.4 Major Components in a ship repair facility

A ship repair facility is designed to undertake inspection, maintenance, refurbishment, and modification of vessels ranging from small crafts to large ocean-going ships. A typical layout for a Ship Repair Facility is shown in Figure 6.1.

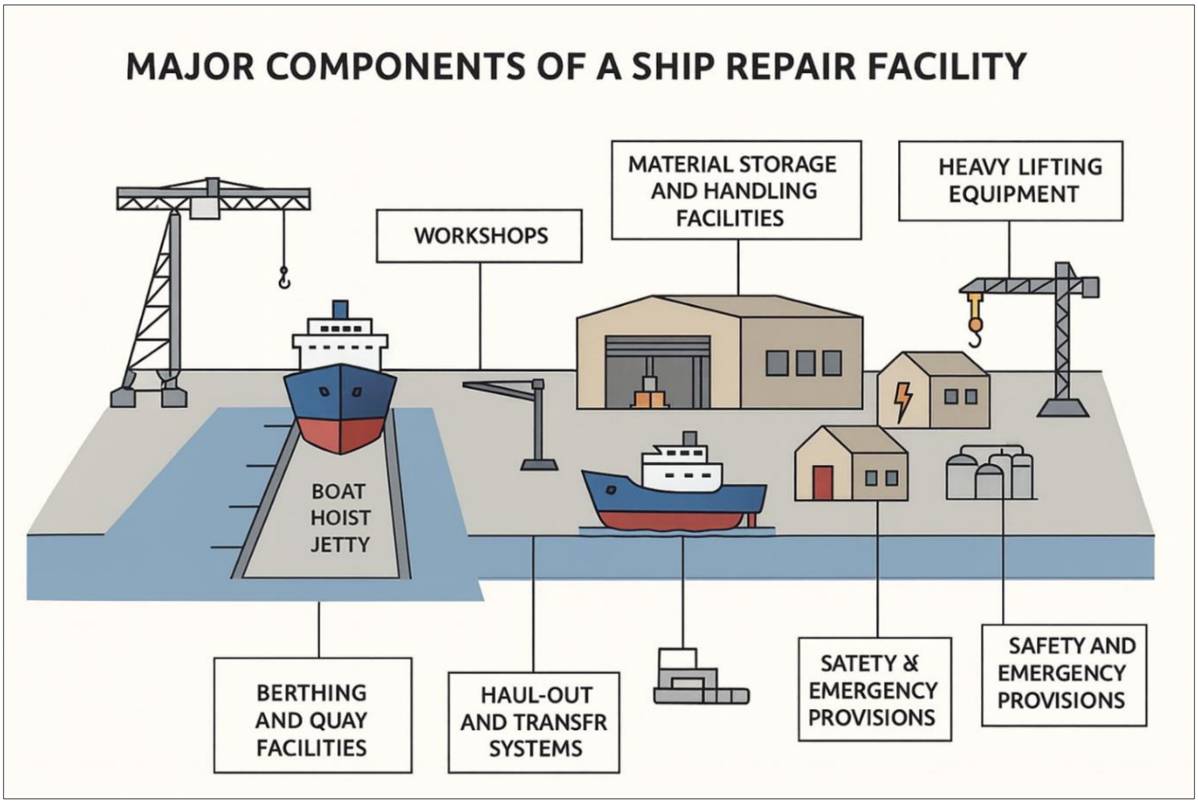



Figure 6.1 A typical layout for a Ship Repair Facility

### 6.4.1 Vessel Handling & Hoisting Infrastructure

- **Slipway Structure:** Sloped RCC platform constructed to haul vessels from water onto land for repairs.
- **Side Slipway:** Dedicated for smaller vessels or secondary operations.
- **Transfer Area (Concrete Platform):** Used for positioning vessels after lifting and before shifting to repair bays.

Typical image for ship lift and transfer system is shown in Figure 6.2.

- **Marine Boat Hoist (800T capacity):** Heavy-duty mobile hoist for lifting vessels out of water vertically.
- **Hydraulic Trailer:** Used to transport vessels from lifting point to repair bays. A typical marine boat trailer is illustrated in the Figure 6.3.

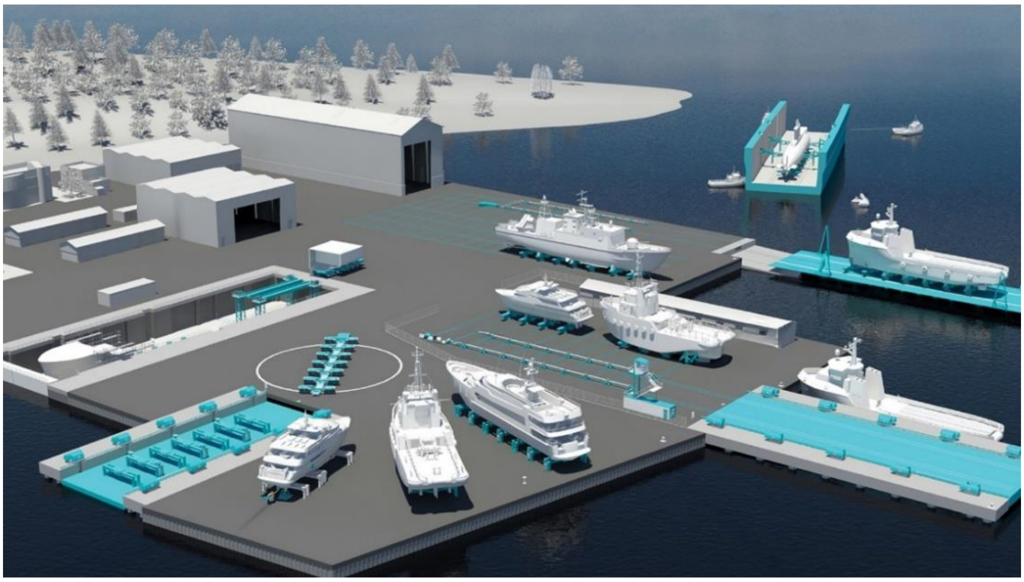


Figure 6.2 Typical image for ship lift and transfer system


Figure 6.3 Typical image for boat trailers

### 6.4.2 Repair Bays

- **Primary Repair Bays:** Concrete or paved areas where vessels are serviced after transfer. Typical images for repair bays are shown in Figure 6.4
- **Small Vessel Bays:** Separate platform or bays for smaller boats.
- **Bay Extensions:** Additional raft foundation slabs around repair bays for space expansion.

Figure 6.4 A Typical image of Repair Bay

### 6.4.3 Utility & Operational Facilities

- Electrical Substation: Supplies power to the hoist system, workshops, and general lighting.
- Heavy Lifting Equipment: Gantry cranes, jib cranes, and mobile cranes for lifting ship components. Dockside cranes for loading/unloading equipment and stores.

- Water Supply and Drainage System: Includes overhead tanks, pipelines, storm drainage, and wash-down points.
- Sewage and Effluent Disposal Unit: Treatment system for domestic waste from toilets and canteen.

### 6.4.4 Workshops & Industrial Buildings

- Mechanical Workshop: Engines, propellers, rudders, and other mechanical systems. A typical image for Workshop is shown in Figure 6.5.
- Fabrication & Welding Shop: Steel/aluminium hull repairs and fabrication works.
- Electrical & Electronics Workshop: Lighting, navigation systems, and wiring repairs.
- Paint Shop / Surface Preparation Area: Blasting, coating, and corrosion prevention.
- General Store (for tools, spares, and consumables).

Figure 6.5 A typical image Mechanical Workshop

### 6.4.5 Administrative & Support Facilities

- **Administrative Building:** With rooms for engineers, supervisors, and administrative staff.

- **Fire & Safety Building:** Equipped with emergency tools, fire extinguishers, and first aid.
- **Canteen Block:** Dining area for 50–70 workers, with kitchen and seating.
- **Toilet Blocks:** Separate sanitation units for men and women located near the work zone.

### 6.4.6 Open Yard Facilities

- **Scrap Yard:** For damaged vessel parts, decommissioned machinery, and recyclable metals.
- **Parking / Stack Yard:** For raw materials, trailers, and equipment laydown.
- **Area Reserved for PPP Operators:** For private firms to operate or lease space under Public–Private Partnership.
- **Future Development Zone:** Space allocated for future workshops, automation upgrades, or warehouse expansion. A typical image is shown in Figure 6.6.

Figure 6.6 A typical Open Yard Facilities


Figure 6.7 Typical image for Marine boat hoist

## 6.5 Details of the Vessels considered

The data on the existing vessels plying in the reroute to Patna has been analysed and the following are the observations;

- About 451 vessels are plying in the route.
- The vessel details are given in Table 6.3.

Table 6.3 Details of Vessel movement under IWAI, R.O. Patna

| Sl. No. | Particulars | Year (FY) | Vessels (Nos) | Total |
|---|---|---|---|---|
| 1 | IWAI Vessel in Patna Sector | | 83 | 83 |
| 2 | Private Vessel in Patna Sector | 2020-21 | 132 | 368 |
| 3 | | 2021-22 | 58 | |
| 4 | | 2022-23 | 54 | |
| 5 | | 2023-24 | 68 | |
| 6 | | 2024-25 | 56 | |
| | | | **Total** | **451** |
| Note: - | Maximum Length of Vessel - 77.37m (MV AAI) | | | |
| | Maximum Width of Vessel - 15m (MV AAI) | | | |

The vessels plying in NW-1 can be classified into following categories based on the LOA and furnished hereunder:

- 13.2 % vessels have LOA ≤ 20 m
- 22.1 % vessels have 20 m > LOA ≤ 25 m

- 15.4% vessels have 25 m > LOA ≤ 30 m
- 47.8% vessels have 30m > LOA ≤ 60 m
- 1.5 % vessels have 60 m > LOA ≤ 65 m.

## 6.6 Size of Boat Hoisting Jetty and Capacity of Marine Boat Hoist

As per the details shared by IWAI regarding the vessels plying in the NW-1, about 98.5% of the vessels are having LOA less than 60m. However, there are proposals to handle 77.37m LOA vessels in this route. Since the majority of the vessels are less than 60m it is recommended that the Boat hoisting jetty can be constructed in two phases, namely 60m in the Phase-I and an additional 30m, so that the overall length of the boat hoisting jetty in Phase-II / final phase shall become 90m, which will result in substantial cost saving and incurring additional expenditure as and when the demand justifies. However, in the case of marine boat hoist, capacity may be fixed as 800 Tonnes. Taking in to the account the longest vessels that can be serviced in the newly created facilities.

### 6.6.1 Phase wise development of the Ship repair facility

The phase wise development of the proposed ship repair facility at Patna, Bihar are depicted in Figure 6.8 and Figure 6.9.

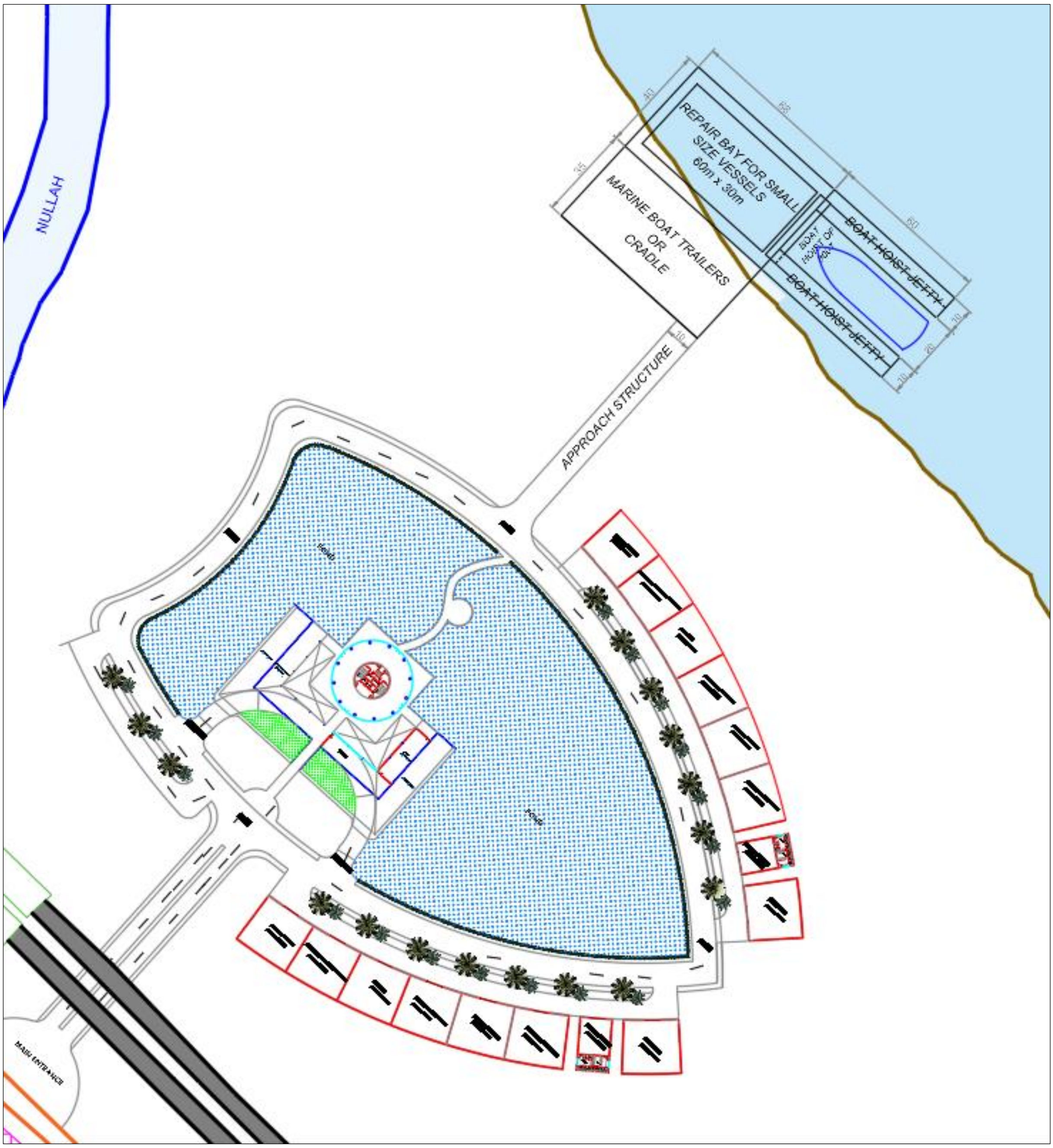



Figure 6.8 Developmental proposal under Phase-I

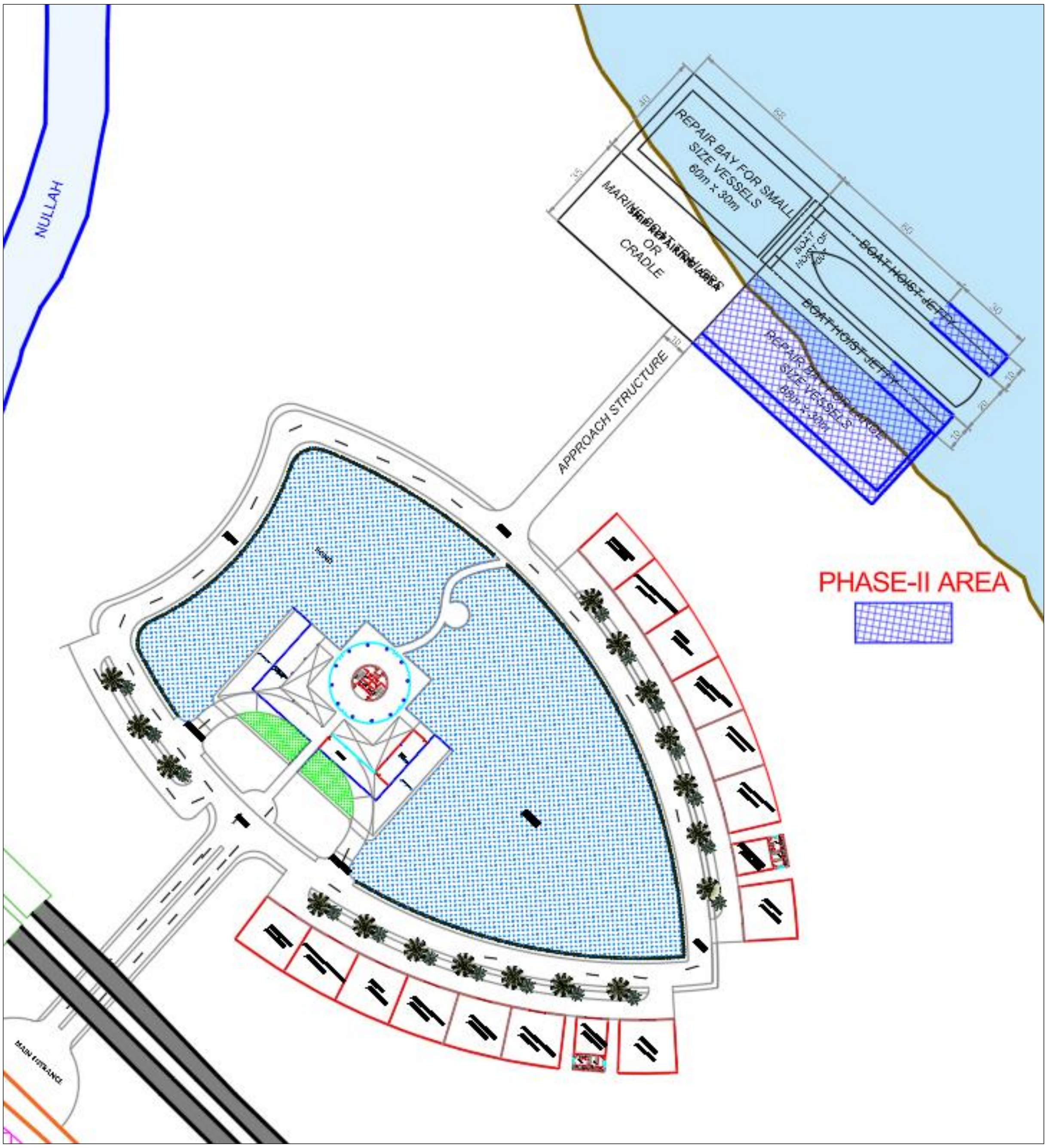



Figure 6.9 Additional developmental proposal under Phase-II

#### 6.6.1.1 Summary of Phasewise development

The phasewise development details are provided in the Table 6.4.

Table 6.4 Phasewise area statement.

| Sl.No | Description | Phase-I Area (Sqm) | Phase-II Area (Sqm) |
|---|---|---|---|
| 1 | Boat Hoist Jetty | 2400 | 1200 |
| 2 | Repair bay | 2720 | 2700 |
| 3 | Marine boat and trailer | 2380 | |
| 4 | Approach Structure | 1600 | |
| 5 | Admin Building + Canteen + Sanitary | 1060 | 400 |
| 6 | Store room | 396 | |
| 7 | Paint store room | 396 | |
| 8 | Sub station | 396 | 150 |
| 9 | Electrical shop | 395 | |
| 10 | Carpentry / Outfitting shop | 395 | |
| 11 | Pipe shop | 395 | |
| 12 | Engine Machine shop | 395 | |
| 13 | Fabrication shop | 399 | 200 |
| 14 | Fire & Safety building | 399 | |
| 15 | Scarp yard | 399 | |
| 16 | Parking / Stockyard | 4465 | 4000 |

# CHAPTER - 7

# PROPOSED SHIP REPAIR FACILITY

# 7 PROPOSED SHIP REPAIR FACILITY

The absence of repair facilities between Varanasi and Kolkata provides a clear competitive advantage for developing an SRF at Patna. With growing IWT traffic on this corridor and IWAI's policy directives to enhance service infrastructure, a Ship Repair Facility at Patna would fill a critical operational void, reduce vessel turnaround time, and align with national inland waterways development objectives. The proposed ship repair facility, general and Structural arrangement of the Facility layout is discussed here under.

## 7.1 Structural Arrangement of boat hoist jetty, transfer bay and repair bay

The proposed cross section of boat hoist jetty consists of open piled type of jetty and the pile diameter is 1.3m. The length of jetty is 60m and width is 10m. The transverse and longitudinal beam dimensions are 1.75m x 2m and 1.5m x 2m. The centre to centre pile spacing is 6.160m in longitudinal direction and 8.25m in transvers direction. The adopted thickness of deck slab is 700mm and the wearing coat of 100mm is provided. The deck level of jetty is +53.50m (MSL). The founding level of pile is -1.50 m (MSL).

The proposed cross section of transfer bay consists of open piled type of jetty and the pile diameter is 1.3m. The length of jetty is 68m and width is 40.0m. The transvers and longitudinal beam dimension are 1.5m x 2.0m and 1.75m x 2m. The centre to centre pile spacing is 6.375m in longitudinal direction and 7.625m and 10.875m in transvers direction. The adopted thickness of deck slab is 800mm and the wearing coat of 100mm is provided. The deck level of jetty is +53.50m (MSL). The founding level of pile is +1.50m (MSL).

The proposed cross section of repair bay consists of open piled type of jetty and the pile diameter is 1.2m. The length of jetty is 68m and width is 35m. The transvers and longitudinal beam dimension are 1.5m x 2m. The centre to centre pile spacing is 6.375m in longitudinal direction and 7.5m in transvers direction. The adopted thickness of deck slab is 700mm and the wearing coat of 100mm is provided. The deck level of jetty is +53.50m (MSL). The founding level of pile is -1.50m (MSL).

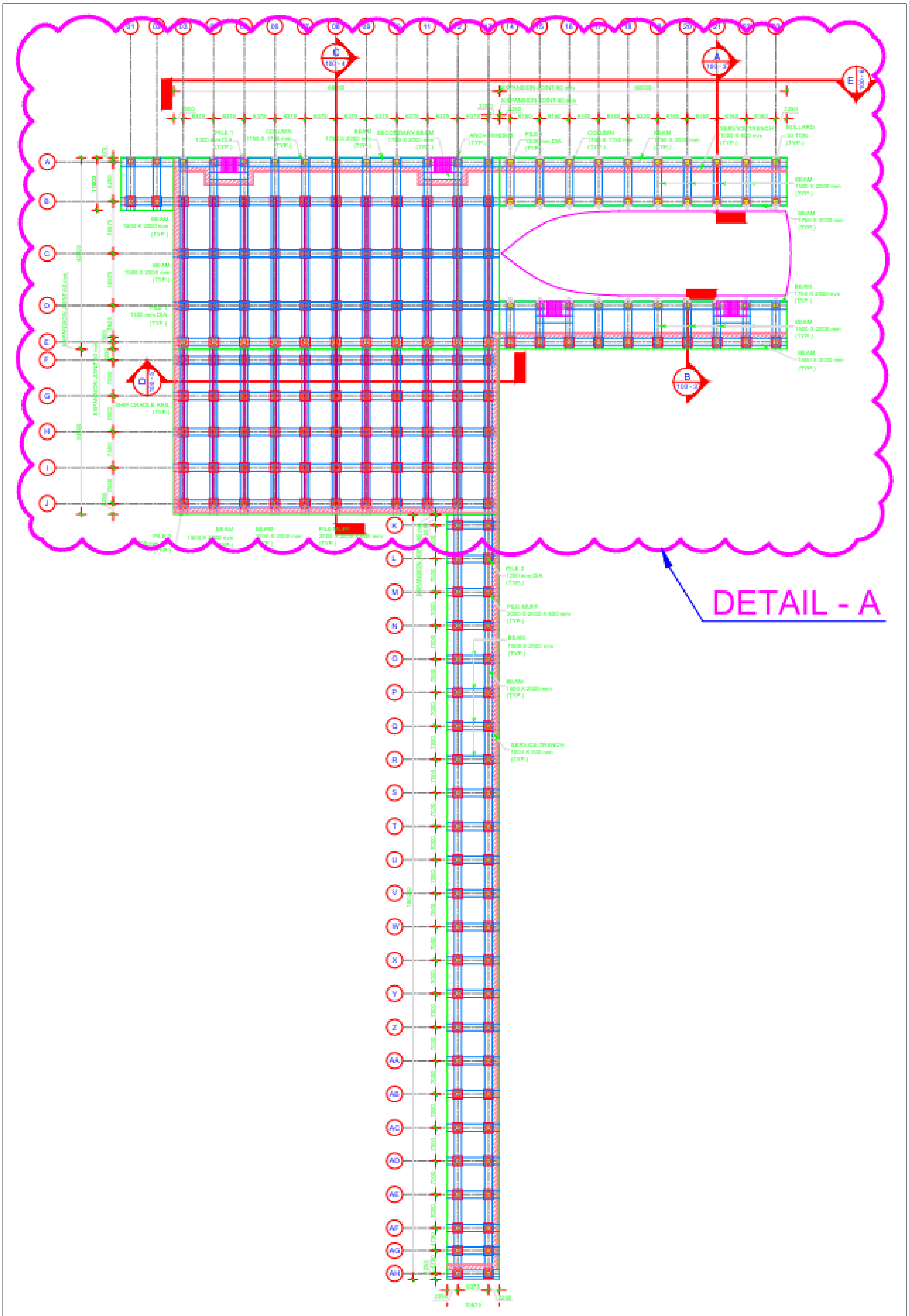



Figure 7.1 General Layout of Proposed Ship repair facility

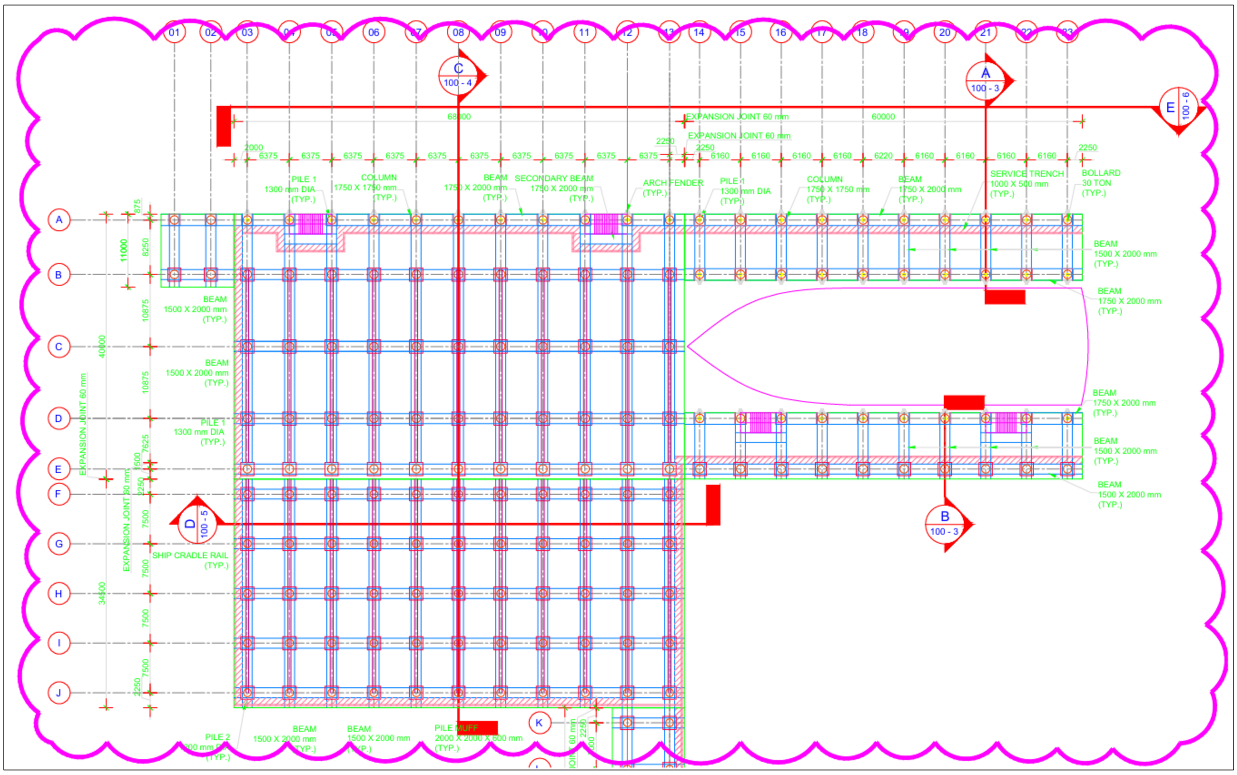


Figure 7.2 Cross section details marked in the Layout (Details at A)

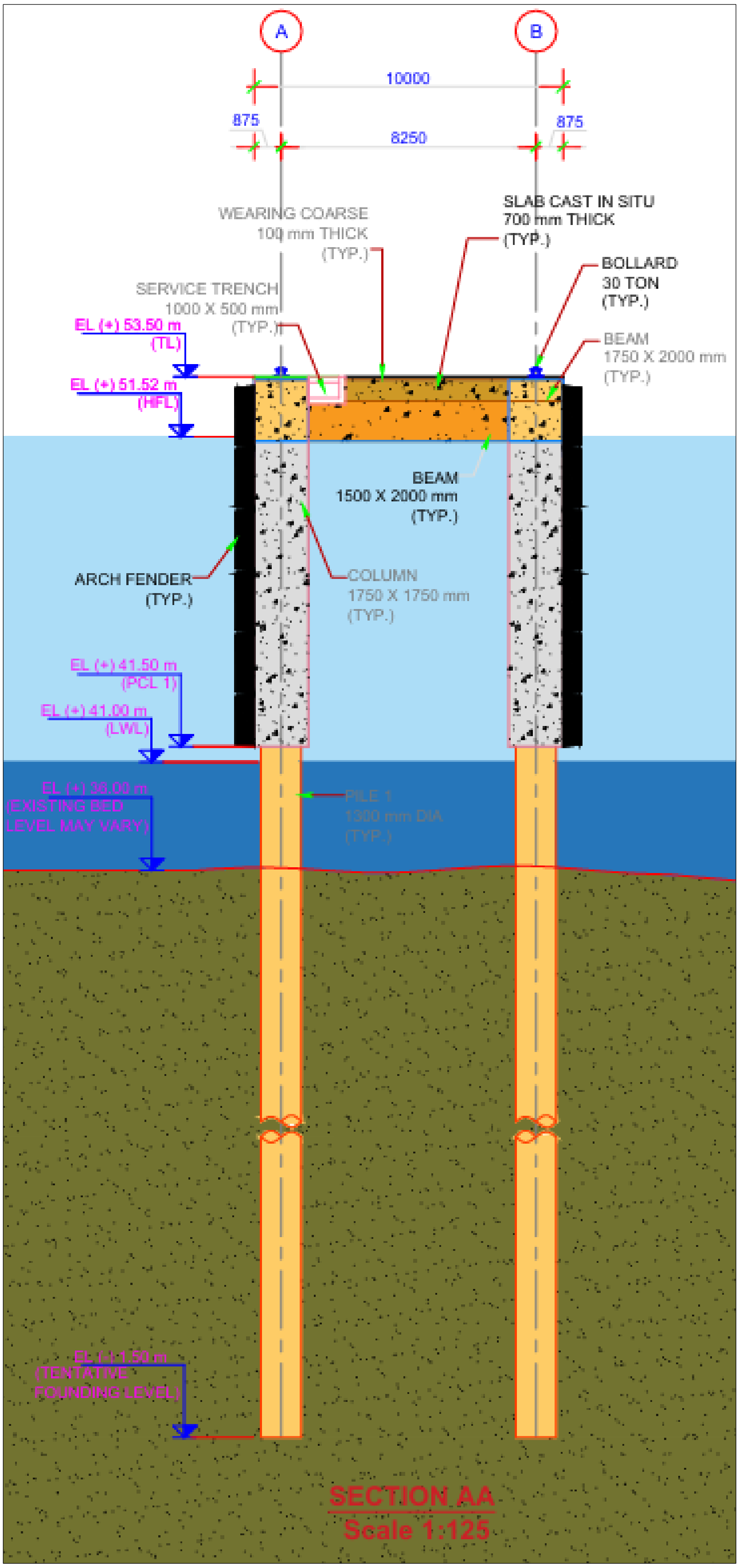



Figure 7.3 Cross section of Boat Hoist Jetty (Section AA)

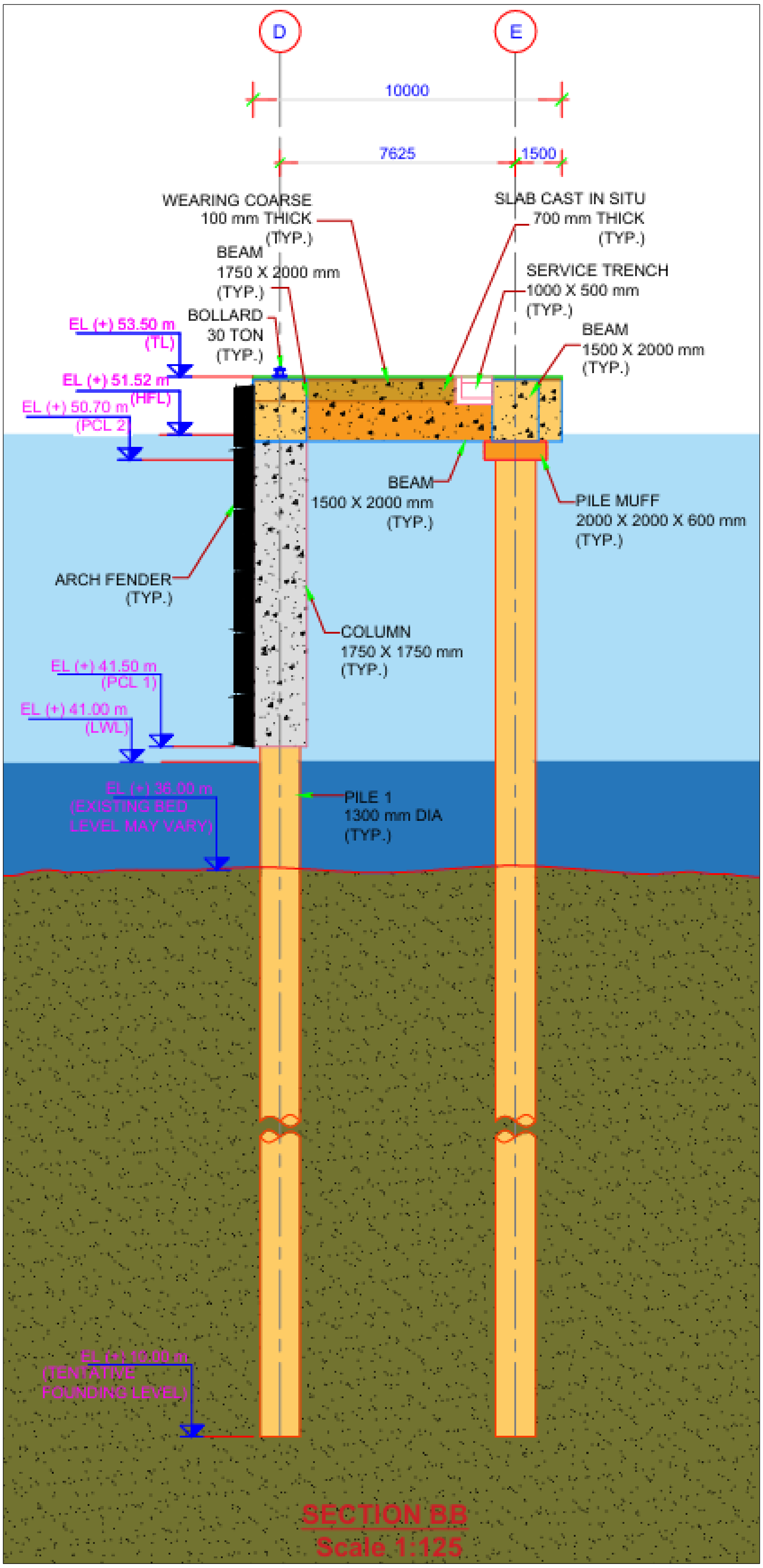



Figure 7.4 Cross section of BB

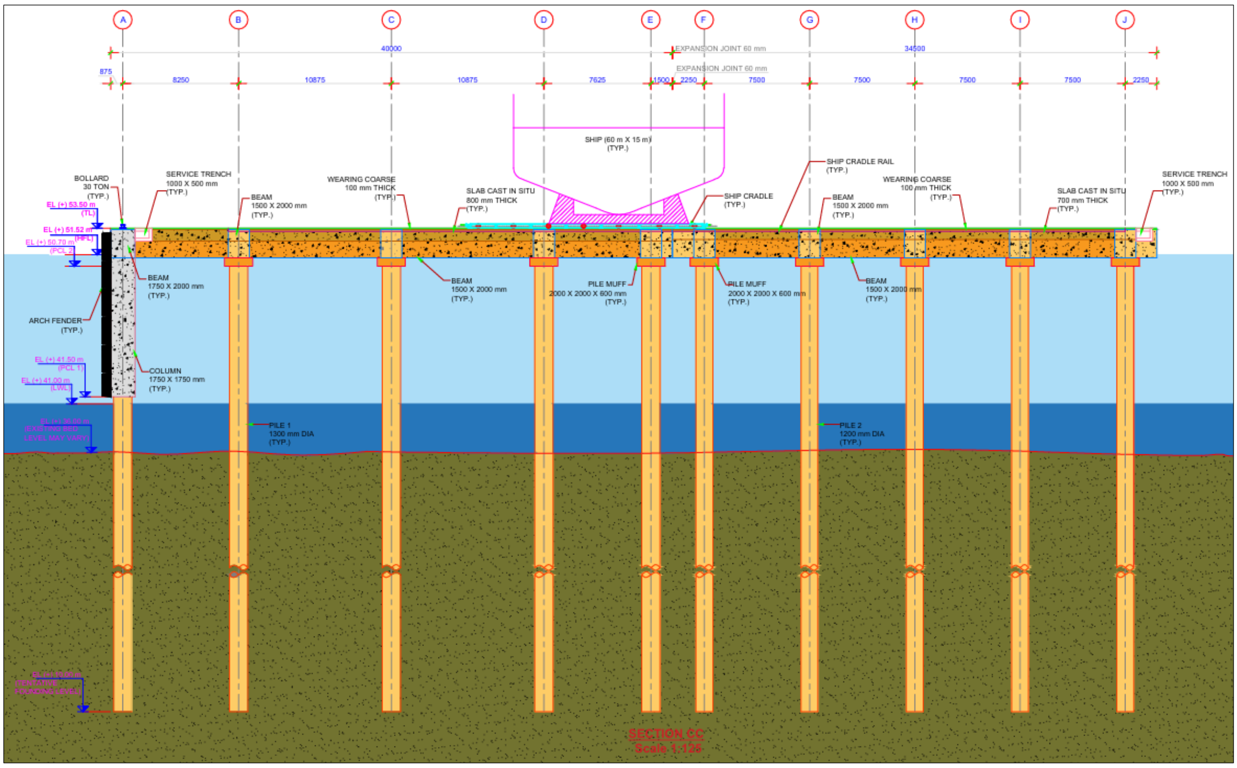



Figure 7.5 Cross section of Transfer Bay

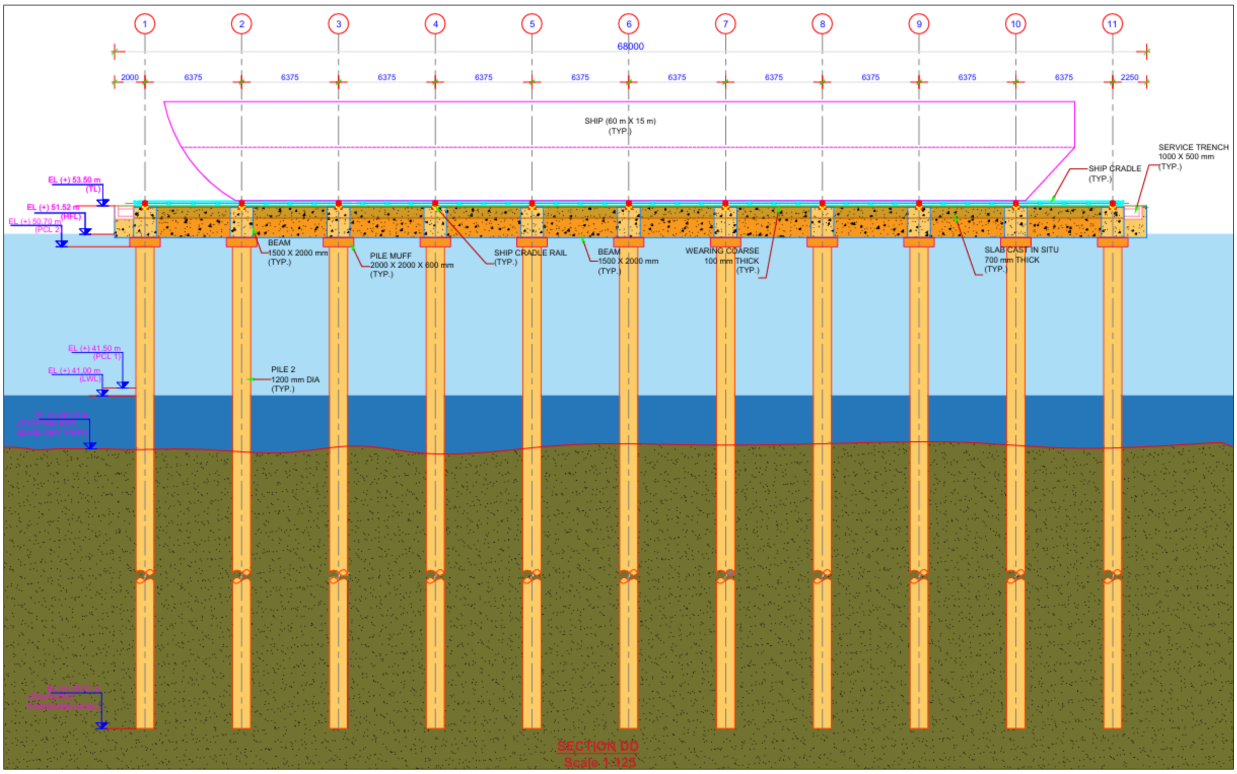



Figure 7.6 Cross section DD

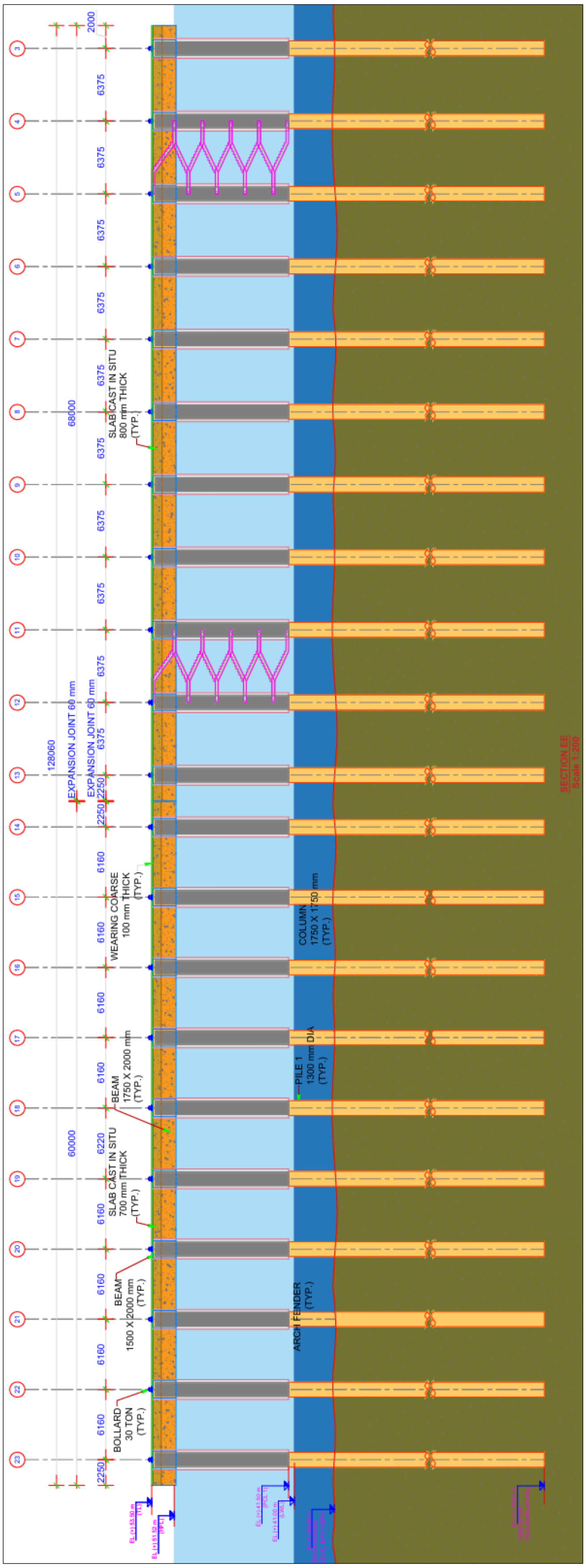


Figure 7.7 Section AA (Front view of Ship repair facility)

## 7.2 Structural sizes (Based on Preliminary design)

The proposed structure is an RCC-framed structure and the proposed sizes are summarized in Table 7.1. These sizes are used in the simulation for structural analysis to generate the dead loads.

Table 7.1 Structural Components

| Sl. No | Structural member | Dimension |
|---|---|---|
| 1 | Piles | 1300mm&1200mm |
| 2 | Beams | 1750mmx2000mm & 1500mmx2000mm |
| 3 | Slab | 700mm & 800mm |
| 4 | Pilemuff | 2000mmx2000mmx600mm |

## 7.3 Loadings for Ship repair facilities

### 7.3.1 Dead Loads

Dead loads will consist of the weights of structure and all equipment of a permanent or semi- permanent nature. Unit weight of various materials used in the structural members is given as follows:

a. Water = 1.0 T/cum

b. Sea water = 1.03 T/cum

c. RCC = 2.5 T/cum

d. Soil = 1.8 T/cum

e. Steel = 7.85 T/cum

f. Sand = 2.0 T/cum

g. Concrete pavers = 2.4 T/cum

h. Foam Concrete =0.6 T/cum.

### 7.3.2 Live Load

A live load of 50kN/ m2 is adopted for design.

### 7.3.3 Seismic Force

Patna, being in Zone-4, experiences moderate to strong earthquakes, making it essential to adopt earthquake-resistant building practices. To ensure the safety of structures in such zones, the Indian Standard (IS) Codes for earthquake-resistant design and construction are crucial. IS 1893: 2016 provides guidelines for earthquake-resistant design, including criteria for buildings, bridges, and other infrastructures in seismic zones. It emphasizes the need for reinforced concrete, structural safety measures, and proper material selection to reduce earthquake damage. Adherence to these codes is necessary for construction in Patna and similar seismic regions to mitigate risks associated with earthquakes. considering 100% dead load + 50 % live load acting on the structure. As per IS code, the site is under (Zone III) and the basic horizontal seismic coefficient is calculated accordingly. The seismic force calculations are given below. Figure 7.8 shows the response spectra for rock and soil and sites for 5% damping.

**Horizontal seismic coefficient Ah= Z I Sa/g**

Z = 0.24, Zone factor (Table 2 of IS: 1893-2016)

I = 1.5, Importance factor (Table 6 of IS: 1893-2016)

R = 3.0, Response reduction factor (Table 7 of IS: 1893-2016)

Sa/g = Average Response acceleration coefficient

(Depends on the natural time period of the structure from STAAD Pro analysis).

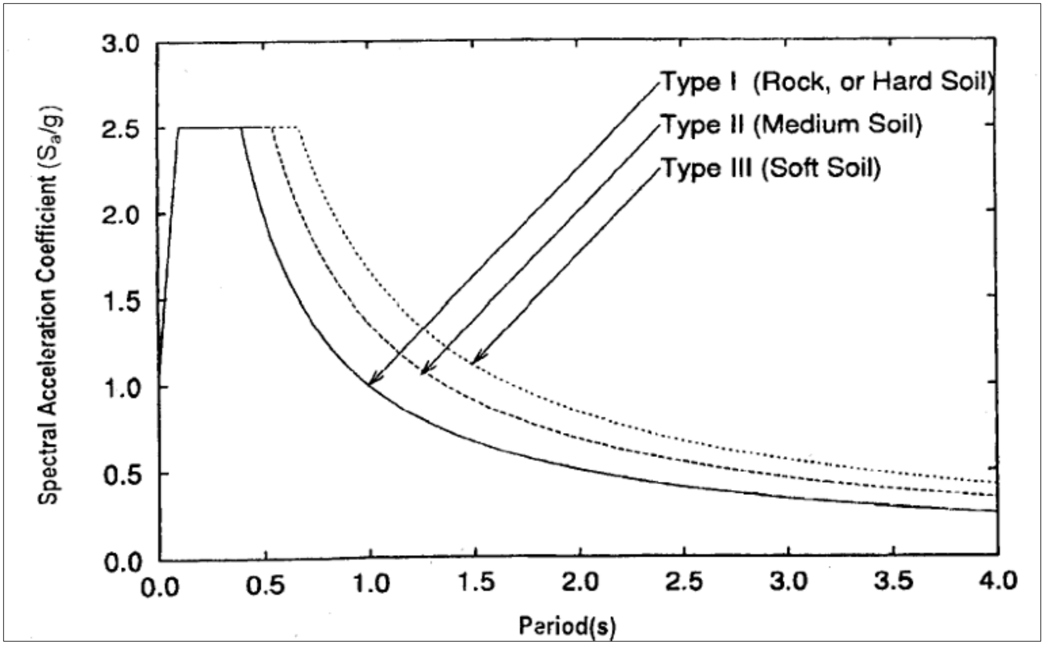



Figure 7.8 Response Spectra for rock and soil and sites for 5% damping

## 7.4 Berthing Force

It is proposed to handle 1260 DWT vessels and the design of the berthing structure considers under moderate conditions. Berthing loads shall be determined under IS 4651-III (2020) for the design vessels. Approach velocities and angles of approach for design vessels shall be considered as per the table given below.

Table 7.2 Parameters for calculation of berthing energy

| Sl.No | Description | Vessel Size in 1260 DWT |
|---|---|---|
| 1 | Berthing velocity (m/sec) | 0.45 |
| 2 | Berthing angle (degrees) | 10 |
| 3 | Mass Coefficient | 1.21 |
| 4 | Displacement Tonnage (Tonne) | 1665 |
| 5 | Eccentricity Coefficient | 0.52 |
| 6 | Softness Coefficient | 0.9 |
| 7 | Normal berthing Energy | 10.1 |
| 8 | Factor of Safety | 2 |
| 9 | Abnormal berthing Energy | 20.2 |
| 10 | Design berthing Energy (Tonne.m) | 22.01 |
| 11 | Fender Selected | Trelleborg Arch Fender- |
| 12 | Maximum Energy Absorption | 22.1 |
| 13 | Maximum Rated Reaction (Tonne) | 567 |

## 7.5 Mooring Force

The mooring force calculations are given below.

| | | | | |
|---|---|---|---|---|
| **Vessel specifications** | | | | |
| Dead Weight Tonnage | DT | = | 1665 | T |
| Overall Length | LOA | = | 90 | m |
| Length between perpendiculars | Lp | = | 85 | m |
| Width of the vessel | B | = | 15 | m |
| Moulded depth | Dm | = | 2.5 | m |
| Average light draft | Dl | = | 1.2 | m |
| **Other data** | | | | |
| Basic Wind Speed | Vb | = | 47 | m/s |
| Current velocity | v | = | 3 | m/s |
| Unit weigth of sea water | w | = | 10.25 | kN/m |
| Acceleration due to gravity | g | = | 9.81 | $m/s^2$ |
| No. of mooring lines | | = | 8 | |
| No. of mooring lines resisting the system | | = | 2 | |
| **Coefficients** | | | | |
| Shape Factor | Cw | = | 1.3 | |
| Coefficients for wind force calculation | | | | |
| Probability factor | k1 | = | 1 | |
| Terrain roughness and height factor | k2 | = | 1.05 | |
| Topography factor | k3 | = | 1 | |
| Importance factor | k4 | = | 1 | |
| Wind directionality factor | Kd | = | 1 | |
| Area averaging factor | Ka | = | 0.8 | |
| Combination factor | Kc | = | 0.9 | |

**Force due to wind**

| | | | | |
|---|---|---|---|---|
| Force due to wind | Fw | = | CwAwP | |
| Shape Factor | Cw | = | 1.3 | |
| Windage Area | Aw | = | 1.175*Lp(Dm -Dl) | |
| | | = | 1.175*85(2.5-1.2) | |
| | Aw | = | 129.84 | m2 |
| Design Wind Speed | Vz | = | Vb*k1*k2*k3 *k4 | |
| | | = | 47*1*1.05*1* 1 | |
| | Vz | = | 49.35 | m/s |
| Wind Pressure | Pz | = | 2 | |
| | | = | 0.6*Vz | |
| | | = | 0.6*49.35^2 | |
| | Pz | = | 1461.25 | $N/m^2$ |
| Design wind pressure | pd | = | Kd*Ka*Kc*pz | |
| | | = | 1*0.8*0.9*146 1.25 | |
| | pd | = | 1052.1 | $N/m^2$ |

The value of pd, however shall not be taken less than 0.70 pz

| | | | | |
|---|---|---|---|---|
| | 0.7pz | = | 0.7*1461.25 | |
| | | = | 1022.88 | |
| Wind pressure to be considered, | | = | 1052.1 | $N/m^2$ |
| | P | = | 1.05 | $kN/m^2$ |
| Force due to wind | Fw | = | CwAwP | |
| | | = | 1.3*129.838* 1.05 | |
| | | = | 177.23 | kN |

**Force due to current**

| | | | |
|---|---|---|---|
| Force due to current | Fc | = | $(wv^2/2g)*Ap$ |
| Area of ship under water | Ap | = | B*Dl |
| | | = | 15*1.2 |

| | | | | |
|---|---|---|---|---|
| | | = | 18 | m2 |
| Force due to current | Fc | = | $(wv^2/2g)*Ap$ | |
| | | = | ((10.25*3^2)/(2*9.81))*18 | |
| | | = | 84.63 | kN |
| Resultant Mooring force | F | = | $(Fw^2 + Fc^2)^{0.5}$ | |
| | | = | (177.23^2 + 84.63^2)^0.5 | |
| Resultant Mooring force | F | = | 196.4 | kN |

*Assuming vessel to be moored by 8 mooring lines and considering only 50 % of the lines resist the force*

| | | | |
|---|---|---|---|
| Mooring force on each mooring line | = | 196.4 / 2 | |
| | = | 98.2 | kN |
| | ~ | 300 | kN |

## 7.6 Wind

The wind forces on structures are calculated as per IS 875 Part 3 with the following wind speed consideration (assumed).

The basic maximum wind speed under the operating condition: 47 m/s. The design wind speed to be obtained from the formula is given below:

Design wind speed, Vz = k1 x K2 x k3 x Vb

Where,

k1 = Risk Co efficient = 1.07 (Table 1),

k2 = Terrain, Height and Structure size factor = 1.05 (Category 2, Class C, Height < 10m (Table 2)),

k3 = Topography factor = 1.0 (Clause: 5.3.3.1).

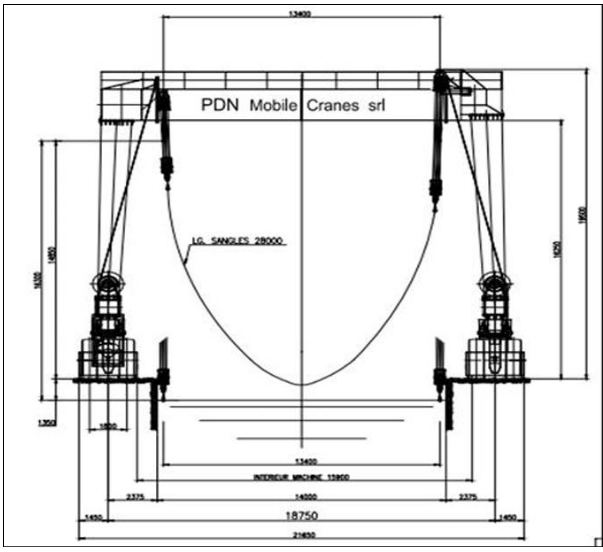
## 7.7 Temperature & Shrinkage

Temperature and Shrinkage forces considered for adequacy check are as follows.

- Min / Max temperature : + 5°C / 40° C
- The coefficient of thermal expansion for RCC structures is taken as 11.7 x 10- 6 / °C.

## 7.8 Boat Hoist Crane

The ship repair structure is designed for 800T capacity of boat hoist carne. The technical details are furnished in Figure 7.9. The customized crane should have 32wheels with spacing of 4.9m centre to centre.




**Capacity and structural steelwork**

| | | |
|---|---|---|
| Max. capacity | **700** | **ton** |
| Machine's load | 350 | ton approx. |
| Steelwork material | steel | S355JR |
| Guaranteed painting thickness (please see the paragraph anti-corrosion protection for all the treatments) | 220 | micron |
| Painting guarantee | | 5 years |

**Dimensions**

| | | |
|---|---|---|
| Dock span | 14000 | mm |
| Max. length at the base | 25908 | mm |
| Max. width | 21650 | mm |
| Max. height | 19500 | mm |
| Clear internal width | 15900 | mm |
| Gauge | 18000 | mm |
| Track | 18750 | mm |
| Clear height under transversal beam | 16250 | mm |

**Steering and tyres**

Steering twin wheel-groups (with hydraulic motor) n°8

**Types of steering:**

- standard steering on all the groups

**Optional:**

***Universal electronic steering, adding other steering capacity:***

1. 90°steering (at half max.capacity in standstill operation)
2. carousel (rotation of the machine on itself around the central point of the same)
3. crab (in diagonal direction)
4. others on demand

**Tyres**

Size 27.00 - 49 n°16

Figure 7.9 Technical specifications for Boat Hoist Crane

## 7.9 Results and Discussions

The P-δ structural analysis was carried out to determine the structural responses such as member forces and deflections. The member loads will be used to design the RCC elements for ship repair facilities. The reinforcement results for each structural element are summarized in this section.

### 7.9.1 Structural members

#### 7.9.1.1 Piles

Based on the Preliminary design adopting the data shared by IWAI, the tentative size of the piles along with the reinforcement have been arrived, at which is summarized in Table 7.3.

Table 7.3 Reinforcement summary for 1300mm & 1200mm dia Pile

| Pile Dia (mm) | No of bars provided | % of reinforcement provided | Lateral ties provided | Crack width (mm) |
|---|---|---|---|---|
| | | | | Short term |
| 1300 | 2 x 33 T32 | 4.0% | 12mm# @150mm spacing c/c | 0.159 |
| 1200 | 2 x 25 T32 | 3.56% | 12mm# @150mm spacing c/c | 0.159 |

#### 7.9.1.2 Column

Based on the Preliminary design adopting the data shared by IWAI, the tentative size of the column along with the reinforcement have been arrived, at which is summarized in Table 7.4.

Table 7.4 Reinforcement summary for column (1750x1750mm)

| Size of Beam (mm) | No of bars provided | % of reinforcement provided | Lateral ties provided | Crack width (mm) |
|---|---|---|---|---|
| | | | | Short term |
| 1750x1750 | 1 x 34 T32 on each side | 3.5% | 12mm# @150mm spacing c/c | 0.18 |

#### 7.9.1.3 Beam

Based on the Preliminary design adopting the data shared by IWAI, the tentative size of the beams along with the reinforcement have been arrived, at which is summarized in Table 7.5.

Table 7.5 Reinforcement summary for beams

| Sl. No. | Size(mm) | Reinforcement | | % of reinforcement | | Stirrups (mm) | Crack width (mm) | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Top | Bottom |
| | | Bottom | Top | Bottom | Top | | Short | Short |
| 1 | 1750x2000 | 30T32 | 30T32 | 0.73 | 0.73 | 12T 10 legged @125 c/c | 0.061 | 0.038 |
| 2 | 1500x2000 | 30T32 | 30T32 | 0.85 | 0.85 | 12T 10 legged @100 c/c | 0.101 | 0.091 |

### 7.9.1.4 Slab

Based on the Preliminary design adopting the data shared by IWAI, the tentative size of the slabs along with the reinforcement have been arrived, at which is summarized in Table 7.6.

Table 7.6 Reinforcement summary for slab

| Sl. No. | Description | Reinforcement | | % of reinforcement | | Stirrups (mm) | Crack width (mm) | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Top | Bottom |
| | | Bottom | Top | Bottom | Top | | Short | Short |
| 1 | Slab (700mm thick) | 25@ 150c/c | 25@ 150c/c | 0.51 | 0.51 | 12T 6 legged @ 150 c/c | 0.051 | 0.047 |
| 2 | Slab (800mm thick) | 25@ 100c/c | 25@ 100c/c | 0.44 | 0.44 | 12T 6 legged @ 100 c/c | 0.035 | 0.016 |

## 7.10 Tower Crane

In order to move/handle heavy goods, materials or tools around a site, it is proposed to install two tower cranes of 10T capacity, one under Phase-1 and other under Phase-2.

## 7.11 Summary & Cost estimate

The proposed ship repair structure is found to be safe against the above-mentioned forces. The capital cost estimates have been prepared for the proposed structure in phase wise development. The total cost of the project based on requirements is about Rs. 284.7 Crores for Phase-I and 89.1 Crores for Phase-II. The total cost of project is Rs. 373.8 Crores (excluding GST).

Table 7.7 Abstract of Capital Cost Estimate for Marine Structures Phase-I

| Sl No | Description of work | Quantity | Unit | Rate Rs. | Amount |
|---|---|---|---|---|---|
| 1 | Mobilization and Demobilization: Provide and bring on site sufficient numbers of piling rigs with all required ancillary equipment and personnel for installing 1300mm dia and 1200mm dia vertical bored cast insitu piles as per specifications and Remove from site all piling plant & equipment in item-1 above, after completion of work. | LS | LS | 15,000,000.00 | 15,000,000.00 |
| 2 | Positioning and setting upon and/or shifting and setting up piling equipment required for piling work at each piling locations as shown in the drawing and as directed including all labour, materials, fuel, tools, equipments etc., complete. For 1300mm and 1200mm Piles | 202.00 | Nos | 150,000.00 | 30,300,000.00 |
| 3 | Supplying, fabricating and providing steel cylindrical liners of 8 mm thick M.S plate to the required depth, 1300mm and 1200mm piles as shown in the drawing including gas cutting, bending, welding at yard & site, transporting, driving of liners, all labour, materials, tools, equipments, fuel etc., complete.<br>Note:- | | | | |

| | | | | | |
|---|---|---|---|---|---|
| | 1. The stiffener shall be measured under this item.<br>2. In case the soil strata found to be not good in the founding level of the liner, extra depth may be provided as per site condition. | | | | |
| | Liner 8mm thick | 1135.00 | Te | 112,200.00 | 127,347,000.00 |
| 4 | Lowering and pitching of fabricated liners of 8mm at each pile location | 202.00 | Nos | 156,000.00 | 31,512,000.00 |
| 5 | Placing, Driving the M.S liners of the specifications as per item 2 above for1300mm dia and 1200mm dia vertical bored piles. The cost inclusive of charges for transporting to the pile location, aligning, lowering, pitching and driving the liners etc. complete as per standard specification and as directed by the Departmental officers | 5053.18 | Rm | 3,480.00 | 17,585,066.40 |
| 6 | Boring for the piles to the required depth through all types of soil strata including cemented sand, boulder layers , weathered rock and hard rock if any upto the founding level and stacking the bored soil at convenient place and transported to the low lying area anywhere inside /outside the harbour area within a lead of 4 km or as directed by the Engineer's representative and pile shaft cleaning and keeping of all records etc. including bentonite solution, labour, tools, equipment, fuel etc..all as per drawing, specification etc complete as directed.<br>Note:<br>i)In case the soil stratum at the founding level is loose the Engineer or his representative may direct the contractor to carryout additional length of boring.<br>ii)The sample of bored materials of regular interval shall be collected and | | | | |

| | | | | | |
|---|---|---|---|---|---|
| | produced for the verification of the Engineer or his representative at no extra cost in the event of any dispute about the type of strata bored the samples so collected shall be referred to an authorized laboratory / agency identified by the Engineer and the decision of such authorized laboratory / agency is final and binding on both parties. However, the cost of such testing shall be borne by the contractor<br>iii) Boring through all type of soil strata means soft soil, weathered rock, cemented sand, boulders and hard rock etc.,<br>iv) The boring in all type of soil measurement will be made on the basis of depth of boring from encountered soft soil level to founding/pile termination level. Then boring in hard rock shall be measured from level of encountered hard rock to pile termination level.<br>v) All the boring depths shall be jointly measured actually at site and Engineer in-charge decision is final. | | | | |
| | Boring for 1300mm dia pile | 3712.50 | Rm | 41,051.00 | 152,401,837.50 |
| | Boring for 1200mm dia pile | 3862.50 | Rm | 33,709.00 | 130,201,012.50 |
| 7 | Trimming of pile heads built up above the cut off level (casted minimum 1m above the required cut off level) and/ or as directed and stacking the debris at convenient place and transported to the low lying area any where inside/ outside the port premises with in a lead of 4 K.M or all as directed by the engineers representative and all associated cleaning of projecting reinforcements including all labour cutting the excess liner up to cut off | 202.00 | Nos | 15,120.00 | 3,054,240.00 |

| | | | | | |
|---|---|---|---|---|---|
| | level, materials, tools, equipments, fuel, shifting of scrap liner to the designated location etc. complete all as directed.( The excess liner scrap material is property of the contractor) | | | | |
| 8 | Dynamic pile load test (High strain Dynamic testing) perform Non-Destructive Integrity test of piles of size 1300mm dia and 1200mm dia according to the approved Specifications and as directed by the Engineer or his representative all as per relevant BIS/ASTM codes including all labour, tool. Equipments, plant, etc., complete.<br>Providing, conducting of routine Dynamic high strain testing using pile Driving analyzer by impacting a 1.5 percent weight of capacity of pile with a fall varying from 1m to 3m including preparing head, providing ply and steel plates, fixing strain gauges etc. all conforming to ASTMD4945. Further include evaluating and submitting report covering<br>Providing, conducting of routine Dynamic high strain testing using pile Driving analyzer by impacting a 1.5 percent weight of capacity of pile with a fall varying from 1m to 3m including preparing head, providing ply and steel plates, fixing strain gauges etc. all conforming to ASTMD4945. Further include evaluating and submitting report covering<br>i) True static capacity of the pile at the time of testing<br>ii) Simulated static load test curve | 2.00 | Nos | 480,000.00 | 960,000.00 |

| | | | | | |
|---|---|---|---|---|---|
| | iii) Total skin friction and end bearing of pile | | | | |
| | iv) Skin friction variation along the length of the pile | | | | |
| | v) Compressive and tensile stresses developed in pile during testing | | | | |
| | vi) Net and total displacement of the pile | | | | |
| 9 | INTEGRITY TEST ON WORKING PILES Conduct non-destructive integrity test on working piles using low strain sonic diagnostic system as specified and as directed by the Engineer for 1300 mm dia and 1200mm dia piles | 202.00 | Nos | 11,400.00 | 2,302,800.00 |
| 10 | ROUTINE AND INITIAL VERTICAL LOAD TEST Supply necessary kentledge and perform vertical load tests on the marine piles 1300mm dia | 1.00 | Nos | 3,370,202.22 | 3,370,202.22 |
| | 1200mm dia | 1.00 | Nos | 2,421,254.00 | 2,421,254.00 |
| 11 | Providing and placing in-situ concrete of grade M40 for piles using tremmie method up to cut off level underneath the bentonite slurry including all sampling testing and records and all labour, materials, tools, equipment, fuel, etc., complete., | 12415.04 | $m^3$ | 21,120.00 | 262,205,680.01 |
| | Note: | | | | |
| | Supply, fabrication of steel reinforcement shall be measured and paid under relevant item. | | | | |
| | (Rate shall include the cost of providing additional concrete above the cut-off level) | | | | |
| 12 | Providing and placing precast concrete of grade M40 for pile muff using tremmie method up to cut off level underneath the bentonite slurry including all sampling testing and records and all labour, materials, | 255.04 | m3 | 16,980.00 | 4,330,538.28 |

| | | | | | |
|---|---|---|---|---|---|
| | tools, equipment, fuel, etc., complete., Note: Supply, fabrication of steel reinforcement shall be measured and paid under relevant item. | | | | |
| 13 | Providing and placing precast concrete of grade M40 for columns using tremmie method up to cut off level underneath the bentonite slurry including all sampling testing and records and all labour, materials, tools, equipment, fuel, etc., complete., Note: Supply, fabrication of steel reinforcement shall be measured and paid under relevant item. | 1303.71 | m3 | 18,240.00 | 23,779,602.00 |
| 14 | Supplying, fabricating and placing of TMT, Fe500D grade steel for pile reinforcement cage in piles including welding, binding, with binding wire all as per drawing, technical specifications and including all labour, materials, tools transport, cage lowering, equipments, fuel etc., complete | 3103.76 | Te | 101,400.00 | 314,721,306.26 |
| 15 | Supplying, fabricating and placing TMT, Fe500D grade steel for reinforcement of pile muff including welding, binding, with binding wire all as per drawing, technical specifications and including all labour, materials, tools transport, cage lowering, equipments, fuel etc., complete. | 44.63 | Te | 101,400.00 | 4,525,642.03 |
| 16 | Supplying, fabricating and placing TMT, Fe500D grade steel for reinforcement of columns including welding, binding, with binding wire all as per drawing, technical specifications and including all | 391.11 | Te | 101,400.00 | 39,658,744.13 |

| | | | | | |
|---|---|---|---|---|---|
| | labour, materials, tools transport, cage lowering, equipments, fuel etc., complete. | | | | |
| DECK STRUCTURES | | | | | |
| 17 | Casting of Precast and cast in situ cement concrete Beams of grade M40 of various sizes as shown in the drawing and or any other size as directed to suit the site condition including shuttering,/ formwork mixing, transporting, placing, vibrating, curing the concrete and all labour, materials, tools, equipment, fuel, all sampling, testing and records etc., complete.<br>Note:<br>1.Supply, Fabrication of steel reinforcement shall be measured and paid under relevant item of Bill no: 1<br>2.Placing the precast units shall be measured and paid under relevant item of Bill No:2 | 6705.50 | m3 | 19,920.00 | 133,573,560.00 |
| 18 | Providing and placing Precast and cast in situ concrete of grade M40 for slabs all as per drawing and or as directed by the Engineer including provision of shuttering, mixing, transporting, placing, vibrating, curing the concrete including all labour, materials, tools, equipment, fuel and all sampling, testing and records etc., complete.<br>Note:<br>Supply, Fabrication of steel reinforcement shall be measured and paid under relevant item of Bill no: 1 | 5299.20 | $m^3$ | 19,920.00 | 105,560,064.00 |

| | | | | | |
|---|---|---|---|---|---|
| 19 | Supplying, fabricating and placing of TMT, Fe500D grade steel bars for Cast in situ beams including lifting hooks for precast units and cutting, bending, welding, binding wire all as per technical specification, drawing, including all labour, materials tools, equipment, fuel and all sampling, testing and records etc., complete. | 1173.46 | Te | 105,600.00 | 123,917,640.00 |
| 20 | Supplying, fabricating and placing of TMT, Fe500D grade steel bars for Cast in situ slabs including lifting hooks for precast units and cutting, bending, welding, binding wire all as per technical specification, drawing, including all labour, materials tools, equipment, fuel and all sampling, testing and records etc., complete. | 1193.00 | Te | 105,600.00 | 125,980,800.00 |
| 21 | Providing and placing in-situ grade M30 for wearing coat concrete over the deck slab, all as per drawings with necessary shuttering, mixing, transporting, placing, vibrating, finishing and curing the concrete including all labour, materials tools, equipment, fuel and all sampling, testing and records etc., complete | 812.70 | $m^3$ | 18,000.00 | 14,628,600.00 |
| 22 | Supplying, handling, transporting and fixing in position of Arc fender(800) with anchor bolts, U hooks, Chains, cutting, concrete chipping, drilling, grouting, necessary welding with deck reinforcement steel and necessary coal tar painting(wherever required) including all materials, labour, consumable items, machineries, tools, tackles, transportation etc... and complete as per Engineer In charge. | 41.00 | Nos | 2,399,366.00 | 98,374,006.00 |

| | | | | | |
|---|---|---|---|---|---|
| 23 | Supplying, handling, transporting and fixing in position of Bollard (30 ton capacity) with necessary cutting, concrete chipping, drilling, grouting, welding with deck reinforcement steel and necessary coal tar painting (wherever required) including all materials, labour, consumable items etc. Complete as per drawing and specifications as directed by the EIC. | 41.00 | Nos | 120,000.00 | 4,920,000.00 |
| 24 | 800T Mobile Hoist Crane | 1.00 | Nos | 360,064,025.00 | 360,064,025.00 |
| 25 | Tower Crane 10 T | 1.00 | Nos | 45,500,000.00 | 45,500,000.00 |
| 26 | Flatbed Trolley for transfer the boat | 1.00 | Nos | 108,019,207.50 | 108,019,207.50 |
| 27 | Indian Standard Crane Rail | 430.00 | RM | 41,569.00 | 17,874,670.00 |
| 28 | Curbs - Rubber | 335.00 | RM | 15,554.00 | 5,210,590.00 |
| 29 | Expansion Joint | | | | |
| | 1. M.S angles and Plate | 3.00 | Te | 121,054.00 | 363,162.00 |
| | 2. Bituminous pad 25mm thick | 30.00 | m2 | 6,374.00 | 191,220.00 |
| 30 | Sealing component | 120.00 | RM | 310.00 | 37,200.00 |
| 31 | Mooring rings | 2.00 | Nos | 6,930.00 | 13,860.00 |
| 32 | Safety chains | 40.00 | RM | 1,232.00 | 49,280.00 |
| 33 | M.S Inserts | 2.00 | Te | 126,856.00 | 253,712.00 |
| | | | | Total | 2310208522 |
| | | | | Electrical work, Plumbing work & Firefighting (5%) | 231020852 |
| | | | | Contingency (5%) | 127061469 |
| | | | | PMC + Work Charge establishment (7%) | 177886056 |
| | | | | Round off | 823101 |
| | | | | Total Amount Rs. (INR) | 2847000000 |

Note:

1. Above Quoted Price is Exclusive of GST on Works Contract. The GST shall be paid Extra as per Actual during execution of the Works.
2. Any access road that may be required from the nearby Road/Highways upto the Ship repair facility is not covered under this DPR/Estimate.

Table 7.8 Abstract of Capital Cost Estimate for Marine Structures Phase-II

| Sl No | Description of work | Quantity | Unit | Rate Rs. | Amount Rs. |
|---|---|---|---|---|---|
| 1 | Mobilization and Demobilization Provide and bring on site sufficient numbers of piling rigs with all required ancillary equipment and personnel for installing 1300mm dia and 1200mm dia vertical bored cast insitu piles as per specifications and Remove from site all piling plant & equipment in item-1 above, after completion of work. | LS | LS | 15,000,000.00 | 15,000,000.00 |
| 2 | Positioning and setting upon and/or shifting and setting up piling equipment required for piling work at each piling locations as shown in the drawing and as directed including all labour, materials, fuel, tools, equipments etc., complete. For 1300mm and 1200mm Piles | 95.00 | Nos | 150,000.00 | 14,250,000.00 |
| 3 | Supplying, fabricating and providing steel cylindrical liners of 8 mm thick M.S plate to the required depth, 1300mm and 1200mm piles as shown in the drawing including gas cutting ,bending, welding at yard & site, transporting, driving of liners, all labour, materials, tools, equipments, fuel etc., complete Note:- 1.The stiffener shall be measured under this item. 2. In case the soil strata found to be not good in the founding level of the liner, extra depth may be provided as per site condition. | | | | |
| | Liner 8mm thick | 534.00 | Te | 93,500.00 | 49,929,000.00 |
| 4 | Lowering and pitching of fabricated liners of 8mm at each pile location | 95.00 | Nos | 130,000.00 | 12,350,000.00 |
| 5 | Placing, Driving the M.S liners of the specifications as per item 2 above for1300mm dia and 1200mm dia vertical bored piles. The cost inclusive of charges for transporting to the pile location, | 2436.50 | Rm | 3,480.00 | 8,479,020.00 |

| | | | | | |
|---|---|---|---|---|---|
| | aligning, lowering, pitching and driving the liners etc. complete as per standard specification and as directed by the Departmental officers | | | | |
| 6 | Boring for the piles to the required depth through all types of soil strata including cemented sand, boulder layers , weathered rock and hard rock if any upto the founding level and stacking the bored soil at convenient place and transported to the low lying area anywhere inside /outside the harbour area within a lead of 4 km or as directed by the Engineer's representative and pile shaft cleaning and keeping of all records etc. including bentonite solution, labour, tools, equipment, fuel etc..all as per drawing, specification etc complete as directed.<br>Note:<br>i)In case the soil stratum at the founding level is loose the Engineer or his representative may direct the contractor to carryout additional length of boring.<br>ii)The sample of bored materials of regular interval shall be collected and produced for the verification of the Engineer or his representative at no extra cost in the event of any dispute about the type of strata bored the samples so collected shall be referred to an authorized laboratory / agency identified by the Engineer and the decision of such authorized laboratory / agency is final and binding on both parties. However the cost of such testing shall be borne by the contractor<br>iii) Boring through all type of soil strata means soft soil, weathered rock, cemented sand, boulders and hard rock etc., | | | | |

| | | | | | |
|---|---|---|---|---|---|
| | iv)The boring in all type of soil measurement will be made on the basis of depth of boring from encountered soft soil level to founding/pile termination level. Then boring in hard rock shall be measured from level of encountered hard rock to pile termination level.<br>v) All the boring depths shall be jointly measured actually at site and Engineer in-charge decision is final. | | | | |
| | Boring for 1300mm dia pile | 750.00 | Rm | 41,051.00 | 30,788,250.00 |
| | Boring for 1200mm dia pile | 2812.50 | Rm | 33,709.00 | 94,806,562.50 |
| 7 | Trimming of pile heads built up above the cut off level (casted minimum 1m above the required cut off level) and/ or as directed and stacking the debris at convenient place and transported to the low lying area anywhere inside/ outside the port premises with in a lead of 4 K.M or all as directed by the engineers representative and all associated cleaning of projecting reinforcements including all labour cutting the excess liner up to cut off level, materials, tools, equipments, fuel, shifting of scrap liner to the designated location etc. complete all as directed.( The excess liner scrap material is property of the contractor) | 95.00 | Nos | 15,120.00 | 1,436,400.00 |
| 8 | Dynamic pile load test (High strain Dynamic testing) perform Non-Destructive Integrity test of piles of size 1300mm dia and 1200mm dia according to the approved Specifications and as directed by the Engineer or his representative all as per relevant BIS/ASTM codes including all labour, tool. Equipments, plant, etc., complete. | 2.00 | Nos | 480,000.00 | 960,000.00 |

| | | | | | |
|---|---|---|---|---|---|
| | Providing, conducting of routine Dynamic high strain testing using pile Driving analyzer by impacting a 1.5 percent weight of capacity of pile with a fall varying from 1m to 3m including preparing head, providing ply and steel plates, fixing strain gauges etc. all conforming to ASTMD4945. Further include evaluating and submitting report covering | | | | |
| | Providing, conducting of routine Dynamic high strain testing using pile Driving analyzer by impacting a 1.5 percent weight of capacity of pile with a fall varying from 1m to 3m including preparing head, providing ply and steel plates, fixing strain gauges etc. all conforming to ASTMD4945. Further include evaluating and submitting report covering | | | | |
| | i) True static capacity of the pile at the time of testing | | | | |
| | ii) Simulated static load test curve | | | | |
| | iii) Total skin friction and end bearing of pile | | | | |
| | iv) Skin friction variation along the length of the pile | | | | |
| | v) Compressive and tensile stresses developed in pile during testing | | | | |
| | vi) Net and total displacement of the pile | | | | |
| 9 | INTEGRITY TEST ON WORKING PILES Conduct non-destructive integrity test on working piles using low strain sonic diagnostic system as specified and as directed by the Engineer for 1300 mm dia and 1200mm dia piles | 95.00 | Nos | 11,400.00 | 1,083,000.00 |
| 10 | ROUTINE AND INITIAL VERTICAL LOAD TEST Supply necessary kentledge and perform vertical load tests on the marine piles according to the specification for 1300 mm dia | 1.00 | Nos | 3,370,202.22 | 3,370,202.22 |

| | | | | | |
|---|---|---|---|---|---|
| | 1200mm dia piles | 1.00 | Nos | 2,421,254.00 | 2,421,254.00 |
| 11 | Providing and placing in-situ concrete of grade M40 for piles using tremmie method up to cut off level underneath the bentonite slurry including all sampling testing and records and all labour, materials, tools, equipment, fuel, etc., complete., Note: Supply, fabrication of steel reinforcement shall be measured and paid under relevant item. (Rate shall include the cost of providing additional concrete above the cut-off level) | 4454.78 | $m^3$ | 21,120.00 | 94,084,919.44 |
| 12 | Providing and placing precast concrete of grade M40 for pile muff using tremmie method up to cut off level underneath the bentonite slurry including all sampling testing and records and all labour, materials, tools, equipment, fuel, etc., complete., Note: Supply, fabrication of steel reinforcement shall be measured and paid under relevant item. | 152.38 | m3 | 16,980.00 | 2,587,428.53 |
| 13 | Providing and placing precast concrete of grade M40 for columns using tremmie method up to cut off level underneath the bentonite slurry including all sampling testing and records and all labour, materials, tools, equipment, fuel, etc., complete., Note: Supply, fabrication of steel reinforcement shall be measured and paid under relevant item. | 500.72 | m3 | 18,240.00 | 9,133,110.00 |
| 14 | Supplying, fabricating and placing of TMT, Fe500D grade steel for pile reinforcement cage in piles including welding, binding, with binding wire all as per drawing, technical specifications and | 1113.69 | Te | 101,400.00 | 112,928,632.00 |

| | | | | | |
|---|---|---|---|---|---|
| | including all labour, materials, tools transport, cage lowering, equipments, fuel etc., complete | | | | |
| 15 | Supplying, fabricating and placing TMT, Fe500D grade steel for reinforcement of pile muff including welding, binding, with binding wire all as per drawing, technical specifications and including all labour, materials, tools transport, cage lowering, equipments, fuel etc., complete. | 26.67 | Te | 101,400.00 | 2,703,999.96 |
| 16 | Supplying, fabricating and placing TMT, Fe500D grade steel for reinforcement of columns including welding, binding, with binding wire all as per drawing, technical specifications and including all labour, materials, tools transport, cage lowering, equipment's, fuel etc., complete. | 150.22 | Te | 101,400.00 | 15,231,864.38 |
| | | | | | DECK STRUCTURES |
| 17 | Casting of Precast and cast in situ cement concrete Beams of grade M40 of various sizes as shown in the drawing and or any other size as directed to suit the site condition including shuttering,/ formwork mixing, transporting, placing, vibrating, curing the concrete and all labour, materials, tools, equipment, fuel, all sampling, testing and records etc., complete.<br>Note:<br>1.Supply, Fabrication of steel reinforcement shall be measured and paid under relevant item of Bill no: 1<br>2.Placing the precast units shall be measured and paid under relevant item of Bill No:2 | 2932.50 | m3 | 19,920.00 | 58,415,400.00 |

| | | | | | |
|---|---|---|---|---|---|
| 18 | Providing and placing Precast and cast in situ concrete of grade M40 for slabs all as per drawing and or as directed by the Engineer including provision of shuttering, mixing, transporting ,placing, vibrating, curing the concrete including all labour, materials, tools, equipment, fuel and all sampling, testing and records etc.,complete.<br>Note:<br>Supply, Fabrication of steel reinforcement shall be measured and paid under relevant item of Bill no: 1 | 1609.88 | $m^3$ | 19,920.00 | 32,068,818.45 |
| 19 | Supplying, fabricating and placing of TMT, Fe500D grade steel bars for Cast in situ beams including lifting hooks for precast units and cutting, bending, welding, binding wire all as per technical specification, drawing, including all labour, materials tools, equipment, fuel and all sampling, testing and records etc., complete. | 513.19 | Te | 105,600.00 | 54,192,600.00 |
| 20 | Supplying, fabricating and placing of TMT, Fe500D grade steel bars for Cast in situ slabs including lifting hooks for precast units and cutting, bending, welding, binding wire all as per technical specification, drawing, including all labour, materials tools, equipment, fuel and all sampling, testing and records etc., complete. | 363.00 | Te | 105,600.00 | 38,332,800.00 |
| 21 | Providing and placing in-situ grade M30 for wearing coat concrete over the deck slab, all as per drawings with necessary shuttering, mixing, transporting, placing, vibrating, finishing and curing the concrete including all labour, materials tools, equipment, fuel and all sampling, testing and records etc., complete | 1704.50 | $m^3$ | 18,000.00 | 30,681,000.00 |

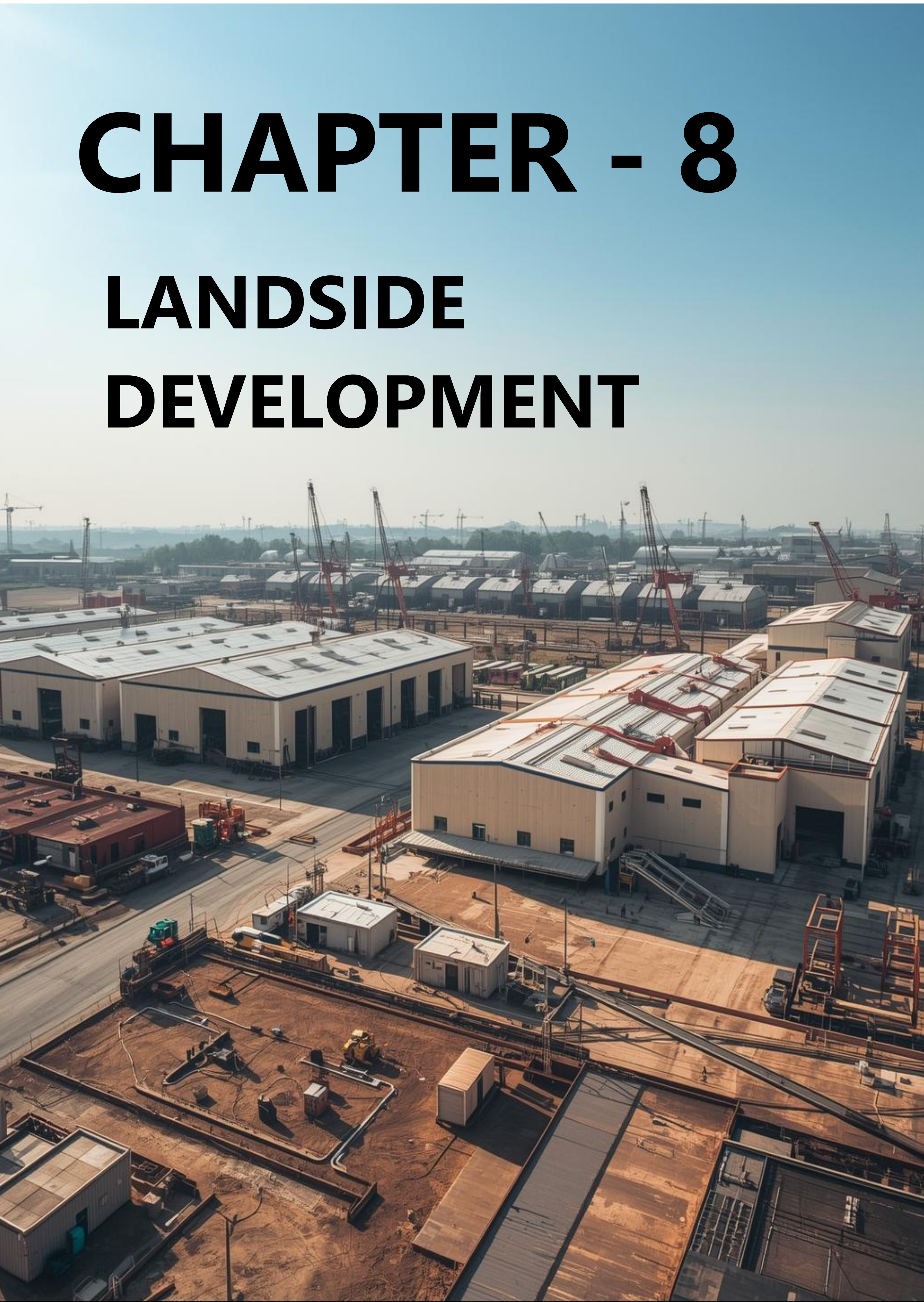
| | | | | | |
|---|---|---|---|---|---|
| 21 | Supplying, handling, transporting and fixing in position of Arc fender (800) with anchor bolts, U hooks, Chains, cutting, concrete chipping, drilling, grouting, necessary welding with deck reinforcement steel and necessary coal tar painting(wherever required) including all materials, labour, consumable items, machineries, tools, tackles, transportation etc... and complete as per Engineer In charge. | 15.00 | Nos | 2,399,366.00 | 35,990,490.00 |
| 22 | Supplying, handling, transporting and fixing in position of Bollard (30 ton capacity) with necessary cutting, concrete chipping, drilling, grouting, welding with deck reinforcement steel and necessary coal tar painting (wherever required) including all materials, labour, consumable items etc. Complete as per drawing and specifications as directed by the EIC. | 15.00 | Nos | 120,000.00 | 1,800,000.00 |
| 23 | Curbs - Rubber | 215.00 | RM | 15,554.00 | 3,344,110.00 |
| 24 | Expansion Joint | | | | |
| | 1. M.S angles and Plate | 3.00 | Te | 121,054.00 | 363,162.00 |
| | 2. Bituminous pad 25mm thick | 30.00 | m2 | 6,374.00 | 191,220.00 |
| 25 | Sealing component | 120.00 | RM | 310.00 | 37,200.00 |
| 26 | Mooring rings | 2.00 | Nos | 6,930.00 | 13,860.00 |
| 27 | Safety chains | 20.00 | RM | 1,232.00 | 24,640.00 |
| 28 | M.S Inserts | 2.00 | Te | 126,856.00 | 253,712.00 |
| | | | | | Amount | 723024751 |
| | Electrical work, Plumbing work & Firefighting (5%) | | | | 72302475 |
| | Contingency (5%) | | | | 39766361 |
| | PMC + Work Charge establishment (7%) | | | | 55672906 |
| | Round off | | | | 233506 |
| | Total Amount Rs. (INR) | | | | 891000000 |

**Note:**

1. Above Quoted Price is Exclusive of GST on Works Contract. The GST shall be paid Extra as per Actual during execution of the Works.
2. Any access road that may be required from the nearby Road/Highways upto the Ship repair facility is not covered under this DPR/Estimate.

# CHAPTER - 8

## LANDSIDE DEVELOPMENT



# 8 PROPOSED STRUCTURES LANDSIDE DEVELOPMENT

The landside development of the proposed Ship Repair Facility at Patna is comprehensively planned to integrate operational, administrative, safety, and welfare functions in a phased and sustainable manner. The overall layout ensures that marine engineering requirements, worker amenities, and future expansion provisions are addressed while maintaining efficient circulation for heavy vehicles and materials.

The Administrative Building (approx. 40 × 20 m) will function as the central hub, accommodating management offices, meeting rooms, and essential services. This building is proposed as a G+3 framed concrete structure with dedicated spaces for security, a punching booth, canteen, and locker rooms for staff use.

To support repair and maintenance operations, dedicated workshops and service buildings are proposed within a 2000 $m^2$ Pre-Engineered Building (PEB) shed. This shed will be divided into fabrication, electrical, and outfitting shops, along with storage and scrap yard facilities. The PEB structure will be constructed using ISMC/ISMB steel members for columns and beams, with ISA sections used as purlins and rafters for galvalume sheet roofing. The main workshop will rest on a pile foundation with a 6 × 6 m grid, topped by an M35 grade concrete slab. Service trenches will be provided on both sides of the shop floor, edged with reinforced concrete fencing, with voids left unfilled below the PEB and trench system to ensure structural integrity and maintainability.

In addition to the PEB, the following approximate facilities are proposed:

- Store Room: 20 × 20 m for general material storage
- Paint Store Room: 20 × 15 m for safe handling of hazardous paints and chemicals
- Substation: 20 × 15 m with adjoining water tank to support power and utilities
- Electrical Shop: 20 × 20 m
- Carpentry / Outfitting Shop: 20 × 20 m
- Pipe Shop: 20 × 20 m

- Engine Machine Shop: 20 × 20 m
- Fabrication Shop: 20 × 20 m
- Fire & Safety Building: 20 × 9.5 m

For workforce welfare, facilities include:

- Canteen (approx. 20 × 10 m), designed to accommodate 50–70 workers at a time, ensuring hygienic dining and resting areas.
- Toilet Blocks (approx. 10 × 6 m each), gender-segregated, with modern water and sanitation provisions.

Additional functional zones include:

- Scrap Yard (approx. 20 × 20 m) for disposal and segregation of decommissioned parts and recyclable materials.
- Parking / Stackyard for equipment laydown and heavy vehicle circulation, supported by a 7.2 m wide driveway around the campus.
- Area for Private Operators, enabling PPP participation and shared use of the facility.
- Future Development Zone, earmarked for expansion or auxiliary industry requirements.

The entire landside facility will be developed at a top level of 53.5 m, with all structures founded on piles to ensure stability against differential settlement and flood impact. The integrated layout not only ensures smooth operations and safe vessel servicing but also prioritizes worker welfare, sustainability, and operational resilience.

The summary of phase-wise development details for landside structures is provided in Table 8.1.

Table 8.1 Summary of Tentative Phasewise area statement.

| Sl.No | Description | Phase-I | Phase-II |
|---|---|---|---|
| 1 | Admin Building + Canteen + Sanitary | 1060 | 400 |
| 2 | Store room | 396 | |
| 3 | Paint store room | 396 | |
| 4 | Sub station | 396 | 150 |
| 5 | Electrical shop | 395 | |
| 6 | Carpentry / Outfitting shop | 395 | |
| 7 | Pipe shop | 395 | |
| 8 | Engine Machine shop | 395 | |
| 9 | Fabrication shop | 399 | 200 |
| 10 | Fire & Safety building | 399 | |
| 11 | Scarp yard | 399 | |
| 12 | Parking / Stockyard | 4465 | 4000 |

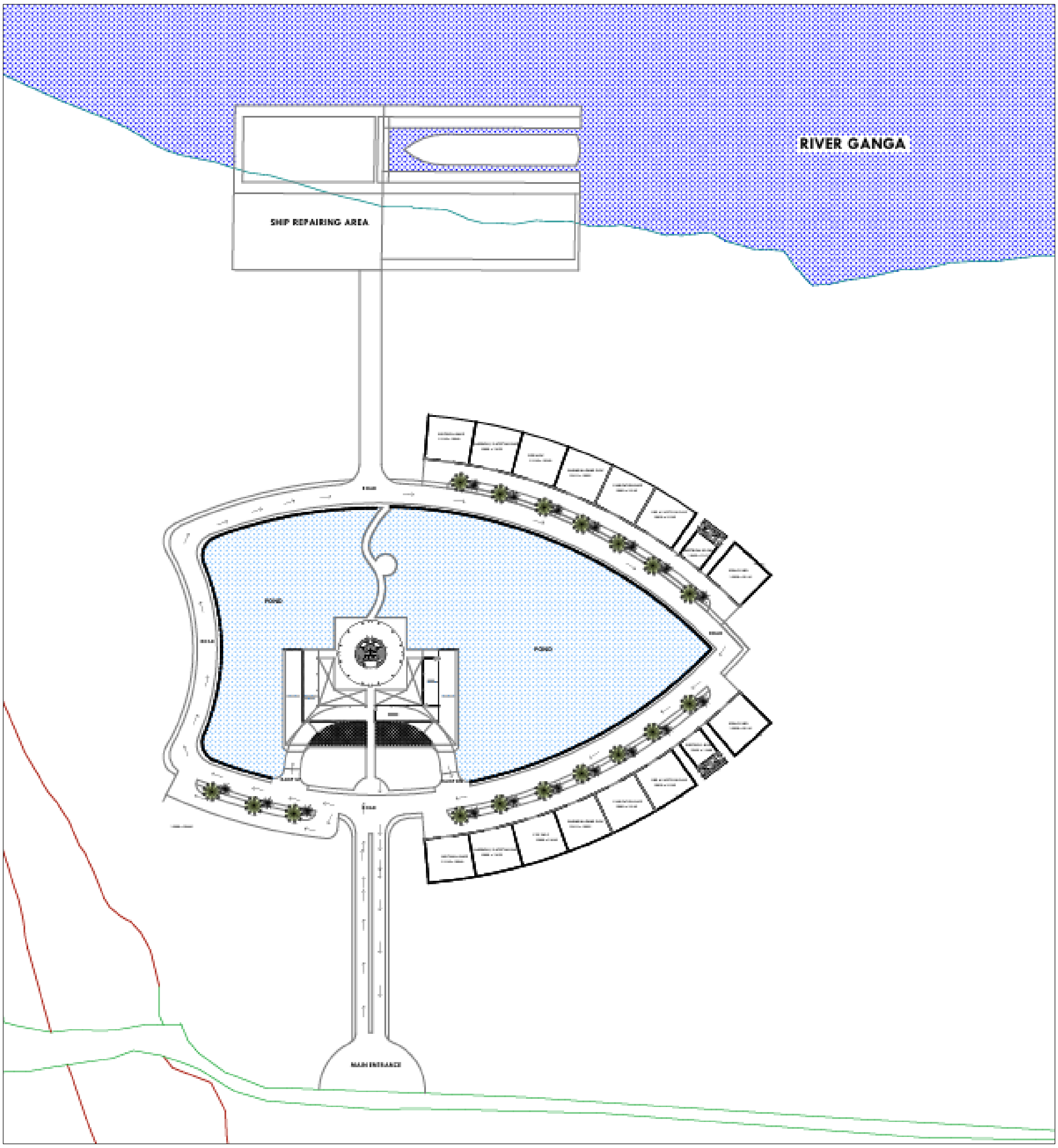



Figure 8.1 Layout for Proposed ship repair facility land side structures

## 8.1 3D View of the Proposed Ship Repair facility

An 3D architectural walkthrough was created using the layout depicted in the previous chapters for a realistic animated view of the Ship Repair Facility, some of the screenshots are extracted hereunder for better understanding.

Figure 8.2 Overall view of the Facility

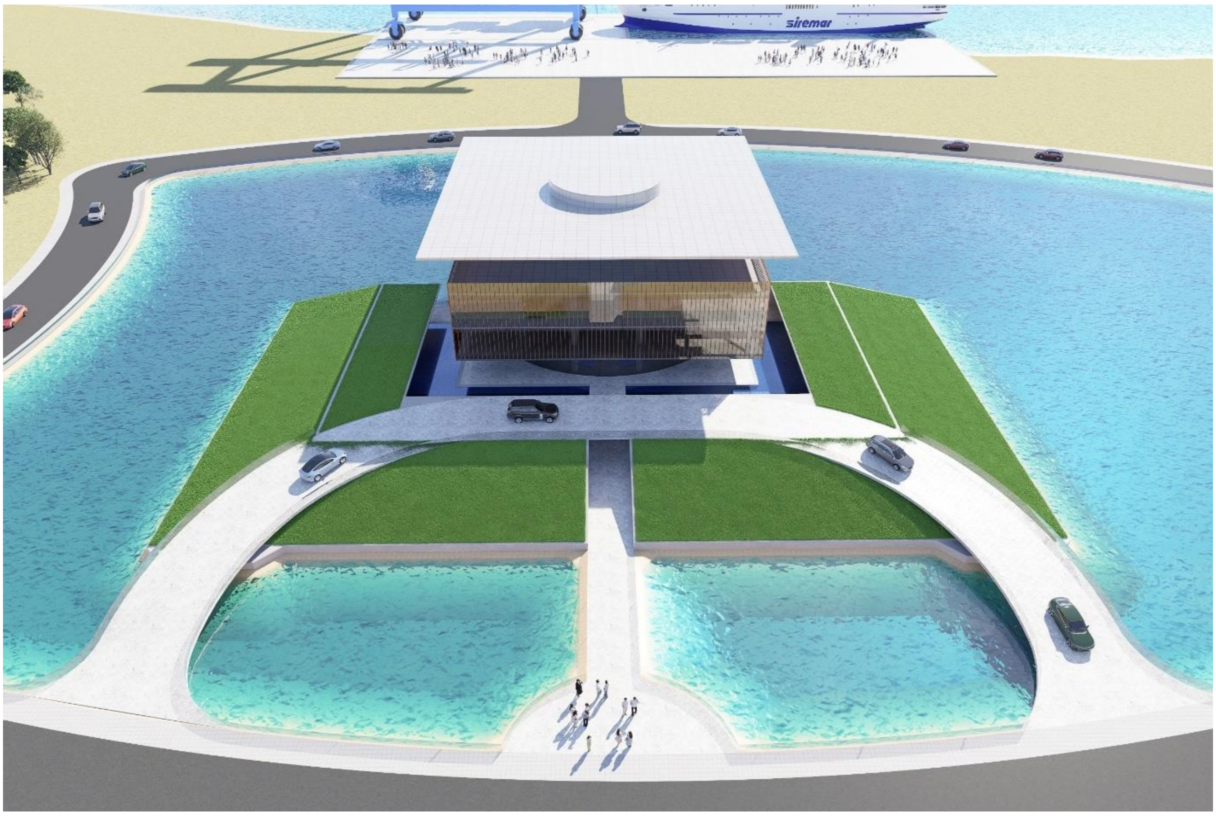



Figure 8.3 3D view of Admin Building

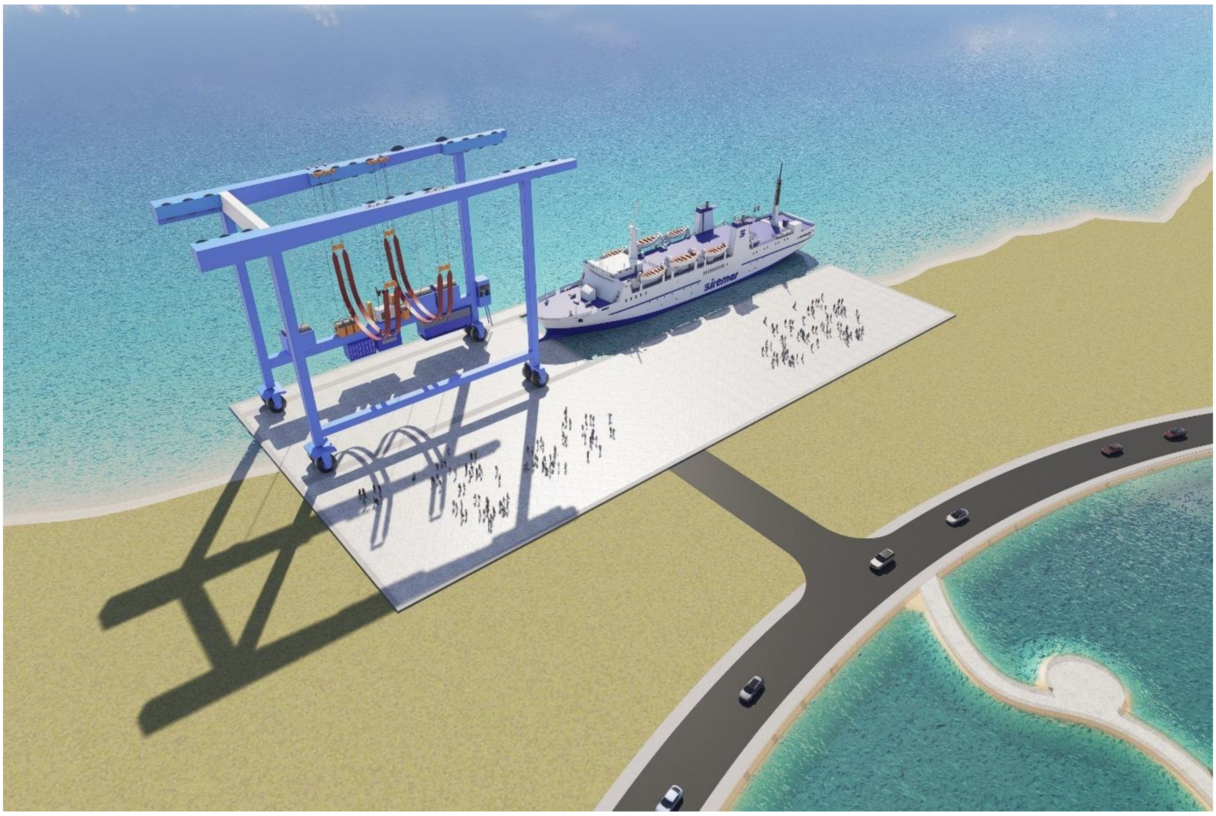


Figure 8.4 View of the Ship repair facility

## 8.2 Cost Estimate

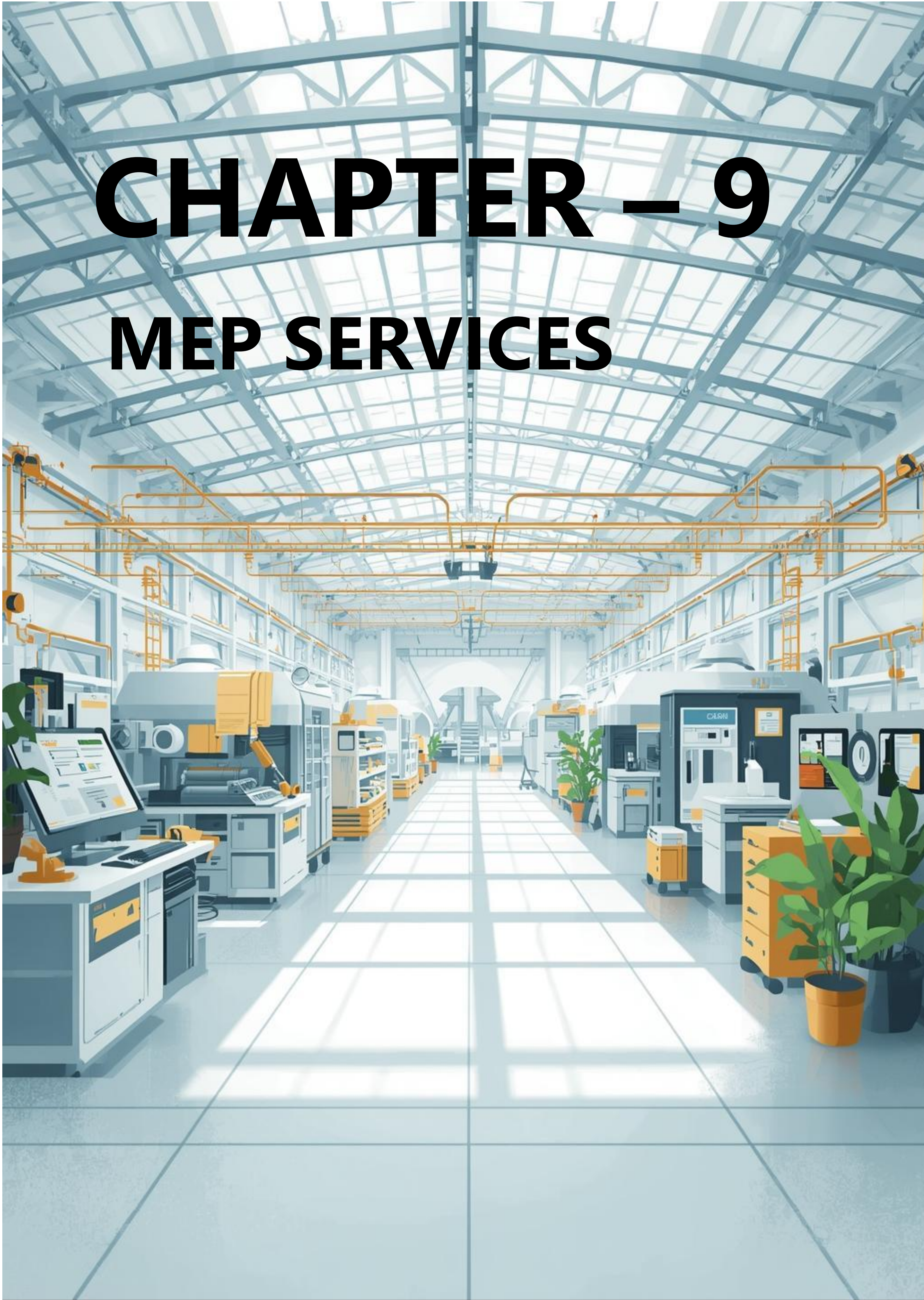
The capital cost estimates have been prepared for the proposed landside structures under two phases, viz., Phase-I and Phase-II. Based on the assessed requirements, the estimated cost for landside development in Phase-I is ₹29.26 crores (excluding GST), while Phase-II is ₹9.75 crores (excluding GST). Accordingly, the total estimated cost for landside facilities amounts to ₹39.02 crores (excluding GST). The abstract of the estimate is presented in Table 8.2.

Table 8.2 Abstract of Capital Cost Estimate for Landside Structures

| Sl. NO | DESCRIPTION | AMOUNT | |
|---|---|---|---|
| | | Phase-I | Phase-II |
| 1 | EARTH WORKS | ₹ 1,931,191.98 | ₹ 643,730.66 |
| 2 | PILING WORKS | ₹ 58,623,576.75 | ₹ 19,541,192.25 |
| 3 | CONCRETE WORKS | ₹ 40,846,935.00 | ₹ 13,615,645.00 |
| 4 | MASONRY WORKS | ₹ 2,023,153.88 | ₹ 674,384.63 |
| 5 | FINISHING WORKS | ₹ 1,990,631.25 | ₹ 663,543.75 |
| 6 | DOOR / WINDOW/ WOODWORK | ₹ 2,653,407.00 | ₹ 884,469.00 |
| 7 | FLOORING / CLADDING WORKS | ₹ 3,284,572.25 | ₹ 1,094,857.42 |
| 8 | ROAD / PAVING WORKS | ₹ 17,350,825.50 | ₹ 5,783,608.50 |
| 9 | ELEVATION WORKS | ₹ 2,628,474.26 | ₹ 876,158.09 |
| 10 | STRUCTURAL STEEL | ₹ 6,901,588.55 | ₹ 2,300,529.52 |
| 11 | SITE DEVELOPMENT | ₹ 48,841,662.80 | ₹ 16,280,554.27 |
| 12 | WATERPROOFING WORKS | ₹ 191,708.55 | ₹ 63,902.85 |
| 13 | METAL WORKS | ₹ 2,662,668.60 | ₹ 887,556.20 |
| 14 | ELECTRICAL WORKS | ₹ 39,057,212.50 | ₹ 13,019,070.83 |
| 15 | PLUMBING WORKS | ₹ 10,684,811.87 | ₹ 3,561,603.96 |
| 16 | HVAC WORKS | ₹ 11,659,901.18 | ₹ 3,886,633.73 |
| 17 | FIRE FIGHTING WORKS | ₹ 9,934,734.53 | ₹ 3,311,578.18 |
| | **Total** | **₹ 261,267,056.42** | **₹ 87,089,018.81** |
| | Contingency (5%) | ₹ 13,063,352.82 | ₹ 4,354,450.94 |
| | PMC + Work Charge establishment (7%) | ₹ 18,288,693.95 | ₹ 6,096,231.32 |
| | **Total Amount Rs. (INR)** | **₹ 292,619,103.19** | **₹ 97,539,701.06** |

# CHAPTER – 9

## MEP SERVICES



# 9 MEP SERVICES

## 9.1 Design Basis for Electrical Works

This document briefly describes the standards and procedure shall be followed for the design and supply, Installation and commissioning of electrical Power supply system for the proposed SRF complex at Patna. Detail engineering work shall be carried out in accordance with basic concepts developed in this report. The design shall be generally in line with IEEE, IEC and relevant international standards. Complete design data & site conditions applicable in this regard shall be taken into consideration for developing an acceptable design and for proper engineering of the system. The technical details and standards which shall be applied to the design of Electrical system under normal, emergency, planned maintenance and abnormal / fault conditions.

## 9.2 Codes Standards and Regulations

- Electrical systems design and supply, installation and commissioning shall be carried out in accordance with Local government of Patna, Bihar and international Codes and Standards.
- Wherever Codes and Standards other than those of specified are applied, the necessary review and approval shall be obtained to ensure that they do not conflict with National or local regulations.
- Equipment of origin other than Patna shall have certification from International testing authorities. Evidence of the appropriate certification shall be obtained prior to commitment to purchase.

## 9.3 Codes Standards and Regulations

- The selection of electrical equipment shall be governed by fitness for purpose, safety, reliability, compatibility with future expansion design margins, suitability for environment, economic consideration, etc.
- English language shall be used for all drawings, texts and communications.

- The SI system of units shall be used.

## 9.4 Service Conditions

- All equipment, materials and installation shall be suitable for operation and their design duty under site conditions.
- Design ambient temperature is 45°C
- Safety Requirements shall be considered in design
  - Safety to personnel and equipment during both operation and maintenance.
  - Reliability of service.
  - Minimal fire risk.
  - Ease of maintenance and convenience of operation.
  - Automatic protection of all electrical equipment through selective relaying system.
  - Electrical supply to equipment and machinery within the design operating limits.
  - Adequate provision for future extension and modification.
  - Maximum interchange ability of equipment.
  - Fail safe feature.
  - Energy efficient equipment (motors, lighting fixtures).
  - Suitability for applicable environmental factors.

## 9.5 Power Supply &Distribution Scheme

Power supply shall be received from Local power supply grid of Project SRF Patna at 33kv, 50Hz and hooked up to client's electrical system through 33kV grade power cables.

Necessary Energy meters with current & potential transformers shall be provided for measuring and recording the energy parameters for Tariff purpose. The accuracy level of energy meter, Current & Potential transformers shall be provided as per local grid guide lines.

Further the 33kV power supply to be extended to MV switch gear panel which consisting withdraw able type Vacuum circuit breaker of 630 Amps ,26.3kA fault rated complete with instrument transformers for both metering and protection, including microprocessor based protection relay and digital metering .The metering shall have communication port to integrate with PLC /SCADA system .The MV switch gear panel shall be provided with one no. of Incomer and two no's of outgoing feeders with one no as spare feeder.(Total-03Nos)

One of the feeders of the MV switch gear panel shall be connected to Distribution transformer through MV cable. The secondary of distribution transformer shall be extended to LV switch gear through LV bus duct of suitable rating.LV switch gear panel have Incoming and Outgoing feeders for distribution power at 415 Volts.LV switch gear panel shall be provided with two sections for Normal supply and emergency supply as per operational requirement .and coupled by a bus coupler. The emergency section bus shall be connected to Diesel operated engine Generator set for feeding the supply during the outage of normal supply.

Uninterrupted Power supply units are proposed for avoid the supply interruption for critical equipment &IT server and security system.

## 9.6 Buses

### 9.6.1 415 V bus

The 415 V bus is divided into 2 sections which is connected by a bus coupler which is normally open. Each section of the 415 V bus is connected to a Auxiliary Distribution Transformer which is rated at 1.6 MVA , 50 Hz, 33 kV/415 V, Dyn11, ONAN cooling and with off circuit tap changer. Each transformer is capable of taking 50% of the total auxiliary load requirement. The short circuit level of this bus is 36 MVA or 50 kA for one sec.

## 9.7 Distribution Transformer

- Distribution transformers shall be of 1.6 MVA, 50Hz, 33kV/433 V, Dyn11vector group, ONAN cooling and suitable for outdoor /Indoor installation. The percentage impedance of the distribution transformer shall be 6.25% with no positive tolerance.
- The distribution transformers shall be solidly grounded on the star side. Off Circuit Tap Changer (OCTC) range of with a range of - 12.5% to +7.5% in steps of 1.25% (16 steps).
- Distribution transformer shall be provided with all standard protection devices including Pressure relief device. Tap changer mechanism shall be operated from both transformer and remotely through PLC.

## 9.8 LT SWITCHBOARD / MOTOR CONTROL CENTRE

- LT Switchboard / MCCs shall be metal clad, free standing, dust, and damp and vermin proof with cubicles designed on modular basis. Unless otherwise specified these shall be of single front construction. The degree of protection for all indoor Main distribution board (MDB) &Motor control centers (MCC) enclosures shall be IP-54 and that for outdoor shall be IP-55. The short time rating of MDB shall be 50KA for 1 sec.
- The horizontal bus bars and vertical droppers shall be adequately sized, braced and supported to withstand mechanical and short circuit forces. The maximum rating of the bus bar, in case of MCCs, shall preferably be limited to 800 Amperes. Short circuit rating of LT boards shall be 50 kA for one second. The LT system shall be with neutral solidly earthed.

- Incomer of Main distribution board shall be suitable for top bus duct entry and all outgoing feeders shall be suitable for Top, cable entry.
- The Main distribution board shall in general house feeders for Motor control centres, sub distribution switchboards, UPS, Lighting, EOT Crane, etc. Motors above 90kW shall be fed from Main distribution board.
- The motor starters shall be suitable for direct on line starting of squirrel cage induction motors up to 7kW and star delta starter for motor ratings above 7kW comprising mainly of MPCB/MCCB, contactor and bimetallic relays.
- Control circuit of motor starter and contactor units shall be supplied with 240V single phase and neutral derived from within each compartment, through separate control transformer. Auxiliary wiring shall not be routed near power buses.
- All the MCCs shall have continuous earth bus bar of uniform size. Facilities shall be provided to ground the MCC at two separate points. Each bus bar vertical panel shall be provided with space heater to avoid moisture condensation. The space heater shall be suitable for 240V single phase 50Hz AC supply and thermostatically controlled.
- All the starter modules shall be provided with ON, OFF and trip indication and stop PB and reset PB for bimetallic relay.
- All the cable entries for power and control cables shall be from bottom/top of the MCC through removable gland plate.
- The MCCs shall be installed in well ventilated room with a clear 800mm space behind each MCC.

## 9.9 Auxiliary Service Boards

- Auxiliary services shall contain mainly switch fuse units. The board may be constructed in fixed execution, compartmentalized, dust, and damp and vermin proof. The boards shall be free standing type. The auxiliary service boards shall mainly feed welding loads and receptacle loads. All Incomers of switch board shall be provided MCCB with trip releases. The short circuit ratings of MCCBs shall be selected as per short circuit ratings shown in SLD.

- Auxiliary service boards shall normally be supplied from Main distribution board. The bus bars inside the boards shall be adequately sized, braced and supported. An earth bus shall be provided along the full length of the boards. Boards shall be complete with all necessary metering instruments, selector switches, control switch gear, push buttons, indicating lights etc. as required.
- The height of auxiliary service boards shall be same as that of other panels located in the same room. The degree of protection for auxiliary service boards shall be IP-54.

## 9.10 L. T. Bus duct

- Sandwich type 415V L.T. bus duct shall run between the distribution transformer and Main distribution board.
- The bus duct shall be IP -55 enclosure suitable for weather, dust and verminproof. Flexible bellow at termination points and expansion joints at straight run as required shall be provided Canopy / rain hoods shall be provided for outdoor area of the bus duct.
- Fire barriers of 30 minutes rating shall be provided within bus duct enclosure where the bus duct passes through a wall.
- Bus duct shall be Short time rating of 50 kA for 1 sec copper Flexible connectors made of copper shall be suitably silver plated.

## 9.11 L. T. CAPACITOR BANK

- Automatic power factor-controlled panel shall be considered for maintain the power factor at of 0.98 to unity.

- Capacitor cubicle shall be metal enclosed, free standing, floor mounting and flush fronted type. APFC relay shall be provided to measure, control and monitor the Capacitor bank. The capacitor panel shall have common bus bar section, LV control section and capacitors switched as per signal form APFC relay .
- The capacitor unit shall be with polypropylene dielectric impregnated with NPCB. It shall be uniform in type and output to provide maximum interchange ability. The KVAR rating of capacitors panel shall be as per BOQ and SLD
- Detuned Series reactor shall be provided along with each capacitor bank to restrict in rush current to capacitor bank during switching and blocking of prominent harmonics.

## 9.12 ELECTRIC MOTORS

- Unless otherwise specified, all motors shall be single speed and suitable for direct online starting.
- All motors shall be supplied in Standard IEC frame sizes. Construction, performance and testing of motors shall satisfy the requirement of relevant Indian standards.
- All motors shall be of TEFC construction and shall have degree of protection IP55 with weather proof protection.
- All unidirectional motors rated above 30kW (i.e. 37kW and above) shall be fitted with space heaters operating at 240V AC. All bi-directional motors shall be provided with space heaters.
- All 415V motors shall be delta connected All unidirectional motors shall be suitable to start at 80% of rated voltage.
- Winding insulation of all motors designed with suitable reinforcement to take care of frequent starting and over voltage experienced by the motor winding during automatic changeover of supply.

- All LT motors shall be of Class `B' insulation with temperature rise limited to Class 'B'.

## 9.13 Lighting and Power Panel

- Lighting and Power panels shall be fed from LDB/Auxiliary service boards. These panels shall be provided with miniature circuit breakers or switches and fuse combination for control and protection of different outgoing circuits. Incomer of all lighting and power panels shall be provided with earth leakage circuit breaker (ELCB).
- Lighting and Power panels shall be complete with necessary instrument, control and indication. Number of out goings circuit of lighting panels shall be, as far as possible, standardized to keep minimum inventory.

## 9.14 EMERGENCY SUPPLY ARRANGEMENT:

- Diesel operated Generator sets with AMF panel are proposed to feed the power supply during local power grid supply failure.
- Power supply from the DG sets shall be extend through Bus ducts to MDB's located at each floor level in electrical room.
- Each MD- MDB panel shall be connected with adequate rated DG set to meet the demand.

## 9.15 UNINTERRUPTED POWER SUPPLY SYSTEM

- The uninterrupted power supply shall be a complete reliable system including inverters, battery charger and battery bank.
- The UPS system shall be of free standing, floor mounting, metal enclosed and vermin proof type having hinged door for front access and suitable for indoor use.

- The UPS shall be operated on 415 V, 3 Phase, 4Wire, 50 Hz incoming supply and output shall be 415V, 3 Phase, 4Wire, 50Hz supply. However, the rating shall be BOQ and after detailed engineering.
- Battery shall be VRLA type maintenance free and Ampere hour rating shall be selected for 30Min or 60Min back up.
- The UPS shall consist of
    - One 1 x 100% common battery shall be provided.
    - Rectifier transformer
    - Thyristor controlled rectifier cum charger with battery current limit.
    - Filter circuit
    - Static by pass switch
    - Other associated accessories
    - AC Distribution Board
    - Electrical isolation enabling maintenance of each section without taking shutdown of complete system.

## 9.16 CONTROL STATION

- Motor shall be provided with a control station in the field.
- The enclosure of control station shall have suitable protection for site conditions.
- The control station shall include the following equipment's as per individual requirements.

- Start/Stop push button

- Stop push button shall generally be stay put type with padlocking arrangement except in the case of critical drives.

## 9.17 ELECTRICALLY OPERATED OVERHEAD CRANE : (EOT CRANE)

- Electrically operated overhead crane wherever required shall be supplied from 415V + 10%, 50 Hz, 3 phase 4 wire system .. The overhead crane shall have its own control and facility e.g. forward/reverse, up/down, inching, etc. as per requirements. Control supply for each crane shall be derived from its power supply through individual control transformer.

## 9.18 CABLES AND CABLE INSTALLATION

Following types of cables shall be used.

33 kV Cables - XLPE / PVC insulated, 1100V Grade PVC Sheathed copper conductor, Armoured.

All LT Power Cables - XLPE / PVC insulated, 1100V Grade PVC Sheathed copper conductor, Armoured.

Lighting circuit cable - PVC insulated, copper conductor, Armoured.

Control cables 1100V Grade - PVC insulated, PVC sheathed, copper Conductor, armoured, multicore.

Fire protection system cable - Copper conductor armoured, multicore and FRLS insulation

Public address system and communication - Unshielded twisted pair cables shall be used

Following minimum size of conductors shall be used.

- Lighting cables 2.5 Sq. mm Copper
- Control cables 2.5 Sq. mm Copper

❖ The following shall be the routes and earthing grades of various voltage grade cable

  - 33 kV cable shall run between the client's 33 kV feeder shall be buried in the ground/ laid in trench .
  - 415 V cables shall be of 1100 V grade and shall run in cable trays on pipe sleeper or built up trenches, from L.T. switch gear to various loads.

- Control cables shall be of 1100 V grade and shall run in separate trays or built up trenches, from L.T. switch gear to push buttons, PLC / DCS etc.
- 1100 V grade copper conductors in fire retardant insulation shall connect all devices of fire protection system. Separate tray shall be provided for these cables.
- P.A. system and communication cables shall be unshielded twisted pair armoured cable and they shall connect the speakers and hand sets to the P.A. system master console. Separate tray shall be provided for these cables.

## 9.19 Cable Sizing

❖ Cables shall be sized considering the factors such as maximum continuous current, ambient temperature, grouping proximity, installation medium, voltage drop limitations and short circuit withstand criteria.

❖ For the purpose of sizing of cables, following maximum allowable voltage drop in cables shall be considered.

| | | |
|---|---|---|
| Power feeders ( MDB to MCC / SDB ) | : | 2% |
| Motor feeders at full load (MCC to motor terminal) | : | 3% |
| Motor feeders during starting | : | 15% |
| Lighting circuit (Lighting panel to farthest fitting) | : | 2% |
| Instrumentation system | : | 3% |

## 9.20 CABLE INSTALLATION

❖ In general, cable laying shall be done as follows:

- Overhead cable trays on the pipe rack wherever available. Otherwise concrete trenches for paved areas and directly buried in ground for unpaved areas shall be used.
- Ladder type cable tray supports shall be of galvanised steel, suitable for spanning 2.0 meters between supports when loaded.

- In unpaved areas, cables shall be directly buried in ground. Where underground cable cross roadways, pipe sleepers on grade etc. they shall be protected by pipe sleeves/ducts. Concrete duct banks shall be used for road crossing. In paved area concrete cable trench shall be used.
- Cables laid underground in concrete trenches shall have precast slab cover with special marking.
- Cable laid on the pipe rack, walk way shall be provided along with the cable trays to facilitate cable laying and maintenance.

❖ Cable trays, racks and trenches shall be sized to allow for 40% future cable reserve.

❖ All cable trays and accessories shall be prefabricated and hot dip galvanised to a thickness of 610 gms / Sq.m

## 9.21 LIGHTING

❖ Entire plant lighting shall be divided into following two categories:

- Normal AC lighting
- Emergency lighting & Exit Signage

❖ Normal lighting panels shall be supplied by three phase and neutral 415V power derived from Main Lighting Distribution Board. MLDB shall be supplied from MDB

❖ The emergency lighting shall be supplied by 220V, AC from UPS system system having battery back-up.

❖ The emergency lighting shall be normally `ON' and continue to operate without any interruption during normal power failure.

❖ The average illumination level over the entire plant area shall be as follows:

a) Control room 400 lux
b) Administration Building 300-400 lux
c) Instrument rack rooms 200 lux
d) Corridors 150 lux

e) Toilets & Lockets room 100 lux

f) Stores 100 lux

g) Switchgear rooms 250 lux

h) Workshops 300-400 lux

i) General access & stairs100 lux

j) Road 5 - 10 lux

k) Outdoor area 30 lux

❖ The following lighting fixtures shall generally be used in the plant:

a) 2x36W, industrial type LED lighting fixtures shall be used in switch gear room,

b) staircase, toilets, etc.

c) 4x18 W, LED fixtures shall be used for offices, control room, etc.

d) 125W High bay LED fixtures shall be used in assembling area.

e) 150W LED lighting fixtures shall be used for High bay areas

❖ Maintenance factor for all indoor lights shall be 0.8 and 0.7 for all outdoor lights. Reflection factors for control rooms shall be 50% for Ceiling, 30% for Wall and 30% for Floor. For all other indoor areas reflection factor will be considered as 30% for Ceiling 30% for Walls and 10% for Floor. No reflection factor will be considered for outdoor areas.

❖ Convenience receptacles shall have necessary mechanical interlocks and earthing facilities. Sockets for welding machines shall be rated for 63A at 415V 3 phase, 50Hz with a scrapping earth. 3 Pin 240 V, 50Hz Power receptacles of 5A and 15A ,3pin shall be provided in all buildings / areas.

## 9.22 EARTHING SYSTEM

❖ Earthing system in general shall cover the following:

- Equipment earthing for personnel safety
- System neutral earthing
- Static and lightning protection

- Instrument signal earthing

- ❖ The system shall envisage an earthing network of proper size of earthing conductor with designed number of earth electrodes attached to it. The following shall be earthed.

System neutral as follows :

- 33kV system earthed
- 415V System Solidly earthed

- Current and potential transformer secondary's.

- Metallic non-current carrying parts of all electrical apparatus such as transformer, switch gear, motor, lighting distribution board, lighting fixtures, cable trays, terminal boxes, junction boxes, instrument cabinets and cases etc.

- Steel structure

- Storage tanks and all equipment

- Cable shields

- Lightning protection system

- ❖ For signal/case/intrinsically safe signal grounding of control room instruments, separate earth pit shall be provided and not connected to main ground grid. Control cabinets shall be connected to this separate earth pit.
- ❖ The earth conductor shall be adequately sized to carry the maximum fault current without undue temperature rise. All joints shall be protected to prevent corrosion.
- ❖ All electrical equipment operating above 250V shall have two separate and distinct connections to earth grid.
- ❖ Earth bus bar will be provided in switch gear and MCC rooms, control rooms and similar rooms where major electrical equipment's are installed.

- The earthing system shall be designed so that satisfactory operation of the earth fault protective devices of the electrical equipment connected to the system will be achieved. The resistance to earth of any part of the earthing system shall not in any case exceed 1 ohm.
- Lightning protection shall be provided for the equipment/structure and buildings which are higher than 20 meters. Separate ground electrode for this purpose shall be located and interconnected with the main electrical ground system

## 9.23 COMMUNICATION SYSTEM

- The plant communication system shall include the following facilities.
  a. Telephone system
  b. Public address system
- Plant communication system shall be fed from UPS system.
- Telephone system shall include the following equipment.
  a. A EPABX telephone exchange of 25 extensions with the interface facility to connect the existing P&T lines.
  b. Power supply unit.
  c. Telephone stations.
  d. Field cable installation as necessary.
- The public address system with talk back facility shall be provided around the plant.
- The PA system shall have the following operational features.
  - Over all or a group of speakers from central station.
  - Two-way communication between any hand set station and central station.
  - Conference facility through central station.
  - Intercommunication between selected hand set stations through central station.

- Direct communication between selected hand set stations.
- Emergency siren over the page channel.

❖ The PA system shall comprise the following principal items:

a. Central broadcast console
b. Amplifier units
c. Field loud speakers

## 9.24 PROTECTION AND METERING

❖ The protective system shall be selected and co-ordinated so as to ensure the following:

❖ Protection of equipment against damage which can occur due to internal or external short circuits or atmospheric discharges.

❖ As far as possible, continuity of operation of those parts of the system not affected by the fault.

❖ Personnel and plant safety.

❖ In general quick acting relays shall be used and all fault tripping shall be done by high speed tripping relays.

## 9.25 FIRE ALARM SYSTEM

❖ The type of fire alarm system shall be conventional type. The fire detection and alarm system shall comprise the following: -

i. Automatic smoke and fire detectors
ii. Ionisation smoke detectors
iii. Optical smoke detectors
iv. Heat detectors
v. Response indicators
vi. Manual call points
vii. Audio Visual hooters
viii. Fire alarm panels

ix. Repeater panels

- ❖ The plant shall be divided into zones as per IS 2189 - 1998. The floor area of each zone shall not exceed 2000 sq.m.
- ❖ There shall be two types of panels for the fire detection and alarm system Viz. Main fire Alarm Panel (MFAP) and repeater panel. The MFAP shall be located in the central control room of T-G building. The MFAP shall control fire detection and alarm system of a zone and receive annunciation of other zones. It shall have control over deluge systems and it shall trip air handling ventilation units if any in its zone.

  The repeater panels shall be located in the guard house and it shall receive the annunciation of each zone.

  The MFAP shall be individually connected to the repeater panels through multi-core cables.
- ❖ Noof detectors / devices in each zone shall not exceed 20 Nos as per IS 2189 - 1988 Clause 3.1.1.
- ❖ Area above false ceiling and below false floor shall also be covered by automatic detection system.
- ❖ The manual call points shall be strategically located in such a way that the search distance shall not exceed 30 M.
- ❖ Hooters shall be of audio-visual type. The xenon beacon (Flash light) of the hooter shall be an integral part of the hooter. The sound level of the hooter shall be minimum 75 dB (A).
- ❖ The MFAP, and Repeater panels shall be micro-processor based, compact sleek, and self-standing type.
- ❖ System shall operate on an input of 240 V single phase. 50 Hz A.C. In the event of A/C failure the standby secondary power supply shall automatically provide the power source. The detectors shall be designed to operate on 24 V DC power supply (24 V DC supply shall be built in the MFAP and repeater panel).

- All cables shall be of 1100 V grade PVC insulated FRLS over all sheathed 1.5 sq.mm armored copper cable.

## 9.26 ELECTRICAL EQUIPMENT LAYOUT

- Transformers shall be mounted on transformer plinth of correct size such that no person may step on the plinth and inadvertently come close to the line parts.
- A clear space of not less than 1000 mm should be provided around the transformer as measured from “the farthest point of transformer” to the coping of the structure supports.
- Oil draining facilities should be provided for transformer if the capacity of oil in one transformer or the aggregate capacity of oil in all the transformers exceeds 2000 litres. The oil soak pit should be located at more than 5 meters from the transformer.
- Spacing between MV. and L.V. switch gears located in the same room should be at least 2 meters.
- MV. Cable trench depth shall be designed to account for the bending radius of the cables. The depth and width of the trench shall be as per the layout drawings. Directly buried cables shall be placed on a layer of sand on the bottom of the trench. The cables shall be covered with 150 mm of sand on top of the largest diameter cable and sand shall be lightly pressed. A protective covering of 75 mm thick second-class red bricks shall then be laid flat. The remainder of the trench shall be back filled with soil rammed and levelled.
- The tray stack shall have a vertical gap of 250 mm between trays. The tray supports shall be derived from insert plates located on the cable vault roof. The cable trays shall be galvanised and pre-fabricated and the accessories shall have adequate bending radius to suit the cables.

# CHAPTER - 10

# OVERALL DEVELOPMENT COST

# 10 OVERALL DEVELOPMENT COST

The overall development cost for the proposed Ship Repair Facility has been estimated in two phases, covering waterside development, landside development, and MEP services. In **Phase-I**, the estimated cost is **₹313.96 crores (excluding GST)**, with major allocations towards waterside works, landside infrastructure, and essential MEP services. In **Phase-II**, the development cost is **₹98.85 crores (excluding GST)**, reflecting additional waterside and landside expansion works along with supporting utilities. Thus, the combined capital outlay for both phases of the project is **₹412.82 crores (excluding GST)**. These estimates form the basis for phased implementation, ensuring optimal utilization of resources while meeting immediate and future repair facility requirements.

Table 10.1 Abstract of Estimate of Total Development Cost under Phase-I

| Sl.No | Description | Amount in Crores |
|---|---|---|
| 1 | Waterside Development (MEP Services included) | 284.70 |
| 2 | Landside Development (MEP Services included) | 29.26 |
| | Grand total (Excluding GST) | 313.96 |

Table 10.2 Abstract of Estimate of Total Development Cost under Phase-II

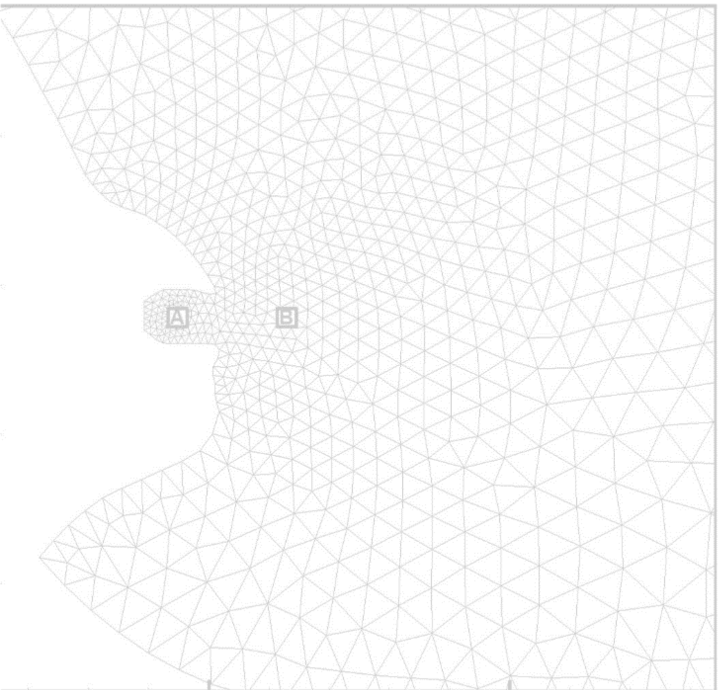
| Sl.No | Description | Amount in Crores |
|---|---|---|
| 1 | Waterside Development (MEP Services included) | 89.10 |
| 2 | Landside Development (MEP Services included) | 9.75 |
| | Grand total (Excluding GST) | 98.85 |

Note:

1. If the project has to be developed by a third party operator, like, CSL, additional handling cost of 15% may be included.

# ANNEXURE -I

# FEASIBILITY STUDY FOR SHIP REPAIRING FACILITY AT PATNA, BIHAR




## INSPECTION REPORT

*Client*

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*Consultant*

**Prof. K. Murali**

**National Technology Centre for Ports Waterways and Coasts (NTCPWC)**

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June 2025

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# 1 PREAMBLE

Inland Waterways Authority of India (IWAI) is embarking various major developmental activities along the waterways under their control including setting up of dedicated ship repairing facilities to support the operational and maintenance requirements of inland vessels operating in these waterways. One of the area identified for such development at NW-1 is Patna, Bihar, where a number of IWAI's own vessels and vessels of private operators are plying, but they have to depend on the Ship yards at Kolkata for any major or minor repairs. Considering the importance of this location and urgent need for developing for such facilities, IWAI has requested NTCPWC to undertake the feasibility of setting up of Ship Repair Facilities at Patna, Bihar in a site already identified by them. Upon concurrence from National Technology Centre for Ports Waterways and Coasts (NTCPWC) and submission of the financial proposal for undertaking the feasibility study for setting up of Ship repair facilities at Patna, Inland Waterways Authority of India (IWAI) issued a formal Work Order bearing no. IWAI/NW-1/ROPatna/Patna/ShipRepairFacility dated on 05.06.2025 to NTCPWC for "Preparation of Feasibility study for Ship Repairing Facility at Patna, Bihar".

# 2 SCOPE AND OBJECTIVES OF THE STUDY

The present project is focused mainly in the following:

1. Site assessment & Review of existing data
   a. Reconnaissance/ Site Survey: To conduct a detailed reconnaissance/ site survey of the proposed site, including geographical, environmental, and socio-economic conditions.
   b. Review of existing data: Collection and examination/ review of previous studies, reports, data, information, maps, charts etc. available IWAI and any other sources. Provisions of the IV Act 2021, details and type of inland vessels flying in the NW- 1.
2. Market Analysis
   a. Demand Assessment: Analyze the current and projected demand for ship repair services in the region. This shall include assessment at the proposed ship yard facility for repair and maintenance of IWT vessels plying in NW-1 for the time-frame 2025, 2030, 2035 and 2045 in consultation with all nodal agencies like Uttar Pradesh Inland Waterways Authority, IWAI, tourist vessel operators, mechanized country boats and other relevant stakeholders/ private agencies.
   b. Competitive Analysis: Assess the competitive landscape, identifying existing ship repair facilities and potential competitors within the region of proposed facility

# 3 SITE INSPECTION

## 3.1 Introduction

As part of the mandate to carry out the Feasibility of development of a dedicated Ship Repairing Facility at Patna, along National Waterway-1 (NW-1), a site visit and reconnaissance survey was carried out by the team headed by Mr. Srinivasakannan, Senior Project Advisor, NTCPWC IIT Madras along with Mr. Arvind Kumar, Director, Susantha Basu, AHS and Arun Kumar, JHS, IWAI on 05th June 2025, for technical feasibility assessment, site conditions & its environment, area availability and connectivity, of the proposed site of Ship repair facility at Patna, Bihar. The observations during the site visit are detailed hereunder.

### 3.1.1. Various documents shared by IWAI

The list of various documents shared by IWAI are as follows

1. Site plan
2. Change in the course of Ganga river at the project site during the past 8 years
3. Minimum and maximum water levels in the adjoining areas viz., Dhiga Ghat and Gandhi Ghat.
4. Details of Vessel sailing in the region of the proposed site
5. NOC Gazette notification
6. Bathymetry Survey charts

## 3.2 Observation and assessments during the site inspection

The proposed site, located at Latitude 25°38′23.92″ N, Longitude 85°06′49.00″ E, lies on the southern bank of the Ganges River, just north of central Patna. This National Waterway – 1 passing through Patna, Bihar is classified as Class VII Waterway, as defined in Gazette Notification CG-DL-E-17122022-241170 dated 16.12.2022. However, there is no established Ship Repair facilities in the entire stretch and all the vessels have to travel to Kolkatta for major/ minor repairs, which resulted in considerable cost and time. The location now identified for setting up of Ship Repair facilities at Patna, Bihar, offers strategic advantages for river-based operations. The proposed site is located on the southern bank of the Ganges River, just north of central Patna, offering strategic proximity to National Waterway–1 and serving as a prime location for inland vessel operations. IWAI in due consultation with other Government department, had identified about 20,000 sq.m of land parcel (200m x 100m), just outside the High water level parallel to the proposed identified location for setting up of the facility. This land parcel is most ideally suitable for setting up of the land based facilities considering its elevation, proximity to the jetty construction and adjoining roads and other areas. The area lies on flat alluvial plains, bordered by agricultural fields and a narrow strip of riparian vegetation along the riverbank. The land falls within the designated riverfront development zone under municipal jurisdiction, with significant portions already earmarked for waterway-related Infrastructure.


**Figure 1 Proposed tentative location for the ship repair facility at Patna**

## 3.3 Rail and road connectivity

The site is well-connected by road through local village access roads that link directly to JP Ganga Path—Patna's dedicated riverfront expressway running parallel to the Ganges. This expressway integrates with major highways such as NH-119A (the Patna–Arrah–Sasaram corridor) and other regional routes, ensuring strong inland connectivity. Rail access is equally efficient, with Patna Junction Railway Station located approximately 4 km from the site, offering both regional and national connectivity. The terrain comprises fertile, gently sloping loamy alluvium typical of the Ganges basin—highly suitable for construction and infrastructure development. Vegetation is sparse and mostly confined to the narrow riparian buffer zone along the riverbank. The site's riverfront location provides direct access to NW-1 and makes it ideal for establishing ship repair and inland vessel servicing facilities. The combination of excellent multimodal access (via river, road, and rail), suitable topography, and existing land allocation enhances its feasibility for rapid infrastructure deployment with minimal earthwork requirements. **Figure 2** to **Figure 8** shows selected photographs captured during the site visit conducted on 5$^{th}$ June 2025


**Figure 2 Site Visit Photo**


**Figure 3 Site Visit Photo**


**Figure 4 Site Visit Photo**


**Figure 5 Site Visit Photo**

## 3.4 Inland Vessel Operations

Data from IWAI R.O. Patna indicates substantial vessel movement in the area, with a cumulative total of 451 vessels operating in the Patna sector from 2020 to 2025. Of these, 83 are IWAI vessels and 368 are privately operated. Vessel sizes range up to 77.37 meters in length and 15 meters in width (MV AAI), underscoring the need for adequate repair infrastructure.

Currently, there are no major ship repair facilities in or around the Patna stretch of NW-1. In the absence of such facilities, inland vessels must travel long distances to receive routine maintenance and emergency services. This not only increases fuel consumption and crew deployment times but also reduces overall fleet efficiency. The establishment of a dedicated ship repair unit in Patna would drastically improve operational turnaround, especially during peak navigation seasons. Details of Vessel movement under IWAI, R.O. Patna is given in **Table 1.**

**Table 1 Details of Vessel movement under IWAI, R.O. Patna**

<table>
<tr><th colspan="5">Details of Vessel movement under IWAI, R.O. Patna</th></tr>
<tr><th>Sl. No.</th><th>Particulars</th><th>Year (FY)</th><th>Vessels (Nos)</th><th>Total</th></tr>
<tr><td>1</td><td colspan="2">IWAI Vessel in Patna Sector</td><td>83</td><td>83</td></tr>
<tr><td>2</td><td rowspan="5">Private Vessel in Patna Sector</td><td>2020-21</td><td>132</td><td rowspan="5">368</td></tr>
<tr><td>3</td><td>2021-22</td><td>58</td></tr>
<tr><td>4</td><td>2022-23</td><td>54</td></tr>
<tr><td>5</td><td>2023-24</td><td>68</td></tr>
<tr><td>6</td><td>2024-25</td><td>56</td></tr>
<tr><td colspan="4">G. Total</td><td>451</td></tr>
<tr><td rowspan="2">Note:-</td><td colspan="4">Maximum Length of Vessel - 77.37m (MV AAI)</td></tr>
<tr><td colspan="4">Maximum Width of Vessel - 15m (MV AAI)</td></tr>
</table>

**Figure 6 Site Visit Photo (MV AAI)**


**Figure 7 Site Visit Photo**


**Figure 8 Site Visit Photo**

### 3.5 Water Level Variability and Channel Monitoring

Hydrological data from 2018 to 2025, collected at Gandhi Ghat and Digha Ghat, shows seasonal fluctuations in water level ranging from 6.6 meters to 9.7 meters annually. High Flood Levels (HFL) were recorded at 50.52 meters at Gandhi Ghat and 52.52 meters at Digha Ghat. These fluctuations are critical in planning infrastructure that must remain functional year-round.

Channel bathymetry data indicates the formation of sandbars toward the riverbank over the same period. Satellite imagery and field verification from 2018 to 2025 confirm sediment accretion trends that present navigational challenges. The development of a ship repair facility must therefore be integrated with ongoing sediment management strategies, including dredging and bank protection.

A comprehensive analysis of satellite imagery and on-site bathymetry surveys reveals the gradual formation of sandbars in the channel adjacent to the proposed site. These formations, visible in Google Earth historical imagery, demonstrate a landward shift in sediment deposition. Such conditions, if left unmanaged, may hinder navigation and pose a risk to vessel safety. The integration of sediment monitoring with real-time water level data will be essential in planning access channels, dock placement, and repair basin locations. Additionally, seasonal dredging schedules must align with hydrological forecasts to maintain a functional draft throughout the year. Minimum & Maximum Water Level of (Gandhi Ghat & (Digha Ghat)) River Ganga from 2018 to 2025 are given in **Table 2** and **Table 3** respectively. The channel analysis and satellite imagery for the year 2018-2025 are shown in the images depicted in **Figure 9** to **Figure 17**.

**Table 2 Minimum & Maximum Water Level of (Gandhi Ghat) River Ganga from 2018 to 2025**

| Year | Min. Water Level (m) | Date | Max. Water Level (m) | Date | Water level Difference (Max-Min) (m) |
|---|---|---|---|---|---|
| 2018 | 41.01 | 25.03.2018 | 49.60 | 13.09.2018 | 8.59 |
| 2019 | 41.65 | 24.03.2019 | 49.79 | 23.09.2019 | 8.14 |
| 2020 | 42.22 | 19-02-2020 | 48.86 | 22.08.2020 | 6.64 |
| 2021 | 41.58 | 07.03.2021 | 50.45 | 15.08.2021 | 8.87 |
| 2022 | 41.94 | 16-05-2022 | 49.59 | 01.09.2022 | 7.65 |
| 2023 | 41.75 | 16.05.2023 | 48.56 | 10.08.2023 | 6.81 |
| 2024 | 41.50 | 15.05.2024 | 50.28 | 20-09-2024 | 8.78 |
| 2025 | 42.02 | 17-05-2025 | | | |
| HFL Gandhi Ghat | | | 50.52 | 21-08-2016 | |

**Table 3 Minimum & Maximum Water Level of (Digha Ghat) River Ganga from 2018 to 2025**

| Year | Min. Water Level (m) | Date | Max. Water Level (m) | Date | Water level Difference (Max-Min) (m) |
|---|---|---|---|---|---|
| 2018 | 41.96 | 26.03.2018 | 50.72 | 13.09.2018 | 8.76 |
| 2019 | 42.61 | 26.03.2019 | 50.94 | 23.09.2019 | 8.33 |
| 2020 | 43.00 | 07-03-2020 | 50.05 | 22-08-2020 | 7.05 |
| 2021 | 42.26 | 08.03.2021 | 51.85 | 15.08.2021 | 9.59 |
| 2022 | 42.64 | 19.05.2022 | 50.76 | 01.09.2022 | 8.12 |
| 2023 | 42.42 | 18.05.2023 | 49.67 | 10.08.2023 | 7.25 |
| 2024 | 42.04 | 19-06-2024 | 51.76 | 20-09-2024 | 9.72 |
| 2025 | 42.58 | 14-05-2025 | | | |
| HFL Gandhi Ghat | | | 50.52 | 21-08-2016 | |

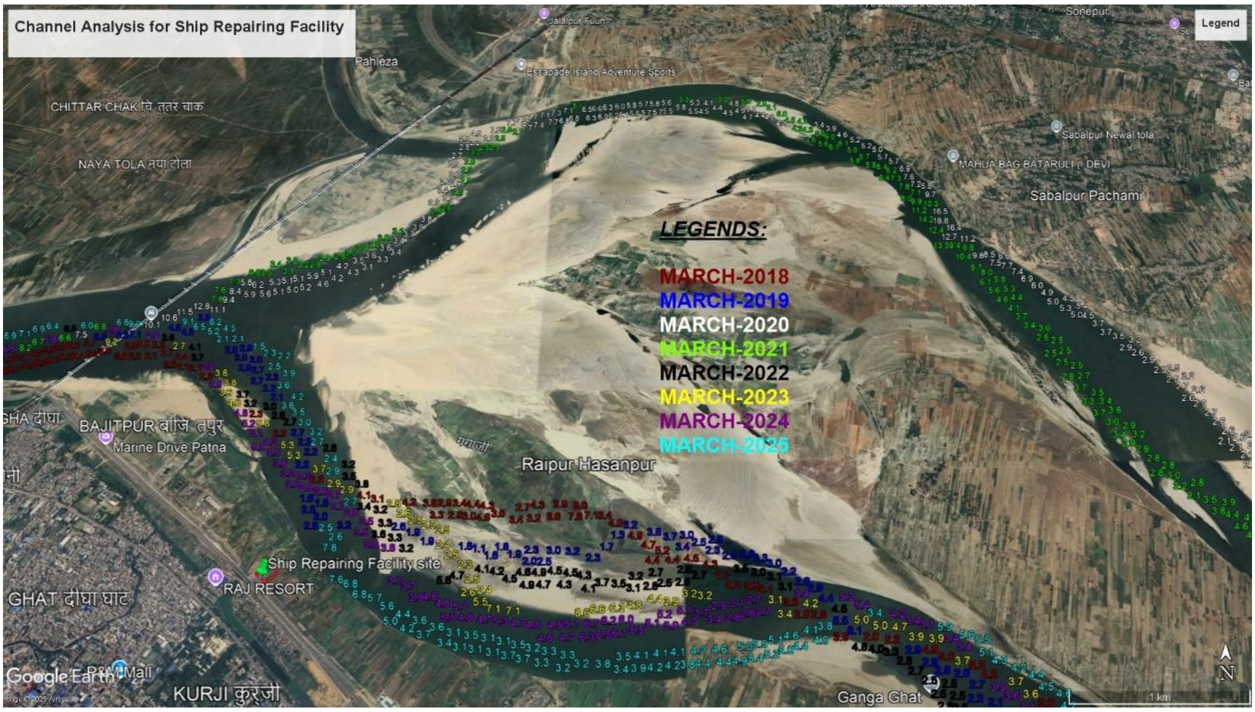



**Figure 9 Channel Analysis**


**Figure 10 Satellite Image Showing Sand Bar Development in 2018 (Source: Google earth)**


**Figure 11 Satellite Image Showing Sand Bar Development in 2019 (Source: Google earth)**


**Figure 12 Satellite Image Showing Sand Bar Development in 2020 (Source: Google earth)**


**Figure 13 Satellite Image Showing Sand Bar Development in 2021 (Source: Google earth)**


**Figure 14  Satellite Image Showing Sand Bar Development in 2022 (Source: Google earth)**


**Figure 15  Satellite Image Showing Sand Bar Development in 2023 (Source: Google earth)**

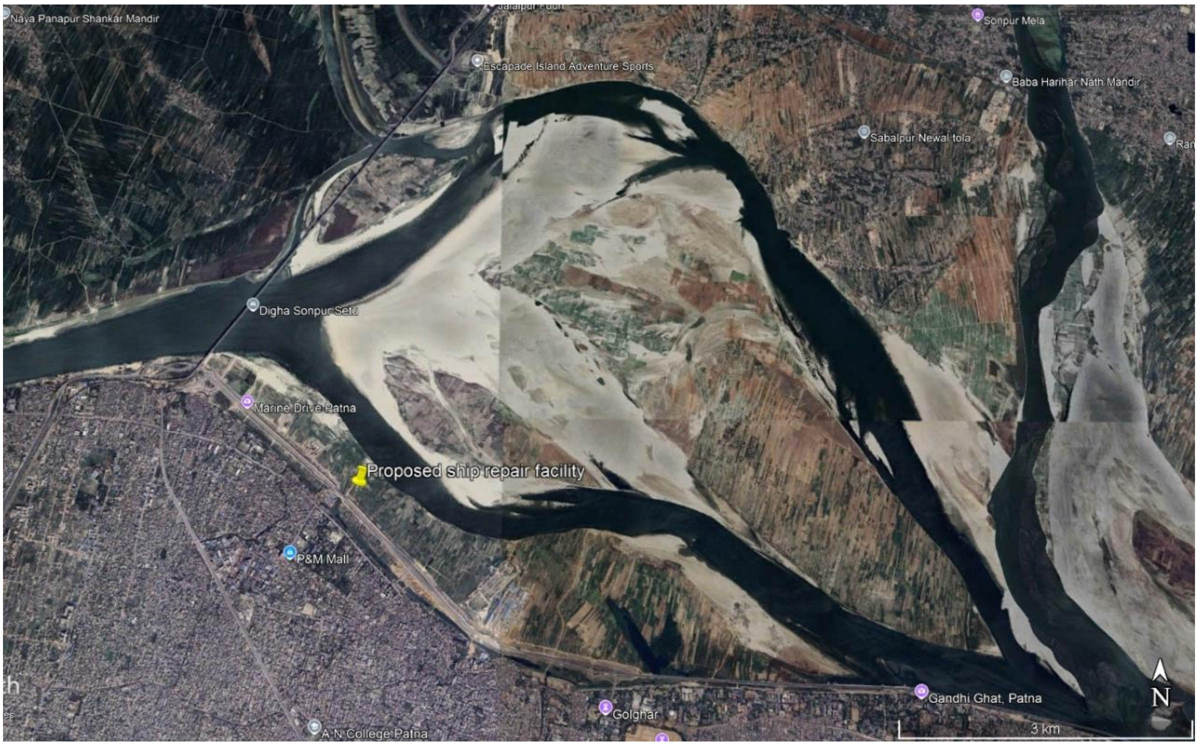



**Figure 16  Satellite Image Showing Sand Bar Development in 2024 (Source: Google earth)**

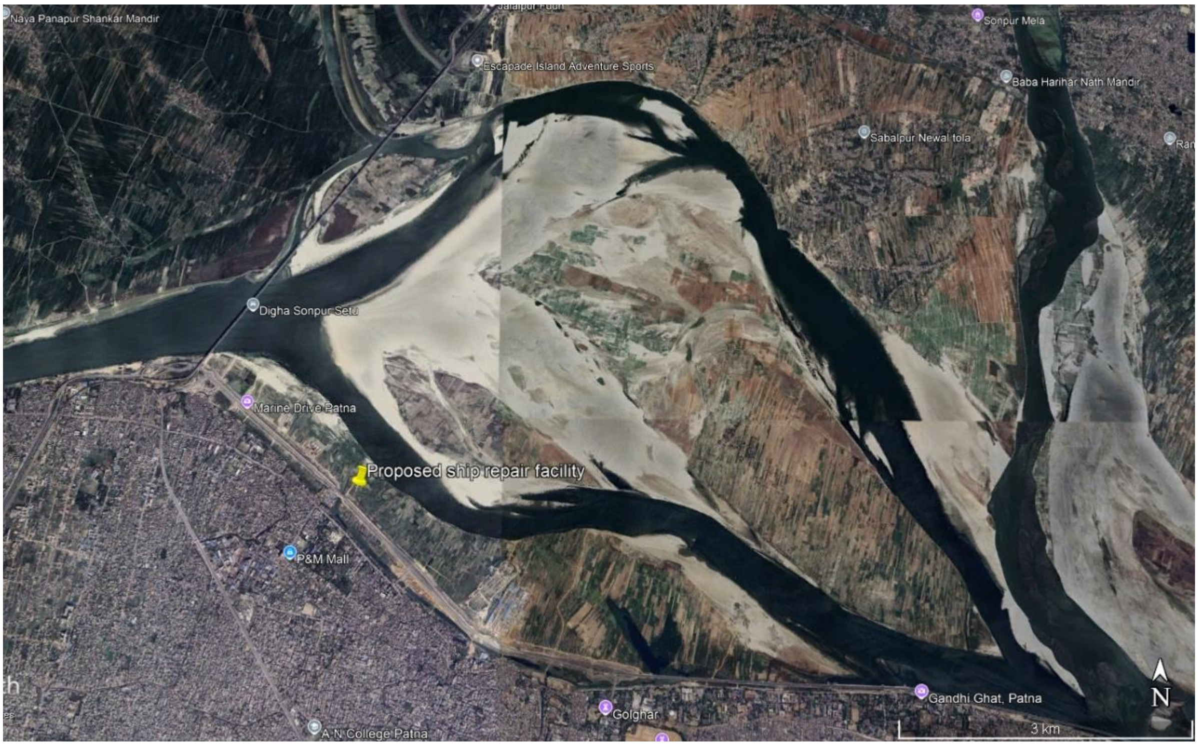



**Figure 17 Satellite Image Showing Sand Bar Development in 2024 (Source: Google earth)**

## 3.6 Bathymetry Survey

The IWAI survey department provided the bathymetry survey chart at the location of the proposed ship repair facility at NW-1, Kurjighat, Patna. The survey locations and bathymetry chart are Shown in **Figure 18** and **Figure 19**.


**Figure 18 Survey Area for Proposed Ship Repair facility (Source: Google earth)**

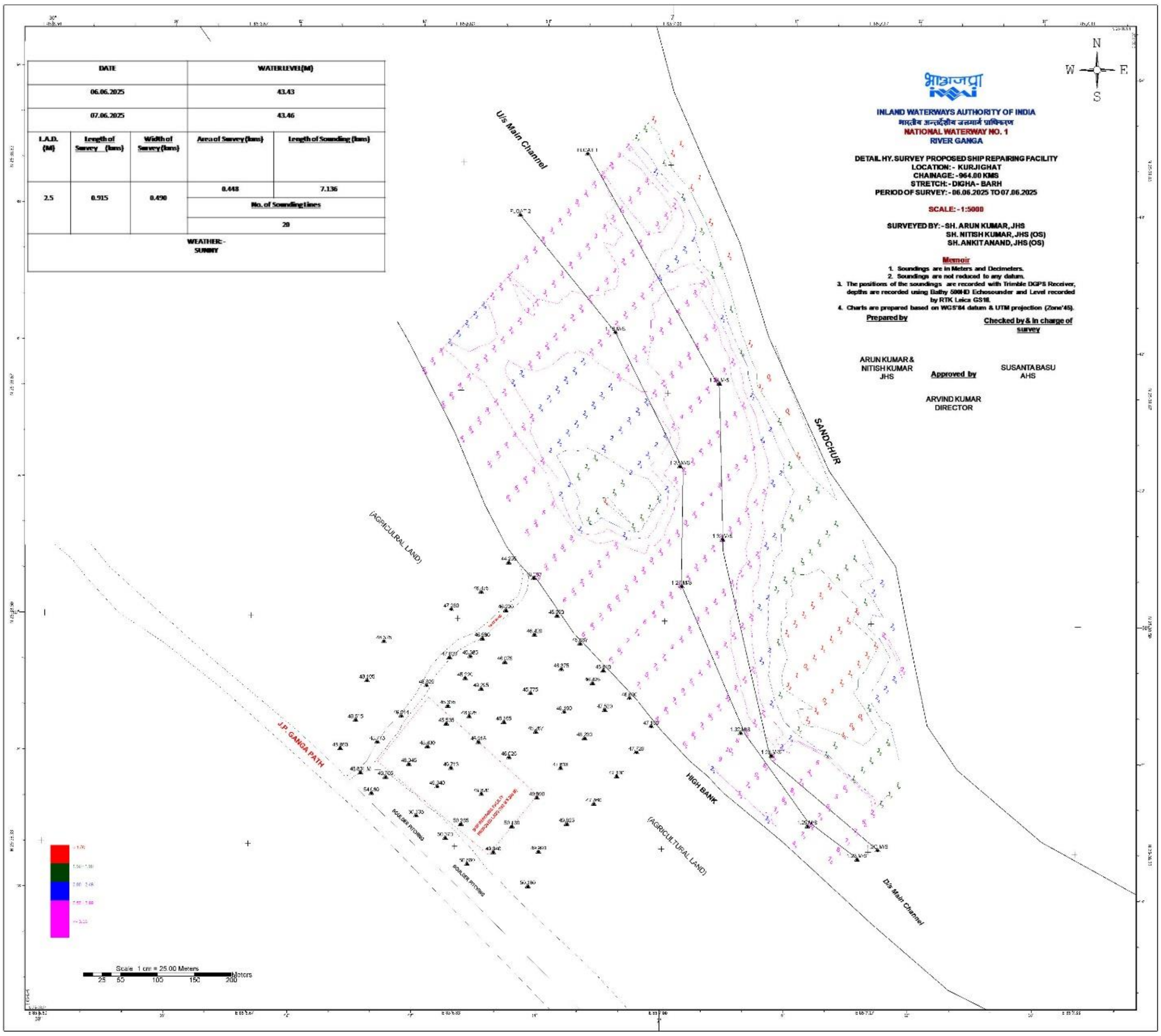



**Figure 19 Bathymetry Chart**

## 3.7 Infrastructure Gaps and Facility Needs

Currently, there are no major ship repair facilities in or around the Patna stretch of NW-1. In the absence of such facilities, inland vessels must travel long distances to receive routine maintenance and emergency services. This not only increases fuel consumption and crew deployment times but also reduces overall fleet efficiency. The establishment of a dedicated ship repair unit in Patna would drastically improve operational turnaround, especially during peak navigation seasons.

Repair facilities must be tailored to the needs of the inland vessel fleet operating in this region. Based on IWAI data and projected traffic, the proposed site should include both afloat repair infrastructure and dry docking capabilities. A typical layout should accommodate:

- One or more dry docks to handle vessels of up to 80 meters in length

- Slipways for mid-size barge and tug maintenance
- Floating jetties for emergency afloat repair
- Covered workshops for mechanical, electrical, and hull repairs
- Equipment for bilge water treatment and hazardous waste handling

The selection of technologies and design criteria must take into account flood-level variations, riverbank stability, and environmental compliance. Environmental impact mitigation measures such as erosion-resistant structures, stormwater drainage, and sediment control systems should be embedded into the project layout. In addition, adequate firefighting systems, lighting, and navigation aids must be planned to ensure safe round-the-clock operations.

A major gap observed in the current waterway infrastructure is the unavailability of rapid-response repair units. The proposed facility at Patna can bridge this by including mobile repair teams and floating workshops that can travel upstream or downstream for on-site diagnostics and minor interventions. Prioritization will be given to areas with high vessel density and significant repair needs but lack adequate facilities. It is also necessary to determine the type of facilities needed depending on the nature of repair to be carried out—either afloat repair or dry docking repairs.

# 4 Recommendations and way forward

After detailed analysis of the site environment, data shared by IWAI and various discussions & deliberations held with IWAI Authorities, the following conclusions are arrived at.

1. Sufficient water depth is available at the identified site, even at the lean seasons, to handle all the IWAI vessels having draft upto 2.5m. However, the water level is varying substantially and the average water level variation is around 8.4m and the maximum level variation is 9.72m. Taking into account such variation, a suitable design preferably, a boat hoisting jetty with other landside infrastructure can be designed.
2. If the top of the proposed Boat Hoisting jetty is fixed, with sufficient free board over and above the highest high water level, preferably around 53m or such elevation for ensuring seamless operation of Ship Repair Facilities (to be reconfirmed during the Detailed Project Report stage), the backup facilities such as repair bay, transfer bay, can be conveniently located immediately behind the boat hoisting jetty over the piles without affecting the natural water flow, while other landside infrastructure viz., workshops, substations, admin

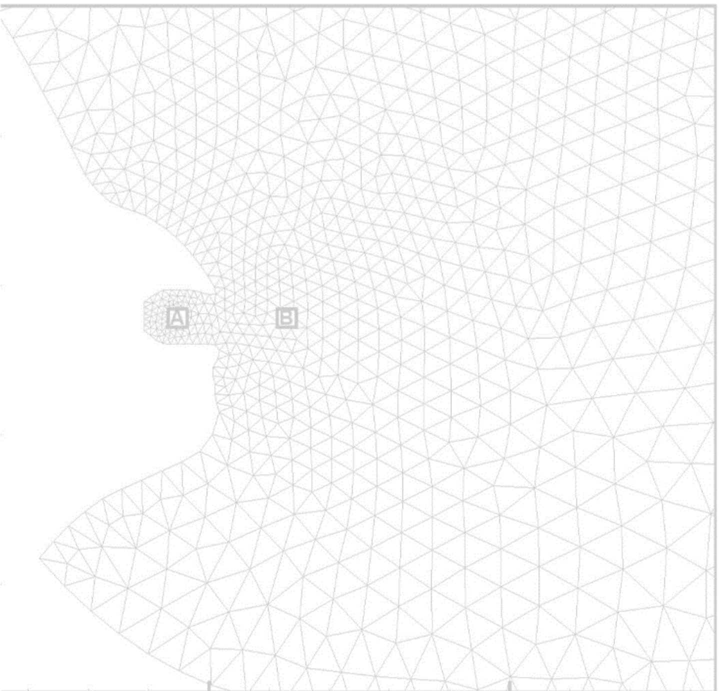
buildings, road & rail connectivity (if possible), etc., can be developed in the area identified by IWAI admeasuring 20,000 Sq.m, as shown in figure 1.

Considering all these aspects, particularly availability of sufficient water spread area with required water depth and land for developing the backup infrastructure facilities, it is recommended that the Ship Repair Facilities can be established at the identified location Patna, Bihar, as shown in figure 1, which will result in both direct and indirect benefits and considerable savings in cost & time, and also create substantial employment potential for the country, as a whole and Bihar/ Patna in particular.

**(Prof. K. Murali)**

# ANNEXURE -II

# FEASIBILITY STUDY FOR SHIP REPAIRING FACILITY AT PATNA, BIHAR




## DRAFT
## FEASIBILITY REPORT

*Client*

## INLAND WATERWAYS AUTHORITY OF INDIA (IWAI)

*Consultant*

**Prof. K. Murali**

NATIONAL TECHNOLOGY CENTRE FOR PORTS WATERWAYS AND COASTS
NTCPWC

SAGARMALA
PORT-LED PROSPERITY

**National Technology Centre for Ports Waterways and Coasts (NTCPWC)**

Department of Ocean Engineering (DOE) Indian

Institute of Technology Madras (IITM)Chennai –

600 036

August 2025

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# 1 INTRODUCTION

The Inland Waterways Authority of India (IWAI), under the Ministry of Ports, Shipping & Waterways, is tasked with developing and regulating inland water transport on the nation’s navigable rivers, including National Waterway-1 (NW-1), the Ganga – Bhagirathi - Hooghly system, which connects key states and cities such as Patna. Under the Jal Marg Vikas Project (JMVP), NW-1 is being enhanced with terminals, dredging, and navigation infrastructure to boost cargo and passenger movement. However, the absence of a dedicated ship repair facility along NW-1 forces vessels to travel long distances, mainly to Kolkata, for repairs, leading to high costs and downtime. Establishing a Ship Repair Facility (SRF) at Patna would enable in regional sustainability, improve vessel turnaround, support the growing inland fleet, and align with national initiatives like JMVP, Atmanirbhar Bharat, and PM Gati Shakti, while creating local employment and boosting regional economic growth.

To address this need, IWAI is undertaking major developmental activities along its waterways, including setting up dedicated ship repair facilities at various waterways across the country to minimise the operating and running expenditure of maintaining its own vessels and also the fleet of other private operators plying in the waterways. Patna, Bihar, has been identified as one of the strategic locations, where both vessels owned by IWAI and also private operators operate extensively. However, due to lack of basic infrastructure facilities for carrying out minimum repairs, the vessels plying in the route had to travel to Kolkata or other shipyards resulting in huge expenditure and time. Hence, IWAI has intended to avail the expertise of the National Technology Centre for Ports, Waterways and Coasts (NTCPWC) to carryout detailed project report inter-alia covering the need, benefits and its usefulness. As a first stage, IWAI has engaged NTCPWC for ensuring the feasibility of establishing the proposed facility at an already identified site. Following concurrence from NTCPWC and submission of a financial proposal, IWAI issued a formal work order (No. IWAI/NW-1/ROPatna/Patna/ShipRepairFacility dated 05.06.2025). Subsequently, a site visit and reconnaissance survey were carried out by the NTCPWC team, led by Mr. Srinivasakannan, Senior Project Advisor, along with IWAI officials, to assess technical feasibility, site conditions, available area, connectivity, and environmental aspects of the proposed location.


Figure 1 Aerial view of Proposed ship repair facility at Patna

## 2 SCOPE AND OBJECTIVES OF THE STUDY

The present project is focused mainly in the following:

1. Site assessment & Review of existing data
   a. Reconnaissance/ Site Survey: To conduct a detailed reconnaissance/ site survey of the proposed site, including geographical, environmental, and socio-economic conditions.
   b. Review of existing data. Collection and examination/ review of previous studies, reports, data, information, maps, charts etc. available IWAI and any other sources. Provisions of the IV Act 2021, details and type of inland vessels flying in the NW- 1.
   c. Identification of Location in Patna Bihar in consultation with stake holders.

2. Market Analysis
   a. Demand Assessment: Analyse the current and projected demand for ship repair services in the region. This shall include assessment at the proposed ship yard facility for repair and maintenance of IWT vessels plying in NW-1 for the time-frame 2025, 2030, 2035 and 2045 in consultation with all nodal agencies like Bihar IWT, IWAI tourist vessel operators, mechanized country boats and other relevant stakeholders / private agencies.
   b. Competitive Analysis: Assess the competitive landscape, identifying existing ship repair facilities and potential competitors within the region of proposed facility

# 3 SITE ENVIRONMENT

The analysis of the prevailing environmental aspects of the project site are essential for the better understanding of the site that will help in development and modification of the ship repair facility (Slipway). Hence an overall environmental data on the location, connectivity, meteorological parameters, geotechnical aspects, and basic details of the project site are presented for better appreciation.

## 3.1 Rainfall

The annual rainfall in the catchment area varies from over 160 cm in some regions of South Bihar to less than 90 cm in the western parts. Rainfall in the region is negligible from November to March. The rainfall commences from April and reaches its peak during July and August. The average annual rainfall is about 120 cm at Patna.

## 3.2 Water level

The maximum and minimum water levels observed at Patna over the period 2005–2025 are tabulated in **Table 1.** The observed Highest Flood Level (HFL) at Patna (Gandhighat) is 50.27 m, and the lowest recorded water level is 43.30 m, with reference to the Mean Sea Level (MSL). It could be observed that during the months of January to May, the water levels at Patna are generally at their lowest, while the highest levels are typically observed during the months of July to September.

**Table 1 Water levels at Patna**

| Parameter | Value |
|---|---|
| Location | Patna (Gandhighat) |
| Observation Period | 2005–2025 |
| Highest Flood Level (HFL) | 50.27 m |
| Lowest Water Level | 43.30 m |
| Reference Datum | Mean Sea Level (MSL) |

## 3.3 Current

From the available data on river velocities at Patna, the Ganga River exhibits distinct seasonal variations. During the normal flow conditions, typically between January and May, the mean flow velocity ranges from approximately 0.8 to 1.2 m/s. In contrast, during the flood season—particularly from July to September, the velocity significantly increases, reaching values of around 3.0 to 4.5 m/s. These high velocities are generally unsuitable for safe vessel alignment along the slipway. However, even during the monsoon period, the minimum flow velocities often remain below 2.0 m/s, which is considered acceptable for slipway operations. Under such conditions, vessels can be positioned using tugboats of adequate capacity to guide them safely to the slipway and transfer them onto trolleys for hauling. To ensure operational safety and stability, additional mooring structures, such as floating buoys, will be deployed during the slipway operation phase. The maximum and minimum mean velocities (m/s) of the river ganga at Patna is shown in Table.2.

**Table 2 Maximum & Minimum Mean Velocities (m/s) of the River Ganga at Patna**

| Month | Minimum Velocity (m/s) | Maximum Velocity (m/s) |
|---|---|---|
| January | 0.8 | 1.0 |
| February | 0.8 | 1.0 |
| March | 0.9 | 1.2 |
| April | 1.0 | 1.5 |
| May | 1.2 | 2.0 |
| June | 1.5 | 3.5 |
| July | 1.8 | 4.5 |
| August | 1.7 | 4.3 |
| September | 1.5 | 4.0 |
| October | 1.2 | 2.5 |
| November | 1.0 | 1.5 |
| December | 0.8 | 1.0 |

### 3.4 Temperature

Patna experiences a humid subtropical climate with hot summers, a pronounced monsoon season, and mild to cool winters. The average high temperature is around 32°C, while the average minimum is about 18°C. During the summer months (April to June), maximum temperatures can soar up to 42°C, especially in May. In contrast, the winter season (December to February) sees minimum temperatures dropping to around 5°C, with January typically being the coldest month.

### 3.5 Geotechnical Data

The geotechnical investigations at the proposed site in Patna is not covered under the scope of the present study. However, inorder to assess the subsurface soil profile and engineering properties for design and construction purposes, the details available in the public domain have been considered. Prior to freeze the design a separate soil investigation need to be carrriedout by IWAI and deatails to be shared. The data presently collected from public domain for the purpose of the feasiblity study includes, drilling multiple boreholes to depths ranging from 10 to 30 meters, standard penetration tests (SPT), and collection of undisturbed and disturbed soil samples. Subsurface conditions in the region generally consist of alluvial deposits, with layers of silty clay, sandy silt, fine to medium sand, and occasional presence of kankar or clay lenses. The groundwater table is usually encountered at shallow depths, often within 2 to 4 meters below ground level, especially near the

Ganga riverfront. The collected soil samples are subjected to laboratory testing to determine key parameters such as cohesion, angle of internal friction, permeability, and bearing capacity. These findings serve as the basis for foundation design and slipway alignment. A summary of typical borehole data and soil profiles is typically presented in tabular form **Table.3.**

**Table 3 Typical Geo technical data**

| Borehole No. | Location | Depth (m) | Soil Stratification | Groundwater Table (m bgl) | SPT (N-value) |
|---|---|---|---|---|---|
| BH-1 | Near riverbank | 20.0 | 0–2 m: Silty Clay2–10 m: Fine Sand10–20 m: Clayey Silt | 2.5 | 8–20 |
| BH-2 | 50 m from river edge | 25.0 | 0–3 m: Sandy Silt3–15 m: Fine Sand15–25 m: Stiff Clay | 3.0 | 10–25 |
| BH-3 | 100 m inland | 30.0 | 0–1.5 m: Topsoil1.5–12 m: Silty Clay12–30 m: Sand with Kankar | 3.2 | 12–30 |
| BH-4 | Adjacent to slipway axis | 20.0 | 0–2 m: Clayey Silt2–8 m: Medium Sand8–20 m: Sandy Silt | 2.0 | 10–22 |

### 3.6 Topographic data

The topography along the National Waterway-1 (NW-1) in the Patna stretch is primarily characterized by alluvial plains with relatively flat terrain gently sloping towards the Ganga River. Ground elevations in the vicinity of the river generally range between 47.0 m and 56.0 m above Mean Sea Level (MSL). The floodplain is broad and low-lying, with variations in surface levels due to natural levees, abandoned channels, and seasonal sediment deposits. Areas closer to the riverbank are typically prone to seasonal inundation, especially during the monsoon months (July to September), while the inland areas gradually rise in elevation. The terrain is largely open with limited vegetation and is conducive to navigation and development of riverine infrastructure, such as terminals, jetties, and slipways. The topography supports efficient access to NW-1 and allows for strategic placement of port infrastructure with suitable cut-and-fill grading where required.

## 4 SEISMICITY

Patna is in Zone IV of Indian Map of Seismic zones (IS-1893 Part-1 2016) which is a severe risk seismic intensity zone (Figure **2**).

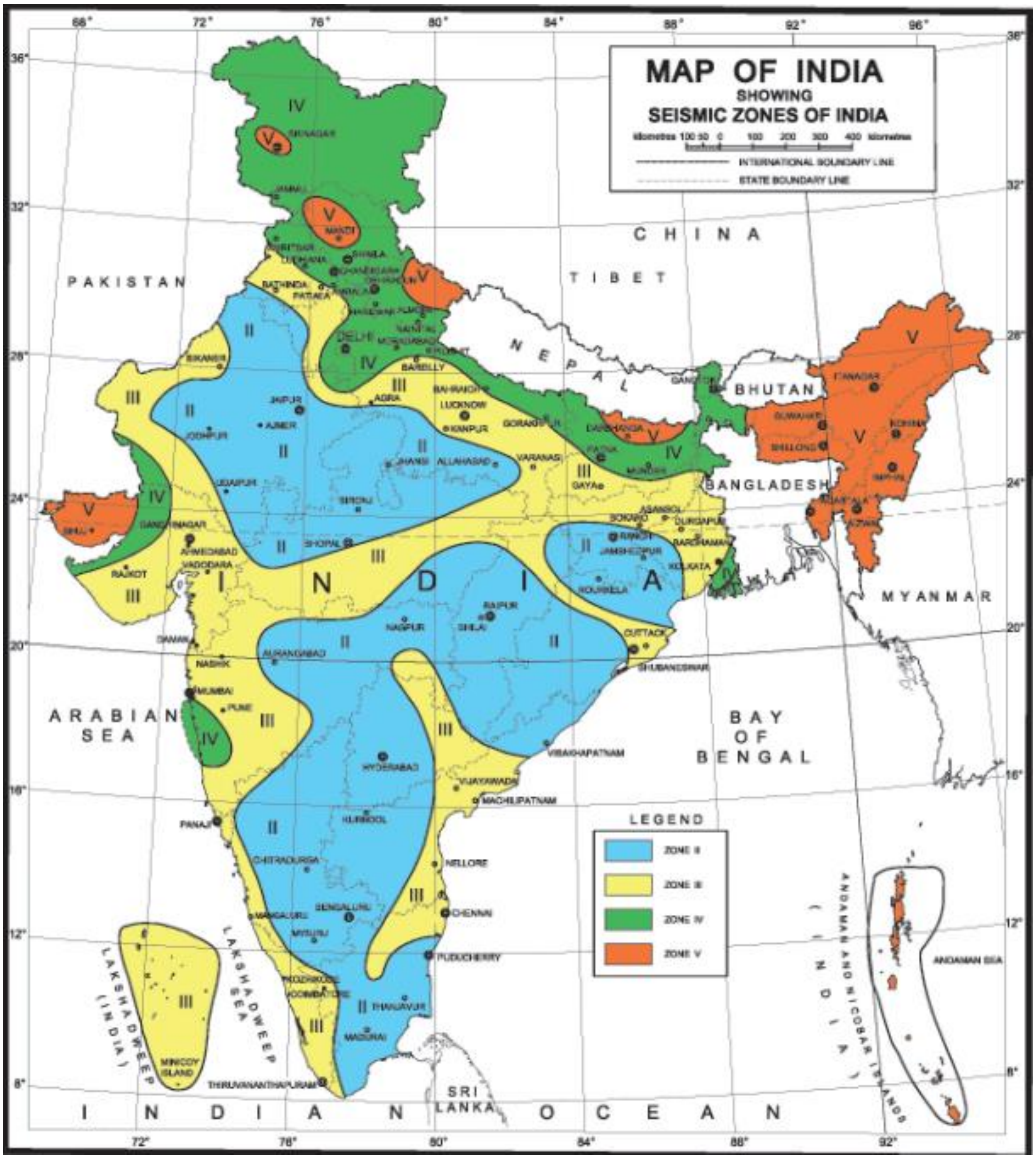


Figure 2 Seismic Zone of India – IS 1893 (Part 1): 2016

# 5 SITE ASSESSMENT AND REVIEW OF THE EXISTING DATA

## 5.1 Introduction

As part of the mandate to carry out the Feasibility of development of a dedicated Ship Repairing Facility at Patna, along National Waterway-1 (NW-1), a site visit and reconnaissance survey was carried out by the team headed by Mr. Srinivasakannan, Senior Project Advisor, NTCPWC IIT Madras along with Mr. Arvind Kumar, Director, Susantha Basu, AHS and Arun Kumar, JHS, IWAI on 05th June 2025, for technical feasibility assessment, site conditions & its environment, area availability and connectivity, of the proposed site of Ship repair facility at Patna, Bihar. The observations during the site visit are detailed hereunder.

### 5.1.1 Documents shared by IWAI

The list of various documents shared by IWAI are as follows

1. Site plan
2. Change in the course of Ganga river at the project site during the past 8 years
3. Minimum and maximum water levels in the adjoining areas viz., Dhiga Ghat and Gandhi Ghat.
4. Details of Vessel sailing in the region of the proposed site
5. NOC Gazette notification
6. Bathymetry Survey charts.
7. List of Vessel Owned by IWAI

### 5.1.2 Review of the existing data

1. A detailed reconnaissance/site survey of the proposed site, including geographical, environmental, and socio-economic conditions, has been conducted.
2. The details received from IWAI for the previous studies, reports, data, information, maps, charts etc., have been viewed and the details available at the Patna site office is taken into cognizance.
3. The identified site by IWAI has been inspected after consultation with the stake holders.

## 5.2 Observation and assessments during the Reconnaissance / Site Survey

The proposed site, located at Latitude 25°38′23.92″ N, Longitude 85°06′49.00″ E, lies on the southern bank of the Ganges River, just north of central Patna. This National Waterway – 1 passing through Patna, Bihar is classified as Class VII Waterway, as defined in Gazette Notification CG-DL-E-17122022-241170 dated 16.12.2022. However, there is no established Ship Repair facilities in the entire stretch and all the vessels have to travel to Kolkatta for major/ minor repairs, which resulted in considerable cost and time. The location now identified for setting up of Ship Repair facilities at Patna, Bihar, offers strategic advantages for river-based operations. The proposed site is located on the southern bank of the Ganges River, just north of central Patna, offering strategic proximity to National Waterway–1 and serving as a prime location for inland vessel operations. IWAI in due consultation with other Government department, had identified about 20,000 sq.m of land parcel (200m x 100m), just outside the High water level parallel to the proposed identified location for setting up of the facility. This land parcel is most ideally suitable for setting up of the land based facilities considering its elevation, proximity to the jetty construction and adjoining roads and other areas. The area lies on flat alluvial plains, bordered by agricultural fields and a narrow strip of riparian vegetation along the riverbank. The land falls within the designated riverfront development zone under municipal jurisdiction, with significant portions already earmarked for waterway-related Infrastructure.


Figure 3 Proposed tentative location for the ship repair facility at Patna

## 5.3 Rail and road connectivity

The site is well-connected by road through local village access roads that link directly to JP Ganga Path - Patna’s dedicated riverfront expressway running parallel to the Ganges. This expressway integrates with major highways such as NH-119A (the Patna–Arrah–Sasaram corridor) and other regional routes, ensuring strong inland connectivity. Rail access is equally efficient, with Patna Junction Railway Station located approximately 4 km from the site, offering both regional and national connectivity. The terrain comprises fertile, gently sloping loamy alluvium typical of the Ganges basin—highly suitable for construction and infrastructure development. Vegetation is sparse and mostly confined to the narrow riparian buffer zone along the riverbank. The site’s riverfront location provides direct access to NW-1 and makes it ideal for establishing ship repair and inland vessel servicing facilities. The combination of excellent multimodal access (via river, road, and rail), suitable topography, and existing land allocation enhances its feasibility for rapid infrastructure deployment with minimal earthwork requirements. **Figure 4** to **Figure 10** shows selected photographs captured during the site visit conducted on 5$^{th}$ June 2025.


Figure 4 Site Visit Photo


Figure 5 Site Visit Photo


Figure 6 Site Visit Photo


Figure 7 Site Visit Photo

### 5.4 Inland Vessel Operations

Data from IWAI R.O. Patna indicates substantial vessel movement in the area, with a cumulative total of 451 vessels operating in the Patna sector from 2020 to 2025. Of these, 83 are IWAI vessels and 368 are privately operated. Vessel sizes range up to 77.37 meters in length and 15 meters in width (MV AAI), underscoring the need for adequate repair infrastructure.

Currently, there are no major ship repair facilities in or around the Patna stretch of NW-1. In the absence of such facilities, inland vessels must travel long distances to receive routine maintenance and emergency services. This not only increases fuel consumption and crew deployment times but also reduces overall fleet efficiency. The establishment of a dedicated ship repair unit in Patna would drastically improve operational turnaround, especially during peak navigation seasons. Details of Vessel movement under IWAI, R.O. Patna is given in **Table 4.**

Table 4 Details of Vessel movement under IWAI, R.O. Patna

| **Details of Vessel movement under IWAI, R.O. Patna** | | | | |
|---|---|---|---|---|
| **Sl. No.** | **Particulars** | **Year (FY)** | **Vessels** | **Total** |
| 1 | IWAI Vessel in Patna Sector | | 83 | 83 |
| 2 | Private Vessel in Patna Sector | 2020-21 | 132 | 368 |
| 3 | | 2021-22 | 58 | |
| 4 | | 2022-23 | 54 | |
| 5 | | 2023-24 | 68 | |
| 6 | | 2024-25 | 56 | |
| **G. Total** | | | | **451** |
| Note: - | Maximum Length of Vessel - 77.37m (MV AAI) | | | |
| | Maximum Width of Vessel - 15m (MV AAI) | | | |

Figure 8 Site Visit Photo (MV AAI)

Figure 9 Site Visit Photo


Figure 10 Site Visit Photo

## 5.5 Water Level Variability and Channel Monitoring

Hydrological data from 2018 to 2025, collected at Gandhi Ghat and Digha Ghat, shows seasonal fluctuations in water level ranging from 6.6 meters to 9.7 meters annually. High Flood Levels (HFL) were recorded at 50.52 meters at Gandhi Ghat and 52.52 meters at Digha Ghat. These fluctuations are critical in planning infrastructure that must remain functional year-round.

Channel bathymetry data indicates the formation of sandbars toward the riverbank over the same period. Satellite imagery and field verification from 2018 to 2025 confirm sediment accretion trends that present navigational challenges. The development of a ship repair facility must therefore be integrated with ongoing sediment management strategies, including dredging and bank protection.

A comprehensive analysis of satellite imagery and on-site bathymetry surveys reveals the gradual formation of sandbars in the channel adjacent to the proposed site. These formations, visible in Google Earth historical imagery, demonstrate a landward shift in sediment deposition. Such conditions, if left unmanaged, may hinder navigation and pose a risk to vessel safety. The integration of sediment monitoring with real-time water level data will be essential in planning access channels, dock placement, and repair basin locations. Additionally, seasonal dredging schedules must align with hydrological forecasts to maintain a functional draft throughout the year. Minimum & Maximum Water Level of (Gandhi Ghat & (Digha Ghat)) River Ganga from 2018 to 2025 are given in **Table 5** and

**Table 6** respectively. The channel analysis and satellite imagery for the year 2018-2025 are shown in the images depicted in **Figure 11** to **Figure 19**.

Table 5 Minimum & Maximum Water Level of (Gandhi Ghat) River Ganga from 2018 to 2025

| Year | Min. Water Level (m) | Date | Max. Water Level (m) | Date | Water level Difference (Max-Min) (m) |
|---|---|---|---|---|---|
| 2018 | 41.01 | 25.03.2018 | 49.60 | 13.09.2018 | 8.59 |
| 2019 | 41.65 | 24.03.2019 | 49.79 | 23.09.2019 | 8.14 |
| 2020 | 42.22 | 19-02-2020 | 48.86 | 22.08.2020 | 6.64 |
| 2021 | 41.58 | 07.03.2021 | 50.45 | 15.08.2021 | 8.87 |
| 2022 | 41.94 | 16-05-2022 | 49.59 | 01.09.2022 | 7.65 |
| 2023 | 41.75 | 16.05.2023 | 48.56 | 10.08.2023 | 6.81 |
| 2024 | 41.50 | 15.05.2024 | 50.28 | 20-09-2024 | 8.78 |
| 2025 | 42.02 | 17-05-2025 | | | |
| HFL Gandhi Ghat | | | 50.52 | 21-08-2016 | |

Table 6 Minimum & Maximum Water Level of (Digha Ghat) River Ganga from 2018 to 2025

| Year | Min. Water Level (m) | Date | Max. Water Level (m) | Date | Water level Difference (Max-Min) (m) |
|---|---|---|---|---|---|
| 2018 | 41.96 | 26.03.2018 | 50.72 | 13.09.2018 | 8.76 |
| 2019 | 42.61 | 26.03.2019 | 50.94 | 23.09.2019 | 8.33 |
| 2020 | 43.00 | 07-03-2020 | 50.05 | 22-08-2020 | 7.05 |
| 2021 | 42.26 | 08.03.2021 | 51.85 | 15.08.2021 | 9.59 |
| 2022 | 42.64 | 19.05.2022 | 50.76 | 01.09.2022 | 8.12 |
| 2023 | 42.42 | 18.05.2023 | 49.67 | 10.08.2023 | 7.25 |
| 2024 | 42.04 | 19-06-2024 | 51.76 | 20-09-2024 | 9.72 |
| 2025 | 42.58 | 14-05-2025 | | | |
| HFL Digha Ghat | | | 52.52 | 23-08-1975 | |

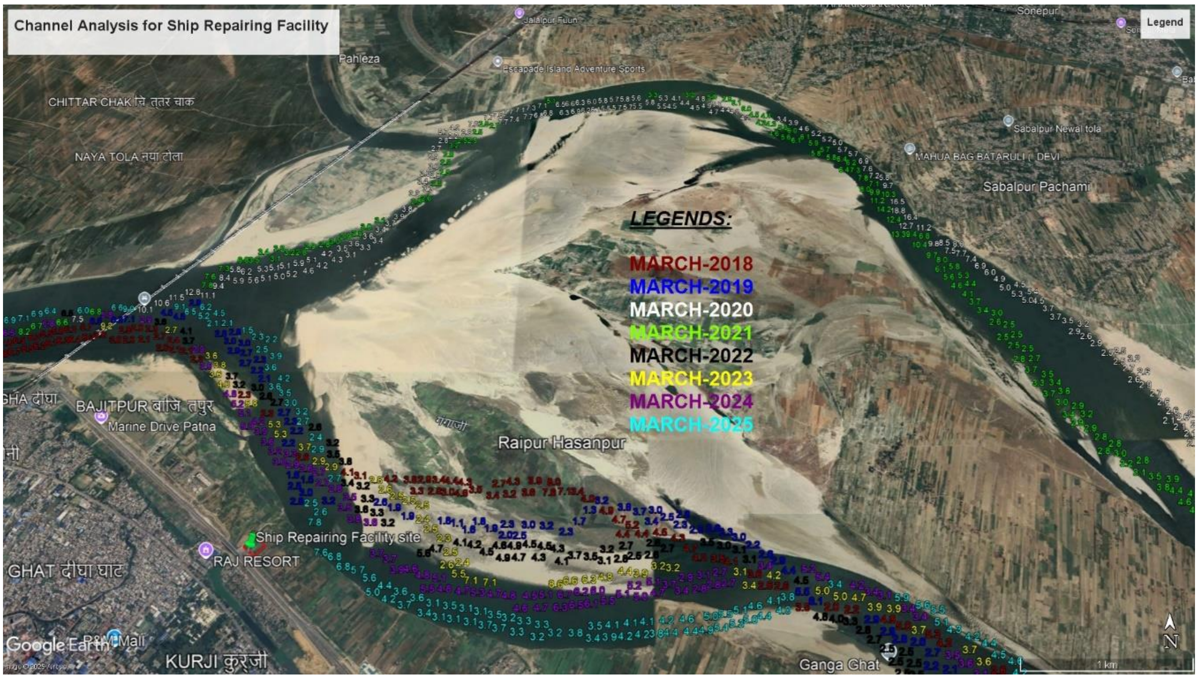


Figure 11 Channel Analysis


Figure 12 Satellite Image Showing Sand Bar Development in 2018 (Source: Google earth)


Figure 13 Satellite Image Showing Sand Bar Development in 2019 (Source: Google earth)


Figure 14 Satellite Image Showing Sand Bar Development in 2020 (Source: Google earth)


Figure 15  Satellite Image Showing Sand Bar Development in 2021 (Source: Google earth)


Figure 16  Satellite Image Showing Sand Bar Development in 2022 (Source: Google earth)


Figure 17 Satellite Image Showing Sand Bar Development in 2023 (Source: Google earth)

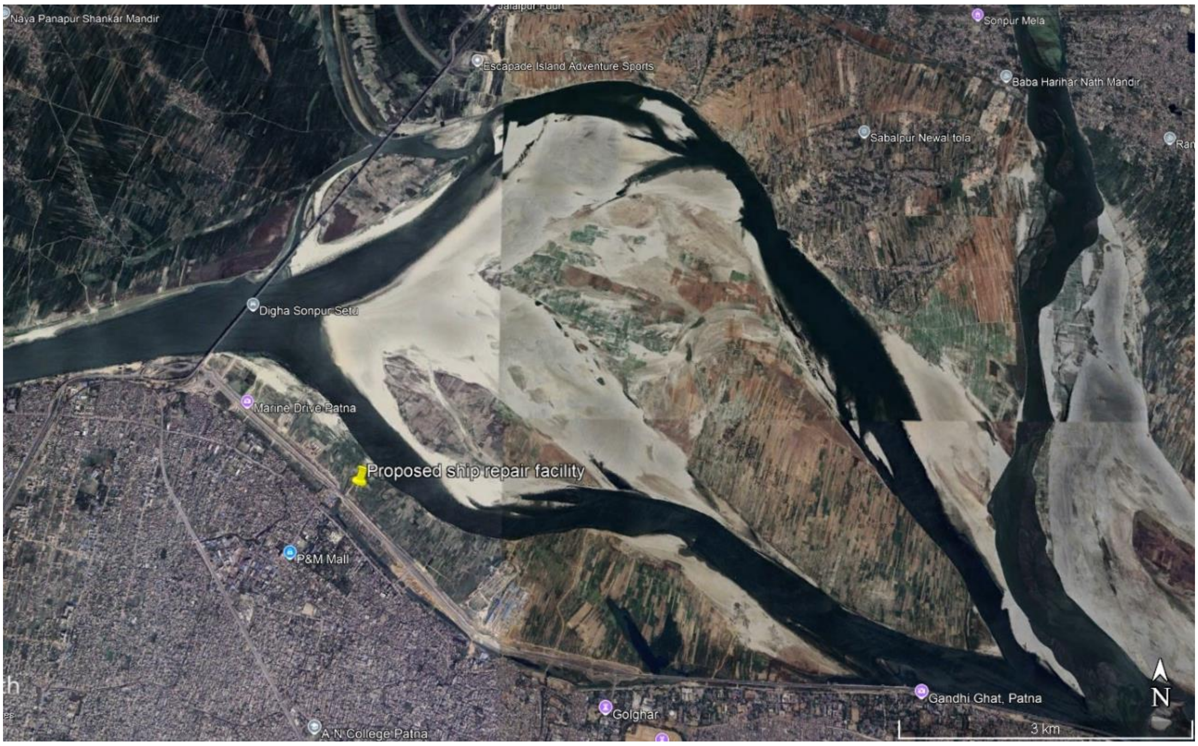


Figure 18 Satellite Image Showing Sand Bar Development in 2024 (Source: Google earth)

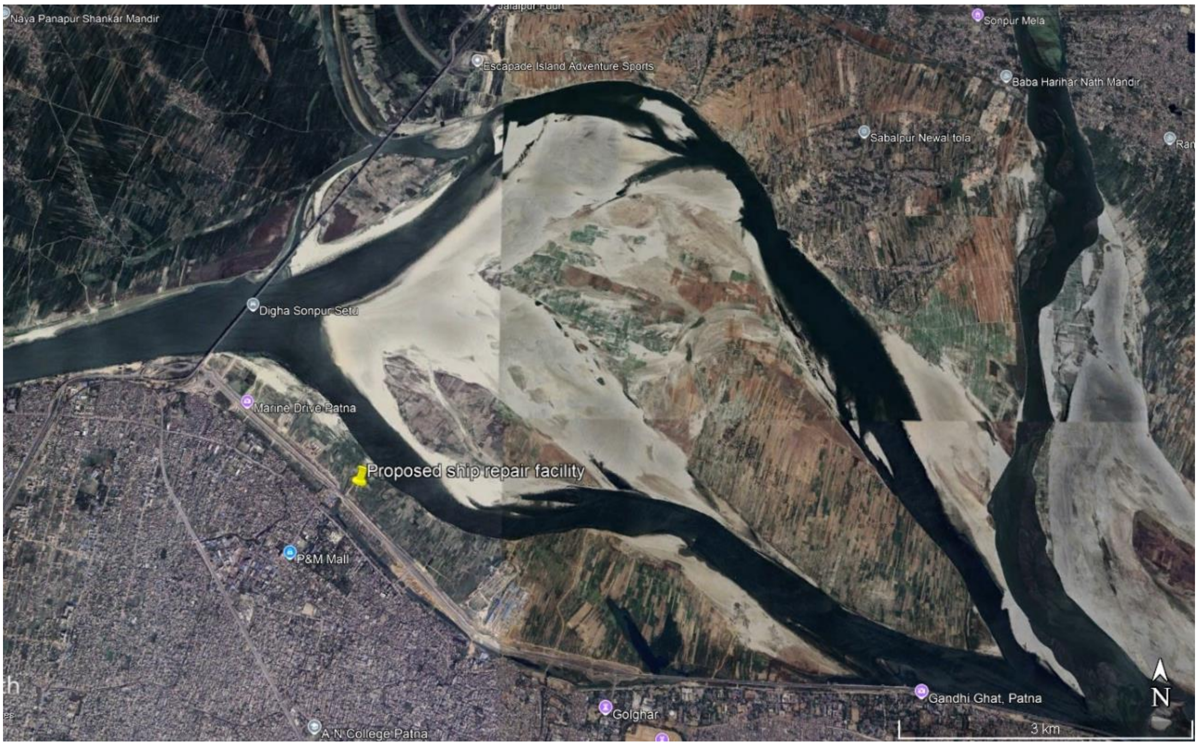

Figure 19 Satellite Image Showing Sand Bar Development in 2024 (Source: Google earth)

## 5.6 Bathymetry Survey

The IWAI survey department provided the bathymetry survey chart at the location of the proposed ship repair facility at NW-1, Kurjighat, Patna. The survey locations and bathymetry chart are Shown in **Figure 20** and **Figure 21**.

Figure 20 Survey Area for Proposed Ship Repair facility (Source: Google earth)

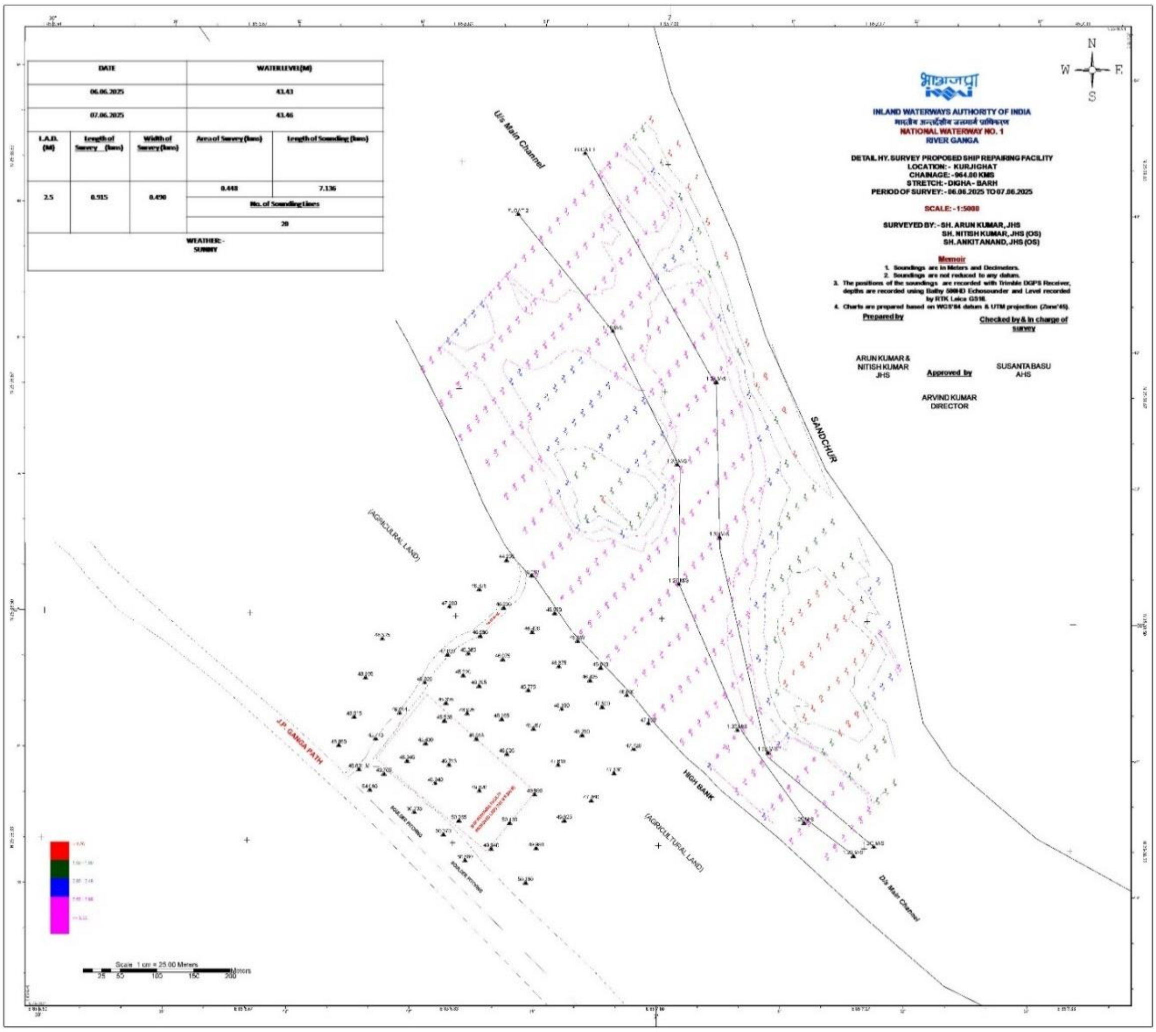


Figure 21 Bathymetry Chart

## 5.7 Details of Vessels plying in NW -1

At present, the vessels operating on NW-1 belong to the IWAI and various other private operators. A summary of the broad range of these vessels is presented in **Error! Reference source not found.**. The vessel data were collected from IWAI.

Table 7 Summary of Vessels Operating on NW-1

| Sl. No. | Category | Name of Vessel | Dimension in mts | Capacity | Capacity Unit | Built Year | Builder |
|---|---|---|---|---|---|---|---|
| 1 | Accommodation boats/house Boats | H.B.Vindhyas | 26.5x9.0x2.2 | 20 | Person | 2002 | A.C.Roy & Co |
| 2 | Accommodation boats/house Boats | H.B.Himgiri | 26.5x9.0x2.2 | 20 | Person | 2002 | A.C.Roy & Co |
| 3 | Accommodation boats/house Boats | H.B.Kalsubai | 26.5x9.0x2.2 | 20 | Person | 2008 | A.C.Roy & Co |
| 4 | Accommodation boats/house Boats | H.B.Vishwakarma | 30.5x7.6x2.5 | 30 | Person | 1986 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5 | Accommodation boats/house Boats | H.B.Dhawalgiri | 26.5x9.0x2.2 | 20 | Person | 2004 | Neptune Marine Pvt.Ltd. |
| 6 | Accommodation boats/house Boats | H.B.Chandradinga | 26.5x9.0x2.2 | 20 | Person | 2005 | Neptune Marine Pvt.Ltd. |
| 7 | Accommodation boats/house Boats | H.B.Kailash | 26.5x9.0x2.2 | 20 | Person | 2008 | A.C.Roy & Co |
| 8 | Accommodation boats/house Boats | H.B.Kedarnath | 26.5x9.0x2.2 | 20 | Person | 2008 | A.C.Roy & Co |
| 9 | Accommodation boats/house Boats | H.B.Nandadevi | 26.5x9.0x2.2 | 20 | Person | 2002 | A.C.Roy & Co |
| 10 | Accommodation boats/house Boats | H.B.Nilgiri | 26.5x9.0x2.2 | 20 | Person | 2008 | A.C.Roy & Co |
| 11 | Accommodation boats/house Boats | H.B.Rajrambha | 26.5x9.0x2.2 | 20 | Person | 2008 | A.C.Roy & Co |
| 12 | Accommodation boats/house Boats | H.B.Devprayag | 26.5x9.0x2.2 | 20 | Person | 2008 | A.C.Roy & Co |
| 13 | Accommodation boats/house Boats | H.B.Sivalik | 26.5x9.0x2.2 | 20 | Person | 2004 | Neptune Marine Pvt.Ltd. |
| 14 | Cargo | M.V. Homi Bhabha | 54.6x9.0x2.4 | 300 | T | 2004 | HDPEL |
| 15 | Cargo | M.V. Lal Bahadur Shastri | 54.6x9.0x2.4 | 300 | T | 2004 | HDPEL |
| 16 | Cargo | M.V.Vishveswary a (POL Tanker) | 54.6x9.0x2.4 | 300 | T | 2006 | HDPEL |
| 17 | Cargo | M.V.Rabindra Nath tagore (Container vessel) | 54.6x9.0x2.4 | 16 | TEU | 2006 | HDPEL |
| 18 | Cargo | M.V.Zakir Hussian | 54.6x11.0x2.1 | 300 | T | 2009 | HDPEL |
| 19 | Cargo | M.V. Rajagopalachari | 62.8x10.6x2.1 | 600 | T | 1988 | Damen Shipyard |
| 20 | Cargo | M.V.V.V.Giri(Under Construction) | 54.6x11.0x2.1 | 300 | T | 2012 | HDPEL |
| 21 | Classic watermaster III | AD Manimala | 10.10 x 3.2 x 1.05 | 80 | cu.m. | 2011 | Aquamec Limited |
| 22 | Classic watermaster IV | AD Falgu | 10.10 x 3.2 x 1.05 | 80 | cu.m. | 2012 | Aquamec Limited |
| 23 | Classic watermaster IV | AD Narmada | 10.10 x 3.2 x 1.05 | 80 | cu.m. | 2014 | Aquamec Limited |
| 24 | Container cranes | One Container crane | | 20 | T | 2005 | TIL Kolkata |
| 25 | Crane Pontoons | CP Ganga-III | 35.0x8.0x1.6 | 4 | T | 2003 | HDPEL |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 26 | Crane Pontoons | CP Brahmaputra-V | 35.0x8.0x1.6 | 4 | T | 2004 | A.C.Roy & Co |
| 27 | Crane Pontoons | CP Brahmaputra-IV | 35.0x8.0x1.6 | 4 | T | 2004 | A.C.Roy & Co |
| 28 | Crane Pontoons | CP Brahmaputra-III | 35.0x8.0x1.6 | 4 | T | 2004 | A.C.Roy & Co |
| 29 | Crane Pontoons | CP Brahmaputra-II | 35.0x8.0x1.6 | 4 | T | 2004 | A.C.Roy & Co |
| 30 | Crane Pontoons | CP Ganga-IV | 35.0x8.0x1.6 | 4 | T | 2003 | HDPEL |
| 31 | Crane Pontoons | CP Ganga-II | 35.0x8.0x1.6 | 4 | T | 2003 | HDPEL |
| 32 | Crane Pontoons | CP Ganga-I | 35.0x8.0x1.6 | 4 | T | 2003 | HDPEL |
| 33 | Crane Pontoons | CP Brahmaputra-I | 35.0x8.0x1.6 | 4 | T | 2004 | A.C.Roy & Co |
| 34 | Cutter suction dredgers | ID-I | 18.3x6.1x1.5 | 120 | | 1984 | Old dredger transferred from DCI |
| 35 | Cutter suction dredgers | CSD Yamuna | 40.0x9.5x2.3 | 500 | | 1988 | Delta Shipyards |
| 36 | Cutter suction dredgers | CSD Mahananda | 34.0x7x1.8 | 500 | | 2004 | Mazagon Dock Ltd |
| 37 | Cutter suction dredgers | CSD Jalangi | 34.0x7x1.8 | 500 | | 2004 | Mazagon Shipyards |
| 38 | Cutter suction dredgers | CSD Tapi | 40.0x9.5x2.3 | 500 | | 2009-10 | Tebma Shipyard Ltd. |
| 39 | Cutter suction dredgers | CSD Alkananada | 40.0x9.5x2.3 | 500 | | 2009-10 | Tebma Shipyard Ltd. |
| 40 | Cutter suction dredgers | CSD Tizu | 34.0x7x1.8 | 500 | | 2004 | Mazagon Dock Ltd |
| 41 | Cutter suction dredgers | CSD Sweta | 40.0x9.5x2.3 | 500 | | 2010-11 | Tebma Shipyard Ltd. |
| 42 | Cutter suction dredgers | ID-IV | 29.0x7.0x1.85 | 300 | | 1991 | Old dredger transferred from DCI |
| 43 | Cutter suction dredgers | CSD Kalada | 18.0x4.0x1.25 | 180 | | 2010 | Startek Shipyards Pvt.Ltd. |
| 44 | Cutter suction dredgers | CSD Champakkara | 18.0x4.0x1.25 | 180 | | 2010 | Startek Shipyards Pvt.Ltd. |
| 45 | Cutter suction dredgers | CSD Shipra | 40.0x9.5x2.3 | 500 | | 2010-11 | Tebma Shipyard Ltd. |
| 46 | Hydraulic surface Dredger | HSD Jia Bhorali | 23.5 x 10 x 2.8 | 260 | BHP | 2012 | HDPEL |
| 47 | Hydraulic Surface Dredgers | HSD Sone | 27.5x10.0x2.8 | | | 2001 | HDPEL |
| 48 | Hydraulic Surface Dredgers | HSD Dhansiri | 27.5x10.0x2.8 | | | 2002 | HDPEL |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 49 | One Container Crane | 20 | T | | | 2005 | TIL Kolkata |
| 50 | Patrol Boats/Inspection Boats | Robin-I | 7.9x2.4x0.9 | | | 1990 | Reinplast |
| 51 | Patrol Boats/Inspection Boats | Falcon-I | 7.6x1.9x0.9 | | | 2005 | KSINC |
| 52 | Patrol Boats/Inspection Boats | Falcon-II | 7.6x1.9x0.9 | | | 2005 | KSINC |
| 53 | Patrol Boats/Inspection Boats | Robin-II | 7.9x2.4x0.9 | | | 1990 | Reinplast |
| 54 | Patrol Boats/Inspection Boats | Kingfisher-I | 7.6x1.9x0.9 | | | 2005 | KSINC |
| 55 | Patrol Boats/Inspection Boats | Hawk-II | 7.6x1.9x0.9 | | | 2005 | KSINC |
| 56 | Patrol Boats/Inspection Boats | Hawk-I | 7.6x1.9x0.9 | | | 2005 | KSINC |
| 57 | Ro-Ro cargo | MV VV Giri | 54.6 x 11 x 2.10 | 300 | T | 2012 | HDPEL |
| 58 | Survey vessels | S.L.Dihang | 25.0x5.8x2.8 | | | 2001 | HDPEl |
| 59 | Survey vessels | S.L.Anupallav | 19x4.8x1.75 | | | 1987 | Rajbagan Dock Yard |
| 60 | Survey vessels | S.L.Koel | 25.0x5.8x2.8 | | | 2008 | A.C.Roy & Co |
| 61 | Survey vessels | S.L.Meghna | 25.0x5.8x2.8 | | | 2008 | A.C.Roy & Co |
| 62 | Survey vessels | S.L.Dwarkeshwar | 25.0x5.8x2.8 | | | 2008 | A.C.Roy & Co |
| 63 | Survey vessels | S.L.Kosi | 21.5x5.8x1.7 | | | 1988 | Delta Shipyard |
| 64 | Survey vessels | S.L.Kamla | 25.0x5.8x2.8 | | | 2003 | Tebma |
| 65 | Survey vessels | S.L.Mandakini | 25.0x5.8x2.8 | | | 2003 | Tebma |
| 66 | Survey vessels | S.L.Ghaghra | 25.0x5.8x2.8 | | | 2008 | A.C.Roy & Co |
| 67 | Survey vessels | S.L.Gandak | 25.0x5.8x2.8 | | | 2007 | A.C.Roy & Co |
| 68 | Survey vessels | S.L.Punpun | 25.0x5.8x2.8 | | | 2008 | A.C.Roy & Co |
| 69 | Survey vessels | S.L.Rihand | 25.0x5.8x2.8 | | | 2008 | A.C.Roy & Co |
| 70 | Survey vessels | S.L.Subansiri | 25.0x5.8x2.8 | | | 2003 | Tebma |
| 71 | Survey vessels | S.L.Dibang | 25.0x5.8x2.8 | | | 2008 | A.C.Roy & Co |
| 72 | Survey vessels | S.L.Burhi Dihing | 25.0x5.8x2.8 | | | 2008 | A.C.Roy & Co |
| 73 | Survey vessels | S.L.lohit | 25.0x5.8x2.8 | | | 2003 | Tebma |
| 74 | Survey vessels | S.L.Barak | 25.0x5.8x2.8 | | | 2003 | Tebma |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 75 | Survey vessels | S.L. Pamba | | | | 2003 | Western Marine Engg. |
| 76 | Terminal barges | F.J.Ganga XXI | 35.0x8.0x1.6 | | | 2009 | A.C.Roy & Co |
| 77 | Terminal barges | F.J.Ganga XIV | 35.0x8.0x1.6 | | | 2009 | A.C.Roy & Co |
| 78 | Terminal barges | F.J Brahmaputra-VI | 35.0x8.0x1.6 | | | 2003-04 | HDPEL |
| 79 | Terminal barges | F.J Brahmaputra-V | 35.0x8.0x1.6 | | | 2003-04 | HDPEL |
| 80 | Terminal barges | F.J Brahmaputra-IV | 35.0x8.0x1.6 | | | 2003-04 | HDPEL |
| 81 | Terminal barges | F.J Brahmaputra-III | 35.0x8.0x1.6 | | | 2003-04 | HDPEL |
| 82 | Terminal barges | F.J Brahmaputra-VIII | 35.0x8.0x1.6 | | | 2008-09 | Techno Steel |
| 83 | Terminal barges | F.J Brahmaputra-I | 35.0x8.0x1.6 | | | 2003-04 | Techno Steel |
| 84 | Terminal barges | F.J Brahmaputra-IX | 35.0x8.0x1.6 | | | 2010-11 | Techno Steel |
| 85 | Terminal barges | F.J.Ganga XX | 35.0x8.0x1.6 | | | 2009 | A.C.Roy & Co |
| 86 | Terminal barges | F.J.Ganga XIX | 35.0x8.0x1.6 | | | 2009 | A.C.Roy & Co |
| 87 | Terminal barges | F.J.Ganga XVIII | 35.0x8.0x1.6 | | | 2009 | A.C.Roy & Co |
| 88 | Terminal barges | F.J.Ganga XVII | 35.0x8.0x1.6 | | | 2009 | A.C.Roy & Co |
| 89 | Terminal barges | F.J.Ganga XVI | 35.0x8.0x1.6 | | | 2009 | A.C.Roy & Co |
| 90 | Terminal barges | F.J Brahmaputra-II | 35.0x8.0x1.6 | | | 2003-04 | Techno Steel |
| 91 | Terminal barges | F.J Brahmaputra-VII | 35.0x8.0x1.6 | | | 2003-04 | HDPEL |
| 92 | Terminal barges | F.J.Ganga XIII | 35.0x8.0x1.6 | | | 2008 | A.C.Roy & Co |
| 93 | Terminal barges | F.J Brahmaputra-XIII | 35.0x8.0x1.6 | | | 2010-11 | Techno Steel |
| 94 | Terminal barges | F.J Brahmaputra-XII | 35.0x8.0x1.6 | | | 2010-11 | Techno Steel |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 95 | Terminal barges | F.J Brahmaputra-XI | 35.0x8.0x1.6 | | | 2010-11 | Techno Steel |
| 96 | Terminal barges | F.J Brahmaputra-X | 35.0x8.0x1.6 | | | 2010-11 | Techno Steel |
| 97 | Terminal barges | F.J.Ganga XV | 35.0x8.0x1.6 | | | 2009 | A.C.Roy & Co |
| 98 | Terminal barges | F.J.Ganga V | 35.0x8.0x1.6 | | | | Tebma |
| 99 | Terminal barges | F.J.Ganga XII | 35.0x8.0x1.6 | | | 2008 | A.C.Roy & Co |
| 100 | Terminal barges | F.J.Ganga XI | 35.0x8.0x1.6 | | | 2009 | A.C.Roy & Co |
| 101 | Terminal barges | F.J.Ganga X | 35.0x8.0x1.6 | | | 2008 | A.C.Roy & Co |
| 102 | Terminal barges | F.J.Ganga IX | 35.0x8.0x1.6 | | | | A.C.Roy & Co |
| 103 | Terminal barges | F.J.Ganga VIII | 35.0x8.0x1.6 | | | | Tebma |
| 104 | Terminal barges | F.J.Ganga VI | 35.0x8.0x1.6 | | | | Tebma |
| 105 | Terminal barges | F.J.Ganga IV | 35.0x8.0x1.6 | | | | Tebma |
| 106 | Terminal barges | F.J.Ganga II | 35.0x8.0x1.6 | | | | HDPEL |
| 107 | Terminal barges | F.J.Ganga I | 35.0x8.0x1.6 | | | | HDPEL |
| 108 | Terminal barges | F.J.Ganga VII | 35.0x8.0x1.6 | | | | Tebma |
| 109 | Terminal barges | F.J.Ganga III | 35.0x8.0x1.6 | | | | Tebma |
| 110 | Tug | WB Mogra | 23.5 x 8 x2.2 | 540 | BHP | 2011 | A.C Roy & Co. |
| 111 | Tug | HPT BR Ambedkar | 23.28 x 7.2 x2.6 | 12 | T | 2013 | A.C Roy & Co. |
| 112 | Tug | MPT Mangal Pandey | 28 x 7.2 x 2.6 | 6 | T | 2013 | A.C Roy & Co. |
| 113 | Tug | HPT Rani Lakshmi bai | 23.28 x 7.2 x2.6 | 12 | T | 2013 | A.C Roy & Co. |
| 114 | Tug | MPT Lala Lajpat Rai | 28 x 7.2 x 2.6 | 6 | T | 2013 | A.C Roy & Co. |
| 115 | Work Boats/Tugs | Tug Bhagat Singh | 25x7x2.5 | 5 | T | 2003 | A.C.Roy & Co |
| 116 | Work Boats/Tugs | MPT Khudiram Bose | 28x7.5x2.6 | 5 | T | 2010 | A.C.Roy & Co |
| 117 | Work Boats/Tugs | W.B.Lily | 25.5x6.56x2.0 | 5 | T | 1988 | delta Shipyards |
| 118 | Work Boats/Tugs | P.T.Tilak | 20.0x7.0x2.0 | 6 | T | 1988 | chowgule & Co Ltd |
| 119 | Work Boats/Tugs | Tug Birsa Munda | 25.0x7.0x2.5 | 5 | T | 2003 | A.C.Roy & Co |
| 120 | Work Boats/Tugs | Tug S.C.Bose | 25.0x7.0x2.5 | 5 | T | 2003 | A.C.Roy & Co |
| 121 | Work Boats/Tugs | Tug Birsa Munda | 28.0X7.5X2.6 | 5 | T | 2003 | A.C.Roy & Co |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 122 | M.V.V.V.Giri | Cargo | 54.6x11.0x2.1 | 300 | T | | HDPEL |
| 123 | HSD | Hydraulic Surface Dredger | 27.5x10.0x2.8 | - | | | HDPEL |
| 124 | W.B.Mogro(Partly Finished | Work Boats/Tug | 23.5x8.0x2.2 | 5 | T | | Neptune Marine Pvt.Ltd. |
| 125 | Work Boat | Work Boats/Tug | 23.5x8.0x2.2 | 5 | T | | Neptune Marine Pvt.Ltd. |
| 126 | Work Boat | Work Boats/Tug | 24.5x8.5x2.2 | 5 | T | | HDPEL |
| 127 | W.B.Jamanthy | Work Boats/Tug | 15.0x5.0x2.0 | 2 | T | | Startek Shipyards Pvt.Ltd. |
| 128 | W.B.Chempakumy | Work Boats/Tug | 15.0x5.0x2.0 | 2 | T | | Startek Shipyards Pvt.Ltd. |
| 129 | Work Boat | Work Boats/Tug | 24.5x8.5x2.0 | 5 | T | | HDPEL |
| 130 | CSD Brahman | Under Construction | 40.0x9.5x2.3 | 500 | | | Temba Shipyards Ltd. |
| 131 | CSD Mandovi | Under Construction | 40.0x9.5x2.3 | 500 | | | Temba Shipyards Ltd. |
| 132 | Pusher RSP-SB-113 | | 21 x 8.2 x 1.20 | | | | |
| 133 | Pusher SCH-2414 | | 16.5 x 8.15 x 1.60 | | | | |
| 134 | Pusher RSP-SB-151 | | 21 x 8.2 x 1.20 | | | | |
| 135 | Pusher RSB-SB-118 | | 21 x 8.2 x 1.20 | | | | |
| 136 | Barge S2 | | 32.5 x 9.5 x 2.17 | 530 | T | | |
| 137 | Barge S2 | | 32.5 x 9.5 x 2.17 | 530 | T | | |
| 138 | Barge S2 | | 32.5 x 9.5 x 2.17 | 530 | T | | |
| 139 | Barge L1 | | 65 x 8.2 x 2.16 | 530 | T | | |

## 5.8 Infrastructure Gaps and Facility Needs

Currently, there are no major ship repair facilities in or around the Patna stretch of NW-1. In the absence of such facilities, inland vessels must travel long distances to receive routine maintenance and emergency services. This not only increases fuel consumption and crew deployment times but also reduces overall fleet efficiency. The establishment of a dedicated ship repair unit in Patna would drastically improve operational turnaround, especially during peak navigation seasons.

Repair facilities must be tailored to the needs of the inland vessel fleet operating in this region. Based on IWAI data and projected traffic, the proposed site should include both afloat repair infrastructure and dry docking capabilities. A typical layout should accommodate:

- One or more dry docks to handle vessels of up to 80 meters in length
- Slipways for mid-size barge and tug maintenance
- Floating jetties for emergency afloat repair
- Covered workshops for mechanical, electrical, and hull repairs
- Equipment for bilge water treatment and hazardous waste handling

The selection of technologies and design criteria must take into account flood-level variations, riverbank stability, and environmental compliance. Environmental impact mitigation measures such as erosion-resistant structures, stormwater drainage, and sediment control systems should be embedded into the project layout. In addition, adequate firefighting systems, lighting, and navigation aids must be planned to ensure safe round-the-clock operations.

A major gap observed in the current waterway infrastructure is the unavailability of rapid-response repair units. The proposed facility at Patna can bridge this by including mobile repair teams and floating workshops that can travel upstream or downstream for on-site diagnostics and minor interventions. Prioritization will be given to areas with high vessel density and significant repair needs but lack adequate facilities. It is also necessary to determine the type of facilities needed depending on the nature of repair to be carried out—either afloat repair or dry docking repairs.

### 5.9 Observation during Reconnaissance / Site Survey

After detailed analysis of the site environment, data shared by IWAI and various discussions & deliberations held with IWAI Authorities, the following conclusions are arrived at.

1. Sufficient water depth is available at the identified site, even at the lean seasons, to handle all the IWAI vessels having draft upto 2.5m. However, the water level is varying substantially and the average water level variation is around 8.4m and the maximum level variation is 9.72m. Taking into account such variation, a suitable design preferably, a boat hoisting jetty with other landside infrastructure can be designed.
2. If the top of the proposed Boat Hoisting jetty is fixed, with sufficient free board over and above the highest high water level, preferably around 53m or such elevation for ensuring seamless operation of Ship Repair Facilities (to be reconfirmed during the Detailed Project Report stage), the backup facilities such as repair bay, transfer bay, can be conveniently located immediately behind the boat hoisting jetty over the piles without affecting the natural water flow, while other landside infrastructure viz., workshops, substations, admin buildings, road & rail connectivity (if possible), etc., can be developed in the area identified by IWAI admeasuring 20,000 Sq.m, as shown in Figure **3**.

A detailed site inspection report was already submitted to IWAI during (Date), which may be read in conjunction with this report.

# 6 MARKET ANALYSIS

## 6.1 Overview

The development of a Ship Repair Facility (SRF) at Patna, Bihar, along the National Waterway-1 (NW-1), is a strategic initiative by the Inland Waterways Authority of India (IWAI). NW-1 connects Haldia to Allahabad via the Ganga-Bhagirathi-Hooghly river system, making Patna a critical midpoint. A robust market analysis is vital to ensure the viability and long-term sustainability of the SRF, considering demand, competition, and stakeholder interest.

## 6.2 Demand Assessment

### 6.2.1 Present Demand

Currently, a substantial number of Inland Water Transport (IWT) vessels, including cargo barges, passenger boats, and mechanized country crafts, operate on NW-1. IWAI Patna, had also shared the details of the vessels plying in this route which has already been captured in Table *7*. With the Government's thrust on increasing IWT share in freight movement, a consistent demand for periodic maintenance and repair of vessels is expected.

Stakeholders such as:

- Uttar Pradesh Inland Waterways Authority
- IWAI
- Private logistic operators
- Tourist operators
- Government and defence vessels

All contribute to the growing need for localized, reliable ship repair facilities. Presently, vessels require travel to Kolkata or Haldia for repairs, leading to increased downtime and costs.

### 6.2.2 Projected Demand (2025 – 2045)

According to traffic projections and published data from the Inland Waterways Authority of India (IWAI), the operational capacity and vessel traffic on National Waterway-1 (NW-1) is expected to increase significantly over the next two decades due to continuous investment under the Jal Marg Vikas Project (JMVP).

In FY 2022–23, NW-1 handled over 10.9 million tonnes of cargo with more than 2,500 vessel trips reported between Haldia and Varanasi (Source: IWAI Annual Report 2022–23). Considering the Government of India's objective to increase modal share of inland waterways and the multimodal connectivity initiatives, the vessel movement along NW-1 is projected to grow at a compound annual growth rate (CAGR) of 6–8% over the next 20 years.

Based on this growth trajectory, the number of active vessels in the Patna region is expected to rise from approximately 320 in 2025 to over 1,000 by 2045. With maintenance needs arising from mechanical wear, riverine navigation issues, and compliance with safety standards, it is estimated that 25–35% of these vessels will require routine or emergency repair annually.

Table 8 Estimated Ship Repair Demand (2025–2045)

| Year | Active Vessels (est.) | % Requiring Repairs | Repair Demand (Vessels/Year) |
|---|---|---|---|
| 2025 | 320 | 25% | 80 |
| 2030 | 520 | 30% | 156 |
| 2035 | 700 | 32% | 224 |
| 2040 | 850 | 33% | 281 |
| 2045 | 1000 | 35% | 350 |

## 6.3 Competitive Analysis

### 6.3.1 Existing Ship Repair Facilities in the Region

A review of existing ship repair facilities along the National Waterway-1 (NW-1) corridor reveals a significant gap between Varanasi and Kolkata, where the availability of dedicated ship repair infrastructure is limited. Below is an analysis of existing facilities operating within or adjacent to this stretch:

Table 9 Major Facilities Beyond Patna Corridor

| Facility | Location | Capacity / Specialization | Status |
|---|---|---|---|
| Syama Prasad Mookerjee Port | Kolkata | Multiple dry docks (up to 160 m), engine and structural workshops | Fully operational |
| Rajabagan Dockyard (GRSE) | Hooghly River | Three dry docks, jetties; handles small to medium IWT vessels | Operational |
| Hooghly Cochin Shipyard Ltd. | Howrah | Dry docks, repair workshops for 15,000 DWT vessels | Operational |
| Kolkata Inland Port (IWAI) | Garden Reach | RCC jetty (70 m), pontoon jetties, container/barge handling | Operational |

### 6.3.2 Facility Gaps in and around Patna, Bihar

- No dedicated, full-service ship repair yards exist between Kolkata (West Bengal), where, the ship repair facilities are exists at the identified ship yard mentioned in Table 9 and Patna

(Bihar). In the Varanasi region, MM Terminal (IWT port, depth ~2.2 m) offers cargo transhipment but no ship infrastructure exists.

- Facilities in eastern Odisha/Northeast are primarily tourist jetties or cargo terminals, not repair yards.
- The inland repair capacity in the region relies heavily on Kolkata and Howrah/GRSE facilities, which involve significant downtime and navigating delays.

### 6.3.3 Facility Gaps Between Varanasi and Patna

1. Location Gap: Patna is positioned nearly 600–700 km upstream of Kolkata/Haldia docks. In absence of repair infrastructure between Varanasi and Kolkata, operators face prolonged downtime.
2. Capacity Gap: Existing facilities mainly serve large vessels and maritime cargo. Repairs for small-to-medium IWT vessels on NW-1 (e.g., barges, tugs, dredgers) are not prioritized.
3. Accessibility Gap: Transporting vessels from central Bihar to Kolkata involves additional logistics and high costs, whereas a local facility would significantly reduce travel and turnaround time.
4. Strategic Value: As per IWAI's strategic initiatives announced in June 2025, the authority has prioritized setting up regional ship repair facilities along NW-1 to support increased traffic and improve service readiness.

### 6.3.4 Existing Ship Repair Facilities in the Region

The absence of repair facilities between Varanasi and Kolkata provides a clear competitive advantage for developing an SRF at Patna. With growing IWT traffic on this corridor and IWAI's policy directives to enhance service infrastructure, a Ship Repair Facility at Patna would fill a critical operational void, reduce vessel turnaround time, and align with national inland waterways development objectives.

## 6.4 Stakeholder Interest

The development of a Ship Repair Facility (SRF) at Patna has garnered interest from multiple stakeholders across the inland water transport ecosystem. The stakeholders include government agencies, vessel operators, cargo logistics firms, terminal operators, local industries, and technical institutions. Each has a vested interest in ensuring that repair and maintenance infrastructure is accessible, reliable, and cost-effective.

1. Inland Waterways Authority of India (IWAI): As the primary agency responsible for the development and regulation of inland waterways, IWAI has expressed support for enhancing support infrastructure like SRFs to improve the reliability of NW-1 operations. The proposed SRF aligns with their vision under the Jal Marg Vikas Project (JMVP).

2. Private Vessel Operators and Logistics Companies: Companies operating cargo barges, dredgers, tugs, and support vessels require timely repair services to reduce downtime. Stakeholder consultations indicate a willingness to use a Patna-based SRF if pricing is competitive and turnaround is efficient.

3. Terminal Operators: Facilities at Patna, Varanasi, and Sahibganj handle multi-modal cargo and rely on support from towing vessels and cargo barges. The absence of nearby repair infrastructure disrupts operational continuity.

4. Local Industries and Shipbuilders: Local mechanical workshops and fabrication units see the SRF as an opportunity to participate as vendors or sub-contractors. The facility will contribute to the local economy and employment.

5. Academic and Research Institutions: Institutions like NIT Patna and other regional polytechnics may contribute through skill training, internships, and R&D collaboration related to ship maintenance technologies.

Overall, there is a strong convergence of interest among stakeholders who view the SRF as a critical enabler of sustainable waterway logistics in Bihar and eastern India.

# 7 METHODOLOGY

## 7.1 Major Components in a ship repair facility

A ship repair facility is designed to undertake inspection, maintenance, refurbishment, and modification of vessels ranging from small crafts to large ocean-going ships. A typical layout for a Ship Repair Facility is shown in Figure 22.

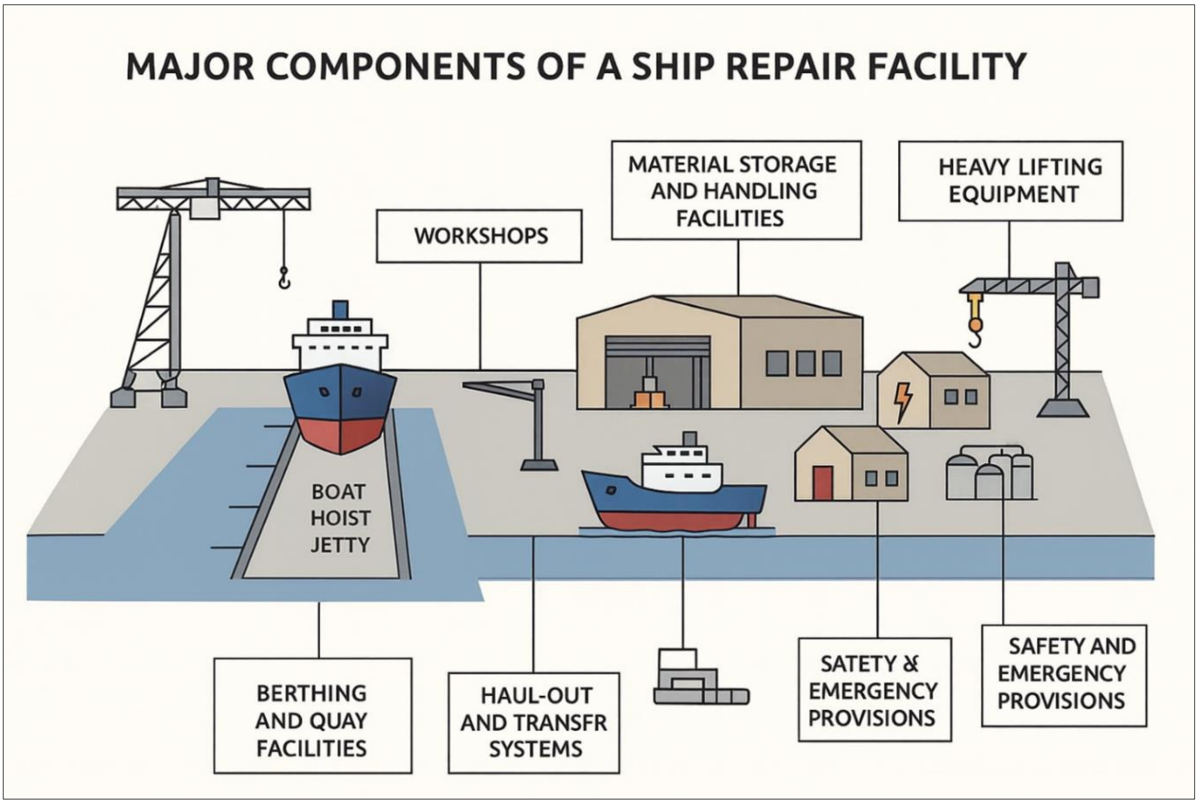


Figure 22 A typical layout for a Ship Repair Facility

### 7.1.1 Vessel Handling & Hoisting Infrastructure

- **Slipway Structure:** Sloped RCC platform constructed to haul vessels from water onto land for repairs.
- **Side Slipway:** Dedicated for smaller vessels or secondary operations.
- **Transfer Area (Concrete Platform**): Used for positioning vessels after lifting and before shifting to repair bays. Typical image for ship lift and transfer system is shown in **Figure 23**.
- **Marine Boat Hoist (700T capacity):** Heavy-duty mobile hoist for lifting vessels out of water vertically.
- **Turning Platform:** Circular or semi-circular slab area enabling directional change of trailers post-hoisting.

- **Hydraulic Trailer:** Used to transport vessels from lifting point to repair bays. A typical marine boat trailer is illustrated in the **Figure 24.**

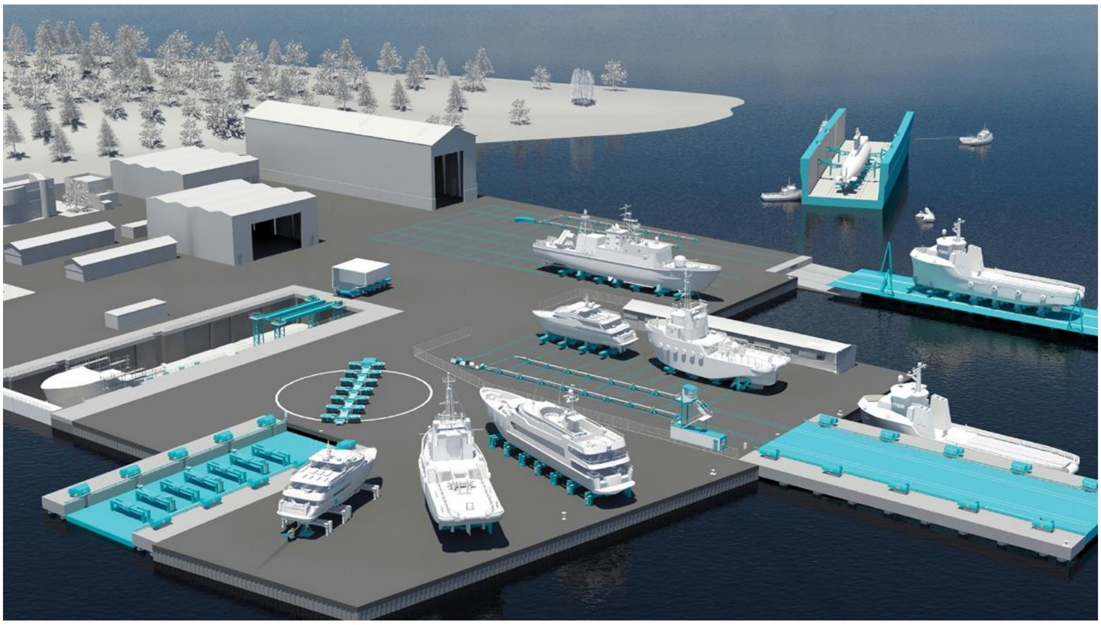

Figure 23 Typical image for ship lift and transfer system

Figure 24 Typical image for boat trailers

### 7.1.2 Repair Bays

- **Primary Repair Bays**: Concrete or paved areas where vessels are serviced after transfer. Typical images for repair bays are shown in **Figure *25***
- **Small Vessel Bays:** Separate platform or bays for smaller boats.
- **Bay Extensions:** Additional raft foundation slabs around repair bays for space expansion.

Figure 25 A Typical image of Repair Bay

### 7.1.3 Utility & Operational Facilities

- Electrical Substation: Supplies power to the hoist system, workshops, and general lighting.
- Heavy Lifting Equipment: Gantry cranes, jib cranes, and mobile cranes for lifting ship components. Dockside cranes for loading/unloading equipment and stores.
- Water Supply and Drainage System: Includes overhead tanks, pipelines, storm drainage, and wash-down points.
- Sewage and Effluent Disposal Unit: Treatment system for domestic waste from toilets and canteen.

### 7.1.4 Workshops & Industrial Buildings

- Mechanical Workshop: Engines, propellers, rudders, and other mechanical systems. A typical image for Workshop is shown in Figure 26.
- Fabrication & Welding Shop: Steel/aluminium hull repairs and fabrication works.
- Electrical & Electronics Workshop: Lighting, navigation systems, and wiring repairs.
- Paint Shop / Surface Preparation Area: Blasting, coating, and corrosion prevention.
- General Store (for tools, spares, and consumables)

Figure 26 A typical image Mechanical Workshop

### 7.1.5 Administrative & Support Facilities

- **Administrative Building:** With rooms for engineers, supervisors, and administrative staff.
- **Fire & Safety Building:** Equipped with emergency tools, fire extinguishers, and first aid.
- **Canteen Block**: Dining area for 50–70 workers, with kitchen and seating.

- **Toilet Blocks:** Separate sanitation units for men and women located near the work zone.

### 7.1.6 Open Yard Facilities

- **Scrap Yard:** For damaged vessel parts, decommissioned machinery, and recyclable metals.
- **Parking / Stack Yard:** For raw materials, trailers, and equipment laydown.
- **Area Reserved for PPP Operators:** For private firms to operate or lease space under Public–Private Partnership.
- **Future Development Zone:** Space allocated for future workshops, automation upgrades, or warehouse expansion. A typical image is shown in **Figure 27**.

Figure 27 A typical Open Yard Facilities

## 7.2 Overview Layout of Ship repair facilities

Based on the details made available, reports and other documents shared by IWAI observations during site visit and detailed discussions held with officials of IWAI, various options of the layout of ship repair facility are arrived and are enumerated hereunder. For the purpose of design, the largest vessel which is plying in this route is of Length 80m, Beam 15m, Height 2.5m. Hence, while planning both the above factors are taken into account for optimization of the ship repair facility with maximum utilization. The total area of ship repair facility is 8.25 acres. After detailed study, two alternative options are considered to arrive at the most viable and workable facility.

1. Option 1, with a ship lift facility along with piled structure parallel to the river flow.
2. Option 2, with a ship lift facility along with piled structure perpendicular to the river flow.

## 7.3 Option 1 - Ship lift with the orientation of the vessel parallel to the river flow

The proposed ship lift facility at Patna is strategically designed with two parallel piled jetties -Piled Jetty 1 and Piled Jetty 2 are oriented along the direction of river flow to facilitate smooth and efficient vessel movement. Each piled jetty is 90 meters in length and 10 meters in width, with a centre-to-centre spacing of 20 meters, allowing sufficient space for vessel positioning, lateral adjustments, and safe lifting operations.

At the perpendicular end of the piled jetties, a transfer area measuring 1,800 $m^2$ serves as the primary zone for shifting vessels from the hoist to repair bays. In addition, a second transfer bay, located parallel to the Boat Hoist Jetty, spans an area of 2,640 $m^2$ and is specifically designed to accommodate larger vessels, particularly those up to 80 meters in length, for repair and maintenance activities.

The general layout and typical cross-section of the ship lift facility (Option-1) are illustrated in Figure 28 and Figure 29.

The landside layout of the proposed Ship Repair Facility at Patna is designed to provide comprehensive support for operational, administrative, safety, and welfare functions. The central Admin Building, measuring 40 × 20 m, will house management offices, meeting rooms, and administrative services. Adjacent to this, a Store Room (14 × 10 m) and Paint Store Room (20 × 15 m) are allocated for secure storage of general equipment and hazardous materials, respectively.

To facilitate marine engineering and vessel maintenance tasks, several purpose-built workshops are proposed:

- Substation: 20 × 14.5 m
- Electrical Shop: 20 × 15 m
- Carpentry / Outfitting Shop: 20 × 15 m
- Pipe Shop: 20 × 15 m
- Engine Machine Shop: 20 × 15 m
- Fabrication Shop: 20 × 20 m

A Fire & Safety Building (20 × 9.5 m) will be provided near the operational zone to ensure rapid response in case of emergencies.

In addition to technical infrastructure, the facility prioritizes workforce welfare:

- A Canteen Building, sized 20 × 10 m, will provide hygienic dining and rest space for workers and staff, with provisions for 50–70 people at a time.
- Toilet Blocks will be strategically placed near workshops and administrative zones, each approximately 10 × 6 m, and gender-segregated, with water and sanitation facilities.

Additional zones include:

- Scrap Yard for decommissioned parts and recyclable metal waste
- Parking / Stackyard for materials and equipment laydown
- Area reserved for Private Operators to enable PPP involvement
- Future Development Zone allowing scope for expansion or auxiliary industries

This integrated facility layout ensures operational efficiency while also promoting worker safety, hygiene, and comfort.

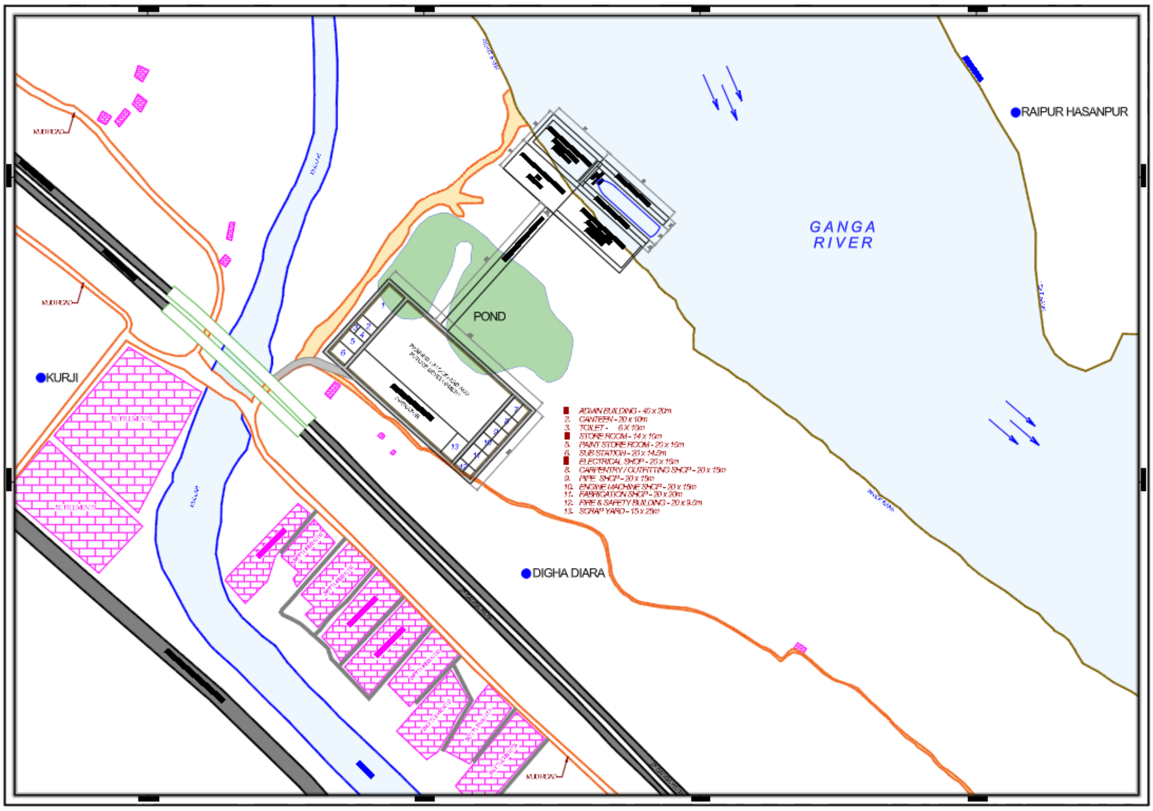


Figure 28 General layout of ship lift facility Parallel to the river flow

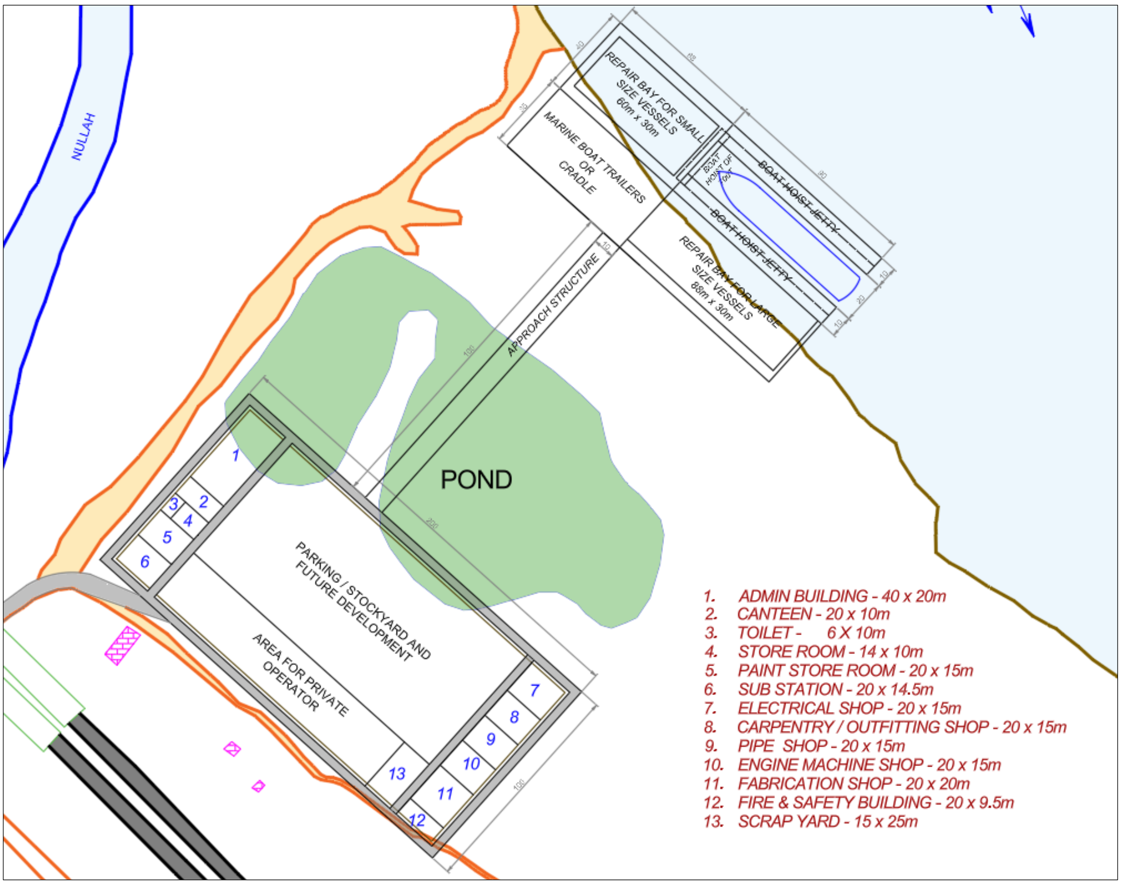


Figure 29 General arrangement of Land and Marine side structures

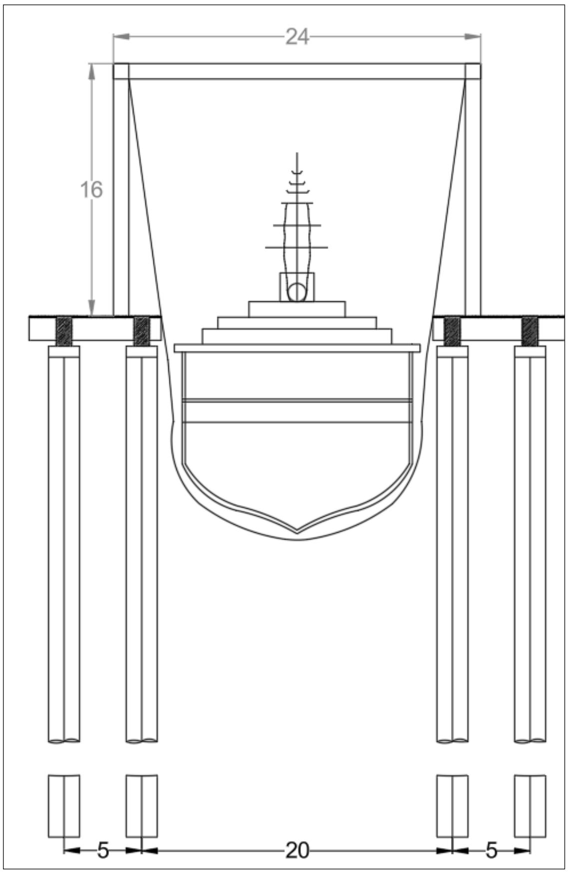


Figure 30 Typical Cross section of Boat Hoist Jetty

### 7.3.1 Details of the Vessels considered

The data on the existing vessels plying in the reroute to Patna has been analysed and the following are the observations;

- About 451 vessels are plying in the route.
- The vessel details are given in Table 10.

Table 10 Details of Vessel movement under IWAI, R.O. Patna

| Sl. No. | Particulars | Year (FY) | Vessels (Nos) | Total |
|---|---|---|---|---|
| 1 | IWAI Vessel in Patna Sector | | 83 | 83 |
| 2 | Private Vessel in Patna Sector | 2020-21 | 132 | 368 |
| 3 | | 2021-22 | 58 | |
| 4 | | 2022-23 | 54 | |
| 5 | | 2023-24 | 68 | |
| 6 | | 2024-25 | 56 | |
| | | | **Total** | **451** |
| Note:- | Maximum Length of Vessel - 77.37m (MV AAI) | | | |
| | Maximum Width of Vessel - 15m (MV AAI) | | | |

The vessels plying in NW-1 can be classified into following categories based on the LOA and furnished hereunder:

- 13.2 % vessels have $LOA \leq 20$ m
- 22.1 % vessels have $20\ m < LOA \leq 25$ m
- 15.4% vessels have $25\ m < LOA \leq 30$ m
- 49.3 % vessels have $30\ m < LOA \leq 65$ m.

### 7.3.2 Size of Boat Hoisting Jetty and Capacity of Marine Boat Hoist

From the details shared by IWAI regarding the vessels plying in the NW-1, about 49.3% of the vessels are having LOA between 30m and 65m. However, there are proposals to handle 77.37m LOA vessels in this route. Since the majority of the vessels are less than 65m it is recommended that the Boat hoisting jetty can be constructed in two phases, namely 60m in the first phase and 90m in the second and final phase, which will result in substantial cost saving and incurring additional expenditure as and when the demand justifies. However, in the case of marine boat hoist, capacity may be fixed as 800 Tonnes. Taking in to the account the longest vessels that can be serviced in the newly created facilities.

### 7.3.3 Marine boat hoist (800 TON) and Trailer

Marine boat hoist is designed to lift and haul heavy loads. This versatile hoist with four sling sets is the efficient, durable machine that allows to leave the larger vessels from the dry dock and lift everything else. The marine boat hoist 800T (Marine travel lift) image is shown in Figure 31.


Figure 31 Typical image for Marine boat hoist

### 7.3.4 Piled structure with RCC deck slab

The proposal inter-alia covers 2 pile supported structures with RCC deck slab. The top level of the piled structure at entry is (+) 53m. Considering the docking draft of the vessel, it is proposed to maintain (-)1.5m below the low water level at the place between piled jetty 1 &2 for that dredging should be done periodically.

### 7.3.5 Transfer area and repair bay

The transfer area is proposed at two locations to optimize vessel repair operations. The first transfer bay, measuring 90 m × 30 m, is aligned parallel to the Marine Boat Hoist Jetty and is designed to accommodate large vessels up to 80 meters in length. The second transfer bay, sized 60 m × 30 m, is proposed perpendicular to the end of the Piled Jetty, serving medium and smaller vessels.

### 7.3.6 Roads

The roads shall be improved for easy movement of vehicles, truck, tractor trailers, forklifts, etc. and width of the road is 3.75m considered as per IRC.

### 7.3.7 Sequence of operations at ship lift facility

Upon docking the vessel between Piled Structure 1 and 2, a 700-tonne capacity Mobile Hoist Crane is carefully positioned to align its lifting ropes under the keel of the vessel. The vessel is securely fastened on both sides using lifting slings and side supports to prevent lateral movement during the lifting process. Once secured, the crane lifts the vessel approximately 1 meter above the deck slab level, ensuring sufficient ground clearance.

The hoisted vessel is then transported longitudinally along the passage between the two piled jetties up to the end of the jetty system, where it is placed on a designated transfer platform or repair bay. For larger vessels, a self-propelled modular trailer (SPMT) or multi-axle hydraulic trailer carries the vessel from the hoisting point to the main transfer area and then to the repair bay. Smaller vessels are shifted to Transfer Bay-2, located perpendicular to the jetties, using cross-movement trailers along a paved or tracked path.

Although Patna is situated far inland and experiences only minimal tidal influence due to its distance from the sea and the fluvial nature of the Ganga River, the region is vulnerable to seasonal flooding, particularly during the monsoon months. Therefore, all transfer operations and related infrastructure are designed with appropriate elevation, slope, and drainage systems to ensure uninterrupted vessel movement and equipment safety even under high-water conditions.

## 7.4 Option 2 - Ship lift with the orientation of the vessel Perpendicular to the river flow

The proposed ship lift facility at Patna is strategically designed with two parallel piled jetties, Piled Jetty 1 and Piled Jetty 2 oriented perpendicular of river flow to facilitate smooth and efficient vessel movement. Each piled jetty is 90 meters in length and 10 meters in width, with a centre-to-centre spacing of 20 meters, allowing sufficient space for vessel positioning, lateral adjustments, and safe lifting operations.

At the parallel end of the piled jetties, a transfer area measuring 1,800 m² serves as the primary zone for shifting vessels from the hoist to repair bays. In addition, a second transfer bay, located parallel to the Boat Hoist Jetty, spans an area of 2,640m² and is specifically designed to accommodate larger vessels, particularly those up to 80 meters in length, for repair and maintenance activities.

The general layout and typical cross-section of the ship lift facility (Option-2) are illustrated in Figure 32 and Figure 33.

The landside layout of the proposed Ship Repair Facility at Patna is designed to provide comprehensive support for operational, administrative, safety, and welfare functions. The central Admin Building, measuring 40 × 20 m, will house management offices, meeting rooms, and administrative services. Adjacent to this, a Store Room (14 × 10 m) and Paint Store Room (20 × 15 m) are allocated for secure storage of general equipment and hazardous materials, respectively.

To facilitate marine engineering and vessel maintenance tasks, several purpose-built workshops are proposed:

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- Engine Machine Shop: 20 × 15 m
- Fabrication Shop: 20 × 20 m

A Fire & Safety Building (20 × 9.5 m) will be provided near the operational zone to ensure rapid response in case of emergencies.

In addition to technical infrastructure, the facility prioritizes workforce welfare:

- A Canteen Building, sized 20 × 10 m, will provide hygienic dining and rest space for workers and staff, with provisions for 50–70 people at a time.
- Toilet Blocks will be strategically placed near workshops and administrative zones, each approximately 10 × 6 m, and gender-segregated, with water and sanitation facilities.

Additional zones include:

- Scrap Yard for decommissioned parts and recyclable metal waste
- Parking / Stackyard for materials and equipment laydown
- Area reserved for Private Operators to enable PPP involvement
- Future Development Zone allowing scope for expansion or auxiliary industries

This integrated facility layout ensures operational efficiency while also promoting worker safety, hygiene, and comfort.

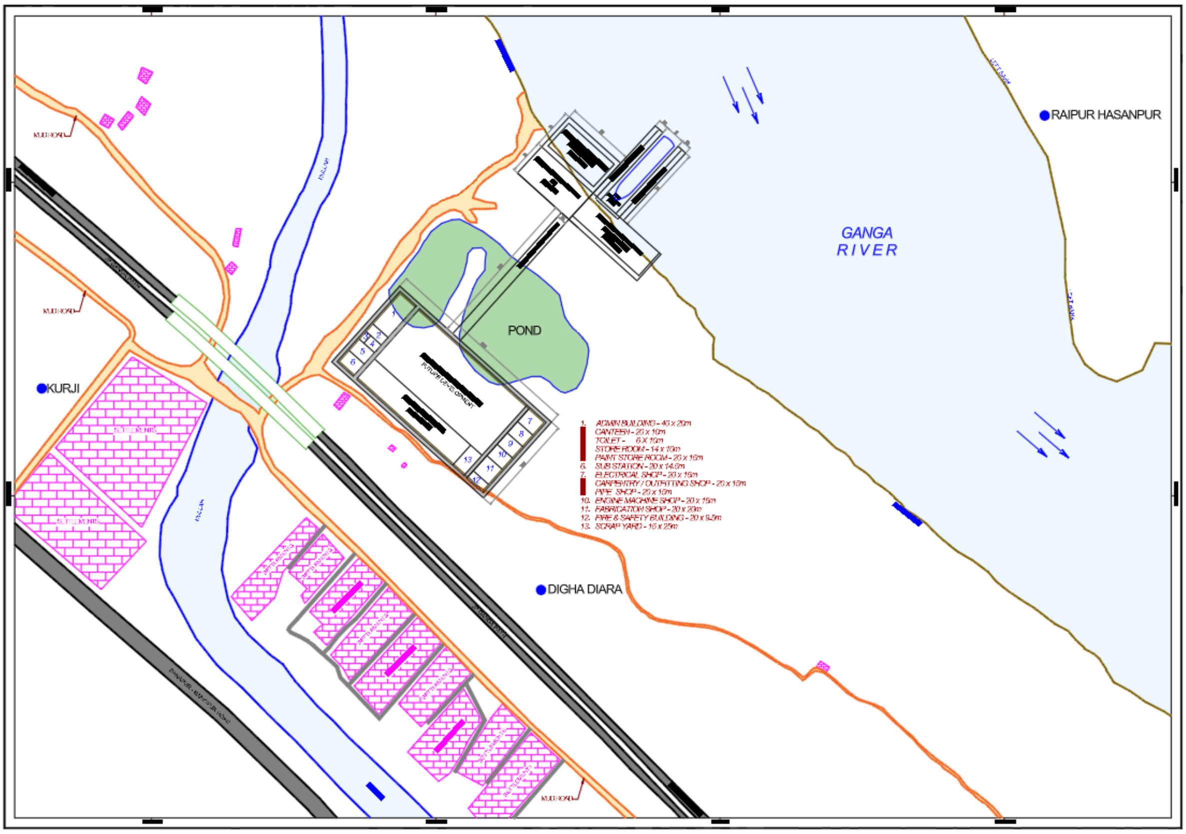


Figure 32 General layout of ship lift facility Perpendicular to the river flow

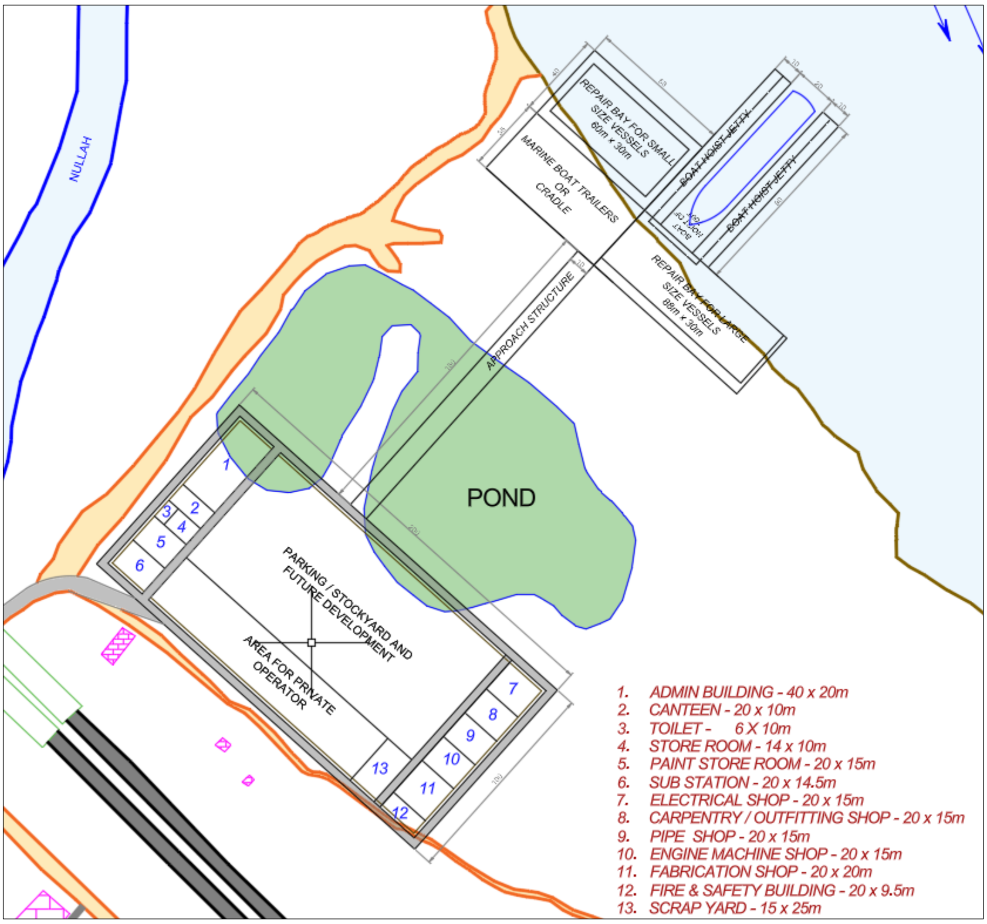


Figure 33 General arrangement of Land and Marine side structures

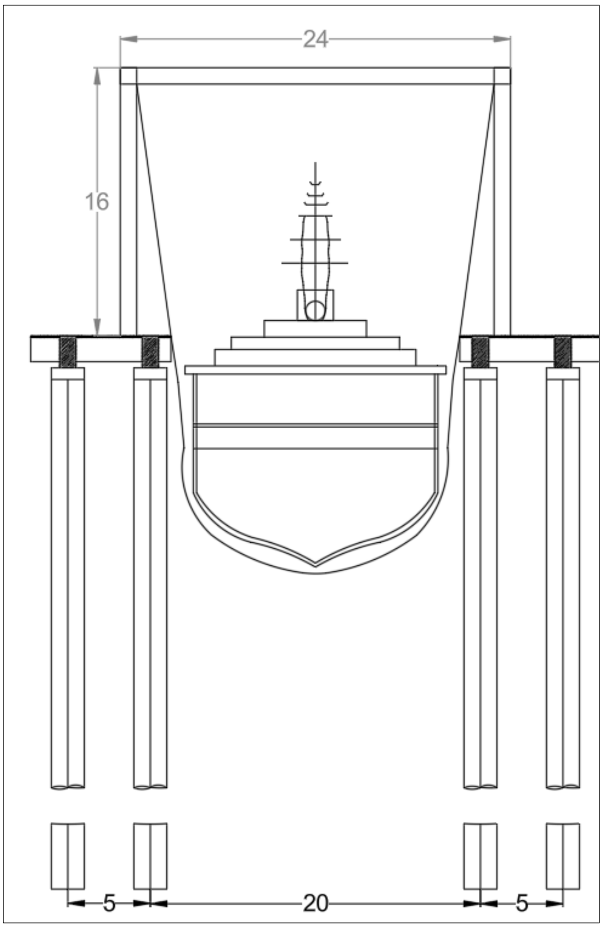


Figure 34 Typical Cross section of Boat Hoist Jetty


Figure 35 Typical image for Wet basin with mobile boat hoist.

## 8 Block cost Estimate

The overall block cost of Phase-1of the project is estimated at Rs. 210 Crores and Phase- 2 cost is Rs. 73. The break-up of the estimate is summarized hereunder:

Table 11 Total Block Cost Estimate for Phase-1

| Sl.No | Description | Amount in Crores |
|---|---|---|
| 1 | Waterside Development – Phase-1 | 180.0 |
| 2 | Landside Development | 20.0 |
| 3 | MEP Services | 10.0 |
| | Total Block cost for Phase-1 | 210.0 |

Table 12 Total Block Cost Estimate for Phase-2

| Sl.No | Description | Amount in Crores |
|---|---|---|
| 1 | Waterside Development – Phase-2 | 68.0 |
| 2 | Landside Development | 5.0 |
| | Total Block cost for Phase-2 | 73.0 |

**Note:**

The total cost is exclusive of GST.

## 9 Summary

This feasibility report presents two alternatives for the proposed ship repair facility at Patna, incorporating the operational methodology of a ship lift system. The objective is to optimise the repair yard layout while meeting all relevant functional and operational requirements. Option-1 involves a ship lift with the orientation of the vessel parallel to the river flow. This arrangement enables smooth and efficient vessel movement, allowing direct approach and departure, thereby minimising manoeuvring time, fuel consumption, and the risk of collision or grounding. It also facilitates better utilisation of the river width for ongoing traffic. Option-2 involves a ship lift with the orientation of the vessel perpendicular to the river flow. While this layout may be feasible in terms of spatial planning, it requires vessels to turn and navigate into the facility, making operations more complex, time-consuming, and potentially hazardous, particularly in strong currents. Considering the above factors, Option-1 is proposed as the preferred alternative for the Patna ship repair facility.

## 10 Recommendations and way forward

After detailed analysis of the site environment, data shared by IWAI and various discussions & deliberations held with IWAI Authorities, the following conclusions are arrived at.

1. Sufficient water depth is available at the identified site, even at the lean seasons, to handle all the IWAI vessels having draft upto 2.5m. However, the water level is varying substantially and the average water level variation is around 8.4m and the maximum level variation is 9.72m. In view of the such huge variation in the water level, it is recommended a suitable design preferably, a boat hoisting jetty with other landside infrastructure can be designed.
2. If the top of the proposed Boat Hoisting jetty is fixed, with sufficient free board over and above the highest high water level, preferably around 53m or such elevation for ensuring seamless operation of Ship Repair Facilities (to be reconfirmed during the Detailed Project Report stage), the backup facilities such as repair bay, transfer bay, can be conveniently located immediately behind the boat hoisting jetty over the piles without affecting the natural water flow, while other landside infrastructure viz., workshops, substations, admin buildings, road & rail connectivity (if possible), etc., can be developed in the area identified by IWAI admeasuring 20,000 Sq.m, as shown in Figure 1.

Considering all these aspects, particularly availability of sufficient water spread area with required water depth and land for developing the backup infrastructure facilities, it is technically feasible and financially viable to establish a Ship Repair Facilities can be established at the identified location Patna, Bihar, as shown in Figure 1, which will result in both direct and indirect benefits and considerable savings in cost & time, and also create substantial employment potential for the country, as a whole and Bihar/ Patna in particular.

Preliminary design for proposed structure and other facilities are under finalisation, IWAI has already been requested to share the Geotechnical data of the proposed site and Topographical chart in closer interval. On receipt of the above details the preliminary design for the proposed facilities shall be freezed and detailed project report shall be forwarded after firming up the block cost estimate of the proposed facilities.

**(Prof. K. Murali)**

# ANNEXURE -III

GRIL®

# G R INFRAPROJECTS LIMITED

(Formerly known as G.R. Agarwal Builders and Developers Limited)

CIN : U45201GJ1995PLC098652

To:
SQME/S.BE/Sh.S. Rastogi
—for n.a. Pls.
Sh. SLJ / Khetri Sir
All key Personnel
02.12.2020

**Ref. No: GRIL/EPC/GNGA/2020/64** **Date: 02.12.2020**

To,
The Team Leader,
Ganga path Highway Project
House No:280, 3rd Floor,
Patliputra colony,
Patna-800023
Mob:7544007321
Email-gangapath219@gmail.com

**Sub:** "Construction of Four Lane Elevated Road as part of under construction Ganga Path (Digha to Deedarganj) from Dulli Ghat (Ch: 13+525.79 Km) to Nuruddin Ghat (Ch: 16+975.79Km), from Dharamshala Ghat (Ch: 19+890 Km) to Old NH-30 (Ch: 20+530.5) along with connectivity to Ashok Rajpath at Kangan Ghat (Ch: 15+700 Km) and Patna Ghat (Ch: 16+600 Km.) with allied facilities at Patna in the State of Bihar on EPC Mode": **Submission of Geo Technical Investigation report from P164 to P169-reg**

**Ref.**

1. Authority's Engineer letter no: AECOM-RODIC/BSRDCL/GANGAPATH/GRIL/20-21/0033 dated 28.11.2020
2. Contractor's letter no: GRIL/EPC/GNGA/2020/43 dated 04.11.2020

Dear Sir,

This is with reference to above subject; please find enclosed herewith Geo Technical Investigation report from P164 to P169 of the subject project.

This is for your kind information please.

Thanking you and assuring our best services.

Yours Faithfully,
**For GR Infraprojects Ltd**

**(Pradyot Kumar)**
**Authorized Representative**

**Enclosure:** One set of original Geo Technical Investigation report from P164 to P169

**Copy:** The Deputy General Manager (T), Project Implementation Unit (PIU), Gulzarbagh, Raja Ghat, Near Holy Trinity School, Ganga Bridge Colony, Gaighat, Post-Gulzarbagh, Patna, Bihar-800007



**CORPORATE OFFICE :**
2nd Floor, Novus Tower
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Old Survey No. 384/1, 384/2, Paiki
and 384/3, Khata No. 464, Kochariya
Ahmedabad, Gujarat-382220, India

JAS-ANZ ICS ISO 9001:2015 Reg. No.:RQ91/6251

Email : info@grinfra.com | Website : www.grinfra.com

2020

# GEO TECHNICAL INVESTIGATION FOR GANAGA PATH ROAD PROJECT AT PATNA IN THE STATE OF BIHAR.

(Bore Holes P-164, P-165, P-166, P-167, P-168, P-169)

**Client**: Bihar State Road Development Corporation Limited

**Authority Engineer**: AECOM JV WITH RODIC CONSULTANTS Pvt. Ltd.

**EPC Contractor**: G R INFRAPROJECTS LTD.

Executed by
**M/s. Anand Raj Infratech Pvt. Ltd.**
**F-159, P.C. Colony, Kankarbagh, Patna- 800020**

# CONTENTS



ANAND RAJ INFRATECH PVT LTD

A.Singh

## *1. Introduction*

Soil exploration, investigation and testing of soil samples for various locations of Elevated portion of Construction of Ganga Path from Digha to Didarganj at Patna – was entrusted to M/s Anand Raj Infratech Pvt. Ltd., Kankarbagh, Patna- 800020. The objective was to ascertain the subsoil characteristics and stratification and other necessary data of soil condition of the site for the proposed foundation of the elevated corridor.

The scope of the work comprised of sinking six boreholes from **P164 to P169**. It included advancing the boreholes by auger and rotary equipment. The boreholes were of 150 mm in diameter. The scope also included conducting standard penetration tests (SPT), collecting disturbed samples at regular intervals for identification and logging purposes, collecting undisturbed tube samples at suitable intervals or at change of strata whichever is earlier and testing these in the laboratory.

Based on the above, this report presents the subsoil profile and laboratory and field test results. On the basis of field tests and laboratory test results and their analysis thereof, the most suitable type of foundation with it's safe bearing capacity is suggested.

## *2. Field Exploration*

Geotechnical Investigation was envisaged in an attempt for optimisation in the design of foundation for the proposed structures to be constructed at this site. The entire Investigation programme had been divided mainly into two parts, I) Field works & II) Laboratory tests.

I) Field works unfold the sub-surface deposit types and their characteristics

II) Laboratory tests would help in determining the relevant physical and geotechnical properties of the sub-surface deposits leading to finalisation of foundation depths of the structures and the bearing capacity with particular reference to the sub-surface types and their strength parameters.

A list of the boreholes with the terminating depth and standing water level are presented in a tabular form below:

| Bore Hole No. | Terminating Depth (m) | R.L. of Borehole Top | Water Table below Borehole top (m) | Date of commencement | Date of completion |
|---|---|---|---|---|---|
| P164 (new) | 70.0 | 48.181 | 1.00 | 09.09.20 | 13.09.20 |
| P165 (new) | 70.0 | 48.755 | 1.35 | 18.08.20 | 22.08.20 |
| P166 (new) | 70.0 | 48.697 | 1.65 | 28.08.20 | 01.09.20 |
| P167 (new) | 70.0 | 48.737 | 1.50 | 23.08.20 | 27.08.20 |
| P168 | 70.0 | 48.940 | 1.00 | 03.09.20 | 07.09.20 |
| P169 | 70.0 | 48.073 | 3.00 | 15.09.20 | 20.09.20 |

The location of boreholes is shown in Figure 1.

***Boring***

Boring was carried out by auger and rotary method as per IS 1892-1979 to sink nominal 150 mm diameter boreholes to desired depths and operated by a team of experienced technicians. Flush jointed seamless casings were used to stabilize the boreholes and prevent caving of the soil inside the boreholes. The casing pipes were advanced by turning in order to minimize the disturbance. Undisturbed soil samples were collected at suitable intervals or at change of strata whichever is met earlier by open drive sampling method since it was intended to ascertain the subsoil characteristics. The standing water table in each borehole was determined at least 24 hours after the termination of boring work.

***Sampling***

Nominal 100 mm diameter undisturbed samples were recovered. The sampling equipment used consists of a two-tier assembly of sample tubes 400 mm in length fitted at its lower end. The sampling assembly was driven by means of a jarring link to its full length or as far down as was found practicable. After withdrawal the ends of the tubes were sealed with wax at both ends and capped before transmission to the laboratory. At close intervals in depth, disturbed samples were collected both from split spoon sampler after the standard penetration test and from cutting edge for identification and logging purpose. These were tagged and packed in polythene packets and transported to the laboratory. The depthwise locations of all the undisturbed and disturbed samples were used in the preparation of borehole log data and for general identification and classification purposes. The details of boring are presented in the Appendix in the form of bore log sheets.

### *Standard Penetration Test*

Standard Penetration Tests were conducted in the boreholes at suitable intervals as per IS: 2131-1963 using a split spoon sampler. The split spoon sampler used is of a standard design having an outer diameter of 50.8 mm and inner diameter of 35 mm, driving with a monkey weighing 63.5 kgs, falling freely from a height of 75 cm. A record of the number of blows required to penetrate every 15 cm to a maximum depth of 45 cm was made. The first 15 cm of drive was considered to be seating drive and was neglected. The total blows required to effect each 15 cm of penetration was recorded. The "N" values were obtained by counting the number of blows required to drive the spoon from 15 cm to 45 cm. On completion of a test, the split spoon sampler was opened and soil specimens were preserved in polythene bags for logging purpose.

### *Measurement of Water Table*

Level of water was noted when struck in. This is termed as observed water level. Standing water level was noted during initial stages of boring, intermediate stage of boring and after 24 hours of removal of casing was also noted and shown in the profile.

### 3. *Laboratory Testing*

For proper identification and classification of the sub-soil deposits and for deriving adequate information regarding its relevant physical and geotechnical properties at the site under investigation, the soil samples from the sampling tubes were extracted in the laboratory by pushing out the core by using the extractor frame. The core was jacked out in a direction that corresponded with the soil movement within the tube during sampling. In general, the following laboratory tests were conducted on the soil samples collected as relevant from the exploratory bore holes and sampling points:

a) Visual Engineering Classification
b) Grain size analysis
c) Consistency Limits.
d) Determination of Natural Moisture Content (water content).
e) Determination of Specific Gravity.
f) Determination of Bulk & Dry Unit Weight.
g) Triaxial Test
h) Direct Shear Test
i) Consolidation Test
j) Chemical Test of water and soil sample for pH, sulphate and chloride.

## 4. *Soil Profile and Properties*

Based on visual classification and results of field and laboratory tests on the samples recovered the proposed site may be divided into the following major soil strata as described below:

**LAYER - I**

This layer consists of Brownish grey filled up soil with sand, bricks silt etc. This is observed in P165, P166, and P167, with thickness varying from 0.5 m to 1.7 m. The 'N' value varies from 5 to 6.

The engineering properties are as follows:-

| | |
|---|---|
| Bulk density | 1.83 – 1.84 gm /c.c. |
| Liquid limit | Non Plastic |
| Plastic limit | Non Plastic |
| Specific Gravity | 2.52 |
| Cohesion | 0.0 kg /cm$^2$ |
| Angle of internal friction | 26° |

According to IS classification system, it may be classified as SM, CL

**LAYER - II**

This layer consists of Soft to medium stiff yellowish grey / dark grey sandy clayey silt. The 'N' value varies from 2 to 7.

The engineering properties are as follows:-

| | |
|---|---|
| Bulk density | 1.79 – 1.84 gm /c.c. |
| Liquid limit | 26% - 41% |
| Plastic limit | 18% - 21% |
| Specific Gravity | 2.51 – 2.64 |
| Cohesion | 0.15 – 0.39 kg /cm$^2$ |
| Angle of internal friction | 2° - 3° |
| Compression Index Cc | 0.181 – 0.214 |
| Initial void ratio eo | 0.79 – 0.83 |

According to IS classification system, it may be classified as CI, CL, CL-ML, ML

**LAYER - III**

This layer consists of Medium dense greyish micaceous silty fine sand. The 'N' value varies from 6 to 25.

The engineering properties are as follows:-

| | |
|---|---|
| Bulk density | 1.84 – 1.86 gm /c.c. |
| Liquid limit | Non Plastic |
| Plastic limit | Non Plastic |
| Specific Gravity | 2.59 – 2.64 |
| Cohesion | 0 kg /cm$^2$ |
| Angle of internal friction | 30° - 32° |

According to IS classification system, it may be classified as SM

**LAYER - IV**

This layer consists of Stiff to very stiff brownish yellow / yellowish grey sandy silty clay with kankar. The 'N' value varies from 11 to 59.

The engineering properties are as follows:-

| | |
|---|---|
| Bulk density | 1.85 – 1.91 gm /c.c. |
| Liquid limit | 33% - 41% |
| Plastic limit | 19% - 21% |
| Specific Gravity | 2.60 – 2.65 |
| Cohesion | 0.55 – 1.17 kg /cm$^2$ |
| Angle of internal friction | 2° - 5° |
| Compression Index Cc | 0.132 – 0.181 |
| Initial void ratio eo | 0.80 – 0.73 |

According to IS classification system, it may be classified as CI, CL

**LAYER - V**

This layer consists of Very stiff to hard brownish yellow sandy silty clay / clayey silt with kankar. The 'N' value varies from 19 to 73.

The engineering properties are as follows:-

| | |
|---|---|
| Bulk density | 1.92 – 2.01 gm /c.c. |
| Liquid limit | 28% - 42% |
| Plastic limit | 19% - 23% |
| Specific Gravity | 2.61 – 2.66 |
| Cohesion | 0.98 – 1.23 kg /cm$^2$ |
| Angle of internal friction | 3° - 7° |
| Compression Index Cc | 0.118 – 0.121 |
| Initial void ratio eo | 0.72 – 0.74 |

According to IS classification system, it may be classified as CL, CI, CL-ML

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PATNA

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**LAYER - VI**

This layer consists of Very dense yellowish grey micaceous silty fine sand. The 'N' value varies from 31 to refusal.

The engineering properties are as follows:-

| | |
|---|---|
| Bulk density | 1.95 – 1.98 gm /c.c. |
| Liquid limit | Non Plastic |
| Plastic limit | Non Plastic |
| Specific Gravity | 2.36 – 2.66 |
| Cohesion | 0 kg /cm$^2$ |
| Angle of internal friction | 33° - 35° |

According to IS classification system, it may be classified as SM, SM-SP, SP

A profile through the boreholes is shown in Figure 2.

## 5. *Recommendations on Foundation*

The foundation proposed for the elevated structure is R.C.C. Bored Piles from the consideration of the superstructure load. The safe capacities of R.C.C. bored piles are shown below in the following table. The configuration of the pile, i.e., the diameter and the length would be fixed by the designer, but for a guide line some typical calculations showing the pile capacity for pile diameter 1.9 m have been shown. However, these capacities shall be checked by load test as per provisions of IS 2911 (Part 4) latest version.

**Table: Pile Capacity for 1.9 m dia. pile, with max. scour level 7.1 m, Cutoff level 43.55 m**

| Location | Pile length (m) | Length (m) below scour level | Safe Vertical Capacity (ton) | Safe Lateral Capacity (ton) | Safe Uplift Capacity (ton) |
|---|---|---|---|---|---|
| P164 (new) | 53.5 | 17.05 | 1226 | 21.7 | 444 |
| | 55.0 | 18.55 | 1366 | | 493 |
| | 56.0 | 19.55 | 1463 | | 528 |
| | 57.0 | 20.55 | 1561 | | 565 |
| | 58.0 | 21.55 | 1662 | | 603 |
| | 59.0 | 22.55 | 1766 | | 643 |
| | 60.0 | 23.55 | 1871 | | 685 |
| P165 (new) | 53.5 | 17.05 | 1243 | 21.8 | 462 |
| | 55.0 | 18.55 | 1381 | | 511 |
| | 56.0 | 19.55 | 1475 | | 546 |
| | 57.0 | 20.55 | 1571 | | 582 |
| | 58.0 | 21.55 | 1670 | | 620 |
| | 59.0 | 22.55 | 1771 | | 659 |
| | 60.0 | 23.55 | 1875 | | 701 |
| P166 (new) | 53.5 | 17.05 | 1227 | 22.2 | 452 |
| | 55.0 | 18.55 | 1364 | | 501 |
| | 56.0 | 19.55 | 1458 | | 536 |
| | 57.0 | 20.55 | 1554 | | 572 |
| | 58.0 | 21.55 | 1653 | | 610 |
| | 59.0 | 22.55 | 1754 | | 649 |
| | 60.0 | 23.55 | 1857 | | 690 |

| Location | Pile length (m) | Length (m) below scour level | Safe Vertical Capacity (ton) | Safe Lateral Capacity (ton) | Safe Uplift Capacity (ton) |
|---|---|---|---|---|---|
| P167 (new) | 53.5 | 17.05 | 1229 | 22.1 | 451 |
| | 55.0 | 18.55 | 1367 | | 500 |
| | 56.0 | 19.55 | 1462 | | 535 |
| | 57.0 | 20.55 | 1559 | | 571 |
| | 58.0 | 21.55 | 1659 | | 609 |
| | 59.0 | 22.55 | 1761 | | 649 |
| | 60.0 | 23.55 | 1865 | | 690 |
| P168 | 53.5 | 17.05 | 1221 | 20.8 | 446 |
| | 55.0 | 18.55 | 1359 | | 495 |
| | 56.0 | 19.55 | 1454 | | 529 |
| | 57.0 | 20.55 | 1551 | | 566 |
| | 58.0 | 21.55 | 1650 | | 604 |
| | 59.0 | 22.55 | 1752 | | 643 |
| | 60.0 | 23.55 | 1856 | | 685 |
| P169 | 53.5 | 17.05 | 1210 | 21.3 | 445 |
| | 55.0 | 18.55 | 1347 | | 494 |
| | 56.0 | 19.55 | 1440 | | 528 |
| | 57.0 | 20.55 | 1537 | | 561 |
| | 58.0 | 21.55 | 1635 | | 602 |
| | 59.0 | 22.55 | 1736 | | 641 |
| | 60.0 | 23.55 | 1838 | | 682 |

(S.K.Bose)
B.E.(Cal), M.I.G.S., M.I.E

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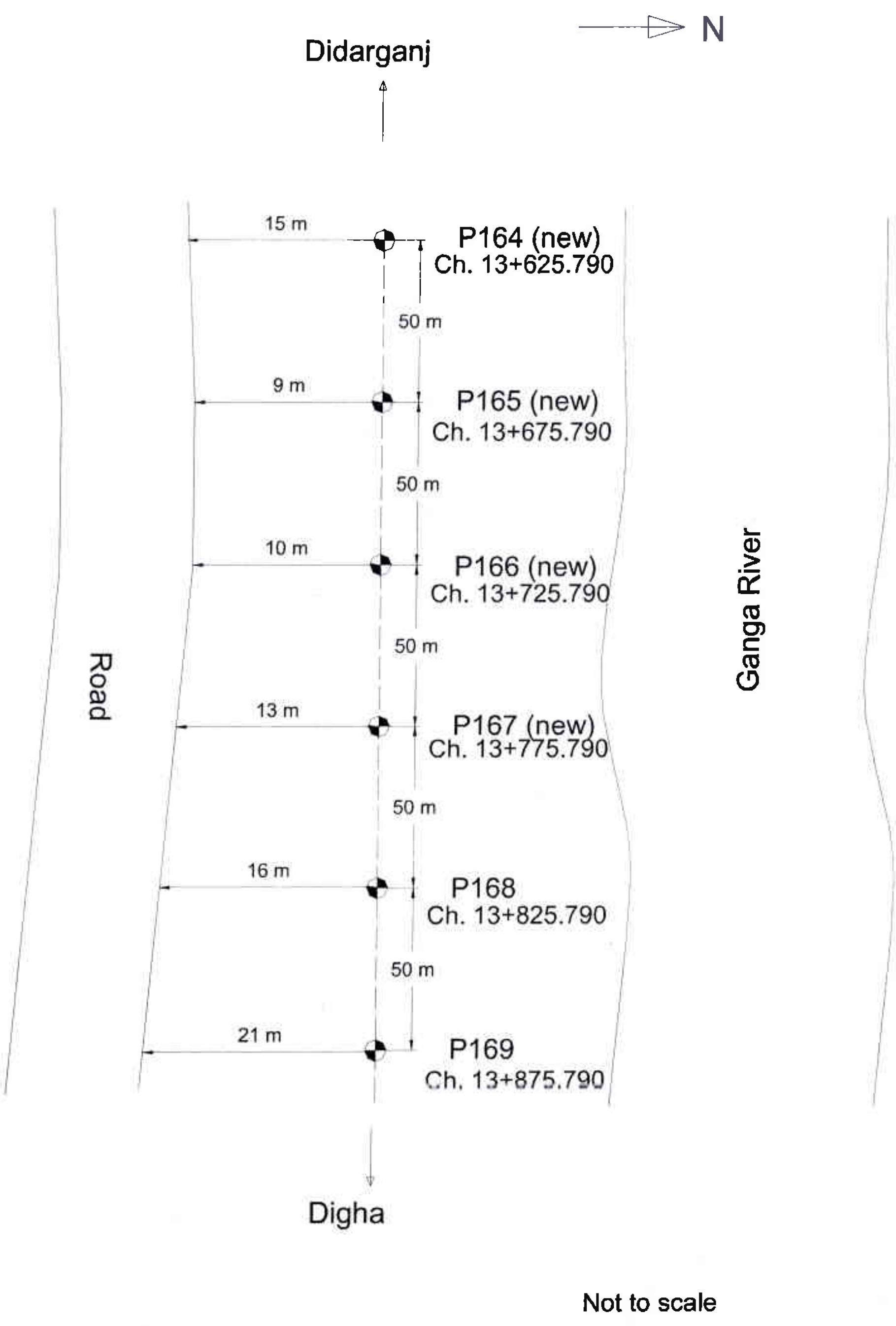
A Singh

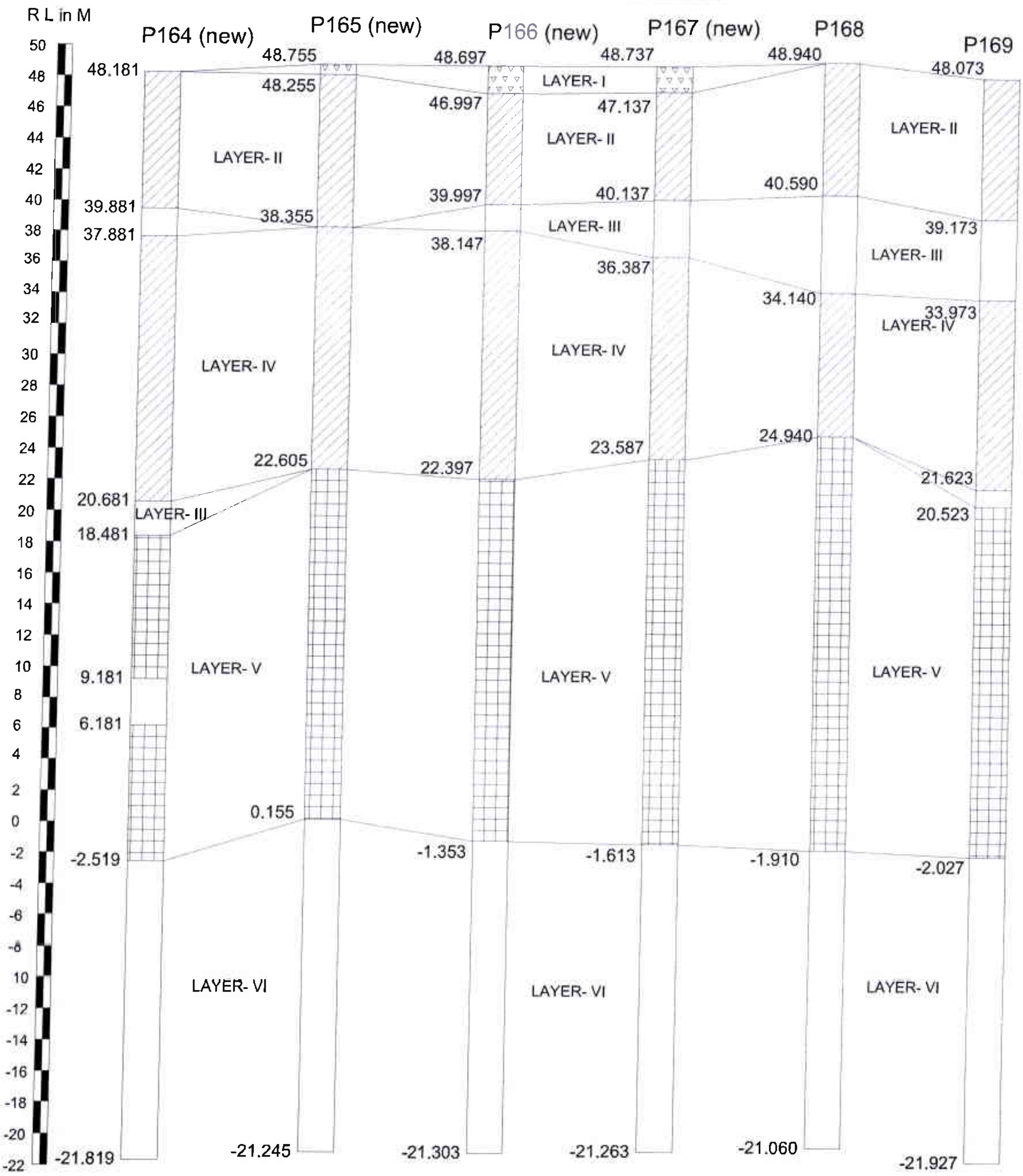
**Figure 1: Location of Boreholes**



**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

Fig 2 : SUB SOIL PROFILE




| LAYER | Description | Hatch | IS Symbol |
|---|---|---|---|
| LAYER- I | Brownish grey filled up soil with sand, bricks silt etc. | | SM, CL |
| LAYER- II | Soft to medium stiff yellowish grey / dark grey sandy clayey silt | | CI, CL, CL-ML |
| LAYER- III | Medium dense greyish micaceous silty fine sand | | SM |
| LAYER- IV | Stiff to very stiff brownish yellow / yellowish grey sandy silty clay with kankar | | CI, CL |
| LAYER- V | Very stiff to hard yellowish grey sandy clayey silt / silty clay with kankar and gravels | | CI, CL-ML |
| LAYER- VI | Very dense yellowish grey micaceous silty fine sand | | SM, SM-SP, SP |

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*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## FIELD BORE LOG

Project: Construction of Ganga Path at Patna

Type of Boring : Rotary

Dia. of Bore Hole : 150 mm

**Bore Hole No.** **P164 (new)**

R.L. (M) 48.181

| Coordinates | |
|---|---|
| Easting | Northing |
| 320863.8585 | 2833362.4339 |

**Chainage 13+625.790**

Commenced on 09.09.20

Completed on 13.09.20

G.W.T. 1.000 m

| DESCRIPTION | DEPTH | | COLLECTION OF SAMPLES | | | | | |
|---|---|---|---|---|---|---|---|---|
| | From (m) | To (m) | TYPE | DEPTH (M) | SPT 0 - 15 | SPT 15 - 30 | SPT 30 - 45 | N - Value |
| Soft to medium stiff brownish grey sandy silty clay | 0.00 | 8.30 | DS | 0.50 | | | | |
| | | | DS | 1.00 | | | | |
| | | | SPT | 1.50 | 1 | 1 | 2 | 3 |
| | | | SPT | 3.00 | 1 | 2 | 3 | 5 |
| | | | UDS | 4.00 | | | | |
| | | | SPT | 4.50 | 2 | 3 | 4 | 7 |
| | | | SPT | 6.00 | 2 | 2 | 4 | 6 |
| | | | UDS | 7.00 | | | | |
| | | | SPT | 7.50 | 2 | 3 | 4 | 7 |
| Medium dense greyish micaceous silty fine sand | 8.30 | 10.30 | SPT | 9.00 | 6 | 8 | 9 | 17 |
| | | | DS | 10.00 | | | | |
| Stiff to very stiff brownish yellow / yellowish grey sandy silty clay with kankar | 10.30 | 27.50 | SPT | 10.50 | 4 | 6 | 7 | 13 |
| | | | SPT | 12.00 | 3 | 7 | 7 | 14 |
| | | | UDS | 13.00 | | | | |
| | | | SPT | 13.50 | 4 | 8 | 9 | 17 |
| | | | SPT | 15.00 | 5 | 8 | 10 | 18 |
| | | | UDS | 16.00 | | | | |
| | | | SPT | 16.50 | 6 | 12 | 15 | 27 |
| | | | SPT | 18.00 | 7 | 10 | 12 | 22 |
| | | | UDS | 19.00 | | | | |
| | | | SPT | 19.50 | 7 | 11 | 13 | 24 |
| | | | SPT | 21.00 | 8 | 11 | 14 | 25 |
| | | | UDS | 22.00 | | | | |
| | | | SPT | [illegible] | [illegible] | [illegible] | 11 | 20 |
| | | | SPT | 24.00 | 4 | 7 | 9 | 16 |
| | | | UDS | 25.00 | | | | |
| | | | SPT | 25.50 | 5 | 10 | 12 | 22 |
| | | | SPT | 27.00 | 6 | 11 | 13 | 24 |
| Very dense yellowish grey micaceous silty fine sand | 27.50 | 29.70 | DS | 28.00 | | | | |
| | | | SPT | 28.50 | 16 | 35 | 45 | 80 |
| Very stiff to hard yellowish grey sandy silty clay with kankar and gravels | 29.70 | | SPT | 30.00 | 6 | 8 | 11 | 19 |
| | | | DS | 31.00 | | | | |
| | | | SPT | 31.50 | 7 | 17 | 22 | 39 |
| | | | SPT | 33.00 | 10 | 18 | 24 | 42 |
| | | | DS | 34.00 | | | | |

SPT - Standard Penetration Test | UDS - Undisturbed Samples | DS - Disturbed Samples

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*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**Bore Hole No.** **P164** **(contd.)**

| DESCRIPTION | DEPTH From (m) | DEPTH To (m) | TYPE | DEPTH (M) | SPT 0 - 15 | SPT 15 - 30 | SPT 30 - 45 | N - Value |
|---|---|---|---|---|---|---|---|---|
| | | | SPT | 34.50 | 9 | 19 | 25 | 44 |
| | | | SPT | 36.00 | 8 | 18 | 20 | 38 |
| | | | DS | 37.00 | | | | |
| | | 39.00 | SPT | 37.50 | 10 | 20 | 23 | 43 |
| Very dense yellowish grey micaceous silty fine sand | 39.00 | | SPT | 39.00 | 12 | 21 | 25 | 46 |
| | | | DS | 40.00 | | | | |
| | | 42.00 | SPT | 40.50 | 13 | 23 | 26 | 49 |
| Very stiff to hard yellowish grey sandy silty clay / clayey silt with kankar and gravels | 42.00 | | SPT | 42.00 | 15 | 25 | 50 | 75 |
| | | | DS | 43.00 | | | | |
| | | | SPT | 43.50 | 16 | 24 | 49 | 73 |
| | | | SPT | 45.00 | 16 | 27 | 35 | 62 |
| | | | DS | 46.00 | | | | |
| | | | SPT | 46.50 | 17 | 28 | 37 | 65 |
| | | | SPT | 48.00 | 16 | 25 | 45 | 70 |
| | | | DS | 49.00 | | | | |
| | | 50.70 | SPT | 49.50 | 16 | 26 | 47 | 73 |
| Very dense yellowish grey micaceous silty fine sand | 50.70 | | SPT | 51.00 | 35 | 51 for 15 cm | | >100 |
| | | | DS | 52.00 | | | | |
| | | | SPT | 52.50 | 40 | 52 for 13 cm | | >100 |
| | | | SPT | 54.00 | 53 for 10 cm | | | >100 |
| | | | DS | 55.00 | | | | |
| | | | SPT | 55.50 | 42 | 51 for 10 cm | | >100 |
| | | | SPT | 57.00 | 54 for 14 cm | | | >100 |
| | | | DS | 58.00 | | | | |
| | | | SPT | 58.50 | 53 for 13 cm | | | >100 |
| | | | SPT | 60.00 | 52 for 9 cm | | | >100 |
| | | | DS | 61.00 | | | | |
| | | | SPT | 61.50 | 53 for 8 cm | | | >100 |
| | | | SPT | 63.00 | 54 for 9 cm | | | >100 |
| | | | DS | 64.00 | | | | |
| | | | SPT | 64.50 | 53 for 7 cm | | | >100 |
| | | | SPT | 66.00 | 54 for 8 cm | | | >100 |
| | | | DS | 67.00 | | | | |
| | | | SPT | 67.50 | 51 for 14 cm | | | >100 |
| | | 70.00 | SPT | 70.00 | 52 for 15 cm | | | >100 |
| | Borehole terminated | | | | | | | |

SPT - Standard Penetration Test | UDS - Undisturbed Samples | DS - Disturbed Samples

**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**FIELD BORE LOG**

Project: Construction of Ganga Path at Patna

| | | | | |
|---|---|---|---|---|
| Type of Boring : | Rotary | Location : Badal Ghat | | **Chainage 13+675.790** |
| Dia. of Bore Hole : | 150 mm | Coordinates | | Commenced on 18.08.20 |
| **Bore Hole No.** | **P165 (new)** | Easting | Northing | Completed on 22.08.20 |
| R.L. (M) | 48.755 | 320907.5437 | 2833338.1218 | G.W.T. 1.350 m |

| DESCRIPTION | DEPTH From (m) | DEPTH To (m) | TYPE | DEPTH (M) | SPT 0 - 15 | SPT 15 - 30 | SPT 30 - 45 | N - Value |
|---|---|---|---|---|---|---|---|---|
| Brownish grey filled up soil | 0.00 | 0.50 | DS | 0.50 | | | | |
| Soft to medium stiff yellowish grey / dark grey sandy clayey silt | 0.50 | 10.40 | DS | 1.00 | | | | |
| | | | SPT | 1.50 | 1 | 2 | 2 | 4 |
| | | | SPT | 3.00 | 1 | 2 | 3 | 5 |
| | | | UDS | 4.00 | | | | |
| | | | SPT | 4.50 | 2 | 3 | 3 | 6 |
| | | | SPT | 6.00 | 2 | 2 | 2 | 4 |
| | | | UDS | 7.00 | | | | |
| | | | SPT | 7.50 | 3 | 3 | 3 | 6 |
| | | | SPT | 9.00 | 2 | 3 | 4 | 7 |
| | | | UDS | 10.00 | | | | |
| Stiff to very stiff brownish yellow / yellowish grey sandy silty clay with kankar | 10.40 | 26.15 | SPT | 10.50 | 5 | 5 | 6 | 11 |
| | | | SPT | 12.00 | 6 | 7 | 7 | 14 |
| | | | UDS | 13.00 | | | | |
| | | | SPT | 13.50 | 7 | 8 | 8 | 16 |
| | | | SPT | 15.00 | 4 | 5 | 7 | 12 |
| | | | UDS | 16.00 | | | | |
| | | | SPT | 16.50 | 5 | 6 | 7 | 13 |
| | | | SPT | 18.00 | 5 | 7 | 9 | 16 |
| | | | UDS | 19.00 | | | | |
| | | | SPT | 19.50 | 5 | 8 | 12 | 20 |
| | | | SPT | 21.00 | 6 | 9 | 13 | 22 |
| | | | UDS | 22.00 | | | | |
| | | | SPT | 22.50 | 7 | 9 | 14 | 23 |
| | | | SPT | 24.00 | 8 | 10 | 15 | 25 |
| | | | UDS | 25.00 | | | | |
| | | | SPT | 25.50 | 10 | 12 | 16 | 28 |
| Very stiff to hard yellowish grey sandy clayey silt / silty clay with kankar and gravels | 26.15 | | SPT | 27.00 | 5 | 12 | 19 | 31 |
| | | | UDS | 28.00 | | | | |
| | | | SPT | 28.50 | 9 | 14 | 21 | 35 |
| | | | SPT | 30.00 | 7 | 13 | 19 | 32 |
| | | | UDS | 31.00 | | | | |
| | | | SPT | 31.50 | 9 | 15 | 22 | 37 |
| | | | SPT | 33.00 | 11 | 17 | 24 | 41 |
| | | | DS | 34.00 | | | | |

SPT - Standard Penetration Test | UDS - Undisturbed Samples | DS - Disturbed Samples

ANAND RAJ INFRATECH PVT. LTD.

**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**Bore Hole No.** **P165** **(contd.)**

| DESCRIPTION | DEPTH | | COLLECTION OF SAMPLES | | | | | |
|---|---|---|---|---|---|---|---|---|
| | From (m) | To (m) | TYPE | DEPTH (M) | SPT 0 - 15 | SPT 15 - 30 | SPT 30 - 45 | N - Value |
| Very stiff to hard yellowish grey sandy silty clay with kankar and gravels | | | SPT | 34.50 | 12 | 18 | 26 | 44 |
| | | | SPT | 36.00 | 10 | 19 | 28 | 47 |
| | | | DS | 37.00 | | | | |
| | | | SPT | 37.50 | 14 | 21 | 30 | 51 |
| | | | SPT | 39.00 | 17 | 27 | 35 | 62 |
| | | | DS | 40.00 | | | | |
| | | | SPT | 40.50 | 19 | 29 | 37 | 66 |
| | | | SPT | 42.00 | 9 | 14 | 16 | 30 |
| | | | DS | 43.00 | | | | |
| | | | SPT | 43.50 | 18 | 27 | 30 | 57 |
| | | | SPT | 45.00 | 21 | 34 | 41 | 75 |
| | | | DS | 46.00 | | | | |
| | | | SPT | 46.50 | 16 | 18 | 21 | 39 |
| | | 48.60 | SPT | 48.00 | 6 | 12 | 17 | 29 |
| Very dense yellowish grey micaceous silty fine sand | 48.60 | | DS | 49.00 | | | | |
| | | | SPT | 49.50 | 7 | 13 | 18 | 31 |
| | | | SPT | 51.00 | 20 | 36 | 48 | 84 |
| | | | DS | 52.00 | | | | |
| | | | SPT | 52.50 | 29 | 38 | 49 | 87 |
| | | | SPT | 54.00 | 25 | 43 | 50 for 11 cm | >100 |
| | | | DS | 55.00 | | | | |
| | | | SPT | 55.50 | 27 | 30 | 52 for 14 cm | >100 |
| | | | SPT | 57.00 | | 57 for 10 cm | | >100 |
| | | | DS | 58.00 | | | | |
| | | | SPT | 58.50 | 48 | 55 for 9 cm | | >100 |
| | | | SPT | 60.00 | 49 | 54 for 7 cm | | >100 |
| | | | DS | 61.00 | | | | |
| | | | SPT | 61.50 | | 58 for 12 cm | | >100 |
| | | | SPT | 63.00 | | 61 for 10 cm | | >100 |
| | | | DS | 64.00 | | | | |
| | | | SPT | 64.50 | | 53 for 7 cm | | >100 |
| | | | SPT | 66.00 | | 50 for 5 cm | | >100 |
| | | | DS | 67.00 | | | | |
| | | | SPT | 67.50 | | 57 for 3 cm | | >100 |
| | | 70.00 | SPT | 70.00 | | 51 for 6 cm | | >100 |
| | Borehole terminated | | | | | | | |

SPT - Standard Penetration Test | UDS - Undisturbed Samples | DS - Disturbed Samples

**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

***FIELD BORE LOG***

Project: Construction of Ganga Path at Patna

| | | | | | |
|---|---|---|---|---|---|
| Type of Boring | : Rotary | Location : Mittan Ghat | | **Chainage 13+725.790** | |
| Dia. of Bore Hole : | 150 mm | Coordinates | | Commenced on | 28.08.20 |
| **Bore Hole No.** | **P166 (new)** | Easting | Northing | Completed on | 01.09.20 |
| R.L. (M) | 48.697 | 320952.3894 | 2833316.0233 | G.W.T. | 1.650 m |

| DESCRIPTION | DEPTH | | COLLECTION OF SAMPLES | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | SPT | | | N - Value |
| | From (m) | To (m) | TYPE | DEPTH (M) | 0 - 15 | 15 - 30 | 30 - 45 | |
| Brownish grey filled up soil with sand, bricks silt etc. | 0.00 | 1.70 | DS | 0.50 | | | | |
| | | | DS | 1.00 | | | | |
| Soft to medium stiff yellowish grey / dark grey sandy clayey silt | 1.70 | 8.70 | SPT | 1.50 | 1 | 2 | 3 | 5 |
| | | | SPT | 3.00 | 1 | 1 | 2 | 3 |
| | | | UDS | 4.00 | | | | |
| | | | SPT | 4.50 | 2 | 2 | 3 | 5 |
| | | | SPT | 6.00 | 1 | 1 | 1 | 2 |
| | | | UDS | 7.00 | | | | |
| | | | SPT | 7.50 | 2 | 2 | 3 | 5 |
| Medium dense greyish micaceous silty fine sand | 8.70 | 10.55 | SPT | 9.00 | 3 | 4 | 4 | 8 |
| | | | DS | 10.00 | | | | |
| | | | SPT | 10.50 | 5 | 6 | 7 | 13 |
| Stiff to very stiff brownish yellow / yellowish grey sandy silty clay with kankar | 10.55 | 26.30 | SPT | 12.00 | 3 | 4 | 5 | 9 |
| | | | UDS | 13.00 | | | | |
| | | | SPT | 13.50 | 3 | 5 | 7 | 12 |
| | | | SPT | 15.00 | 5 | 11 | 12 | 23 |
| | | | UDS | 16.00 | | | | |
| | | | SPT | 16.50 | 6 | 12 | 13 | 25 |
| | | | SPT | 18.00 | 5 | 13 | 14 | 27 |
| | | | UDS | 19.00 | | | | |
| | | | SPT | 19.50 | 4 | 13 | 15 | 28 |
| | | | SPT | 21.00 | 4 | 14 | 15 | 29 |
| | | | UDS | 22.00 | | | | |
| | | | SPT | 22.50 | 6 | 8 | 9 | 17 |
| | | | SPT | 24.00 | 5 | 9 | 10 | 19 |
| | | | UDS | 25.00 | | | | |
| | | | SPT | 25.50 | 7 | 10 | 12 | 22 |
| Very stiff to hard brownish yellow sandy silty clay / clayey silt with kankar | 26.30 | | SPT | 27.00 | 12 | 18 | 20 | 38 |
| | | | DS | 28.00 | | | | |
| | | | SPT | 28.50 | 20 | 33 | 33 | 66 |
| | | | SPT | 30.00 | 19 | 34 | 35 | 69 |
| | | | DS | 31.00 | | | | |
| | | | SPT | 31.50 | 12 | 22 | 28 | 50 |
| | | | SPT | 33.00 | 14 | 24 | 31 | 55 |
| | | | DS | 34.00 | | | | |

SPT - Standard Penetration Test | UDS - Undisturbed Samples | DS - Disturbed Samples

**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

| **Bore Hole No.** **P166** **(contd.)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| DESCRIPTION | DEPTH | | COLLECTION OF SAMPLES | | | | | |
| | | | | | SPT | | | N - Value |
| | From (m) | To (m) | TYPE | DEPTH (M) | 0 - 15 | 15 - 30 | 30 - 45 | |
| Very stiff to hard brownish yellow sandy silty clay / clayey silt with kankar | | 50.05 | SPT | 34.50 | 10 | 25 | 31 | 56 |
| | | | SPT | 36.00 | 10 | 15 | 26 | 41 |
| | | | DS | 37.00 | | | | |
| | | | SPT | 37.50 | 13 | 16 | 28 | 44 |
| | | | SPT | 39.00 | 16 | 23 | 27 | 50 |
| | | | DS | 40.00 | | | | |
| | | | SPT | 40.50 | 17 | 15 | 26 | 41 |
| | | | SPT | 42.00 | 18 | 20 | 29 | 49 |
| | | | DS | 43.00 | | | | |
| | | | SPT | 43.50 | 16 | 21 | 30 | 51 |
| | | | SPT | 45.00 | 18 | 27 | 35 | 62 |
| | | | DS | 46.00 | | | | |
| | | | SPT | 46.50 | 15 | 26 | 34 | 60 |
| | | | SPT | 48.00 | 16 | 22 | 30 | 52 |
| | | | DS | 49.00 | | | | |
| | | | SPT | 49.50 | 17 | 25 | 32 | 57 |
| Very dense yellowish grey micaceous silty fine sand | 50.05 | 70.00 | SPT | 51.00 | 22 | 50 for 14 cm | | >100 |
| | | | DS | 52.00 | | | | |
| | | | SPT | 52.50 | 24 | 52 for 13 cm | | >100 |
| | | | SPT | 54.00 | | 53 for 14 cm | | >100 |
| | | | DS | 55.00 | | | | |
| | | | SPT | 55.50 | 35 | 53 for 13 cm | | >100 |
| | | | SPT | 57.00 | 24 | 51 for 12 cm | | >100 |
| | | | DS | 58.00 | | | | |
| | | | SPT | 58.50 | 31 | 53 for 10 cm | | >100 |
| | | | SPT | 60.00 | 43 | 51 for 7 cm | | >100 |
| | | | DS | 61.00 | | | | |
| | | | SPT | 61.50 | 43 | 53 for 9 cm | | >100 |
| | | | SPT | 63.00 | | 51 for 14 cm | | >100 |
| | | | DS | 64.00 | | | | |
| | | | SPT | 64.50 | | 52 for 10 cm | | >100 |
| | | | SPT | 66.00 | | 53 for 11 cm | | >100 |
| | | | DS | 67.00 | | | | |
| | | | SPT | 67.50 | | 54 for 9 cm | | >100 |
| | | | SPT | 70.00 | | 52 for 13 cm | | >100 |
| | Borehole terminated | | | | | | | |
| SPT - Standard Penetration Test | UDS - Undisturbed Samples | | | | DS - Disturbed Samples | | | |

**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## FIELD BORE LOG

Project: Construction of Ganga Path at Patna

| | | | |
|---|---|---|---|
| Type of Boring : Rotary | Location : Mittan Ghat | | **Chainage 13+775.790** |
| Dia. of Bore Hole : 150 mm | Coordinates | | Commenced on 23.08.20 |
| **Bore Hole No. P167 (new)** | Easting | Northing | Completed on 27.08.20 |
| R.L. (M) 48.737 | 320998.2836 | 2833296.1939 | G.W.T. 1.500 m |

| DESCRIPTION | DEPTH From (m) | DEPTH To (m) | TYPE | DEPTH (M) | SPT 0 - 15 | SPT 15 - 30 | SPT 30 - 45 | N - Value |
|---|---|---|---|---|---|---|---|---|
| Brownish grey filled up soil | 0.00 | 1.60 | DS | 0.50 | | | | |
| | | | DS | 1.00 | | | | |
| Soft to medium stiff yellowish grey / dark grey sandy silty clay | 1.60 | 8.60 | SPT | 1.50 | 2 | 3 | 3 | 6 |
| | | | SPT | 3.00 | 2 | 3 | 4 | 7 |
| | | | UDS | 4.00 | | | | |
| | | | SPT | 4.50 | 3 | 3 | 3 | 6 |
| | | | SPT | 6.00 | 1 | 1 | 2 | 3 |
| | | | UDS | 7.00 | | | | |
| | | | SPT | 7.50 | 1 | 1 | 1 | 2 |
| Medium dense greyish micaceous silty fine sand | 8.60 | 12.35 | SPT | 9.00 | 10 | 8 | 8 | 16 |
| | | | DS | 10.00 | | | | |
| | | | SPT | 10.50 | 2 | 6 | 12 | 18 |
| | | | SPT | 12.00 | 4 | 9 | 6 | 15 |
| Stiff to very stiff brownish yellow / yellowish grey sandy silty clay with kankar | 12.35 | 25.15 | UDS | 13.00 | | | | |
| | | | SPT | 13.50 | 5 | 6 | 8 | 14 |
| | | | SPT | 15.00 | 6 | 10 | 15 | 25 |
| | | | UDS | 16.00 | | | | |
| | | | SPT | 16.50 | 6 | 11 | 16 | 27 |
| | | | SPT | 18.00 | 7 | 8 | 8 | 16 |
| | | | UDS | 19.00 | | | | |
| | | | SPT | 19.50 | 7 | 8 | 10 | 18 |
| | | | SPT | 21.00 | 6 | 10 | 13 | 23 |
| | | | UDS | 22.00 | | | | |
| | | | SPT | 22.50 | 4 | 6 | 7 | 13 |
| | | | SPT | 24.00 | 4 | 5 | 7 | 12 |
| | | | UDS | 25.00 | | | | |
| Very stiff to hard brownish yellow sandy silty clay with kankar | 25.15 | | SPT | 25.50 | 9 | 10 | 11 | 21 |
| | | | SPT | 27.00 | 11 | 13 | 17 | 30 |
| | | | UDS | 28.00 | | | | |
| | | | SPT | 28.50 | 9 | 15 | 19 | 34 |
| | | | SPT | 30.00 | 7 | 17 | 21 | 38 |
| | | | DS | 31.00 | | | | |
| | | | SPT | 31.50 | 11 | 16 | 23 | 39 |
| | | | SPT | 33.00 | 13 | 19 | 25 | 44 |
| | | | DS | 34.00 | | | | |

SPT - Standard Penetration Test | UDS - Undisturbed Samples | DS - Disturbed Samples

**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

| Bore Hole No. **P167** (contd.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| DESCRIPTION | DEPTH | | COLLECTION OF SAMPLES | | | | | |
| | | | | | SPT | | | |
| | From (m) | To (m) | TYPE | DEPTH (M) | 0 - 15 | 15 - 30 | 30 - 45 | N - Value |
| Very stiff to hard brownish yellow sandy silty clay with kankar | | | SPT | 34.50 | 5 | 6 | 10 | 16 |
| | | | SPT | 36.00 | 6 | 7 | 11 | 18 |
| | | | UDS | 37.00 | | | | |
| | | | SPT | 37.50 | 9 | 11 | 14 | 25 |
| | | | SPT | 39.00 | 12 | 18 | 21 | 39 |
| | | | DS | 40.00 | | | | |
| | | | SPT | 40.50 | 7 | 12 | 17 | 29 |
| | | | SPT | 42.00 | 10 | 16 | 20 | 36 |
| | | | DS | 43.00 | | | | |
| | | | SPT | 43.50 | 9 | 17 | 15 | 32 |
| | | | SPT | 45.00 | 17 | 19 | 23 | 42 |
| | | | DS | 46.00 | | | | |
| | | | SPT | 46.50 | 19 | 21 | 24 | 45 |
| | | | SPT | 48.00 | 18 | 21 | 27 | 48 |
| | | | DS | 49.00 | | | | |
| | | 50.35 | SPT | 49.50 | 11 | 24 | 30 | 54 |
| Very dense yellowish grey micaceous silty fine sand | 50.35 | | SPT | 51.00 | 24 | 50 for 14 cm | | >100 |
| | | | DS | 52.00 | | | | |
| | | | SPT | 52.50 | 30 | 53 for 12 cm | | >100 |
| | | | SPT | 54.00 | 38 | 56 for 10 cm | | >100 |
| | | | DS | 55.00 | | | | |
| | | | SPT | 55.50 | 29 | 53 for 11 cm | | >100 |
| | | | SPT | 57.00 | 35 | 56 for 7 cm | | >100 |
| | | | DS | 58.00 | | | | |
| | | | SPT | 58.50 | 40 | 51 for 7 cm | | >100 |
| | | | SPT | 60.00 | 44 | 50 for 5 cm | | >100 |
| | | | DS | 61.00 | | | | |
| | | | SPT | 61.50 | 28 | 52 for 13 cm | | >100 |
| | | | SPT | 63.00 | 30 | 54 for 10 cm | | >100 |
| | | | DS | 64.00 | | | | |
| | | | SPT | 64.50 | 31 | 52 for 13 cm | | >100 |
| | | | SPT | 66.00 | 48 | 56 for 9 cm | | >100 |
| | | | DS | 67.00 | | | | |
| | | | SPT | 67.50 | 56 for 6 cm | | | >100 |
| | | 70.00 | SPT | 70.00 | 53 for 12 cm | | | >100 |
| | Borehole terminated | | | | | | | |
| SPT - Standard Penetration Test | UDS - Undisturbed Samples | | DS - Disturbed Samples | | | | | |

**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**FIELD BORE LOG**

Project: Construction of Ganga Path at Patna

| | | | |
|---|---|---|---|
| Type of Boring : | Rotary | | **Chainage 13+825.790** |
| Dia. of Bore Hole : | 150 mm | Coordinates | Commenced on 03.09.20 |
| **Bore Hole No.** | **P168** | Easting: 321045.1114 / Northing: 2833278.6829 | Completed on 07.09.20 |
| R.L. (M) | 48.940 | | G.W.T. 1.000 m |

| DESCRIPTION | DEPTH From (m) | DEPTH To (m) | TYPE | DEPTH (M) | SPT 0 - 15 | SPT 15 - 30 | SPT 30 - 45 | N - Value |
|---|---|---|---|---|---|---|---|---|
| Soft to medium stiff reddish brown / dark grey sandy silty clay | 0.00 | 8.35 | DS | 0.50 | | | | |
| | | | DS | 1.00 | | | | |
| | | | SPT | 1.50 | 1 | 2 | 2 | 4 |
| | | | SPT | 3.00 | 1 | 2 | 3 | 5 |
| | | | UDS | 4.00 | | | | |
| | | | SPT | 4.50 | 2 | 2 | 3 | 5 |
| | | | SPT | 6.00 | 2 | 2 | 2 | 4 |
| | | | UDS | 7.00 | | | | |
| | | | SPT | 7.50 | 2 | 2 | 2 | 4 |
| Medium dense greyish micaceous silty fine sand | 8.35 | 14.80 | SPT | 9.00 | 7 | 12 | 12 | 24 |
| | | | DS | 10.00 | | | | |
| | | | SPT | 10.50 | 3 | 3 | 3 | 6 |
| | | | SPT | 12.00 | 7 | 9 | 12 | 21 |
| | | | DS | 13.00 | | | | |
| | | | SPT | 13.50 | 3 | 6 | 8 | 14 |
| Stiff to very stiff brownish yellow / yellowish grey sandy silty clay with kankar | 14.80 | 24.00 | SPT | 15.00 | 5 | 9 | 12 | 21 |
| | | | UDS | 16.00 | | | | |
| | | | SPT | 16.50 | 4 | 7 | 10 | 17 |
| | | | SPT | 18.00 | 5 | 9 | 11 | 20 |
| | | | UDS | 19.00 | | | | |
| | | | SPT | 19.50 | 3 | 6 | 10 | 16 |
| | | | SPT | 21.00 | 4 | 6 | 11 | 17 |
| | | | UDS | 22.00 | | | | |
| | | | SPT | 22.50 | 5 | 6 | 9 | 15 |
| Very stiff to hard brownish yellow sandy silty clay with kankar | 24.00 | | SPT | 24.00 | 6 | 7 | 9 | 16 |
| | | | UDS | 25.00 | | | | |
| | | | SPT | 25.50 | 7 | 8 | 11 | 19 |
| | | | SPT | 27.00 | 6 | 9 | 12 | 21 |
| | | | UDS | 28.00 | | | | |
| | | | SPT | 28.50 | 5 | 12 | 21 | 33 |
| | | | SPT | 30.00 | 9 | 15 | 23 | 38 |
| | | | UDS | 31.00 | | | | |
| | | | SPT | 31.50 | 10 | 14 | 23 | 37 |
| | | | SPT | 33.00 | 9 | 16 | 25 | 41 |
| | | | DS | 34.00 | | | | |

SPT - Standard Penetration Test | UDS - Undisturbed Samples | DS - Disturbed Samples

ANAND RAJ INFRATECH PVT. LTD.

**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**Bore Hole No.** **P168** **(contd.)**

| DESCRIPTION | DEPTH | | COLLECTION OF SAMPLES | | | | | |
|---|---|---|---|---|---|---|---|---|
| | From (m) | To (m) | TYPE | DEPTH (M) | SPT 0 - 15 | SPT 15 - 30 | SPT 30 - 45 | N - Value |
| Very stiff to hard brownish yellow sandy silty clay / clayey silt with kankar | | | SPT | 34.50 | 10 | 17 | 26 | 43 |
| | | | SPT | 36.00 | 11 | 14 | 17 | 31 |
| | | | UDS | 37.00 | | | | |
| | | | SPT | 37.50 | 13 | 18 | 27 | 45 |
| | | | SPT | 39.00 | 10 | 20 | 26 | 46 |
| | | | DS | 40.00 | | | | |
| | | | SPT | 40.50 | 11 | 21 | 27 | 48 |
| | | | SPT | 42.00 | 10 | 19 | 23 | 42 |
| | | | DS | 43.00 | | | | |
| | | | SPT | 43.50 | 11 | 21 | 24 | 45 |
| | | | SPT | 45.00 | 15 | 18 | 21 | 39 |
| | | | DS | 46.00 | | | | |
| | | | SPT | 46.50 | 18 | 20 | 22 | 42 |
| | | | SPT | 48.00 | 14 | 21 | 24 | 45 |
| | | | DS | 49.00 | | | | |
| | | 50.85 | SPT | 49.50 | 16 | 21 | 26 | 47 |
| Very dense yellowish grey micaceous silty fine sand | 50.85 | | SPT | 51.00 | 21 | 25 | 51 for 10 cm | >100 |
| | | | DS | 52.00 | | | | |
| | | | SPT | 52.50 | 22 | 35 | 53 for 8 cm | >100 |
| | | | SPT | 54.00 | 24 | 42 | 52 for 7 cm | >100 |
| | | | DS | 55.00 | | | | |
| | | | SPT | 55.50 | 30 | 44 | 54 for 6 cm | >100 |
| | | | SPT | 57.00 | 33 | 53 for 10 cm | | >100 |
| | | | DS | 58.00 | | | | |
| | | | SPT | 58.50 | 38 | 52 for 7 cm | | >100 |
| | | | SPT | 60.00 | 40 | 53 for 6 cm | | >100 |
| | | | DS | 61.00 | | | | |
| | | | SPT | 61.50 | 53 for 13 cm | | | >100 |
| | | | SPT | 63.00 | 42 | 54 for 5 cm | | >100 |
| | | | DS | 64.00 | | | | |
| | | | SPT | 64.50 | 54 for 11 cm | | | >100 |
| | | | SPT | 66.00 | 51 for 9 cm | | | >100 |
| | | | DS | 67.00 | | | | |
| | | | SPT | 67.50 | 53 for 8 cm | | | >100 |
| | | 70.00 | SPT | 70.00 | 54 for 10 cm | | | >100 |
| | Borehole terminated | | | | | | | |

SPT - Standard Penetration Test | UDS - Undisturbed Samples | DS - Disturbed Samples

**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## FIELD BORE LOG

Project: Construction of Ganga Path at Patna

| | | | |
|---|---|---|---|
| Type of Boring : Rotary | | | Chainage 13+875.790 |
| Dia. of Bore Hole : 150 mm | Coordinates | | Commenced on 15.09.20 |
| **Bore Hole No.** **P169** | Easting | Northing | Completed on 20.09.20 |
| R.L. (M) 48.073 | 321092.7174 | 2833263.4076 | G.W.T. 3.000 m |

| DESCRIPTION | DEPTH | | COLLECTION OF SAMPLES | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | SPT | | | N - Value |
| | From (m) | To (m) | TYPE | DEPTH (M) | 0 - 15 | 15 - 30 | 30 - 45 | |
| Soft to medium stiff brownish grey sandy silt / silty clay | 0.00 | 8.90 | DS | 0.50 | | | | |
| | | | DS | 1.00 | | | | |
| | | | SPT | 1.50 | 1 | 1 | 2 | 3 |
| | | | SPT | 3.00 | 1 | 2 | 2 | 4 |
| | | | UDS | 4.00 | | | | |
| | | | SPT | 4.50 | 1 | 2 | 2 | 4 |
| | | | SPT | 6.00 | 1 | 1 | 2 | 3 |
| | | | UDS | 7.00 | | | | |
| | | | SPT | 7.50 | 1 | 2 | 2 | 4 |
| Medium dense greyish micaceous silty fine sand | 8.90 | 14.10 | SPT | 9.00 | 5 | 6 | 8 | 14 |
| | | | DS | 10.00 | | | | |
| | | | SPT | 10.50 | 6 | 8 | 10 | 18 |
| | | | SPT | 12.00 | 7 | 11 | 14 | 25 |
| | | | DS | 13.00 | | | | |
| | | | SPT | 13.50 | 6 | 12 | 15 | 27 |
| Stiff to very stiff brownish yellow / yellowish grey sandy silty clay with kankar | 14.10 | 26.45 | SPT | 15.00 | 4 | 7 | 10 | 17 |
| | | | UDS | 16.00 | | | | |
| | | | SPT | 16.50 | 5 | 8 | 11 | 19 |
| | | | SPT | 18.00 | 11 | 29 | 30 | 59 |
| | | | UDS | 19.00 | | | | |
| | | | SPT | 19.50 | 7 | 9 | 13 | 22 |
| | | | SPT | 21.00 | 8 | 10 | 14 | 24 |
| | | | UDS | 22.00 | | | | |
| | | | SPT | 22.50 | 6 | 8 | 9 | 17 |
| | | | SPT | 24.00 | 7 | 10 | 11 | 21 |
| | | | UDS | 25.00 | | | | |
| | | | SPT | 25.50 | 11 | 15 | 20 | 35 |
| Very dense yellowish grey micaceous silty fine sand | 26.45 | 27.55 | SPT | 27.00 | 10 | 22 | 30 | 52 |
| Very stiff to hard brownish yellow sandy silty clay with kankar | 27.55 | | UDS | 28.00 | | | | |
| | | | SPT | 28.50 | 15 | 16 | 25 | 41 |
| | | | SPT | 30.00 | 17 | 18 | 26 | 44 |
| | | | UDS | 31.00 | | | | |
| | | | SPT | 31.50 | 15 | 25 | 32 | 57 |
| | | | SPT | 33.00 | 16 | 21 | 30 | 51 |
| | | | DS | 34.00 | | | | |

| | | |
|---|---|---|
| SPT - Standard Penetration Test | UDS - Undisturbed Samples | DS - Disturbed Samples |

**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

| Bore Hole No. **P169** (contd.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| DESCRIPTION | DEPTH | | COLLECTION OF SAMPLES | | | | | |
| | From (m) | To (m) | TYPE | DEPTH (M) | SPT 0 - 15 | SPT 15 - 30 | SPT 30 - 45 | N - Value |
| Very stiff to hard brownish yellow sandy silty clay / clayey silt with kankar | | | SPT | 34.50 | 10 | 14 | 15 | 29 |
| | | | SPT | 36.00 | 8 | 7 | 10 | 17 |
| | | | UDS | 37.00 | | | | |
| | | | SPT | 37.50 | 9 | 13 | 15 | 28 |
| | | | SPT | 39.00 | 10 | 16 | 20 | 36 |
| | | | UDS | 40.00 | | | | |
| | | | SPT | 40.50 | 21 | 24 | 26 | 50 |
| | | | SPT | 42.00 | 22 | 25 | 28 | 53 |
| | | | DS | 43.00 | | | | |
| | | | SPT | 43.50 | 18 | 26 | 35 | 61 |
| | | | SPT | 45.00 | 17 | 23 | 30 | 53 |
| | | | DS | 46.00 | | | | |
| | | | SPT | 46.50 | 15 | 20 | 31 | 51 |
| | | | SPT | 48.00 | 12 | 22 | 26 | 48 |
| | | | DS | 49.00 | | | | |
| | | 50.10 | SPT | 49.50 | 10 | 22 | 28 | 50 |
| Very dense yellowish grey micaceous silty fine sand with kankar | 50.10 | | SPT | 51.00 | 36 | 52 | 52 for 10 cm | >100 |
| | | | DS | 52.00 | | | | |
| | | | SPT | 52.50 | 32 | 53 | 53 for 9 cm | >100 |
| | | | SPT | 54.00 | 34 | 52 | 52 for 13 cm | >100 |
| | | | DS | 55.00 | | | | |
| | | | SPT | 55.50 | 17 | 24 | 34 | 58 |
| | | | SPT | 57.00 | 16 | 26 | 35 | 61 |
| | | | DS | 58.00 | | | | |
| | | | SPT | 58.50 | 32 | 54 | 54 for 11 cm | >100 |
| | | | SPT | 60.00 | 35 | 55 | 55 for 10 cm | >100 |
| | | | DS | 61.00 | | | | |
| | | | SPT | 61.50 | 37 | 52 | 52 for 9 cm | >100 |
| | | | SPT | 63.00 | 40 | 53 | 53 for 10 cm | >100 |
| | | | DS | 64.00 | | | | |
| | | | SPT | 64.50 | 53 for 12 cm | | | >100 |
| | | | SPT | 66.00 | 51 for 9 cm | | | >100 |
| | | | DS | 67.00 | | | | |
| | | | SPT | 67.50 | 53 for 13 cm | | | >100 |
| | | 70.00 | SPT | 70.00 | 54 for 9 cm | | | >100 |
| | Borehole terminated | | | | | | | |
| SPT - Standard Penetration Test | UDS - Undisturbed Samples | | DS - Disturbed Samples | | | | | |

ANAND RAJ INFRATECH PVT. LTD.

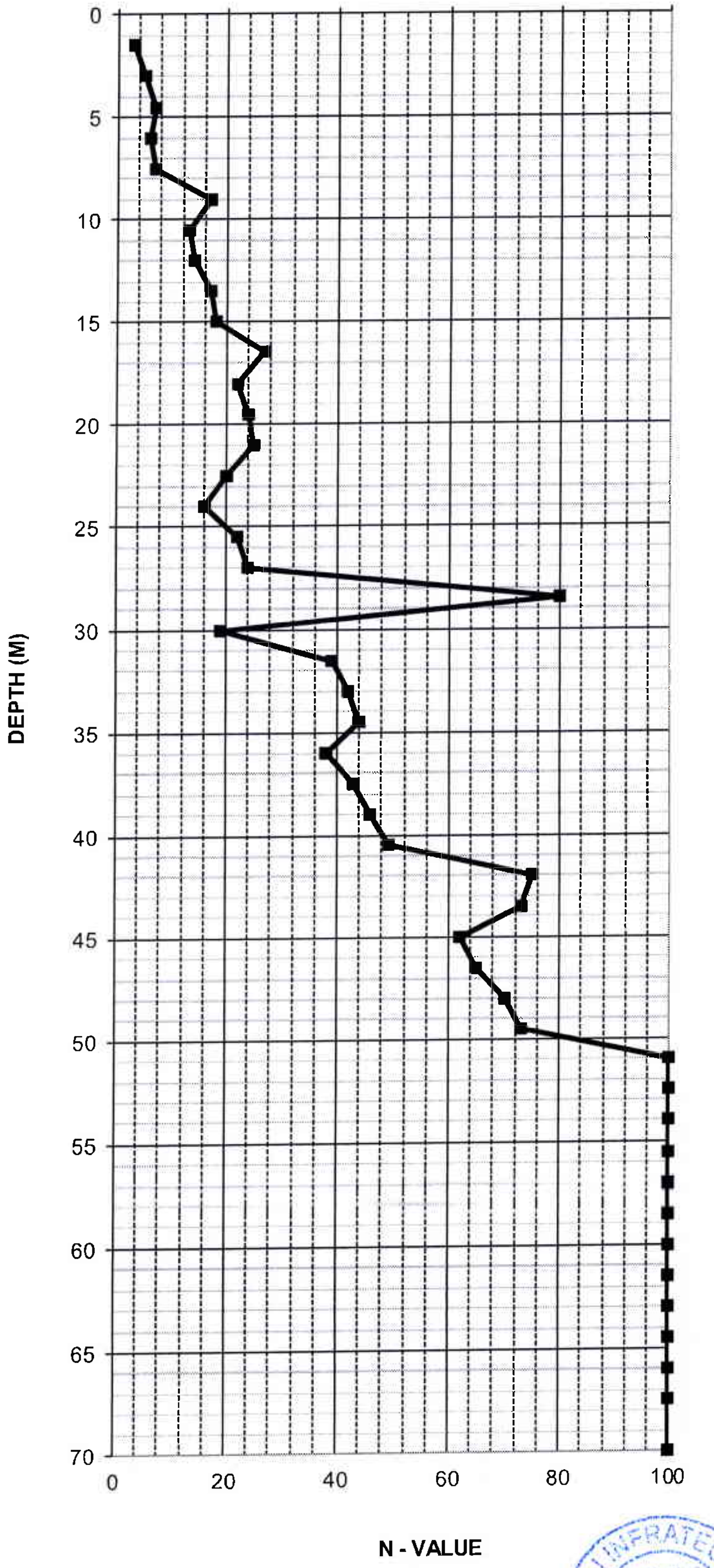
A Singh

**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

FIELD 'N' VALUE FOR BORE HOLE NO. P164

| DEPTH (m) | Field N Value |
|---|---|
| 1.50 | 3 |
| 3.00 | 5 |
| 4.50 | 7 |
| 6.00 | 6 |
| 7.50 | 7 |
| 9.00 | 17 |
| 10.50 | 13 |
| 12.00 | 14 |
| 13.50 | 17 |
| 15.00 | 18 |
| 16.50 | 27 |
| 18.00 | 22 |
| 19.50 | 24 |
| 21.00 | 25 |
| 22.50 | 20 |
| 24.00 | 16 |
| 25.50 | 22 |
| 27.00 | 24 |
| 28.50 | 80 |
| 30.00 | 19 |
| 31.50 | 39 |
| 33.00 | 42 |
| 34.50 | 44 |
| 36.00 | 38 |
| 37.50 | 43 |
| 39.00 | 46 |
| 40.50 | 49 |
| 42.00 | 75 |
| 43.50 | 73 |
| 45.00 | 62 |
| 46.50 | 65 |
| 48.00 | 70 |
| 49.50 | 73 |
| 51.00 | 100 |
| 52.50 | 100 |
| 54.00 | 100 |
| 55.50 | 100 |
| 57.00 | 100 |
| 58.50 | 100 |
| 60.00 | 100 |
| 61.50 | 100 |
| 63.00 | 100 |
| 64.50 | 100 |
| 66.00 | 100 |
| 67.50 | 100 |
| 70.00 | 100 |

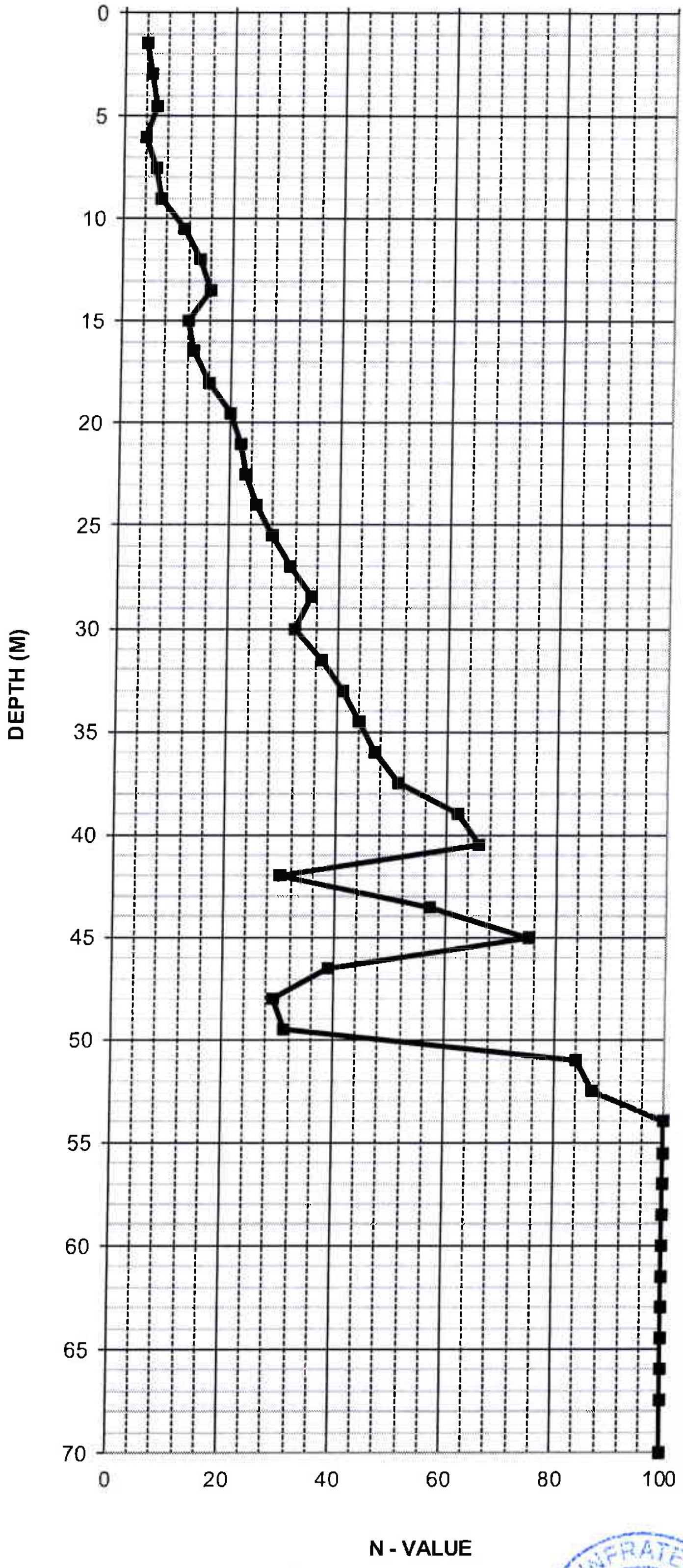


**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

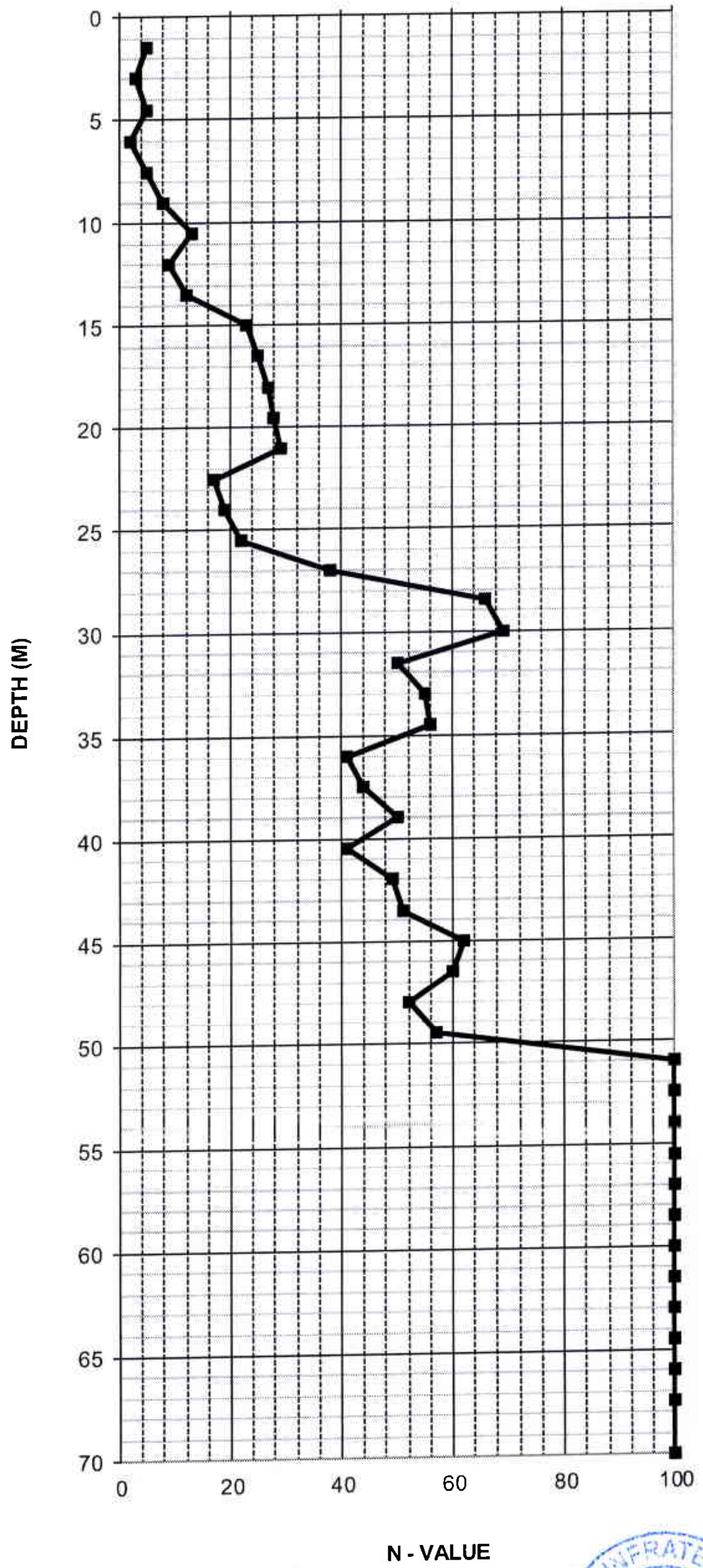
**FIELD 'N' VALUE FOR BORE HOLE NO. P165**

| DEPTH (m) | Field N Value |
|---|---|
| 1.50 | 4 |
| 3.00 | 5 |
| 4.50 | 6 |
| 6.00 | 4 |
| 7.50 | 6 |
| 9.00 | 7 |
| 10.50 | 11 |
| 12.00 | 14 |
| 13.50 | 16 |
| 15.00 | 12 |
| 16.50 | 13 |
| 18.00 | 16 |
| 19.50 | 20 |
| 21.00 | 22 |
| 22.50 | 23 |
| 24.00 | 25 |
| 25.50 | 28 |
| 27.00 | 31 |
| 28.50 | 35 |
| 30.00 | 32 |
| 31.50 | 37 |
| 33.00 | 41 |
| 34.50 | 44 |
| 36.00 | 47 |
| 37.50 | 51 |
| 39.00 | 62 |
| 40.50 | 66 |
| 42.00 | 30 |
| 43.50 | 57 |
| 45.00 | 75 |
| 46.50 | 39 |
| 48.00 | 29 |
| 49.50 | 31 |
| 51.00 | 84 |
| 52.50 | 87 |
| 54.00 | 100 |
| 55.50 | 100 |
| 57.00 | 100 |
| 58.50 | 100 |
| 60.00 | 100 |
| 61.50 | 100 |
| 63.00 | 100 |
| 64.50 | 100 |
| 66.00 | 100 |
| 67.50 | 100 |
| 70.00 | 100 |



## FIELD 'N' VALUE FOR BORE HOLE NO. P166

| DEPTH (m) | Field N Value |
|---|---|
| 1.50 | 5 |
| 3.00 | 3 |
| 4.50 | 5 |
| 6.00 | 2 |
| 7.50 | 5 |
| 9.00 | 8 |
| 10.50 | 13 |
| 12.00 | 9 |
| 13.50 | 12 |
| 15.00 | 23 |
| 16.50 | 25 |
| 18.00 | 27 |
| 19.50 | 28 |
| 21.00 | 29 |
| 22.50 | 17 |
| 24.00 | 19 |
| 25.50 | 22 |
| 27.00 | 38 |
| 28.50 | 66 |
| 30.00 | 69 |
| 31.50 | 50 |
| 33.00 | 55 |
| 34.50 | 56 |
| 36.00 | 41 |
| 37.50 | 44 |
| 39.00 | 50 |
| 40.50 | 41 |
| 42.00 | 49 |
| 43.50 | 51 |
| 45.00 | 62 |
| 46.50 | 60 |
| 48.00 | 52 |
| 49.50 | 57 |
| 51.00 | 100 |
| 52.50 | 100 |
| 54.00 | 100 |
| 55.50 | 100 |
| 57.00 | 100 |
| 58.50 | 100 |
| 60.00 | 100 |
| 61.50 | 100 |
| 63.00 | 100 |
| 64.50 | 100 |
| 66.00 | 100 |
| 67.50 | 100 |
| 70.00 | 100 |

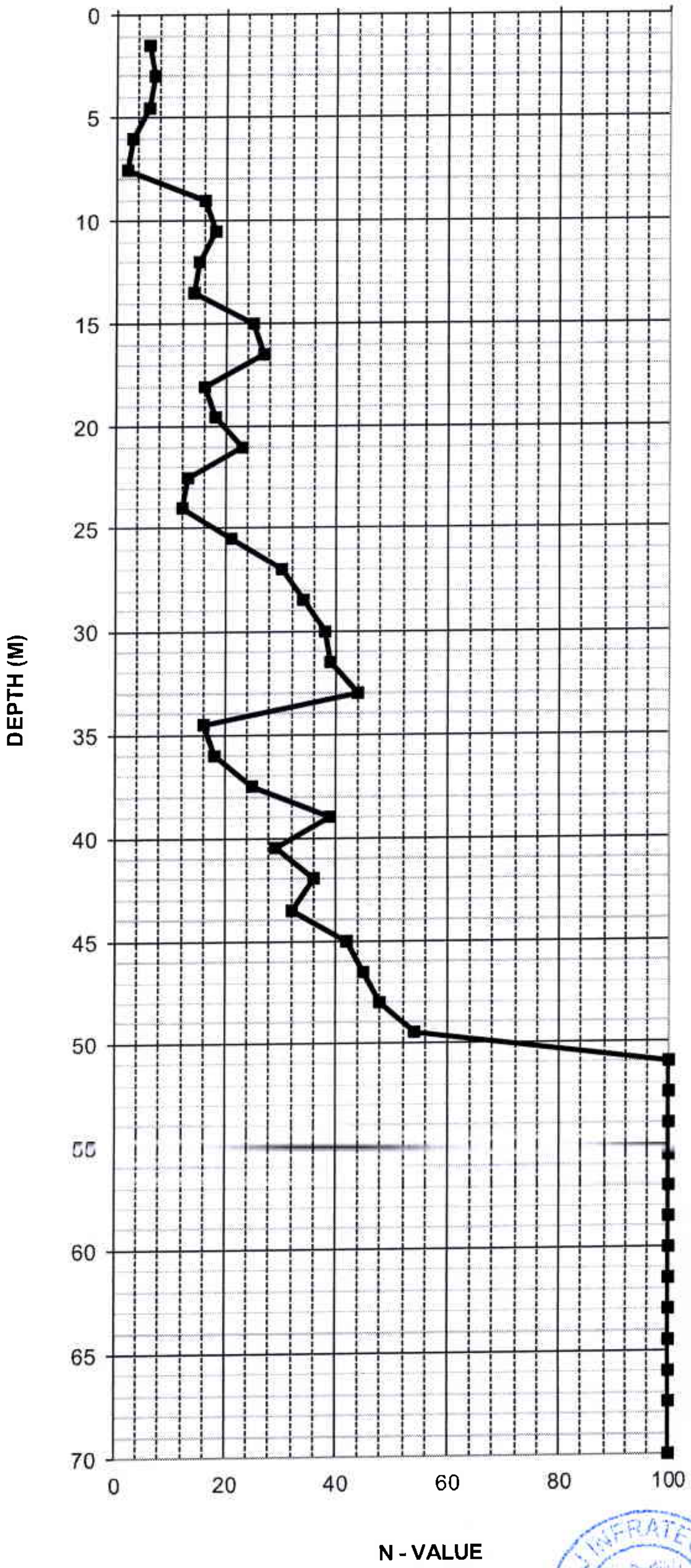


**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**FIELD 'N' VALUE FOR BORE HOLE NO. P167**

| DEPTH (m) | Field N Value |
|---|---|
| 1.50 | 6 |
| 3.00 | 7 |
| 4.50 | 6 |
| 6.00 | 3 |
| 7.50 | 2 |
| 9.00 | 16 |
| 10.50 | 18 |
| 12.00 | 15 |
| 13.50 | 14 |
| 15.00 | 25 |
| 16.50 | 27 |
| 18.00 | 16 |
| 19.50 | 18 |
| 21.00 | 23 |
| 22.50 | 13 |
| 24.00 | 12 |
| 25.50 | 21 |
| 27.00 | 30 |
| 28.50 | 34 |
| 30.00 | 38 |
| 31.50 | 39 |
| 33.00 | 44 |
| 34.50 | 16 |
| 36.00 | 18 |
| 37.50 | 25 |
| 39.00 | 39 |
| 40.50 | 29 |
| 42.00 | 36 |
| 43.50 | 32 |
| 45.00 | 42 |
| 46.50 | 45 |
| 48.00 | 48 |
| 49.50 | 54 |
| 51.00 | 100 |
| 52.50 | 100 |
| 54.00 | 100 |
| 55.50 | 100 |
| 57.00 | 100 |
| 58.50 | 100 |
| 60.00 | 100 |
| 61.50 | 100 |
| 63.00 | 100 |
| 64.50 | 100 |
| 66.00 | 100 |
| 67.50 | 100 |
| 70.00 | 100 |

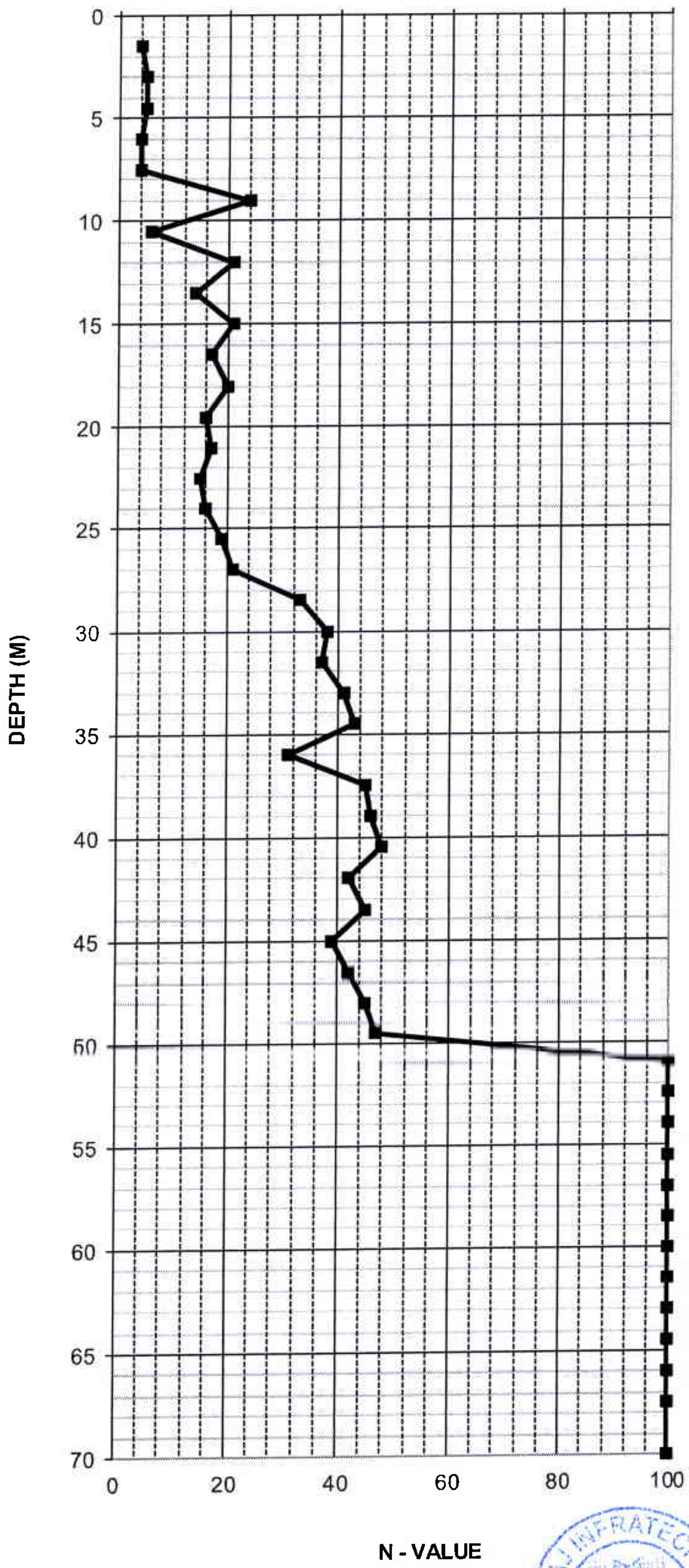


**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**FIELD 'N' VALUE FOR BORE HOLE NO. P168**

| DEPTH (m) | Field N Value |
|---|---|
| 1.50 | 4 |
| 3.00 | 5 |
| 4.50 | 5 |
| 6.00 | 4 |
| 7.50 | 4 |
| 9.00 | 24 |
| 10.50 | 6 |
| 12.00 | 21 |
| 13.50 | 14 |
| 15.00 | 21 |
| 16.50 | 17 |
| 18.00 | 20 |
| 19.50 | 16 |
| 21.00 | 17 |
| 22.50 | 15 |
| 24.00 | 16 |
| 25.50 | 19 |
| 27.00 | 21 |
| 28.50 | 33 |
| 30.00 | 38 |
| 31.50 | 37 |
| 33.00 | 41 |
| 34.50 | 43 |
| 36.00 | 31 |
| 37.50 | 45 |
| 39.00 | 46 |
| 40.50 | 48 |
| 42.00 | 42 |
| 43.50 | 45 |
| 45.00 | 39 |
| 46.50 | 42 |
| 48.00 | 45 |
| 49.50 | 47 |
| 51.00 | 100 |
| 52.50 | 100 |
| 54.00 | 100 |
| 55.50 | 100 |
| 57.00 | 100 |
| 58.50 | 100 |
| 60.00 | 100 |
| 61.50 | 100 |
| 63.00 | 100 |
| 64.50 | 100 |
| 66.00 | 100 |
| 67.50 | 100 |
| 70.00 | 100 |

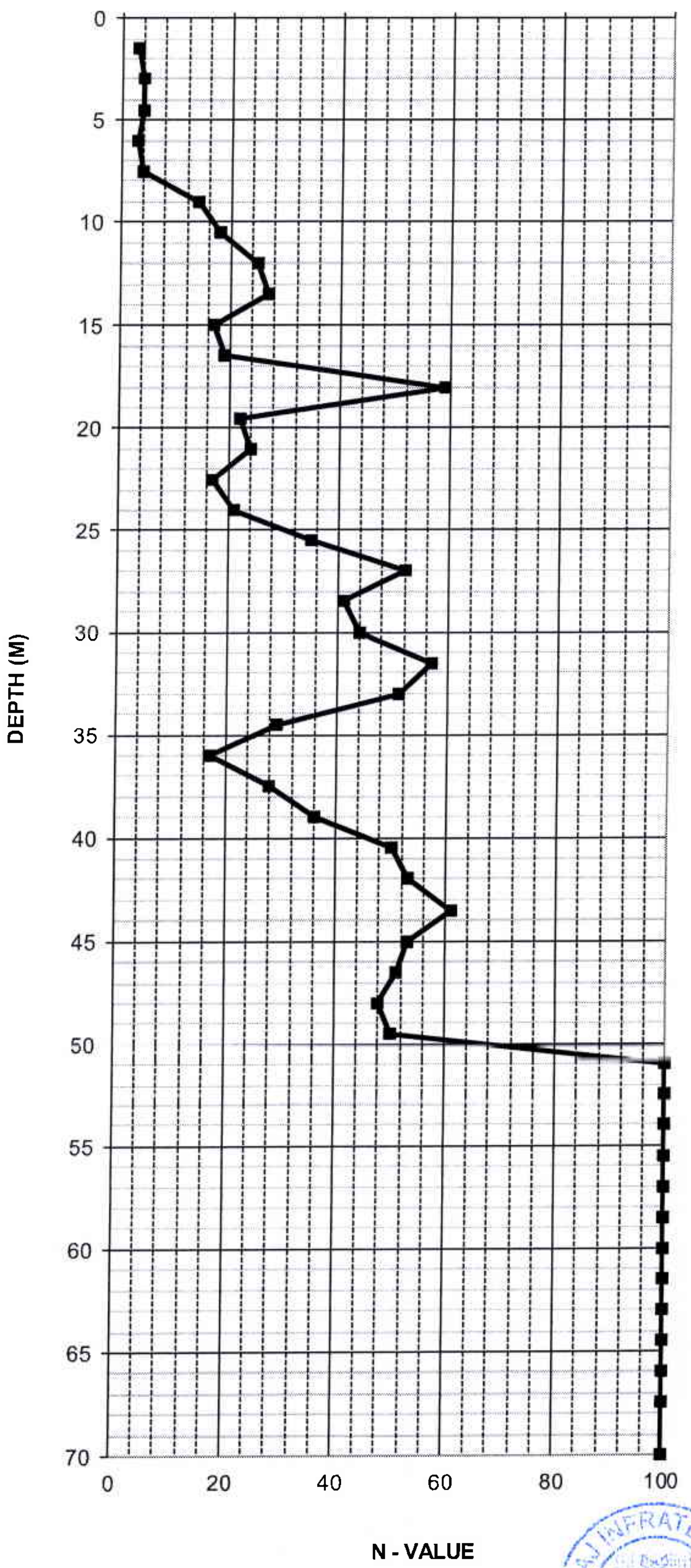


**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## FIELD 'N' VALUE FOR BORE HOLE NO. P169

| DEPTH (m) | Field N Value |
|---|---|
| 1.50 | 3 |
| 3.00 | 4 |
| 4.50 | 4 |
| 6.00 | 3 |
| 7.50 | 4 |
| 9.00 | 14 |
| 10.50 | 18 |
| 12.00 | 25 |
| 13.50 | 27 |
| 15.00 | 17 |
| 16.50 | 19 |
| 18.00 | 59 |
| 19.50 | 22 |
| 21.00 | 24 |
| 22.50 | 17 |
| 24.00 | 21 |
| 25.50 | 35 |
| 27.00 | 52 |
| 28.50 | 41 |
| 30.00 | 44 |
| 31.50 | 57 |
| 33.00 | 51 |
| 34.50 | 29 |
| 36.00 | 17 |
| 37.50 | 28 |
| 39.00 | 36 |
| 40.50 | 50 |
| 42.00 | 53 |
| 43.50 | 61 |
| 45.00 | 53 |
| 46.50 | 51 |
| 48.00 | 48 |
| 49.50 | 50 |
| 51.00 | 100 |
| 52.50 | 100 |
| 54.00 | 100 |
| 55.50 | 100 |
| 57.00 | 100 |
| 58.50 | 100 |
| 60.00 | 100 |
| 61.50 | 100 |
| 63.00 | 100 |
| 64.50 | 100 |
| 66.00 | 100 |
| 67.50 | 100 |
| 70.00 | 100 |



**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## LABORATORY TEST RESULTS FOR BORE HOLE NO. P164

| Bore Hole | Sl. No. | Type of sample | Depth (m) | Soil type as per (IS:1498-1970) | Particle size distribution | | | | Atterberg Limit | | | NMC (%) | Bulk Density (gm/cc) | Dry Density (gm/cc) | Specofic Gravity | Shear Strength | | | Consolidation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Gravel | Sand | Silt | Clay | LL | PL | PI | | | | | Cohesion C (kg/cm2) | ø (degree) | Test Type | Compression Index Cc | Initial void ratio eo |
| P164 | 1 | DS | 1.00 | CI | 0.00 | 3.17 | 55.26 | 41.57 | 39 | 20 | 19 | 28.26 | 1.82 | 1.42 | 2.56 | 0.21 | | Unconfined Compression | | |
| P164 | 2 | SPT | 3.00 | CI | 0.00 | 2.96 | 54.09 | 42.95 | 39 | 20 | 19 | 29.35 | 1.83 | 1.41 | 2.58 | | | | | |
| P164 | 3 | UDS | 4.00 | CI | 0.00 | 3.08 | 56.25 | 40.67 | 38 | 20 | 18 | 31.05 | 1.84 | 1.40 | 2.55 | 0.34 | 3 | Triaxial (U.U) | 0.212 | 0.81 |
| P164 | 4 | SPT | 6.00 | CI | 0.00 | 4.05 | 61.05 | 34.90 | 39 | 20 | 19 | 33.25 | 1.84 | 1.38 | 2.61 | | | | | |
| P164 | 5 | UDS | 7.00 | CI | 0.00 | 4.20 | 55.25 | 40.55 | 39 | 20 | 19 | 30.14 | 1.86 | 1.43 | 2.62 | 0.39 | 2 | Triaxial (U.U) | 0.205 | 0.81 |
| P164 | 6 | SPT | 9.00 | SM | 0.00 | 82.70 | 17.30 | 0.00 | | Non Plastic | | 32.05 | 1.85 | 1.40 | 2.62 | | | | | |
| P164 | 7 | DS | 10.00 | SM | 2.30 | 81.09 | 16.61 | 0.00 | | Non Plastic | | 25.26 | 1.84 | 1.47 | 2.63 | 0.00 | 32 | Direct Shear | | |
| P164 | 8 | SPT | 12.00 | CI | 2.65 | 7.05 | 53.65 | 36.65 | 37 | 20 | 17 | 26.36 | 1.85 | 1.46 | 2.64 | | | | | |
| P164 | 9 | UDS | 13.00 | CI | 3.20 | 6.60 | 60.25 | 29.95 | 37 | 21 | 16 | 30.14 | 1.86 | 1.43 | 2.64 | 0.89 | 4 | Triaxial (U.U) | 0.163 | 0.76 |
| P164 | 10 | SPT | 15.00 | CI | 5.00 | 4.85 | 62.51 | 27.64 | 39 | 19 | 20 | 21.22 | 1.86 | 1.53 | 2.65 | | | | | |
| P164 | 11 | UDS | 16.00 | CI | 4.80 | 5.15 | 57.14 | 32.91 | 37 | 20 | 17 | 22.05 | 1.86 | 1.52 | 2.67 | 0.91 | 4 | Triaxial (U.U) | 0.164 | 0.78 |
| P164 | 12 | SPT | 18.00 | CI | 2.55 | 7.30 | 51.60 | 38.55 | 38 | 20 | 18 | 24.15 | 1.85 | 1.49 | 2.66 | | | | | |
| P164 | 13 | UDS | 19.00 | CI | 3.00 | 6.05 | 53.25 | 37.70 | 38 | 20 | 18 | 20.48 | 1.86 | 1.54 | 2.65 | 0.97 | 3 | Triaxial (U.U) | 0.152 | 0.75 |
| P164 | 14 | SPT | 21.00 | CI | 10.00 | 7.15 | 54.15 | 28.70 | 39 | 21 | 18 | 23.06 | 1.87 | 1.52 | 2.65 | | | | | |
| P164 | 15 | UDS | 22.00 | CI | 8.00 | 9.00 | 56.25 | 26.75 | 37 | 22 | 15 | 25.41 | 1.87 | 1.49 | 2.62 | 0.95 | 2 | Triaxial (U.U) | 0.142 | 0.75 |
| P164 | 16 | SPT | 24.00 | CI | 1.80 | 7.20 | 60.26 | 30.74 | 39 | 21 | 18 | 22.58 | 1.87 | 1.53 | 2.61 | | | | | |
| P164 | 17 | UDS | 25.00 | CI | 1.67 | 8.50 | 61.52 | 28.31 | 40 | 20 | 20 | 27.06 | 1.88 | 1.48 | 2.63 | 1.06 | 3 | Triaxial (U.U) | 0.131 | 0.73 |
| P164 | 18 | SPT | 27.00 | CI | 1.30 | 5.70 | 60.78 | 32.22 | 40 | 20 | 20 | 20.14 | 1.88 | 1.56 | 2.62 | | | | | |
| P164 | 19 | DS | 28.00 | SM | 0.00 | 67.83 | 32.17 | 0.00 | | Non Plastic | | 22.26 | 1.87 | 1.53 | 2.65 | 0.00 | 33 | Direct Shear | | |
| P164 | 20 | SPT | 30.00 | CI | 2.80 | 6.20 | 49.58 | 41.42 | 39 | 20 | 19 | 26.25 | 1.88 | 1.49 | 2.65 | | | | | |
| P164 | 21 | DS | 31.00 | CI | 11.45 | 7.15 | 47.85 | 33.55 | 40 | 21 | 19 | 29.25 | 1.88 | 1.45 | 2.62 | 1.18 | | Unconfined Compression | | |
| P164 | 22 | SPT | 33.00 | CI | 4.60 | 7.40 | 50.14 | 37.86 | 39 | 20 | 19 | 24.18 | 1.88 | 1.51 | 2.65 | | | | | |
| P164 | 23 | DS | 34.00 | CI | 5.00 | 8.22 | 52.26 | 34.52 | 40 | 20 | 20 | 26.58 | 1.89 | 1.49 | 2.64 | 1.15 | | Unconfined Compression | | |
| P164 | 24 | SPT | 36.00 | CI | 4.08 | 9.06 | 50.13 | 36.68 | 40 | 20 | 20 | 24.89 | 1.89 | 1.51 | 2.65 | | | | | |

SPT - Standard Penetration Test UDS - Undisturbed Samples DS - Disturbed Samples

**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

### LABORATORY TEST RESULTS FOR BORE HOLE NO. P164 (contd.)

| Bore Hole | Sl. No. | Type of sample | Depth (m) | Soil type as per (IS:1498-1970) | Particle size distribution | | | | Atterberg Limit | | | NMC (%) | Bulk Density (gm/cc) | Dry Density (gm/cc) | Specofic Gravity | Shear Strength | | | Consolidation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Gravel | Sand | Silt | Clay | LL | PL | PI | | | | | Cohesion C (kg/cm2) | ø (degree) | Test Type | Compression Index Cc | Initial void ratio eo |
| P164 | 25 | DS | 37.00 | CI | 3.70 | 8.30 | 49.25 | 38.75 | 39 | 20 | 19 | 20.14 | 1.89 | 1.57 | 2.62 | 1.18 | | Unconfined Compression | | |
| P164 | 26 | SPT | 39.00 | SM | 0.00 | 66.00 | 34.00 | 0.00 | | Non Plastic | | 20.56 | 1.90 | 1.58 | 2.63 | | | | | |
| P164 | 27 | DS | 40.00 | SM | 0.00 | 67.20 | 32.80 | 0.00 | | Non Plastic | | 19.58 | 1.90 | 1.59 | 2.63 | 0.00 | 32 | Direct Shear | | |
| P164 | 28 | SPT | 42.00 | CL-ML | 0.00 | 23.00 | 63.25 | 13.75 | 28 | 23 | 5 | 19.25 | 1.90 | 1.59 | 2.64 | | | | | |
| P164 | 29 | DS | 43.00 | CL-ML | 0.00 | 26.00 | 62.14 | 11.86 | 29 | 23 | 6 | 21.14 | 1.89 | 1.56 | 2.67 | 1.21 | | Unconfined Compression | | |
| P164 | 30 | SPT | 45.00 | CL-ML | 0.00 | 14.00 | 67.04 | 18.96 | 29 | 22 | 7 | 21.05 | 1.91 | 1.58 | 2.67 | | | | | |
| P164 | 31 | DS | 46.00 | CI | 0.00 | 14.60 | 60.22 | 25.18 | 38 | 19 | 19 | 23.25 | 1.91 | 1.55 | 2.65 | 1.16 | | Unconfined Compression | | |
| P164 | 32 | SPT | 46.50 | CI | 0.00 | 15.20 | 53.25 | 31.55 | 38 | 20 | 18 | 20.47 | 1.92 | 1.59 | 2.65 | | | | | |
| P164 | 33 | SPT | 48.00 | CI | 0.00 | 17.00 | 51.47 | 31.53 | 39 | 20 | 19 | 19.62 | 1.93 | 1.61 | 2.67 | | | | | |
| P164 | 34 | SPT | 49.50 | CI | 0.00 | 16.30 | 51.66 | 32.04 | | Non Plastic | | 19.75 | 1.92 | 1.60 | 2.67 | | | | | |
| P164 | 35 | SPT | 51.00 | SM | 0.00 | 86.70 | 13.30 | 0.00 | | Non Plastic | | 20.14 | 1.92 | 1.60 | 2.65 | 0.00 | 33 | Direct Shear | | |
| P164 | 36 | SPT | 52.50 | SM | 0.00 | 87.00 | 13.00 | 0.00 | | Non Plastic | | 21.08 | 1.93 | 1.59 | 2.66 | | | | | |
| P164 | 37 | SPT | 54.00 | SM | 0.00 | 85.90 | 14.10 | 0.00 | | Non Plastic | | 21.63 | 1.94 | 1.60 | 2.67 | 0.00 | 33 | Direct Shear | | |
| P164 | 38 | SPT | 55.50 | SM | 0.00 | 86.75 | 13.25 | 0.00 | | Non Plastic | | 22.05 | 1.95 | 1.60 | 2.67 | | | | | |
| P164 | 39 | SPT | 57.00 | SM | 4.60 | 81.20 | 14.20 | 0.00 | | Non Plastic | | 22.41 | 1.94 | 1.58 | 2.67 | 0.00 | 34 | Direct Shear | | |
| P164 | 40 | SPT | 58.50 | SM | 6.35 | 80.05 | 13.60 | 0.00 | | Non Plastic | | 20.15 | 1.94 | 1.61 | 2.66 | | | | | |
| P164 | 41 | SPT | 60.00 | SM | 2.00 | 85.00 | 13.00 | 0.00 | | Non Plastic | | 21.07 | 1.95 | 1.61 | 2.67 | 0.00 | 34 | Direct Shear | | |
| P164 | 42 | SPT | 61.50 | SM | 3.65 | 82.05 | 14.30 | 0.00 | | Non Plastic | | 20.85 | 1.94 | 1.61 | 2.67 | | | | | |
| P164 | 43 | SPT | 63.00 | SM-SP | 0.00 | 92.00 | 8.00 | 0.00 | | Non Plastic | | 20.14 | 1.95 | 1.62 | 2.66 | 0.00 | 35 | Direct Shear | | |
| P164 | 44 | SPT | 64.50 | SM-SP | 0.00 | 92.85 | 7.15 | 0.00 | | Non Plastic | | 19.25 | 1.94 | 1.63 | 2.66 | | | | | |
| P164 | 45 | SPT | 66.00 | SM-SP | 0.00 | 93.00 | 7.00 | 0.00 | | Non Plastic | | 19.35 | 1.97 | 1.65 | 2.67 | 0.00 | 35 | Direct Shear | | |
| P164 | 46 | SPT | 67.50 | SM-SP | 0.00 | 92.90 | 7.10 | 0.00 | | Non Plastic | | 19.47 | 1.97 | 1.65 | 2.67 | | | | | |
| P164 | 47 | SPT | 70.00 | SM-SP | 0.00 | 93.50 | 6.50 | 0.00 | | Non Plastic | | 18.95 | 1.96 | 1.65 | 2.67 | 0.00 | 35 | Direct Shear | | |

SPT - Standard Penetration Test UDS - Undisturbed Samples

**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## LABORATORY TEST RESULTS FOR BORE HOLE NO. P165

| Bore Hole | Sl. No. | Type of sample | Depth (m) | Soil type as per (IS:1498-1970) | Particle size distribution | | | | Atterberg Limit | | | NMC (%) | Bulk Density (gm/cc) | Dry Density (gm/cc) | Specofic Gravity | Cohesion C (kg/cm2) | Shear Strength | | Consolidation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Gravel | Sand | Silt | Clay | LL | PL | PI | | | | | | ø (degree) | Test Type | Compressio n Index Cc | Initial void ratio eo |
| P165 | 1 | DS | 1.00 | CL-ML | [illegible] | 3.54 | 60.14 | 36.32 | 28 | 23 | 5 | 30.24 | 1.84 | 1.41 | 2.51 | 0.24 | Unconfined Compression | | | |
| P165 | 2 | SPT | 3.00 | CL-ML | [illegible] | 4.05 | 58.26 | 37.69 | 29 | 22 | 7 | 32.05 | 1.83 | 1.39 | 2.51 | | | | | |
| P165 | 3 | UDS | 4.00 | CL-ML | [illegible] | 3.61 | 59.62 | 36.77 | 28 | 23 | 5 | 34.43 | 1.84 | 1.37 | 2.51 | 0.34 | 2 | Triaxial (U.U) | 0.203 | 0.82 |
| P165 | 4 | SPT | 6.00 | CL-ML | [illegible] | 2.65 | 62.41 | 34.94 | 28 | 23 | 5 | 33.14 | 1.84 | 1.38 | 2.56 | | | | | |
| P165 | 5 | UDS | 7.00 | CL-ML | [illegible] | 1.94 | 58.60 | 39.46 | 28 | 22 | 6 | 40.11 | 1.83 | 1.31 | 2.61 | 0.28 | 4 | Triaxial (U.U) | 0.186 | 0.81 |
| P165 | 6 | SPT | 9.00 | CL-ML | [illegible] | 4.85 | 60.47 | 34.68 | 28 | 23 | 5 | 34.58 | 1.84 | 1.37 | 2.62 | | | | | |
| P165 | 7 | UDS | 10.00 | CL-ML | [illegible] | 5.42 | 58.47 | 36.11 | 29 | 23 | 6 | 31.20 | 1.84 | 1.40 | 2.63 | 0.42 | 3 | Triaxial (U.U) | 0.182 | 0.80 |
| P165 | 8 | SPT | 12.00 | CI | [illegible] | 6.25 | 60.25 | 33.50 | 41 | 20 | 21 | 26.54 | 1.85 | 1.46 | 2.65 | | | | | |
| P165 | 9 | UDS | 13.00 | CI | [illegible] | 2.58 | 58.22 | 38.44 | 41 | 21 | 20 | 20.22 | 1.84 | 1.53 | 2.66 | 0.79 | 5 | Triaxial (U.U) | 0.151 | 0.81 |
| P165 | 10 | SPT | 15.00 | CI | [illegible] | 3.54 | 62.41 | 33.84 | 40 | 19 | 21 | 21.04 | 1.86 | 1.54 | 2.65 | | | | | |
| P165 | 11 | UDS | 16.00 | CI | [illegible] | 4.34 | 58.66 | 37.00 | 40 | 20 | 20 | 23.32 | 1.86 | 1.51 | 2.67 | 0.75 | 2 | Triaxial (U.U) | 0.146 | 0.78 |
| P165 | 12 | SPT | 18.00 | CI | [illegible] | 5.04 | 63.52 | 31.29 | 40 | 20 | 20 | 22.28 | 1.85 | 1.51 | 2.67 | | | | | |
| P165 | 13 | UDS | 19.00 | CI | [illegible] | 6.45 | 61.80 | 31.75 | 40 | 20 | 20 | 25.49 | 1.85 | 1.47 | 2.61 | 0.93 | 3 | Triaxial (U.U) | 0.143 | 0.76 |
| P165 | 14 | SPT | 21.00 | CI | [illegible] | 5.08 | 60.14 | 32.74 | 39 | 21 | 18 | 23.06 | 1.85 | 1.50 | 2.62 | | | | | |
| P165 | 15 | UDS | 22.00 | CI | [illegible] | 11.12 | 61.77 | 24.13 | 40 | 22 | 18 | 21.58 | 1.85 | 1.52 | 2.60 | 1.06 | 4 | Triaxial (U.U) | 0.136 | 0.77 |
| P165 | 16 | SPT | 24.00 | CI | 1.51 | 10.58 | 55.48 | 32.43 | 39 | 21 | 18 | 20.14 | 1.85 | 1.54 | 2.61 | | | | | |
| P165 | 17 | UDS | 25.00 | CI | [illegible] | 12.09 | 60.14 | 22.46 | 41 | 20 | 21 | 28.94 | 1.85 | 1.43 | 2.63 | 1.12 | 2 | Triaxial (U.U) | 0.130 | 0.75 |
| P165 | 18 | SPT | 27.00 | CL-ML | [illegible] | 12.41 | 59.25 | 25.69 | 28 | 23 | 5 | 27.65 | 1.86 | 1.46 | 2.62 | | | | | |
| P165 | 19 | UDS | 28.00 | CL-ML | [illegible] | 5.33 | 62.55 | 32.12 | 29 | 23 | 6 | 29.12 | 1.86 | 1.44 | 2.64 | 0.98 | 5 | Triaxial (U.U) | 0.131 | 0.76 |
| P165 | 20 | SPT | 30.00 | CI | [illegible] | 8.14 | 56.25 | 35.47 | 39 | 19 | 20 | 28.05 | 1.87 | 1.46 | 2.65 | | | | | |
| P165 | 21 | UDS | 31.00 | CI | [illegible] | 21.42 | 58.14 | 10.99 | 40 | 21 | 19 | 30.07 | 1.88 | 1.45 | 2.62 | 1.21 | 3 | Triaxial (U.U) | 0.128 | 0.72 |
| P165 | 22 | SPT | 33.00 | CI | [illegible] | 20.85 | 58.42 | 20.41 | 39 | 19 | 20 | 31.06 | 1.88 | 1.43 | 2.63 | | | | | |
| P165 | 23 | DS | 34.00 | CI | [illegible] | 17.20 | 60.22 | 22.41 | 41 | 21 | 20 | 33.82 | 1.89 | 1.41 | 2.64 | 1.15 | Unconfined Compression | | | |
| P165 | 24 | SPT | 36.00 | CI | [illegible] | 16.05 | 59.06 | 24.75 | 40 | 20 | 20 | 26.85 | 1.89 | 1.49 | 2.65 | | | | | |

SPT - Standard Penetration Test UDS - Undisturbed Samples DS - Disturbed Samples

**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**LABORATORY TEST RESULTS FOR BORE HOLE NO. P165 (contd.)**

| Bore Hole | Sl. No. | Type of sample | Depth (m) | Soil type as per (IS:1498-1970) | Particle size distribution | | | | Atterberg Limit | | | NMC (%) | Bulk Density (gm/cc) | Dry Density (gm/cc) | Specofic Gravity | Shear Strength | | | Consolidation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Gravel | Sand | Silt | Clay | LL | PL | PI | | | | | Cohesion C (kg/cm2) | ø (degree) | Test Type | Compression Index Cc | Initial void ratio eo |
| P165 | 25 | DS | 37.00 | CI | 0.00 | 9.63 | 60.14 | 30.23 | 39 | 20 | 19 | 21.01 | 1.89 | 1.56 | 2.62 | 1.26 | | Unconfined Compression | | |
| P165 | 26 | SPT | 39.00 | CI | 0.00 | 10.52 | 55.81 | 33.67 | 40 | 20 | 20 | 22.14 | 1.89 | 1.55 | 2.63 | | | | | |
| P165 | 27 | DS | 40.00 | CI | 0.00 | 8.52 | 60.58 | 30.90 | 41 | 20 | 21 | 23.08 | 1.90 | 1.54 | 2.63 | 1.24 | | Unconfined Compression | | |
| P165 | 28 | SPT | 42.00 | CI | 5.06 | 9.06 | 60.47 | 25.41 | 40 | 21 | 19 | 20.85 | 1.90 | 1.57 | 2.64 | | | | | |
| P165 | 29 | DS | 43.00 | CI | 18.74 | 16.63 | 62.58 | 2.05 | 41 | 21 | 20 | 22.56 | 1.90 | 1.55 | 2.67 | 1.20 | | Unconfined Compression | | |
| P165 | 30 | SPT | 45.00 | CI | 6.58 | 17.26 | 60.85 | 15.31 | 41 | 22 | 19 | 21.85 | 1.90 | 1.56 | 2.67 | | | | | |
| P165 | 31 | DS | 46.00 | CI | 0.00 | 19.15 | 56.25 | 24.60 | 39 | 19 | 20 | 22.56 | 1.91 | 1.56 | 2.65 | 1.14 | | Unconfined Compression | | |
| P165 | 32 | SPT | 46.50 | CI | 0.00 | 16.25 | 51.58 | 32.17 | 39 | 20 | 19 | 22.08 | 1.92 | 1.57 | 2.65 | | | | | |
| P165 | 33 | SPT | 48.00 | CI | 11.08 | 17.68 | 54.22 | 17.02 | 39 | 20 | 19 | 21.82 | 1.93 | 1.58 | 2.67 | 1.20 | | Unconfined Compression | | |
| P165 | 34 | SPT | 49.50 | SM | 0.00 | 30.06 | 19.94 | 0.00 | Non Plastic | | | 20.85 | 1.92 | 1.59 | 2.67 | | | | | |
| P165 | 35 | SPT | 51.00 | SM | 0.00 | 32.83 | 17.17 | 0.00 | Non Plastic | | | 23.16 | 1.92 | 1.56 | 2.65 | 0.00 | 33 | Direct Shear | | |
| P165 | 36 | SPT | 52.50 | SM | 0.00 | 32.47 | 17.53 | 0.00 | Non Plastic | | | 23.95 | 1.93 | 1.56 | 2.66 | | | | | |
| P165 | 37 | SPT | 54.00 | SM | 0.00 | 33.14 | 16.86 | 0.00 | Non Plastic | | | 24.79 | 1.94 | 1.55 | 2.67 | 0.00 | 33 | Direct Shear | | |
| P165 | 38 | SPT | 55.50 | SM | 0.00 | 30.95 | 19.05 | 0.00 | Non Plastic | | | 24.85 | 1.94 | 1.55 | 2.67 | | | | | |
| P165 | 39 | SPT | 57.00 | SM | 3.40 | 77.73 | 18.87 | 0.00 | Non Plastic | | | 26.07 | 1.94 | 1.54 | 2.67 | 0.00 | 34 | Direct Shear | | |
| P165 | 40 | SPT | 58.50 | SM | 0.00 | 76.59 | 23.41 | 0.00 | Non Plastic | | | 23.95 | 1.95 | 1.57 | 2.66 | | | | | |
| P165 | 41 | SPT | 60.00 | SM | 0.00 | 79.49 | 20.51 | 0.00 | Non Plastic | | | 24.48 | 1.95 | 1.57 | 2.67 | 0.00 | 33 | Direct Shear | | |
| P165 | 42 | SPT | 61.50 | SM | 0.00 | 80.74 | 19.26 | 0.00 | Non Plastic | | | 23.08 | 1.94 | 1.58 | 2.67 | | | | | |
| P165 | 43 | SPT | 63.00 | SM | 11.30 | 71.30 | 17.40 | 0.00 | Non Plastic | | | 22.36 | 1.95 | 1.59 | 2.66 | 0.00 | 34 | Direct Shear | | |
| P165 | 44 | SPT | 64.50 | SM | 0.00 | 81.47 | 18.53 | 0.00 | Non Plastic | | | 20.47 | 1.94 | 1.61 | 2.66 | | | | | |
| P165 | 45 | SPT | 66.00 | SW-SM | 0.00 | 93.71 | 6.29 | 0.00 | Non Plastic | | | 21.19 | 1.96 | 1.62 | 2.67 | 0.00 | 34 | Direct Shear | | |
| P165 | 46 | SPT | 67.50 | SM | 0.00 | 86.54 | 13.46 | 0.00 | Non Plastic | | | 21.84 | 1.96 | 1.61 | 2.67 | | | | | |
| P165 | 47 | SPT | 70.00 | SM | 25.02 | 55.03 | 19.95 | 0.00 | Non Plastic | | | 22.04 | 1.95 | 1.60 | 2.67 | 0.00 | 35 | Direct Shear | | |

SPT - Standard Penetration Test    UDS - Undisturbed Samples

**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## LABORATORY TEST RESULTS FOR BORE HOLE NO. P166

| Bore Hole | Sl. No. | Type of sample | Depth (m) | Soil type as per (IS:1498-1970) | Particle size distribution: Gravel | Sand | Silt | Clay | Atterberg Limit: LL | PL | PI | NMC (%) | Bulk Density (gm/cc) | Dry Density (gm/cc) | Specofic Gravity | Shear Strength: Cohesion C (kg/cm2) | ø (degree) | Test Type | Consolidation: Compression Index Cc | Initial void ratio co |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P166 | 1 | DS | 1.00 | SM | 25.00 | 35.00 | 40.00 | 0.00 | | Non Plastic | | 28.24 | 1.83 | 1.43 | 2.52 | 0.00 | 26 | Direct Shear | | |
| P166 | 2 | SPT | 3.00 | CL | 0.00 | 4.26 | 55.05 | 40.69 | 34 | 20 | 14 | 30.84 | 1.82 | 1.39 | 2.54 | | | | | |
| P166 | 3 | UDS | 4.00 | CL | 0.00 | 3.78 | 50.15 | 46.07 | 34 | 20 | 14 | 31.41 | 1.83 | 1.39 | 2.54 | 0.21 | 3 | Triaxial (U.U) | 0.214 | 0.83 |
| P166 | 4 | SPT | 6.00 | CL-ML | 0.00 | 3.92 | 56.25 | 39.83 | 28 | 23 | 5 | 35.58 | 1.79 | 1.32 | 2.56 | | | | | |
| P166 | 5 | UDS | 7.00 | CL-ML | 0.00 | 4.07 | 60.25 | 35.68 | 29 | 23 | 6 | 33.57 | 1.81 | 1.36 | 2.55 | 0.19 | 2 | Triaxial (U.U) | 0.206 | 0.83 |
| P166 | 6 | SPT | 9.00 | SM | 0.00 | 76.00 | 24.00 | 0.00 | | Non Plastic | | 25.23 | 1.84 | 1.47 | 2.63 | | | | | |
| P166 | 7 | SPT | 10.50 | CI | 4.70 | 9.30 | 63.25 | 22.75 | 38 | 19 | 19 | 22.51 | 1.85 | 1.51 | 2.62 | 0.59 | 5 | Triaxial (U.U) | 0.181 | 0.81 |
| P166 | 8 | SPT | 12.00 | CI | 2.40 | 7.20 | 60.14 | 30.26 | 38 | 20 | 18 | 21.25 | 1.84 | 1.52 | 2.55 | | | | | |
| P166 | 9 | UDS | 13.00 | CI | 3.26 | 6.04 | 51.48 | 39.22 | 39 | 21 | 18 | 20.26 | 1.86 | 1.55 | 2.59 | 0.55 | 2 | Triaxial (U.U) | 0.139 | 0.80 |
| P166 | 10 | SPT | 15.00 | CI | 2.00 | 7.10 | 52.66 | 38.24 | 38 | 19 | 19 | 20.36 | 1.85 | 1.54 | 2.57 | | | | | |
| P166 | 11 | UDS | 16.00 | CI | 2.20 | 7.50 | 63.25 | 27.05 | 38 | 20 | 18 | 22.25 | 1.86 | 1.52 | 2.68 | 0.81 | 4 | Triaxial (U.U) | 0.135 | 0.79 |
| P166 | 12 | SPT | 18.00 | CI | 4.00 | 10.00 | 60.58 | 25.42 | 39 | 20 | 19 | 23.31 | 1.86 | 1.51 | 2.56 | | | | | |
| P166 | 13 | UDS | 19.00 | CI | 2.80 | 8.20 | 65.25 | 23.75 | 38 | 20 | 18 | 28.54 | 1.86 | 1.45 | 2.57 | 0.98 | 4 | Triaxial (U.U) | 0.127 | 0.76 |
| P166 | 14 | SPT | 21.00 | CI | 2.10 | 11.30 | 62.65 | 23.95 | 39 | 21 | 18 | 34.74 | 1.87 | 1.39 | 2.64 | | | | | |
| P166 | 15 | UDS | 22.00 | CI | 2.60 | 10.15 | 61.05 | 26.20 | 39 | 22 | 17 | 30.14 | 1.86 | 1.43 | 2.63 | 0.94 | 3 | Triaxial (U.U) | 0.131 | 0.74 |
| P166 | 16 | SPT | 24.00 | CI | 0.00 | 11.04 | 58.59 | 30.37 | 39 | 21 | 18 | 26.29 | 1.87 | 1.48 | 2.53 | | | | | |
| P166 | 17 | UDS | 25.00 | CI | 0.00 | 7.65 | 57.15 | 35.20 | 40 | 20 | 20 | 24.85 | 1.90 | 1.52 | 2.54 | 1.17 | 2 | Triaxial (U.U) | 0.121 | 0.74 |
| P166 | 18 | SPT | 27.00 | ML | 0.60 | 37.40 | 55.84 | 6.16 | | Non Plastic | | 26.59 | 1.89 | 1.49 | 2.60 | | | | | |
| P166 | 19 | DS | 28.00 | ML | 0.80 | 34.20 | 63.24 | 1.76 | | Non Plastic | | 27.06 | 1.90 | 1.50 | 2.62 | | | | | |
| P166 | 20 | SPT | 30.00 | ML | 1.20 | 37.15 | 59.57 | 2.08 | | Non Plastic | | 26.93 | 1.91 | 1.50 | 2.61 | | | | | |
| P166 | 21 | DS | 31.00 | CI | 2.00 | 11.00 | 56.25 | 30.75 | 40 | 21 | 19 | 24.85 | 1.90 | 1.52 | 2.62 | 1.17 | | Unconfined Compression | | |
| P166 | 22 | SPT | 33.00 | CI | 2.30 | 11.20 | 61.05 | 25.45 | 40 | 19 | 21 | 23.02 | 1.89 | 1.54 | 2.66 | | | | | |
| P166 | 23 | DS | 34.00 | CI | 3.00 | 12.00 | 60.47 | 24.53 | 39 | 21 | 18 | 22.14 | 1.90 | 1.56 | 2.65 | 1.21 | | Unconfined Compression | | |
| P166 | 24 | SPT | 36.00 | CI | 1.90 | 10.65 | 58.36 | 29.09 | 39 | 20 | 19 | 20.58 | 1.91 | 1.58 | 2.56 | | | | | |

SPT - Standard Penetration Test    UDS - Undisturbed Samples    DS - Disturbed Samples

**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## LABORATORY TEST RESULTS FOR BORE HOLE NO. P166 (contd.)

| Bore Hole | Sl. No. | Type of sample | Depth (m) | Soil type as per (IS:1498-1970) | Particle size distribution | | | | Atterberg Limit | | | NMC (%) | Bulk Density (gm/cc) | Dry Density (gm/cc) | Specofic Gravity | Shear Strength | | | Consolidation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Gravel | Sand | Silt | Clay | LL | PL | PI | | | | | Cohesion C (kg/cm2) | ø (degree) | Test Type | Compression Index Cc | Initial void ratio eo |
| P166 | 25 | DS | 37.00 | CI | 2.75 | 11.10 | 58.65 | 27.50 | 39 | 20 | 19 | 26.05 | 1.90 | 1.51 | 2.60 | 1.15 | | Unconfined Compression | | |
| P166 | 26 | SPT | 39.00 | CL-ML | 0.00 | 17.35 | 59.57 | 23.08 | 28 | 23 | 5 | 27.49 | 1.90 | 1.49 | 2.62 | | | | | |
| P166 | 27 | DS | 40.00 | CI | 2.00 | 9.00 | 50.26 | 38.74 | 41 | 20 | 21 | 24.98 | 1.91 | 1.53 | 2.62 | 1.24 | | Unconfined Compression | | |
| P166 | 28 | SPT | 42.00 | CI | 2.70 | 10.30 | 62.14 | 24.86 | 40 | 21 | 19 | 24.69 | 1.92 | 1.54 | 2.61 | | | | | |
| P166 | 29 | DS | 43.00 | CI | 5.00 | 12.00 | 55.26 | 27.74 | 41 | 21 | 20 | 23.06 | 1.92 | 1.56 | 1.59 | 1.26 | | Unconfined Compression | | |
| P166 | 30 | SPT | 45.00 | CI | 4.60 | 12.20 | 57.85 | 25.35 | 40 | 22 | 18 | 25.14 | 1.91 | 1.53 | 2.53 | | | | | |
| P166 | 31 | DS | 46.00 | CI | 3.35 | 11.05 | 59.25 | 26.35 | 39 | 19 | 20 | 24.91 | 1.92 | 1.54 | 2.62 | 1.22 | | Unconfined Compression | | |
| P166 | 32 | SPT | 46.50 | CI | 4.07 | 12.30 | 60.14 | 23.49 | 39 | 20 | 19 | 22.06 | 1.93 | 1.58 | 2.63 | | | | | |
| P166 | 33 | SPT | 48.00 | CI | 3.65 | 13.05 | 61.85 | 21.45 | 40 | 20 | 20 | 21.71 | 1.93 | 1.59 | 2.62 | 1.25 | | Unconfined Compression | | |
| P166 | 34 | SPT | 49.50 | CI | 3.21 | 12.01 | 60.24 | 24.54 | 40 | 20 | 20 | 20.41 | 1.93 | 1.60 | 2.59 | | | | | |
| P166 | 35 | SPT | 51.00 | SM | 0.00 | 78.55 | 21.45 | 0.00 | Non Plastic | | | 21.82 | 1.92 | 1.58 | 2.61 | 0.00 | 34 | Direct Shear | | |
| P166 | 36 | SPT | 52.50 | SM | 0.00 | 80.60 | 19.40 | 0.00 | Non Plastic | | | 21.74 | 1.93 | 1.59 | 2.64 | | | | | |
| P166 | 37 | SPT | 54.00 | SM | 0.00 | 81.45 | 18.55 | 0.00 | Non Plastic | | | 21.38 | 1.93 | 1.59 | 2.64 | 0.00 | 33 | Direct Shear | | |
| P166 | 38 | SPT | 55.50 | SM | 0.00 | 82.00 | 18.00 | 0.00 | Non Plastic | | | 21.06 | 1.94 | 1.60 | 2.58 | | | | | |
| P166 | 39 | SPT | 57.00 | SM | 0.00 | 84.70 | 15.30 | 0.00 | Non Plastic | | | 21.86 | 1.94 | 1.59 | 2.63 | 0.00 | 34 | Direct Shear | | |
| P166 | 40 | SPT | 58.50 | SM | 0.00 | 85.18 | 14.82 | 0.00 | Non Plastic | | | 22.36 | 1.95 | 1.59 | 2.57 | | | | | |
| P166 | 41 | SPT | 60.00 | SM-SP | 0.00 | 90.35 | 9.65 | 0.00 | Non Plastic | | | 22.55 | 1.95 | 1.59 | 2.61 | 0.00 | 35 | Direct Shear | | |
| P166 | 42 | SPT | 61.50 | SM-SP | 0.00 | 91.67 | 8.33 | 0.00 | Non Plastic | | | 21.08 | 1.94 | 1.60 | 2.60 | | | | | |
| P166 | 43 | SPT | 63.00 | SM-SP | 0.00 | 92.16 | 7.84 | 0.00 | Non Plastic | | | 20.31 | 1.95 | 1.62 | 2.61 | 0.00 | 34 | Direct Shear | | |
| P166 | 44 | SPT | 64.50 | SM-SP | 0.00 | 92.88 | 7.12 | 0.00 | Non Plastic | | | 20.14 | 1.94 | 1.61 | 2.66 | | | | | |
| P166 | 45 | SPT | 66.00 | SM-SP | 0.00 | 91.65 | 8.35 | 0.00 | Non Plastic | | | 22.95 | 1.96 | 1.59 | 2.66 | 0.00 | 35 | Direct Shear | | |
| P166 | 46 | SPT | 67.50 | SM-SP | 0.00 | 92.50 | 7.50 | 0.00 | Non Plastic | | | 21.09 | 1.96 | 1.62 | 2.65 | | | | | |
| P166 | 47 | SPT | 70.00 | SM-SP | 0.00 | 93.85 | 6.15 | 0.00 | Non Plastic | | | 20.36 | 1.96 | 1.63 | 2.66 | 0.00 | 34 | Direct Shear | | |

SPT - Standard Penetration Test UDS - Undisturbed Samples

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**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## LABORATORY TEST RESULTS FOR BORE HOLE NO. P167

| Bore Hole | Sl. No. | Type of sample | Depth (m) | Soil type as per (IS:1490-1970) | Particle size distribution: Gravel | Sand | Silt | Clay | Atterberg Limit: LL | PL | PI | NMC (%) | Bulk Density (gm/cc) | Dry Density (gm/cc) | Specofic Gravity | Shear Strength: Cohesion C (kg/cm2) | ø (degree) | Test Type | Consolidation: Compression Index Cc | Initial void ratio eo |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P167 | 1 | DS | 1.00 | CL | 0.00 | 4.76 | 60.14 | 35.10 | 33 | 21 | 12 | 20.14 | 1.84 | 1.53 | 2.58 | | | | | |
| P167 | 2 | SPT | 3.00 | CL | 0.00 | 6.22 | 58.26 | 35.52 | 33 | 21 | 12 | 21.22 | 1.83 | 1.51 | 2.57 | | | | | |
| P167 | 3 | UDS | 4.00 | CL | 2.00 | 5.04 | 59.62 | 33.34 | 33 | 21 | 12 | 26.25 | 1.84 | 1.46 | 2.59 | 0.34 | 2 | Triaxial (U.U) | 0.194 | 0.80 |
| P167 | 4 | SPT | 6.00 | CL | 0.00 | 6.15 | 62.41 | 31.44 | 32 | 20 | 12 | 33.45 | 1.84 | 1.38 | 2.57 | | | | | |
| P167 | 5 | UDS | 7.00 | CL | 0.00 | 3.80 | 58.60 | 37.60 | 31 | 22 | 9 | 30.18 | 1.83 | 1.41 | 2.56 | 0.15 | 4 | Triaxial (U.U) | 0.206 | 0.82 |
| P167 | 6 | SPT | 9.00 | SM | 0.00 | 87.55 | 12.45 | 0.00 | | Non Plastic | | 27.76 | 1.84 | 1.44 | 2.66 | | | | | |
| P167 | 7 | SPT | 10.50 | SM | 0.00 | 86.40 | 13.60 | 0.00 | | Non Plastic | | 26.58 | 1.84 | 1.45 | 2.62 | 0.00 | 30 | Direct Shear | | |
| P167 | 8 | SPT | 12.00 | SM | 0.00 | 85.78 | 14.22 | 0.00 | | Non Plastic | | 27.13 | 1.85 | 1.46 | 2.55 | | | | | |
| P167 | 9 | UDS | 13.00 | C | 10.65 | 9.05 | 58.22 | 22.08 | 39 | 21 | 18 | 26.74 | 1.84 | 1.45 | 2.59 | 0.84 | 3 | Triaxial (U.U) | 0.152 | 0.79 |
| P167 | 10 | SPT | 15.00 | C | 4.15 | 10.20 | 62.41 | 23.24 | 39 | 19 | 20 | 19.63 | 1.86 | 1.55 | 2.51 | | | | | |
| P167 | 11 | UDS | 16.00 | C | 3.70 | 7.25 | 58.66 | 30.39 | 40 | 20 | 20 | 20.15 | 1.86 | 1.55 | 2.51 | 1.02 | 2 | Triaxial (U.U) | 0.145 | 0.77 |
| P167 | 12 | SPT | 18.00 | C | 4.87 | 10.30 | 63.52 | 21.31 | 40 | 20 | 20 | 22.14 | 1.85 | 1.51 | 2.54 | | | | | |
| P167 | 13 | UDS | 19.00 | C | 6.00 | 11.00 | 61.80 | 21.20 | 40 | 20 | 20 | 22.65 | 1.85 | 1.51 | 2.53 | 1.02 | 4 | Triaxial (U.U) | 0.142 | 0.72 |
| P167 | 14 | SPT | 21.00 | CI | 3.65 | 10.50 | 60.14 | 25.71 | 39 | 21 | 18 | 22.70 | 1.85 | 1.51 | 2.57 | | | | | |
| P167 | 15 | UDS | 22.00 | CI | 2.80 | 7.15 | 61.77 | 28.28 | 40 | 22 | 18 | 21.14 | 1.85 | 1.53 | 2.59 | 0.89 | 4 | Triaxial (U.U) | 0.137 | 0.78 |
| P167 | 16 | SPT | 24.00 | CI | 1.15 | 6.30 | 55.48 | 37.07 | 39 | 21 | 18 | 22.90 | 1.85 | 1.51 | 2.56 | | | | | |
| P167 | 17 | UDS | 25.00 | CI | 0.00 | 7.22 | 60.14 | 32.64 | 41 | 20 | 21 | 24.09 | 1.85 | 1.49 | 2.58 | 0.78 | 3 | Triaxial (U.U) | 0.130 | 0.79 |
| P167 | 18 | SPT | 27.00 | CI | 0.00 | 4.90 | 59.25 | 35.85 | 39 | 20 | 19 | 26.72 | 1.86 | 1.47 | 2.61 | | | | | |
| P167 | 19 | UDS | 28.00 | CI | 0.00 | 6.48 | 62.55 | 30.97 | 39 | 20 | 19 | 25.61 | 1.86 | 1.48 | 2.62 | 1.22 | 3 | Triaxial (U.U) | 0.132 | 0.71 |
| P167 | 20 | SPT | 30.00 | CI | 0.00 | 5.80 | 56.25 | 37.95 | 39 | 19 | 20 | 24.00 | 1.87 | 1.51 | 2.63 | | | | | |
| P167 | 21 | DS | 31.00 | CI | 0.00 | 6.65 | 58.14 | 35.21 | 40 | 21 | 19 | 23.61 | 1.88 | 1.52 | 2.64 | 1.23 | | Unconfined Compression | | |
| P167 | 22 | SPT | 33.00 | CI | 0.00 | 7.58 | 58.42 | 34.00 | 39 | 19 | 20 | 23.63 | 1.88 | 1.52 | 2.52 | | | | | |
| P167 | 23 | DS | 34.00 | CI | 0.00 | 11.05 | 60.22 | 28.73 | 40 | 21 | 19 | 22.09 | 1.89 | 1.55 | 2.59 | 1.20 | | Unconfined Compression | | |
| P167 | 24 | SPT | 36.00 | CI | 0.00 | 9.95 | 59.06 | 30.99 | 40 | 20 | 20 | 23.13 | 1.89 | 1.53 | 2.58 | | | | | |

SPT - Standard Penetration Test    UDS - Undisturbed Samples    DS - Disturbed Samples

**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## LABORATORY TEST RESULTS FOR BORE HOLE NO. P167 (contd.)

| Bore Hole | Sl. No. | Type of sample | Depth (m) | Soil type as per (IS:1498-1970) | Particle size distribution | | | | Atterberg Limit | | | NMC (%) | Bulk Density (gm/cc) | Dry Density (gm/cc) | Specofic Gravity | Shear Strength | | | Consolidation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Gravel | Sand | Silt | Clay | LL | PL | PI | | | | | Cohesion C (kg/cm2) | ø (degree) | Test Type | Compression Index Cc | Initial void ratio eo |
| P167 | 25 | UDS | 37.00 | CI | 0.00 | 10.67 | 59.25 | 30.08 | 40 | 20 | 20 | 23.07 | 1.89 | 1.54 | 2.59 | 1.26 | 3 | Triaxial (U.U) | 0.121 | 0.74 |
| P167 | 26 | SPT | 39.00 | CI | 3.70 | 12.00 | 60.14 | 24.16 | 40 | 20 | 20 | 23.23 | 1.89 | 1.53 | 2.60 | | | | | |
| P167 | 27 | DS | 40.00 | CI | 4.25 | 9.30 | 54.58 | 31.87 | 41 | 20 | 21 | 24.51 | 1.90 | 1.53 | 2.61 | 1.24 | Unconfined Compression | | | |
| P167 | 28 | SPT | 42.00 | CI | 2.00 | 7.00 | 59.25 | 31.75 | 40 | 21 | 19 | 27.60 | 1.90 | 1.49 | 2.58 | | | | | |
| P167 | 29 | DS | 43.00 | CI | 2.60 | 8.15 | 62.54 | 26.71 | 39 | 21 | 18 | 26.06 | 1.92 | 1.52 | 2.60 | 1.21 | Unconfined Compression | | | |
| P167 | 30 | SPT | 45.00 | CI | 1.35 | 11.05 | 60.14 | 27.46 | 40 | 22 | 18 | 28.21 | 1.93 | 1.51 | 2.64 | | | | | |
| P167 | 31 | DS | 46.00 | CI | 2.65 | 9.10 | 63.25 | 25.00 | 39 | 19 | 20 | 27.19 | 1.93 | 1.52 | 2.63 | 1.19 | Unconfined Compression | | | |
| P167 | 32 | SPT | 46.50 | CI | 3.00 | 11.20 | 62.05 | 23.75 | 37 | 20 | 17 | 28.14 | 1.95 | 1.52 | 2.63 | | | | | |
| P167 | 33 | SPT | 48.00 | CI | 3.30 | 10.20 | 58.16 | 28.34 | 37 | 20 | 17 | 27.61 | 1.98 | 1.55 | 2.64 | 1.21 | Unconfined Compression | | | |
| P167 | 34 | SPT | 49.50 | CI | 0.00 | 9.60 | 55.60 | 34.80 | 38 | 20 | 18 | 23.97 | 2.01 | 1.62 | 2.62 | | | | | |
| P167 | 35 | SPT | 51.00 | SM | 0.00 | 86.70 | 13.30 | 0.00 | Non Plastic | | | 22.06 | 1.95 | 1.60 | 2.63 | 0.00 | 33 | Direct Shear | | |
| P167 | 36 | SPT | 52.50 | SM | 0.00 | 87.05 | 12.95 | 0.00 | Non Plastic | | | 18.14 | 1.96 | 1.66 | 2.61 | | | | | |
| P167 | 37 | SPT | 54.00 | SM | 0.00 | 87.66 | 12.34 | 0.00 | Non Plastic | | | 19.37 | 1.94 | 1.63 | 2.60 | 0.00 | 33 | Direct Shear | | |
| P167 | 38 | SPT | 55.50 | SM | 0.00 | 86.20 | 13.80 | 0.00 | Non Plastic | | | 20.11 | 1.94 | 1.62 | 2.62 | | | | | |
| P167 | 39 | SPT | 57.00 | SM | 0.00 | 87.45 | 12.55 | 0.00 | Non Plastic | | | 20.71 | 1.94 | 1.61 | 2.63 | 0.00 | 33 | Direct Shear | | |
| P167 | 40 | SPT | 58.50 | SM | 0.00 | 85.15 | 14.85 | 0.00 | Non Plastic | | | 18.05 | 1.95 | 1.65 | 2.60 | | | | | |
| P167 | 41 | SPT | 60.00 | SM | 0.00 | 82.08 | 17.92 | 0.00 | Non Plastic | | | 19.68 | 1.95 | 1.63 | 2.64 | 0.00 | 33 | Direct Shear | | |
| P167 | 42 | SPT | 61.50 | SM | 0.00 | 80.78 | 19.22 | 0.00 | Non Plastic | | | 22.92 | 1.94 | 1.58 | 2.64 | | | | | |
| P167 | 43 | SPT | 63.00 | SM | 0.00 | 78.00 | 22.00 | 0.00 | Non Plastic | | | 23.21 | 1.95 | 1.58 | 2.65 | 0.00 | 34 | Direct Shear | | |
| P167 | 44 | SPT | 64.50 | SM | 0.00 | 81.60 | 18.40 | 0.00 | Non Plastic | | | 26.70 | 1.94 | 1.53 | 2.66 | | | | | |
| P167 | 45 | SPT | 66.00 | SM | 0.00 | 83.00 | 17.00 | 0.00 | Non Plastic | | | 24.08 | 1.96 | 1.58 | 2.66 | 0.00 | 35 | Direct Shear | | |
| P167 | 46 | SPT | 67.50 | SM | 0.00 | 84.50 | 15.50 | 0.00 | Non Plastic | | | 22.80 | 1.96 | 1.60 | 2.66 | | | | | |
| P167 | 47 | SPT | 70.00 | SM-SP | 0.00 | 90.00 | 10.00 | 0.00 | Non Plastic | | | 22.17 | 1.95 | 1.60 | 2.67 | 0.00 | 35 | Direct Shear | | |

SPT - Standard Penetration Test UDS - Undisturbed Samples

**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## LABORATORY TEST RESULTS FOR BORE HOLE NO. P168

| Bore Hole | Sl. No. | Type of sample | Depth (m) | Soil type as per (IS:1498-1970) | Particle size distribution | | | | Atterberg Limit | | | NMC (%) | Bulk Density (gm/cc) | Dry Density (gm/cc) | Specofic Gravity | Shear Strength | | | Consolidation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Gravel | Sand | Silt | Clay | LL | PL | PI | | | | | Cohesion C (kg/cm2) | ø (degree) | Test Type | Compression Index Cc | Initial void ratio eo |
| P168 | 1 | DS | 1.00 | CL | 0.00 | 5.37 | 49.65 | 44.98 | 33 | 22 | 11 | 23.25 | 1.83 | 1.48 | 2.61 | | | | | |
| P168 | 2 | SPT | 3.00 | CL | 0.00 | 7.55 | 45.68 | 46.77 | 33 | 21 | 12 | 23.25 | 1.83 | 1.48 | 2.62 | | | | | |
| P168 | 3 | UDS | 4.00 | CL | 0.00 | 6.60 | 51.44 | 41.96 | 34 | 22 | 12 | 30.22 | 1.85 | 1.42 | 2.60 | 0.30 | 3 | Triaxial (U.U) | 0.203 | 0.82 |
| P168 | 4 | SPT | 6.00 | CI | 0.00 | 5.80 | 52.65 | 41.55 | 37 | 20 | 17 | 31.41 | 1.85 | 1.41 | 2.63 | | | | | |
| P168 | 5 | UDS | 7.00 | CI | 0.00 | 3.22 | 51.08 | 45.70 | 37 | 20 | 17 | 32.04 | 1.85 | 1.40 | 2.59 | 0.24 | 2 | Triaxial (U.U) | 0.198 | 0.81 |
| P168 | 6 | SPT | 9.00 | SM | 0.00 | 82.70 | 17.30 | 0.00 | | Non Plastic | | 25.66 | 1.86 | 1.48 | 2.58 | | | | | |
| P168 | 7 | SPT | 10.50 | SM | 0.00 | 84.27 | 15.73 | 0.00 | | Non Plastic | | 26.25 | 1.85 | 1.47 | 2.62 | 0.00 | 32 | Direct Shear | | |
| P168 | 8 | SPT | 12.00 | SM | 0.00 | 85.50 | 14.50 | 0.00 | | Non Plastic | | 24.15 | 1.85 | 1.49 | 2.62 | | | | | |
| P168 | 9 | SPT | 13.50 | SM | 0.00 | 80.55 | 19.45 | 0.00 | | Non Plastic | | 28.25 | 1.84 | 1.43 | 2.60 | 0.00 | 31 | Direct Shear | | |
| P168 | 10 | SPT | 15.00 | CI | 7.35 | 6.27 | 55.65 | 30.73 | 39 | 19 | 20 | 20.25 | 1.86 | 1.55 | 2.62 | | | | | |
| P168 | 11 | UDS | 16.00 | CI | 8.20 | 7.30 | 60.25 | 24.25 | 39 | 20 | 19 | 21.45 | 1.86 | 1.53 | 2.59 | 1.09 | 2 | Triaxial (U.U) | 0.148 | 0.79 |
| P168 | 12 | SPT | 18.00 | CI | 6.40 | 5.60 | 61.52 | 26.48 | 38 | 20 | 18 | 22.26 | 1.85 | 1.51 | 2.58 | | | | | |
| P168 | 13 | UDS | 19.00 | CI | 2.36 | 4.30 | 58.25 | 35.09 | 38 | 20 | 18 | 22.65 | 1.85 | 1.51 | 2.55 | 1.01 | 3 | Triaxial (U.U) | 0.151 | 0.76 |
| P168 | 14 | SPT | 21.00 | CI | 3.00 | 5.27 | 50.65 | 41.08 | 39 | 21 | 18 | 21.05 | 1.85 | 1.53 | 2.59 | | | | | |
| P168 | 15 | UDS | 22.00 | CI | 3.15 | 6.80 | 51.47 | 38.58 | 39 | 22 | 17 | 23.25 | 1.85 | 1.50 | 2.58 | 0.97 | 4 | Triaxial (U.U) | 0.143 | 0.72 |
| P168 | 16 | SPT | 24.00 | CI | 0.00 | 5.95 | 51.44 | 42.61 | 39 | 21 | 18 | 24.05 | 1.85 | 1.49 | 2.57 | | | | | |
| P168 | 17 | UDS | 25.00 | CI | 0.00 | 6.57 | 49.58 | 43.85 | 39 | 20 | 19 | 26.25 | 1.85 | 1.47 | 2.60 | 1.02 | 4 | Triaxial (U.U) | 0.134 | 0.73 |
| P168 | 18 | SPT | 27.00 | CI | 0.70 | 5.48 | 47.94 | 45.88 | 39 | 20 | 19 | 25.14 | 1.86 | 1.49 | 2.60 | | | | | |
| P168 | 19 | UDS | 28.00 | CI | 1.32 | 6.20 | 60.14 | 32.34 | 39 | 20 | 19 | 21.14 | 1.86 | 1.54 | 2.62 | 1.12 | 3 | Triaxial (U.U) | 0.132 | 0.73 |
| P168 | 20 | SPT | 30.00 | ML | 0.00 | 38.70 | 57.18 | 4.12 | | Non Plastic | | 20.14 | 1.87 | 1.56 | 2.63 | | | | | |
| P168 | 21 | UDS | 31.00 | CI | 0.00 | 8.35 | 60.41 | 31.24 | 40 | 21 | 19 | 26.25 | 1.86 | 1.47 | 2.64 | 1.07 | 3 | Triaxial (U.U) | 0.129 | 0.72 |
| P168 | 22 | SPT | 33.00 | CI | 0.00 | 9.15 | 59.58 | 31.27 | 39 | 19 | 20 | 26.35 | 1.87 | 1.48 | 2.63 | | | | | |
| P168 | 23 | DS | 34.00 | CI | 0.00 | 11.40 | 54.84 | 33.76 | 40 | 21 | 19 | 24.15 | 1.87 | 1.51 | 2.63 | 1.16 | | Unconfined Compression | | |
| P168 | 24 | SPT | 36.00 | CI | 0.00 | 10.65 | 51.47 | 37.88 | 40 | 20 | 20 | 21.58 | 1.89 | 1.55 | 2.62 | | | | | |

SPT - Standard Penetration Test UDS - Undisturbed Samples DS - Disturbed Samples

**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## LABORATORY TEST RESULTS FOR BORE HOLE NO. P168 (contd.)

| Bore Hole | Sl. No. | Type of sample | Depth (m) | Soil type as per (IS:1498-1970) | Particle size distribution | | | | Atterberg Limit | | | NMC (%) | Bulk Density (gm/cc) | Dry Density (gm/cc) | Specofic Gravity | Shear Strength | | | Consolidation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Gravel | Sand | Silt | Clay | LL | PL | PI | | | | | Cohesion C (kg/cm2) | ø (degree) | Test Type | Compression Index Cc | Initial void ratio eo |
| P168 | 25 | UDS | 37.00 | CI | 0.00 | 13.18 | 56.25 | 30.57 | 40 | 19 | 21 | 22.06 | 1.88 | 1.54 | 2.63 | 1.21 | 2 | Triaxial (U.U) | 0.118 | 0.72 |
| P168 | 26 | SPT | 39.00 | CL-ML | 0.00 | 14.50 | 65.95 | 19.55 | 28 | 23 | 5 | 22.01 | 1.88 | 1.54 | 2.62 | | | | | |
| P168 | 27 | DS | 40.00 | CL-ML | 0.00 | 16.00 | 64.89 | 19.11 | 28 | 23 | 5 | 21.02 | 1.90 | 1.57 | 2.64 | | | | | |
| P168 | 28 | SPT | 42.00 | CI | 4.20 | 7.30 | 60.25 | 28.25 | 40 | 21 | 19 | 20.25 | 1.88 | 1.56 | 2.65 | 1.02 | | Unconfined Compression | | |
| P168 | 29 | DS | 43.00 | CI | 6.00 | 10.20 | 54.18 | 29.62 | 39 | 21 | 18 | 23.25 | 1.91 | 1.55 | 2.64 | | | | | |
| P168 | 30 | SPT | 45.00 | CI | 5.45 | 12.05 | 56.25 | 26.25 | 40 | 22 | 18 | 21.02 | 1.93 | 1.59 | 2.62 | 1.09 | | Unconfined Compression | | |
| P168 | 31 | DS | 46.00 | CI | 5.70 | 13.30 | 59.58 | 21.42 | 39 | 19 | 20 | 21.05 | 1.95 | 1.61 | 2.64 | | | | | |
| P168 | 32 | SPT | 46.50 | CI | 4.30 | 13.55 | 58.74 | 23.41 | 40 | 20 | 20 | 25.25 | 1.98 | 1.58 | 2.64 | 1.14 | | Unconfined Compression | | |
| P168 | 33 | SPT | 48.00 | CI | 3.85 | 16.05 | 51.47 | 28.63 | 41 | 20 | 21 | 26.24 | 1.99 | 1.58 | 2.64 | | | | | |
| P168 | 34 | SPT | 49.50 | CI | 0.00 | 15.35 | 53.26 | 31.39 | 40 | 21 | 19 | 26.54 | 1.99 | 1.57 | 2.63 | 1.16 | | Unconfined Compression | | |
| P168 | 35 | SPT | 51.00 | SM | 0.00 | 80.00 | 20.00 | 0.00 | Non Plastic | | | 22.05 | 1.96 | 1.61 | 2.63 | 0.00 | 33 | Direct Shear | | |
| P168 | 36 | SPT | 53.00 | SM | 0.00 | 77.25 | 22.75 | 0.00 | Non Plastic | | | 20.02 | 1.90 | 1.58 | 2.61 | | | | | |
| P168 | 37 | SPT | 54.00 | SM | 0.00 | 78.65 | 21.35 | 0.00 | Non Plastic | | | 20.15 | 1.95 | 1.62 | 2.60 | 0.00 | 33 | Direct Shear | | |
| P168 | 38 | SPT | 56.00 | SM | 0.00 | 79.31 | 20.69 | 0.00 | Non Plastic | | | 21.42 | 1.94 | 1.60 | 2.62 | | | | | |
| P168 | 39 | SPT | 57.00 | SM | 0.00 | 82.15 | 17.85 | 0.00 | Non Plastic | | | 19.25 | 1.95 | 1.64 | 2.62 | 0.00 | 33 | Direct Shear | | |
| P168 | 40 | SPT | 58.50 | SM | 0.00 | 83.90 | 16.10 | 0.00 | Non Plastic | | | 19.55 | 1.95 | 1.63 | 2.60 | | | | | |
| P168 | 41 | SPT | 60.00 | SM-SP | 0.00 | 90.10 | 9.90 | 0.00 | Non Plastic | | | 19.47 | 1.95 | 1.63 | 2.64 | 0.00 | 34 | Direct Shear | | |
| P168 | 42 | SPT | 61.50 | SM-SP | 0.00 | 91.20 | 8.80 | 0.00 | Non Plastic | | | 21.14 | 1.96 | 1.62 | 2.65 | | | | | |
| P168 | 43 | SPT | 63.00 | SM-SP | 0.00 | 91.35 | 8.65 | 0.00 | Non Plastic | | | 21.05 | 1.96 | 1.62 | 2.65 | 0.00 | 35 | Direct Shear | | |
| P168 | 44 | SPT | 64.50 | SM-SP | 0.00 | 91.70 | 8.30 | 0.00 | Non Plastic | | | 20.26 | 1.96 | 1.63 | 2.66 | | | | | |
| P168 | 45 | SPT | 66.00 | SM-SP | 0.00 | 92.40 | 7.60 | 0.00 | Non Plastic | | | 22.02 | 1.97 | 1.61 | 2.66 | 0.00 | 34 | Direct Shear | | |
| P168 | 46 | SPT | 67.50 | SM-SP | 0.00 | 91.85 | 8.15 | 0.00 | Non Plastic | | | 21.18 | 1.96 | 1.62 | 2.65 | | | | | |
| P168 | 47 | SPT | 70.00 | SM-SP | 0.00 | 93.10 | 6.90 | 0.00 | Non Plastic | | | 21.08 | 1.97 | 1.63 | 2.65 | 0.00 | 34 | Direct Shear | | |

SPT - Standard Penetration Test    UDS - Undisturbed Samples

**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## LABORATORY TEST RESULTS FOR BORE HOLE NO. P169

| Bore Hole | Sl. No. | Type of sample | Depth (m) | Soil type as per (IS:1498-1970) | Particle size distribution | | | | Atterberg Limit | | | NMC (%) | Bulk Density (gm/cc) | Dry Density (gm/cc) | Specofic Gravity | Shear Strength | | | Consolidation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Gravel | Sand | Silt | Clay | LL | PL | PI | | | | | Cohesion C (kg/cm2) | ø (degree) | Test Type | Compression Index Cc | Initial void ratio eo |
| P169 | 1 | DS | 1.00 | ML | 0.00 | 12.65 | 70.14 | 17.21 | 26 | 23 | 3 | 25.65 | 1.82 | 1.45 | 2.63 | | | | | |
| P169 | 2 | SPT | 3.00 | ML | 0.00 | 9.70 | 72.15 | 18.15 | 26 | 23 | 3 | 24.58 | 1.83 | 1.47 | 2.63 | | | | | |
| P169 | 3 | UDS | 4.00 | CI | 0.00 | 3.15 | 56.25 | 40.60 | 38 | 20 | 18 | 30.25 | 1.83 | 1.40 | 2.62 | 0.19 | 2 | Triaxial (U.U) | 0.203 | 0.82 |
| P169 | 4 | SPT | 6.00 | CI | 0.00 | 3.05 | 54.85 | 42.10 | 38 | 20 | 18 | 31.55 | 1.83 | 1.39 | 2.61 | | | | | |
| P169 | 5 | UDS | 7.00 | CI | 0.00 | 2.27 | 59.25 | 38.48 | 39 | 20 | 19 | 30.14 | 1.82 | 1.40 | 2.59 | 0.23 | 4 | Triaxial (U.U) | 0.198 | 0.81 |
| P169 | 6 | SPT | 9.00 | SM-SP | 0.00 | 90.10 | 9.90 | 0.00 | | Non Plastic | | 26.25 | 1.86 | 1.47 | 2.55 | | | | | |
| P169 | 7 | SPT | 10.50 | SM-SP | 0.00 | 92.30 | 7.70 | 0.00 | | Non Plastic | | 24.15 | 1.86 | 1.50 | 2.61 | 0.00 | 32 | Direct Shear | | |
| P169 | 8 | SPT | 12.00 | SM-SP | 0.00 | 91.75 | 8.25 | 0.00 | | Non Plastic | | 25.66 | 1.86 | 1.48 | 2.61 | | | | | |
| P169 | 9 | SPT | 13.50 | SM-SP | 0.00 | 92.67 | 7.33 | 0.00 | | Non Plastic | | 25.29 | 1.87 | 1.49 | 1.60 | 0.00 | 32 | Direct Shear | | |
| P169 | 10 | SPT | 15.00 | CI | 3.80 | 4.20 | 60.25 | 31.75 | 40 | 19 | 21 | 20.14 | 1.85 | 1.54 | 2.64 | | | | | |
| P169 | 11 | UDS | 16.00 | CI | 4.28 | 5.12 | 55.15 | 35.45 | 40 | 20 | 20 | 26.25 | 1.85 | 1.47 | 2.64 | 0.86 | 3 | Triaxial (U.U) | 0.148 | 0.79 |
| P169 | 12 | SPT | 18.00 | CI | 2.70 | 4.30 | 59.25 | 33.75 | 40 | 20 | 20 | 24.58 | 1.85 | 1.48 | 2.59 | | | | | |
| P169 | 13 | UDS | 19.00 | CI | 4.00 | 6.35 | 54.15 | 35.50 | 39 | 19 | 20 | 29.25 | 1.85 | 1.43 | 2.60 | 1.03 | 2 | Triaxial (U.U) | 0.151 | 0.76 |
| P169 | 14 | SPT | 21.00 | CI | 3.25 | 9.30 | 60.25 | 27.20 | 39 | 19 | 20 | 26.25 | 1.86 | 1.47 | 2.60 | | | | | |
| P169 | 15 | UDS | 22.00 | CI | 2.60 | 10.15 | 54.48 | 32.77 | 39 | 20 | 19 | 30.14 | 1.86 | 1.43 | 2.62 | 0.98 | 2 | Triaxial (U.U) | 0.143 | 0.72 |
| P169 | 16 | SPT | 24.00 | CI | 2.35 | 11.05 | 48.25 | 38.35 | 40 | 21 | 19 | 30.47 | 1.85 | 1.42 | 2.62 | | | | | |
| P169 | 17 | UDS | 25.00 | CI | 2.80 | 13.20 | 48.95 | 35.05 | 39 | 20 | 19 | 28.47 | 1.86 | 1.45 | 2.61 | 1.06 | 3 | Triaxial (U.U) | 0.134 | 0.73 |
| P169 | 18 | SPT | 27.00 | SM | 2.41 | 74.55 | 23.04 | 0.00 | | Non Plastic | | 26.25 | 1.86 | 1.47 | 2.62 | | | | | |
| P169 | 19 | UDS | 28.00 | CL-ML | 0.00 | 17.00 | 62.54 | 20.46 | 29 | 22 | 7 | 24.15 | 1.86 | 1.50 | 2.65 | 1.17 | 4 | Triaxial (U.U) | 0.132 | 0.73 |
| P169 | 20 | SPT | 30.00 | CL-ML | 0.00 | 18.75 | 64.85 | 16.40 | 29 | 22 | 7 | 23.25 | 1.87 | 1.52 | 2.65 | | | | | |
| P169 | 21 | UDS | 31.00 | CI | 8.20 | 13.30 | 55.26 | 23.24 | 38 | 21 | 17 | 20.14 | 1.86 | 1.55 | 2.64 | 1.13 | 4 | Triaxial (U.U) | 0.129 | 0.72 |
| P169 | 22 | SPT | 33.00 | CI | 12.00 | 14.15 | 53.25 | 20.60 | 40 | 20 | 20 | 23.25 | 1.87 | 1.52 | 2.63 | | | | | |
| P169 | 23 | DS | 34.00 | CI | 6.25 | 15.32 | 51.47 | 26.96 | 40 | 21 | 19 | 24.58 | 1.87 | 1.50 | 2.63 | 1.21 | Unconfined Compression | | | |
| P169 | 24 | SPT | 36.00 | CI | 0.00 | 7.58 | 53.28 | 39.14 | 40 | 21 | 19 | 26.25 | 1.87 | 1.48 | 2.63 | | | | | |

SPT - Standard Penetration Test UDS - Undisturbed Samples DS - Disturbed Samples

**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## LABORATORY TEST RESULTS FOR BORE HOLE NO. P169 (contd.)

| Bore Hole | Sl. No. | Type of sample | Depth (m) | Soil type as per (IS:1498-1970) | Particle size distribution | | | | Atterberg Limit | | | NMC (%) | Bulk Density (gm/cc) | Dry Density (gm/cc) | Specofic Gravity | Shear Strength | | | Consolidation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Gravel | Sand | Silt | Clay | LL | PL | PI | | | | | Cohesion C (kg/cm2) | ø (degree) | Test Type | Compression Index Cc | Initial void ratio eo |
| P169 | 25 | UDS | 37.00 | CI | 0.00 | 6.45 | 61.05 | 32.50 | 38 | 19 | 19 | 23.25 | 1.87 | 1.52 | 2.60 | 1.16 | 2 | Triaxial (U.U) | 0.121 | 0.71 |
| P169 | 26 | SPT | 39.00 | CI | 0.00 | 7.18 | 62.65 | 30.17 | 39 | 20 | 19 | 24.15 | 1.88 | 1.51 | 2.60 | | | | | |
| P169 | 27 | UDS | 40.00 | CI | 0.00 | 5.80 | 54.15 | 40.05 | 39 | 20 | 19 | 23.26 | 1.88 | 1.53 | 2.63 | 1.20 | 3 | Triaxial (U.U) | | |
| P169 | 28 | SPT | 42.00 | CI | 0.00 | 4.66 | 53.58 | 36.75 | 38 | 20 | 18 | 23.05 | 1.87 | 1.52 | 2.61 | | | | | |
| P169 | 29 | DS | 43.00 | CI | 0.00 | 7.56 | 53.25 | 36.19 | 39 | 21 | 18 | 22.01 | 1.88 | 1.54 | 2.63 | 1.16 | Unconfined Compression | | | |
| P169 | 30 | SPT | 45.00 | CI | 9.30 | 8.00 | 54.15 | 28.55 | 39 | 21 | 18 | 20.15 | 1.89 | 1.57 | 2.65 | | | | | |
| P169 | 31 | DS | 46.00 | CI | 7.15 | 11.20 | 59.55 | 22.10 | 40 | 20 | 20 | 24.16 | 1.92 | 1.55 | 2.64 | 1.14 | Unconfined Compression | | | |
| P169 | 32 | SPT | 46.50 | CI | 8.00 | 10.30 | 60.20 | 21.50 | 40 | 20 | 20 | 23.52 | 1.94 | 1.57 | 2.62 | | | | | |
| P169 | 33 | SPT | 48.00 | CI | 5.40 | 11.00 | 54.47 | 29.13 | 39 | 20 | 19 | 21.47 | 1.96 | 1.61 | 2.64 | 1.09 | Unconfined Compression | | | |
| P169 | 34 | SPT | 49.50 | CI | 0.00 | 12.30 | 54.89 | 32.81 | 39 | 21 | 18 | 21.58 | 1.96 | 1.61 | 2.63 | | | | | |
| P169 | 35 | SPT | 51.00 | SM | 0.00 | 82.00 | 18.00 | 0.00 | Non Plastic | | | 23.26 | 1.91 | 1.55 | 2.63 | 0.00 | 33 | Direct Shear | | |
| P169 | 36 | SPT | 53.00 | SM | 0.00 | 83.65 | 16.35 | 0.00 | Non Plastic | | | 23.05 | 1.91 | 1.55 | 2.63 | | | | | |
| P169 | 37 | SPT | 54.00 | SM-SP | 2.65 | 87.05 | 10.30 | 0.00 | Non Plastic | | | 22.14 | 1.92 | 1.57 | 2.65 | 0.00 | 34 | Direct Shear | | |
| P169 | 38 | SPT | 56.00 | SM-SP | 3.10 | 88.40 | 8.50 | 0.00 | Non Plastic | | | 21.05 | 1.92 | 1.59 | 2.64 | | | | | |
| P169 | 39 | SPT | 57.00 | SM-SP | 3.60 | 88.35 | 8.05 | 0.00 | Non Plastic | | | 24.15 | 1.93 | 1.55 | 2.62 | 0.00 | 33 | Direct Shear | | |
| P169 | 40 | SPT | 58.50 | SM-SP | 4.00 | 87.10 | 8.90 | 0.00 | Non Plastic | | | 23.22 | 1.93 | 1.57 | 2.63 | | | | | |
| P169 | 41 | SPT | 60.00 | SM-SP | 4.30 | 88.15 | 7.55 | 0.00 | Non Plastic | | | 20.14 | 1.93 | 1.61 | 2.63 | 0.00 | 34 | Direct Shear | | |
| P169 | 42 | SPT | 61.50 | SM-SP | 5.45 | 87.05 | 7.50 | 0.00 | Non Plastic | | | 19.58 | 1.94 | 1.62 | 2.65 | | | | | |
| P169 | 43 | SPT | 63.00 | SM-SP | 2.85 | 90.10 | 7.05 | 0.00 | Non Plastic | | | 19.35 | 1.96 | 1.64 | 2.65 | 0.00 | 34 | Direct Shear | | |
| P169 | 44 | SPT | 64.50 | SP | 3.35 | 91.75 | 4.90 | 0.00 | Non Plastic | | | 20.14 | 1.95 | 1.62 | 2.65 | | | | | |
| P169 | 45 | SPT | 66.00 | SP | 2.00 | 93.70 | 4.30 | 0.00 | Non Plastic | | | 19.47 | 1.96 | 1.64 | 2.65 | 0.00 | 35 | Direct Shear | | |
| P169 | 46 | SPT | 67.50 | SP | 1.80 | 94.20 | 4.00 | 0.00 | Non Plastic | | | 19.68 | 1.96 | 1.64 | 2.66 | | | | | |
| P169 | 47 | SPT | 70.00 | SP | 3.15 | 92.45 | 4.40 | 0.00 | Non Plastic | | | 19.66 | 1.96 | 1.64 | 2.65 | 0.00 | 35 | Direct Shear | | |

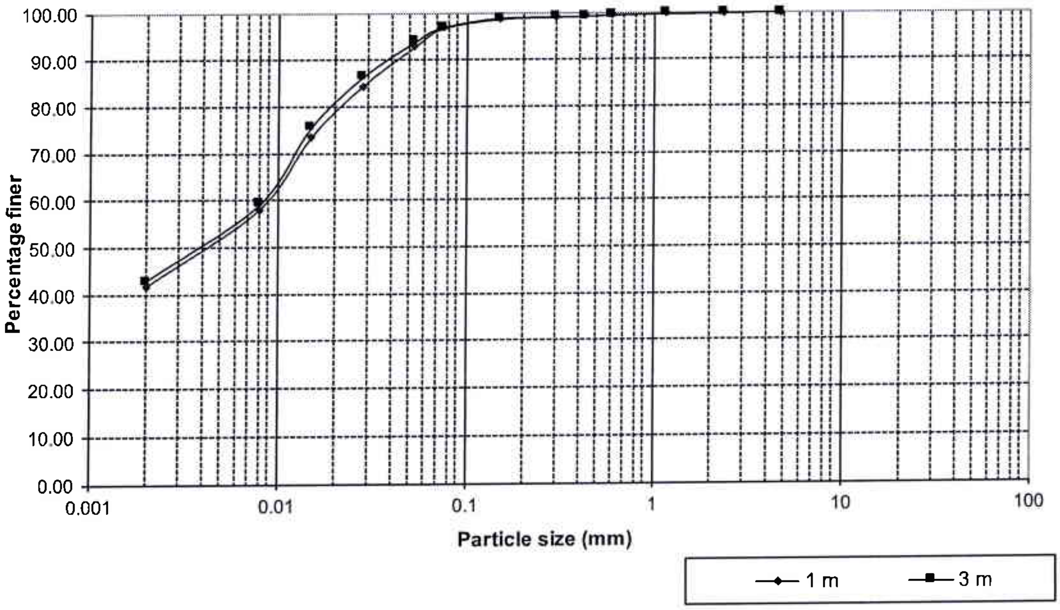
SPT - Standard Penetration Test UDS - Undisturbed Samples

**CHEMICAL TEST RESULTS ON SOIL AND GROUND WATER SAMPLE**

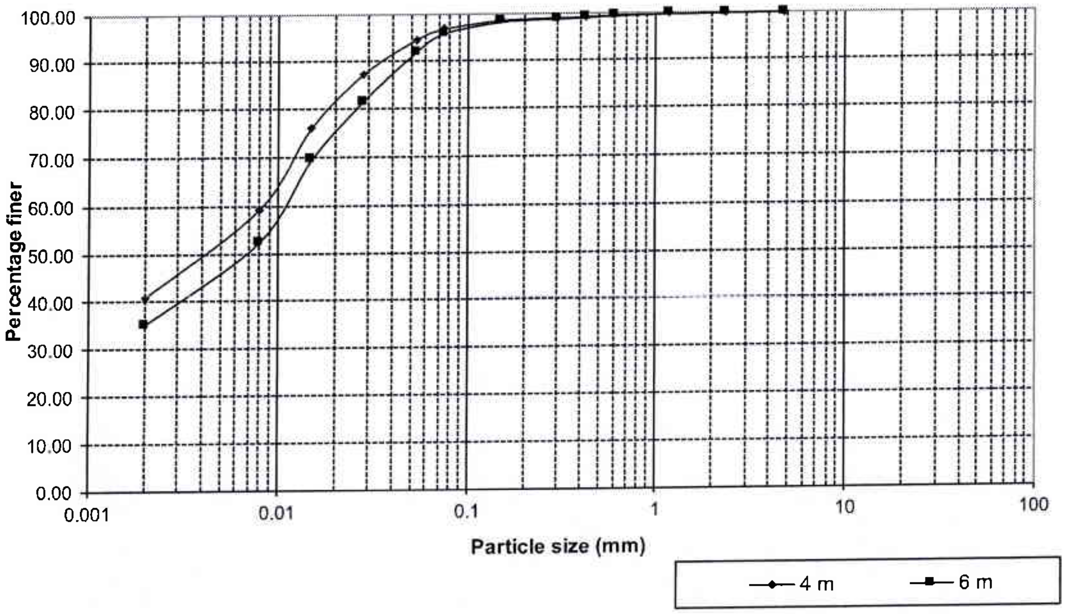
| Chemical Tests on Soil samples | | | | | Chemical Tests on Water samples | | |
|---|---|---|---|---|---|---|---|
| Borehole No. | Depth (m) | pH Value | Chloride (%) | Sulphate (%) | pH Value | Chloride (mg/litre) | Sulphate (mg/litre) |
| P164 | 6.0 | 6.65 | 0.03 | 0.03 | 6.68 | 32.1 | 36.8 |
| P165 | 8.0 | 6.70 | 0.05 | 0.04 | 6.71 | 23.6 | 41.9 |
| P166 | 7.0 | 6.65 | 0.04 | 0.02 | 6.64 | 24.9 | 35.8 |
| P167 | 8.5 | 6.68 | 0.05 | 0.03 | 6.70 | 33.7 | 44.6 |
| P168 | 6.0 | 6.66 | 0.06 | 0.04 | 6.68 | 31.9 | 40.3 |
| P169 | 7.5 | 6.70 | 0.04 | 0.02 | 6.71 | 30.4 | 41.1 |

**M/s Anand Raj Infratech Pvt. Ltd.**
*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P164 | 1 m | 41.57 | 55.26 | 3.17 | 0.00 | |
| P164 | 3 m | 42.95 | 54.09 | 2.96 | 0.00 | |




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P164 | 4 m | 40.67 | 56.25 | 3.08 | 0.00 | |
| P164 | 6 m | 34.90 | 61.05 | 4.05 | 0.00 | |

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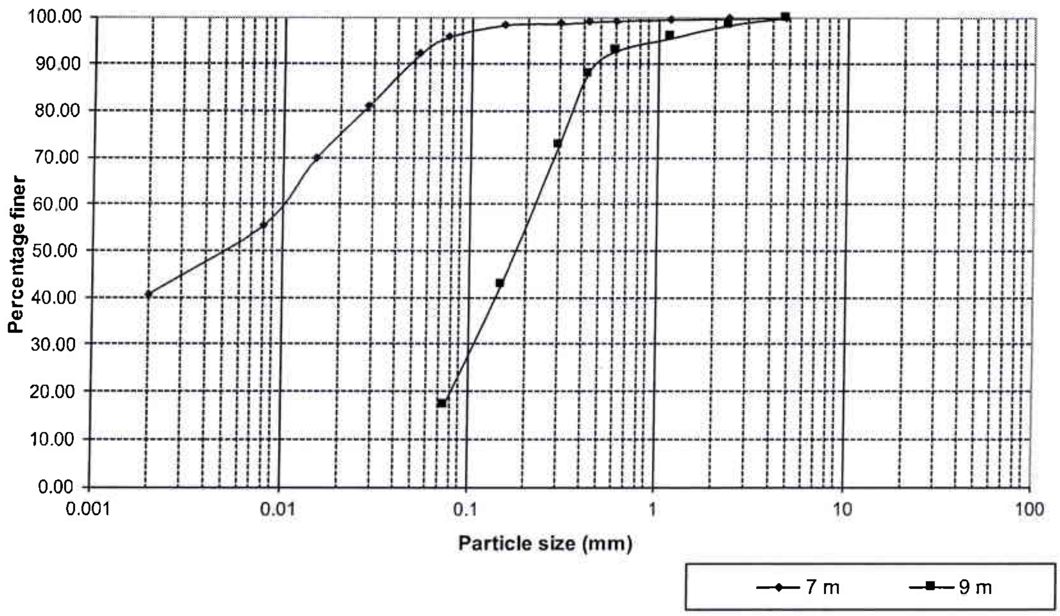
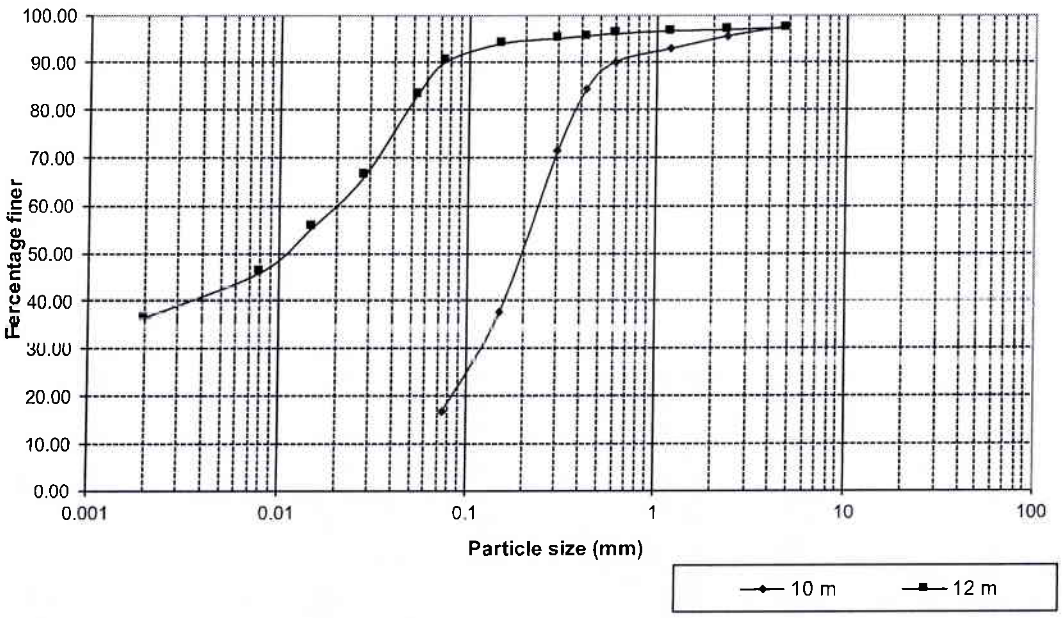
**PARTICLE SIZE DISTRIBUTION CURVES**

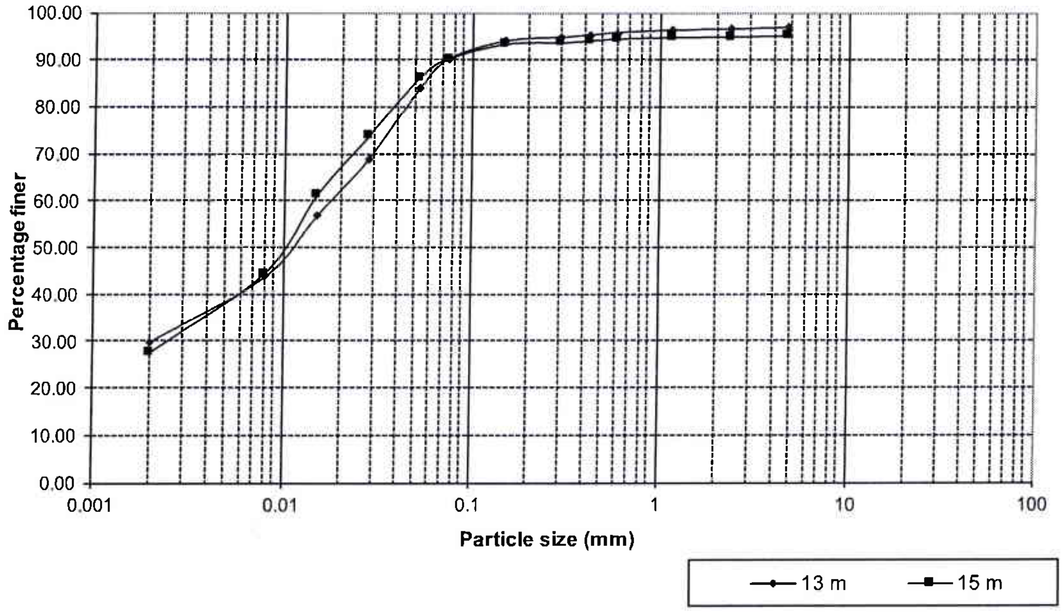



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P164 | 7 m | 40.55 | 55.25 | 4.20 | 0.00 | |
| P164 | 9 m | 0.00 | 17.30 | 82.70 | 0.00 | 1.02 |

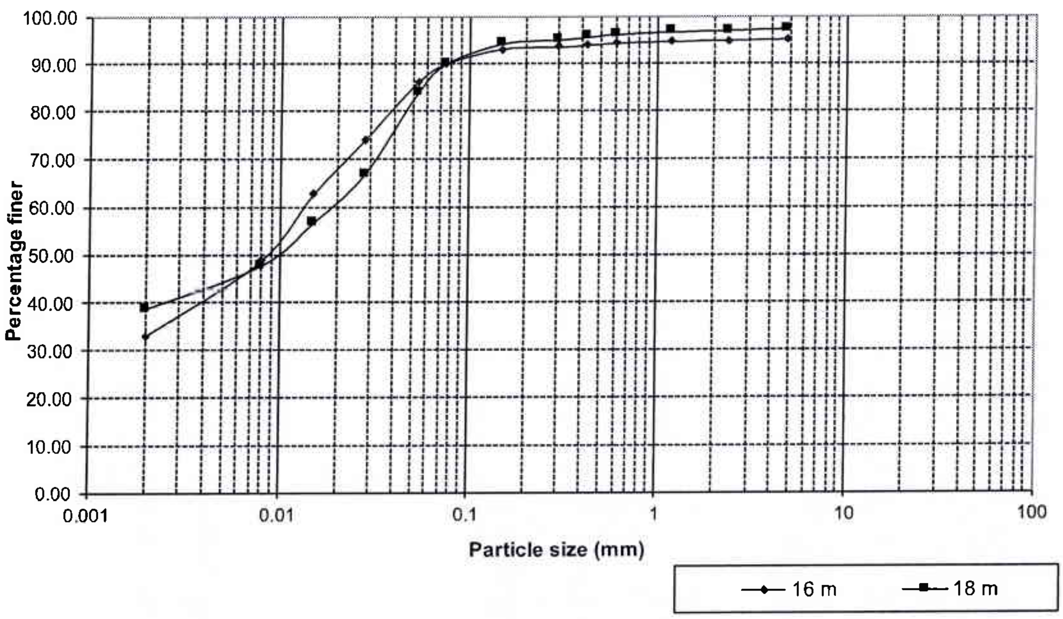



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P164 | 10 m | 0.00 | 16.61 | 81.09 | 2.30 | 1.05 |
| P164 | 12 m | 36.65 | 53.65 | 7.05 | 2.65 | |

**PARTICLE SIZE DISTRIBUTION CURVES**

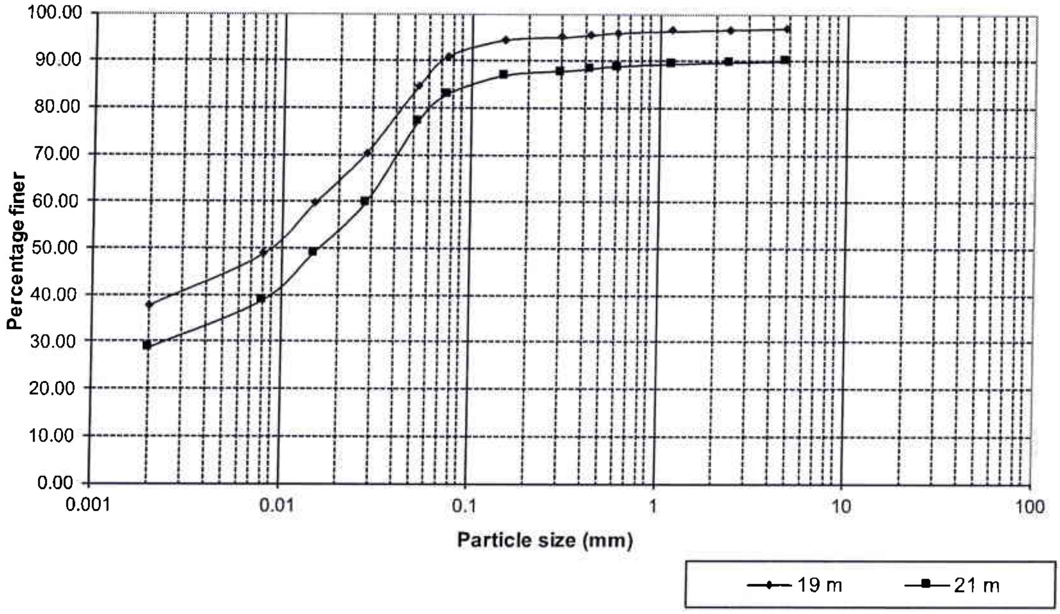



| *Grain size (mm)* | | *< 0.002* | *0.002 - 0.075* | *0.075 - 4.75* | *> 4.75* | **Silt factor (for sands)** |
|---|---|---|---|---|---|---|
| **Bore Hole** | **Sample** | **Clay (%)** | **Silt (%)** | **Sand (%)** | **Gravel (%)** | |
| P164 | 13 m | 29.95 | 60.25 | 6.60 | 3.20 | |
| P164 | 15 m | 27.64 | 62.51 | 4.85 | 5.00 | |

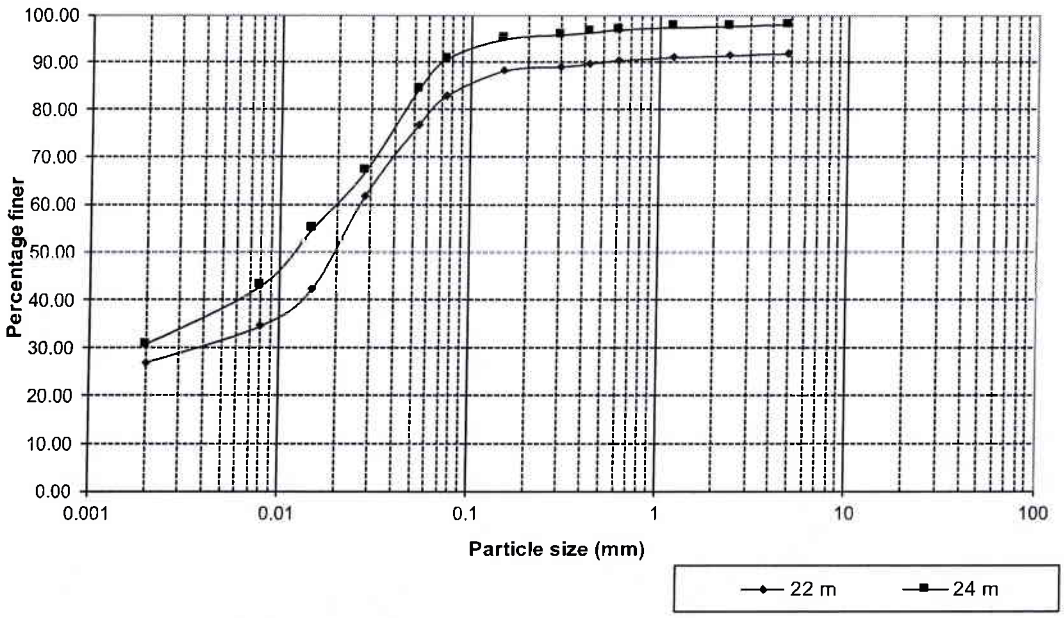



| *Grain size (mm)* | | *< 0.002* | *0.002 - 0.075* | *0.075 - 4.75* | *> 4.75* | **Silt factor (for sands)** |
|---|---|---|---|---|---|---|
| **Bore Hole** | **Sample** | **Clay (%)** | **Silt (%)** | **Sand (%)** | **Gravel (%)** | |
| P164 | 16 m | 32.91 | 57.14 | 5.15 | 4.80 | |
| P164 | 18 m | 38.55 | 51.60 | 7.30 | 2.55 | |

**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P164 | 19 m | 37.70 | 53.25 | 6.05 | 3.00 | |
| P164 | 21 m | 28.70 | 54.15 | 7.15 | 10.00 | |




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P164 | 22 m | 26.75 | 56.25 | 9.00 | 8.00 | |
| P164 | 24 m | 30.74 | 60.26 | 7.20 | 1.80 | |

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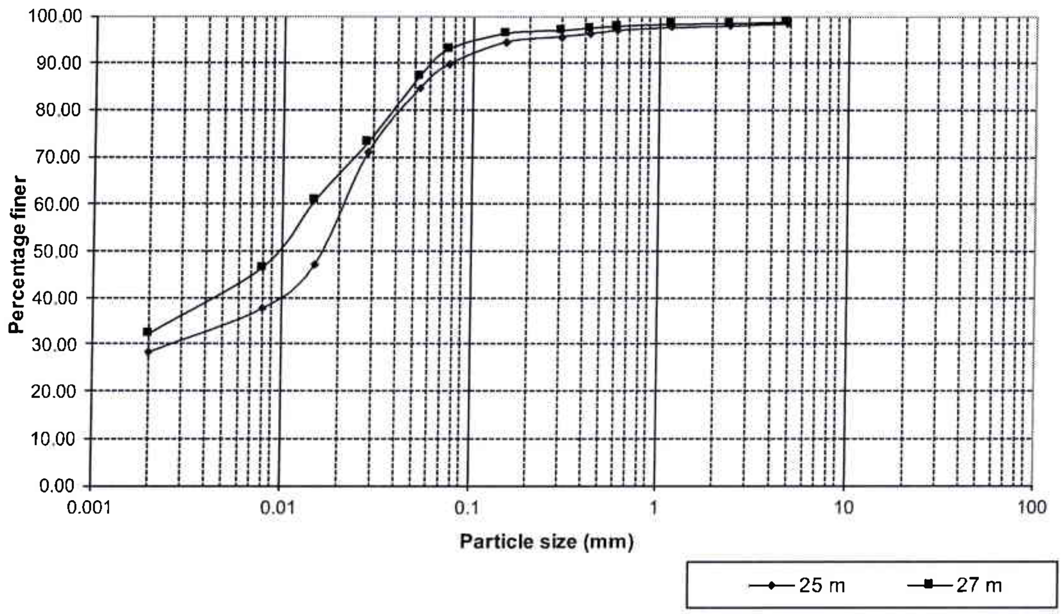
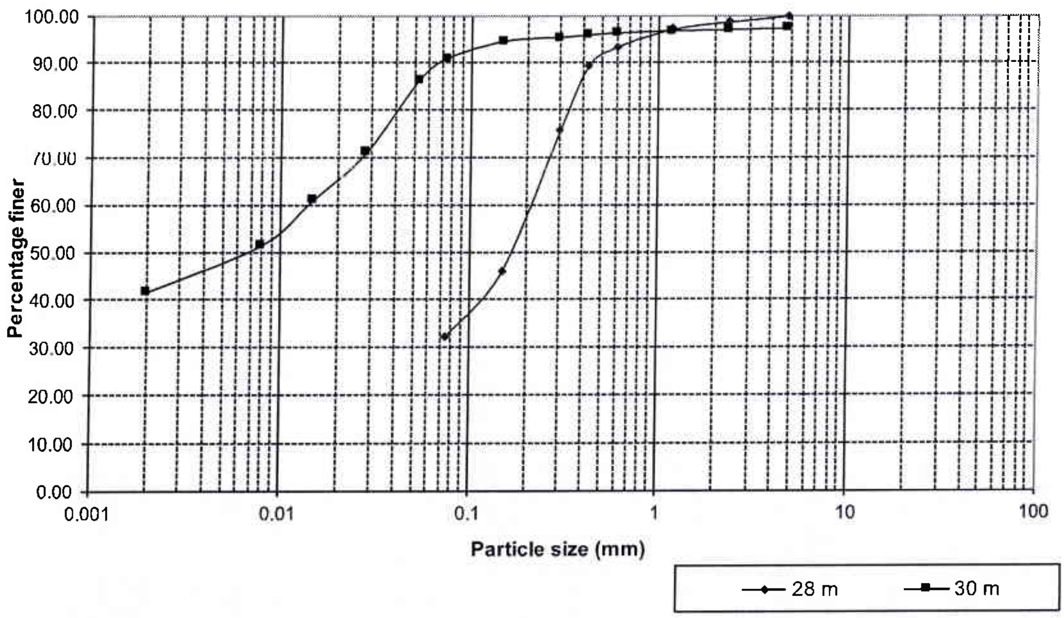
**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P164 | 25 m | 28.31 | 61.52 | 8.50 | 1.67 | |
| P164 | 27 m | 32.22 | 60.78 | 5.70 | 1.30 | |

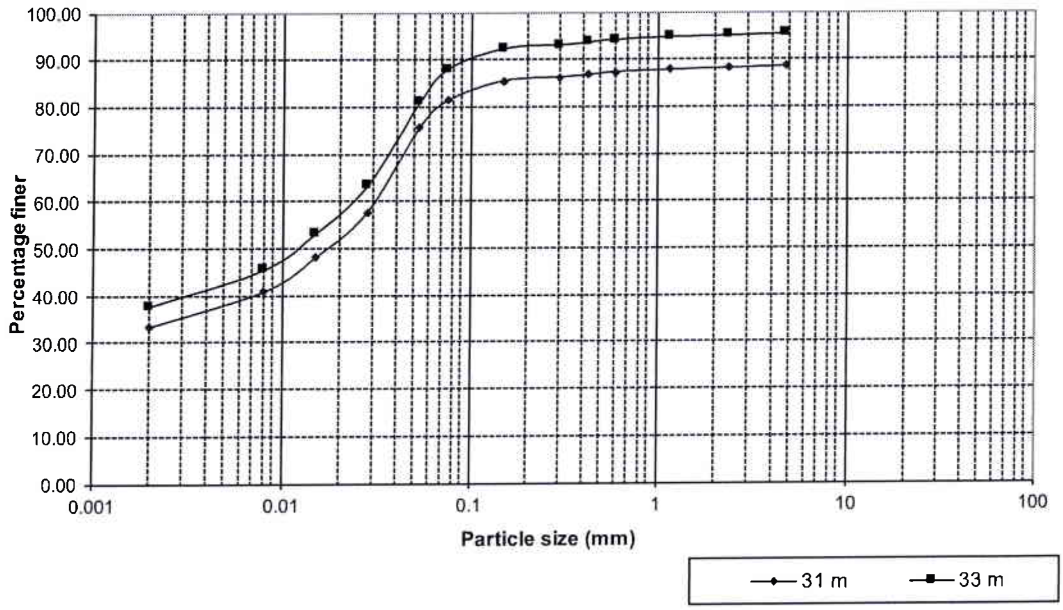



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P164 | 28 m | 0.00 | 32.17 | 67.83 | 0.00 | 0.94 |
| P164 | 30 m | 41.42 | 49.58 | 6.20 | 2.80 | |

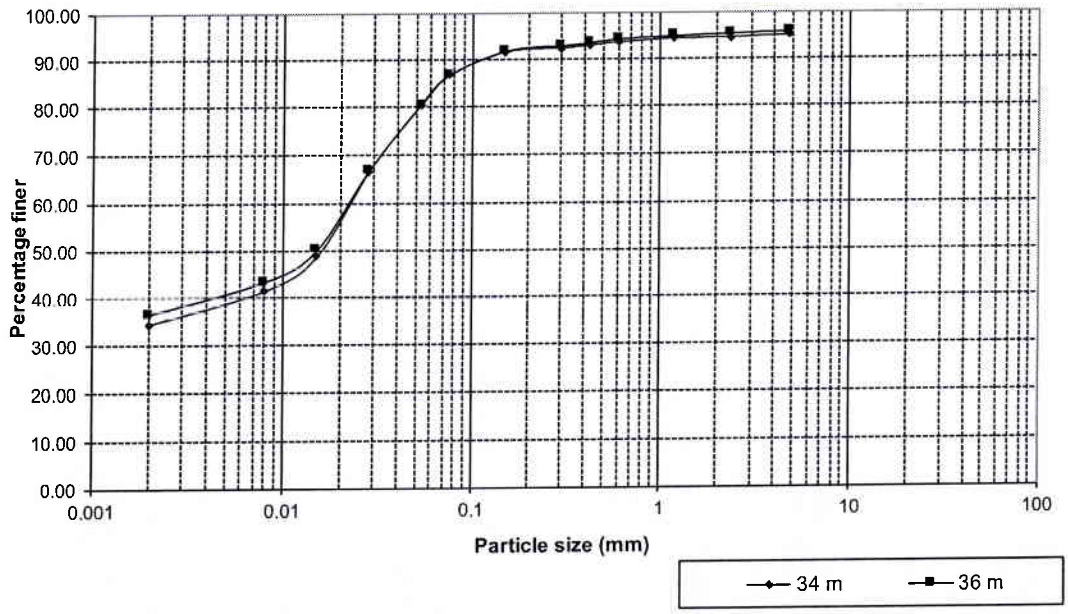
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## PARTICLE SIZE DISTRIBUTION CURVES




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P164 | 31 m | 33.55 | 47.85 | 7.15 | 11.45 | |
| P164 | 33 m | 37.86 | 50.14 | 7.40 | 4.60 | |

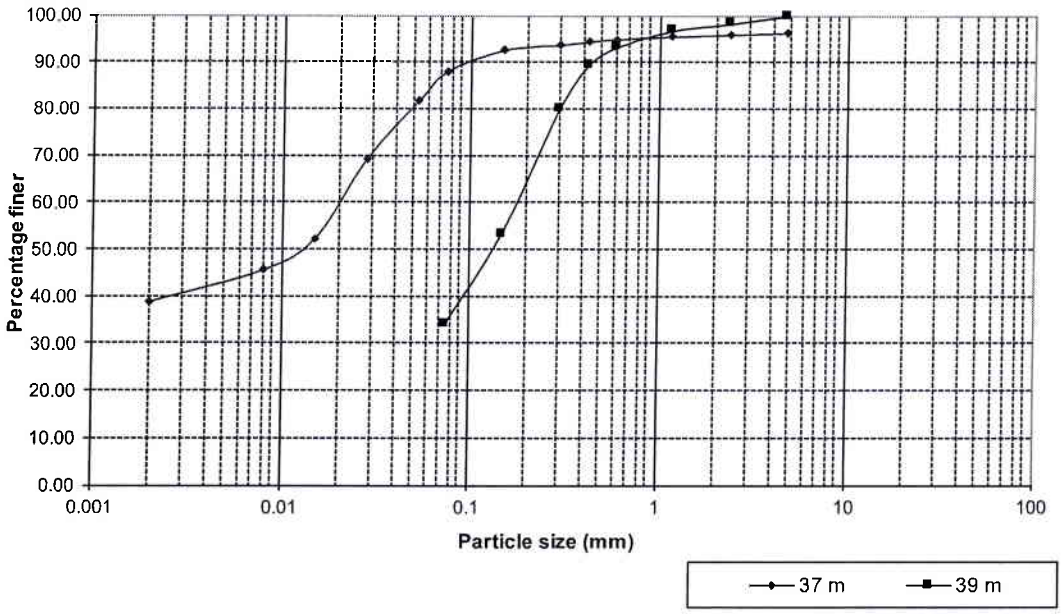



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P164 | 34 m | 34.52 | 52.26 | 8.22 | 5.00 | |
| P164 | 36 m | 36.68 | 50.18 | 9.06 | 4.08 | |

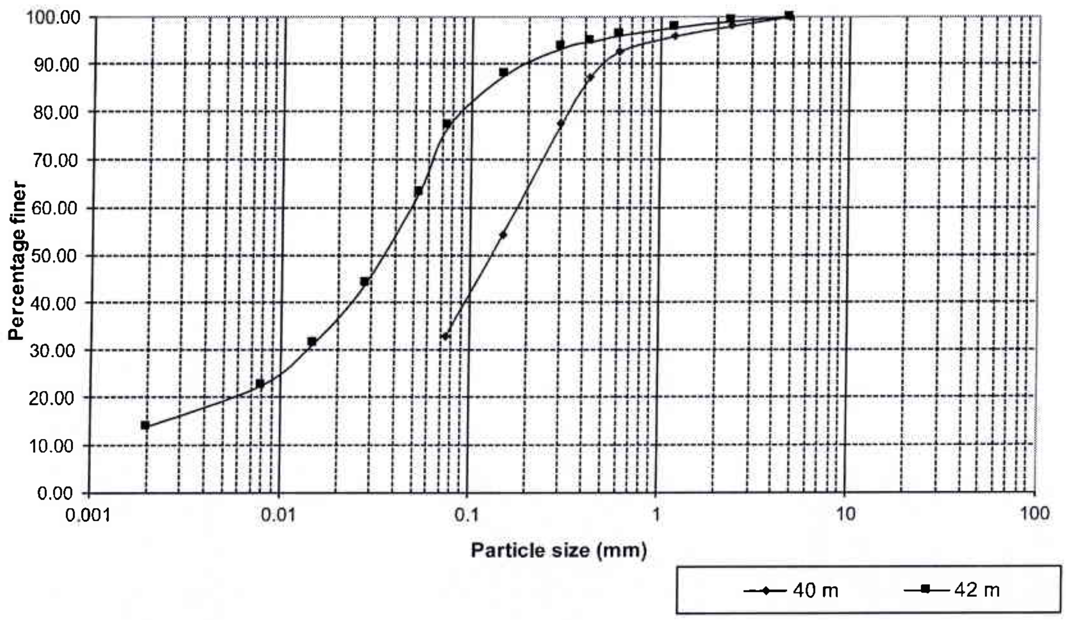
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**PARTICLE SIZE DISTRIBUTION CURVES**

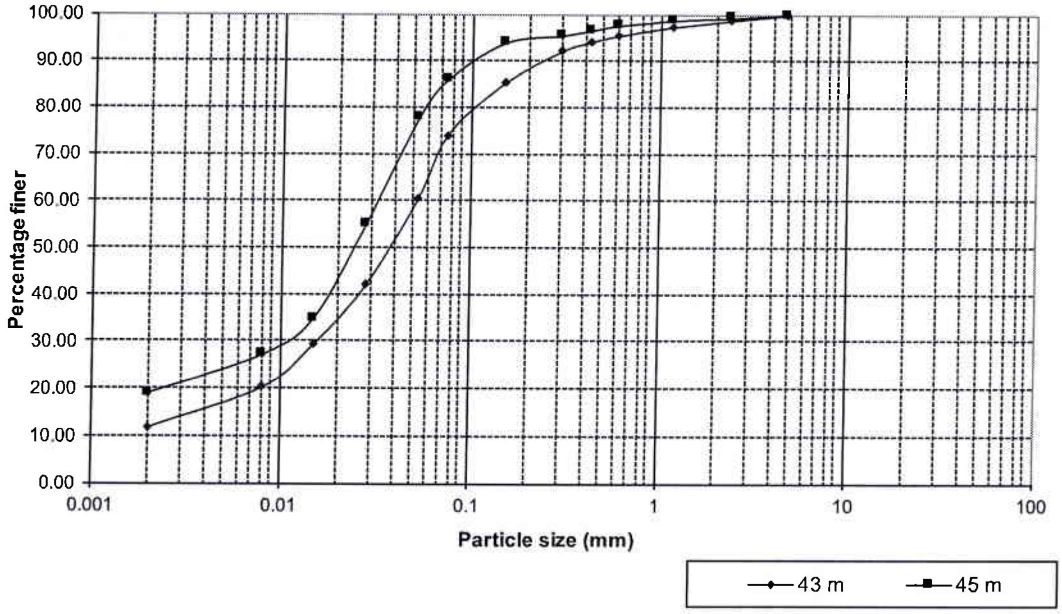



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P164 | 37 m | 38.75 | 49.25 | 8.30 | 3.70 | |
| P164 | 39 m | 0.00 | 34.00 | 66.00 | 0.00 | 0.94 |

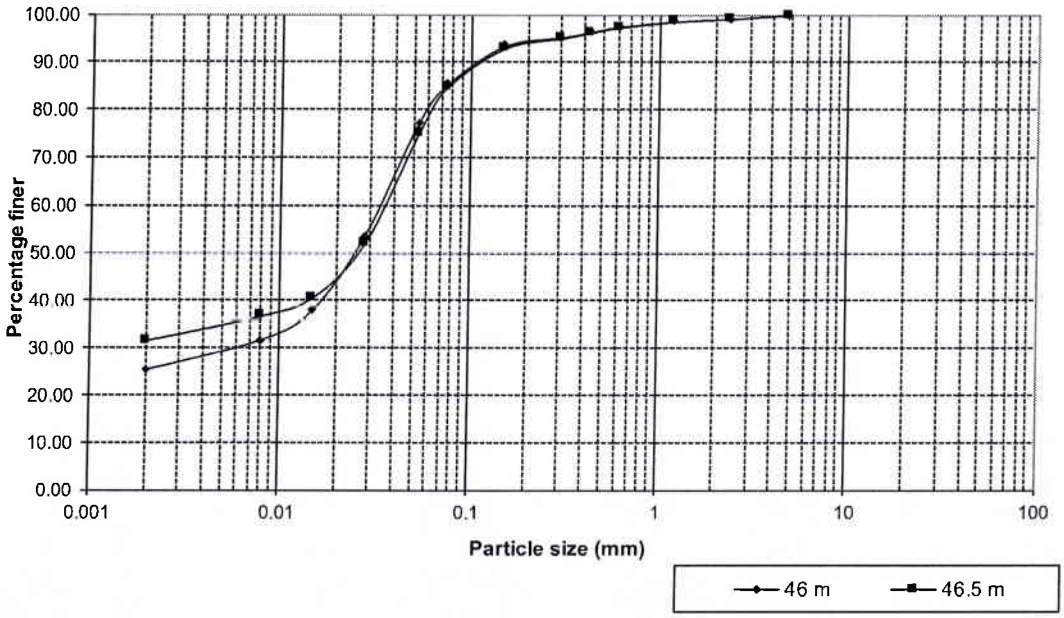



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P164 | 40 m | 0.00 | 32.80 | 67.20 | 0.00 | 0.97 |
| P164 | 42 m | 13.75 | 63.25 | 23.00 | 0.00 | |

**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P164 | 43 m | 11.86 | 62.14 | 26.00 | 0.00 | |
| P164 | 45 m | 18.96 | 67.04 | 14.00 | 0.00 | |

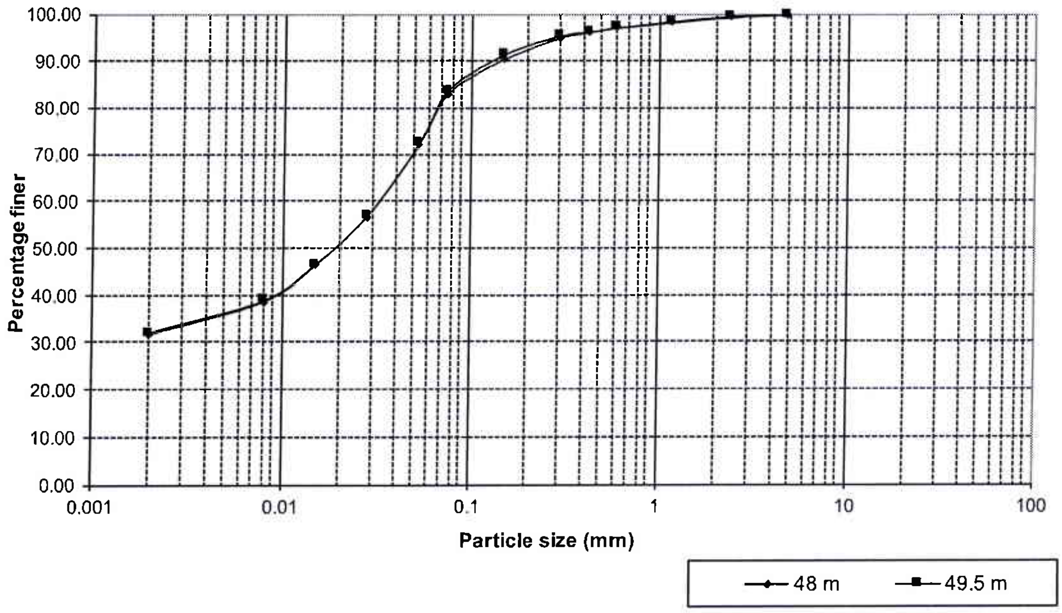



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P164 | 46 m | 25.18 | 60.22 | 14.60 | 0.00 | |
| P164 | 46.5 m | 31.55 | 53.25 | 15.20 | 0.00 | |

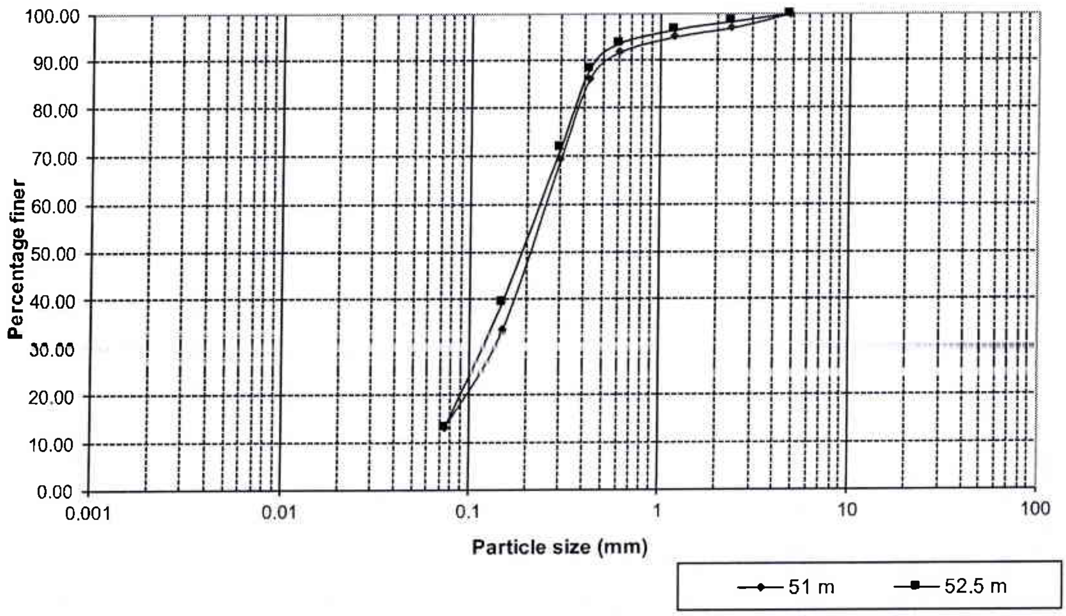
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## PARTICLE SIZE DISTRIBUTION CURVES




| *Grain size (mm)* | | *< 0.002* | *0.002 - 0.075* | *0.075 - 4.75* | *> 4.75* | **Silt factor (for sands)** |
|---|---|---|---|---|---|---|
| **Bore Hole** | **Sample** | **Clay (%)** | **Silt (%)** | **Sand (%)** | **Gravel (%)** | |
| P164 | 48 m | 31.53 | 51.47 | 17.00 | 0.00 | |
| P164 | 49.5 m | 32.04 | 51.66 | 16.30 | 0.00 | |

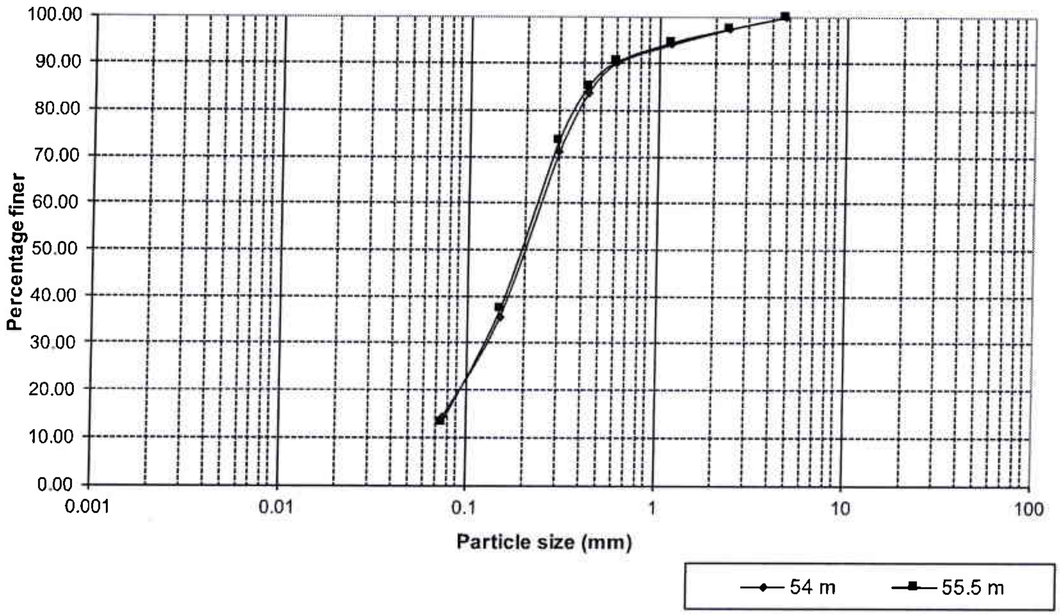



| *Grain size (mm)* | | *< 0.002* | *0.002 - 0.075* | *0.075 - 4.75* | *> 4.75* | **Silt factor (for sands)** |
|---|---|---|---|---|---|---|
| **Bore Hole** | **Sample** | **Clay (%)** | **Silt (%)** | **Sand (%)** | **Gravel (%)** | |
| P164 | 51 m | 0.00 | 13.30 | 86.70 | 0.00 | 1.10 |
| P164 | 52.5 m | 0.00 | 13.00 | 87.00 | 0.00 | 1.01 |

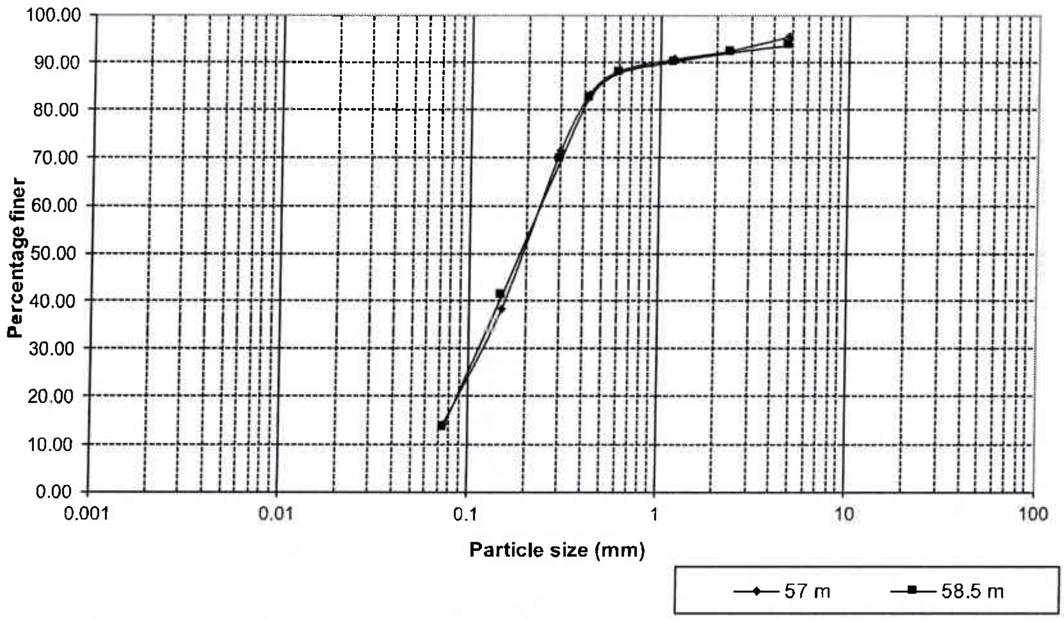
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P164 | 54 m | 0.00 | 14.10 | 85.90 | 0.00 | 1.12 |
| P164 | 55.5 m | 0.00 | 13.25 | 86.75 | 0.00 | 1.09 |

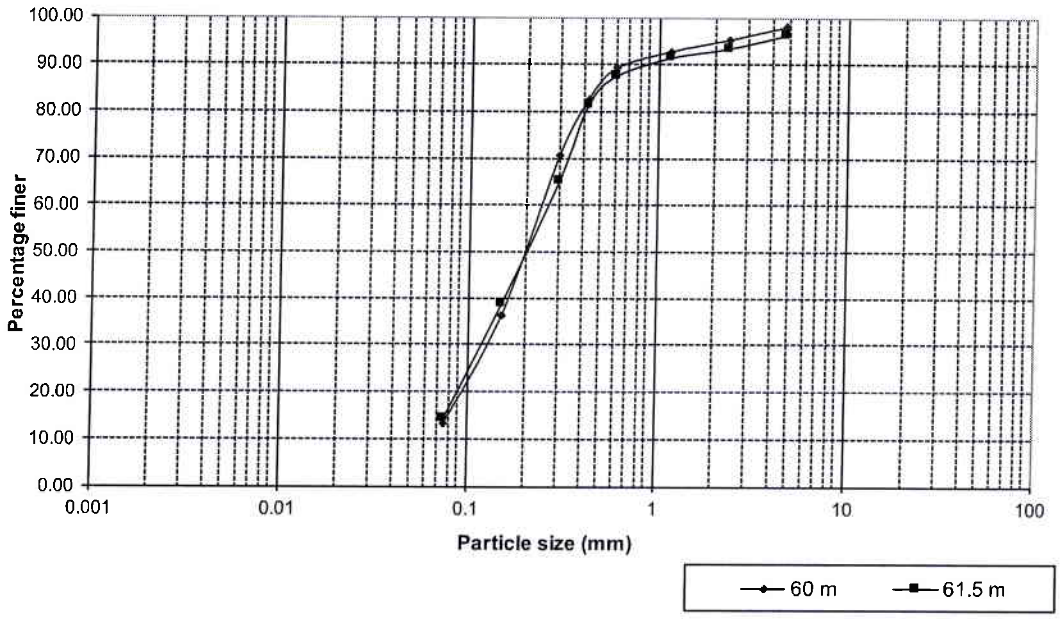



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P164 | 57 m | 0.00 | 14.20 | 81.20 | 4.60 | 1.05 |
| P164 | 58.5 m | 0.00 | 13.60 | 80.05 | 6.35 | 0.97 |

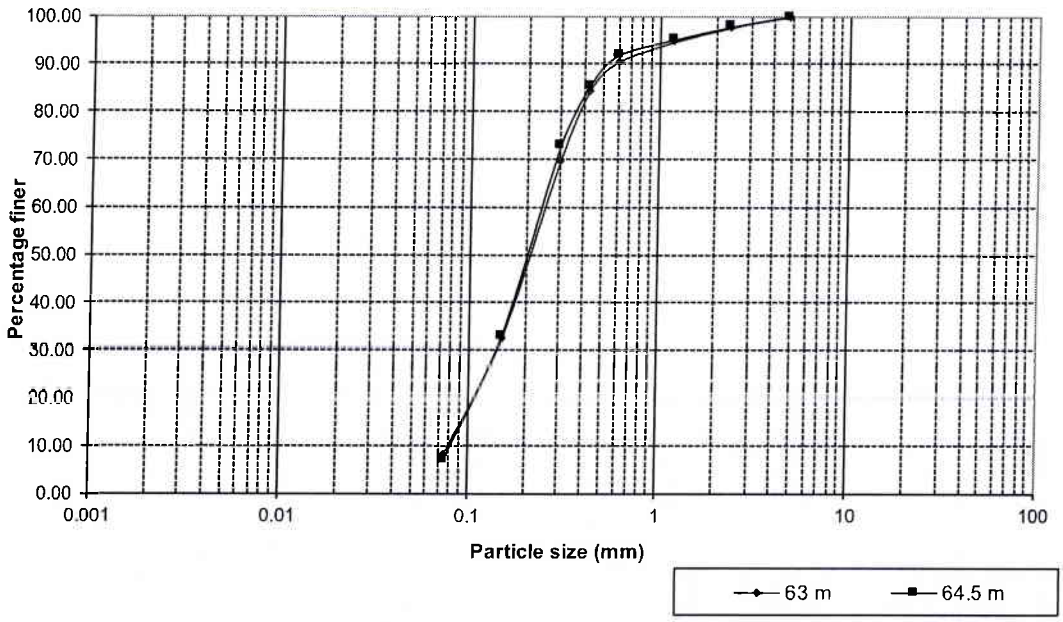
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P164 | 60 m | 0.00 | 13.00 | 85.00 | 2.00 | 1.10 |
| P164 | 61.5 m | 0.00 | 14.30 | 82.05 | 3.65 | 1.08 |



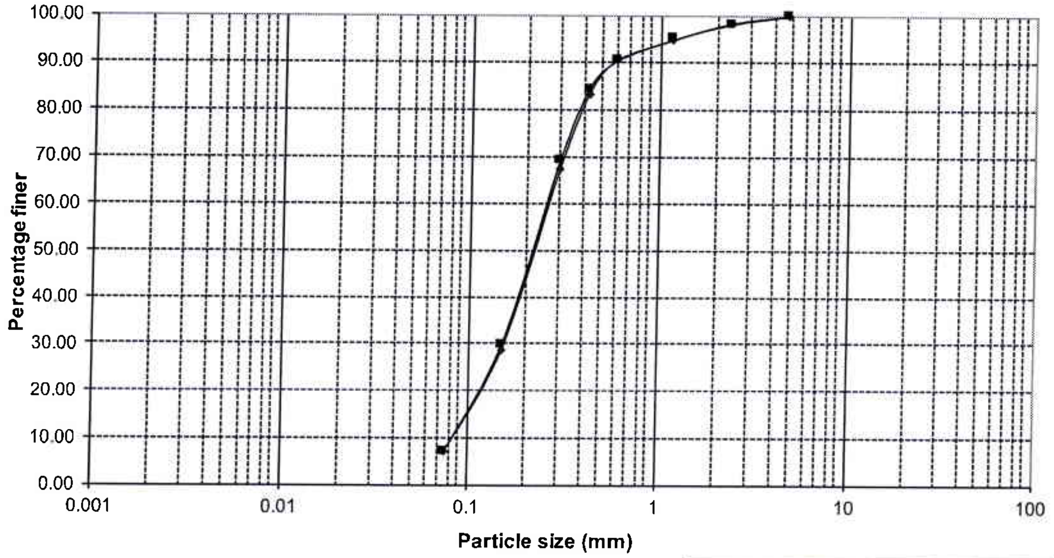

| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P164 | 63 m | 0.00 | 8.00 | 92.00 | 0.00 | 1.11 |
| P164 | 64.5 m | 0.00 | 7.15 | 92.85 | 0.00 | 1.09 |

ANAND RAJ INFRATECH PVT. LTD.

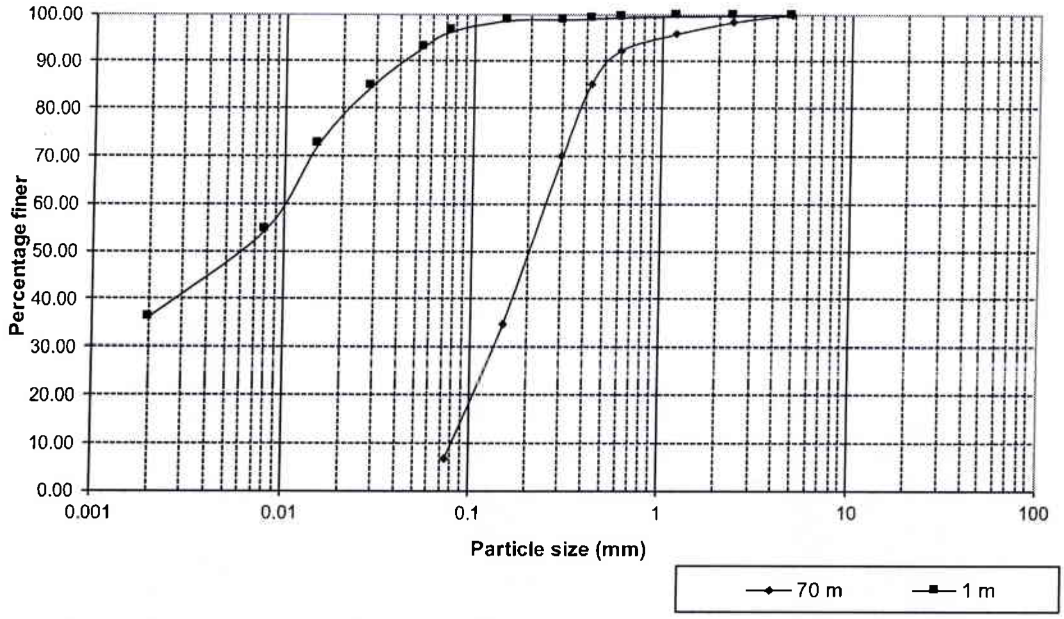
M/s Anand Raj Infratech Pvt. Ltd.

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## PARTICLE SIZE DISTRIBUTION CURVES



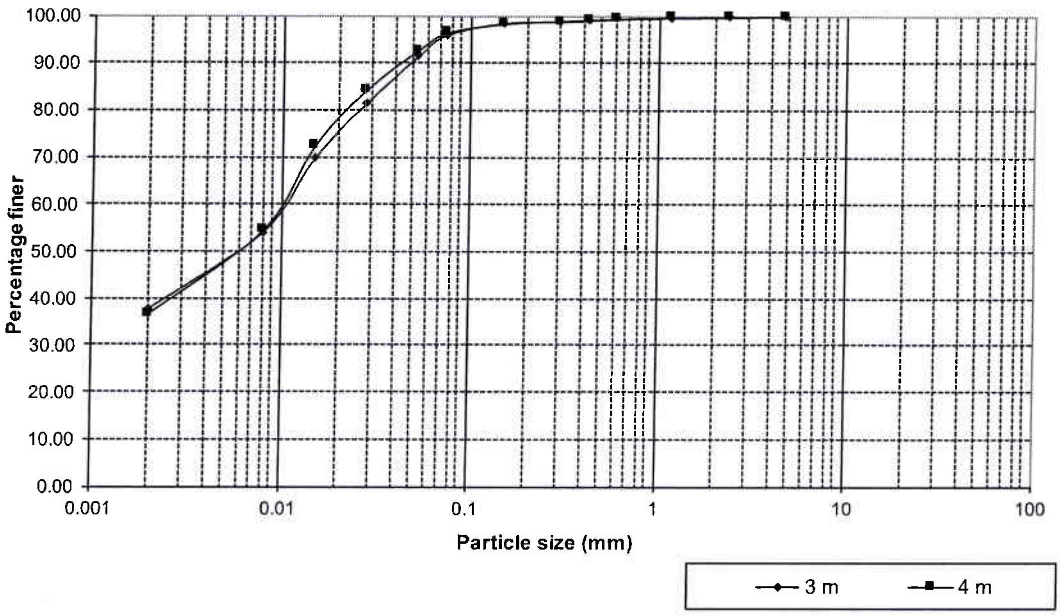

| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P164 | 66 m | 0.00 | 7.00 | 93.00 | 0.00 | 1.11 |
| P164 | 67.5 m | 0.00 | 7.10 | 92.90 | 0.00 | 1.10 |



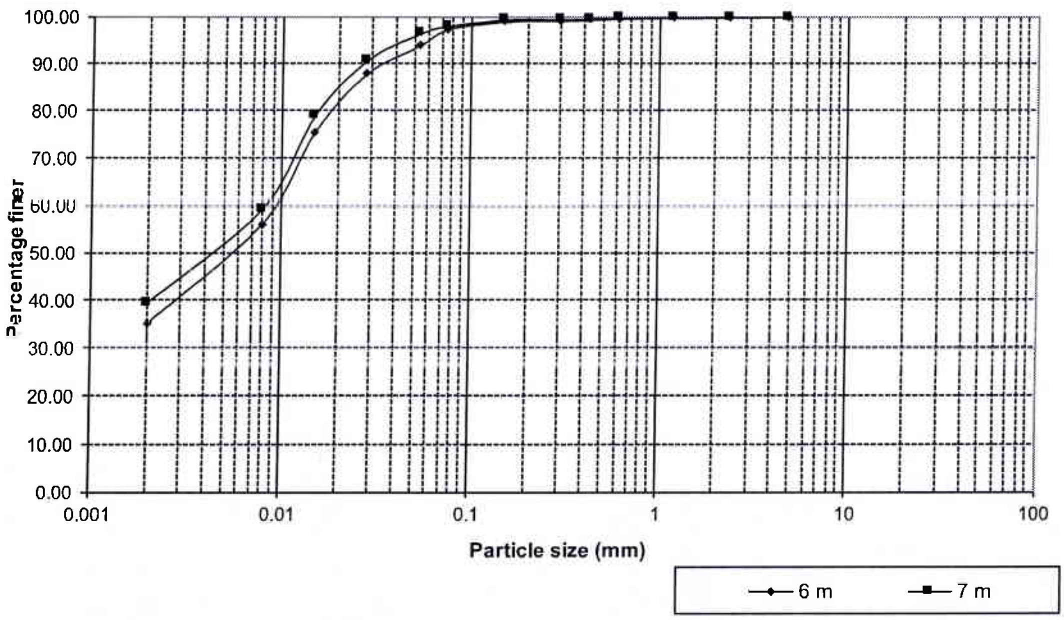

| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P164 | 70 m | 0.00 | 6.50 | 93.50 | 0.00 | 1.06 |
| P165 | 1 m | 36.32 | 60.14 | 3.54 | 0.00 | |

ANAND RAJ INFRATECH PVT. LTD. PATNA

## PARTICLE SIZE DISTRIBUTION CURVES




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P165 | 3 m | 37.69 | 58.26 | 4.05 | 0.00 | |
| P165 | 4 m | 36.77 | 59.62 | 3.61 | 0.00 | |

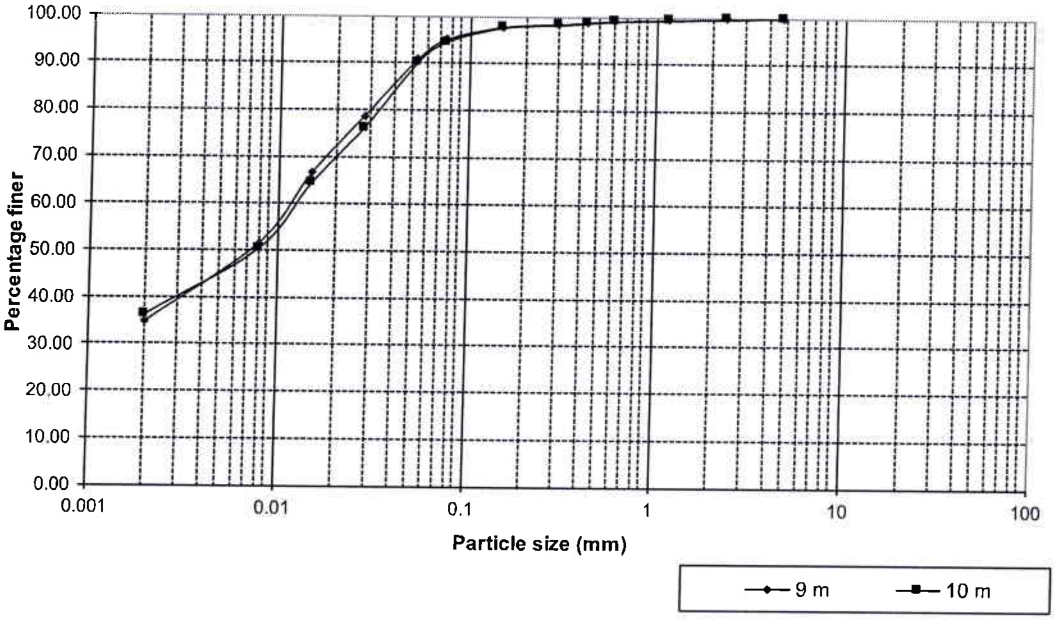



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P165 | 6 m | 34.94 | 62.41 | 2.65 | 0.00 | |
| P165 | 7 m | 39.46 | 58.60 | 1.94 | 0.00 | |

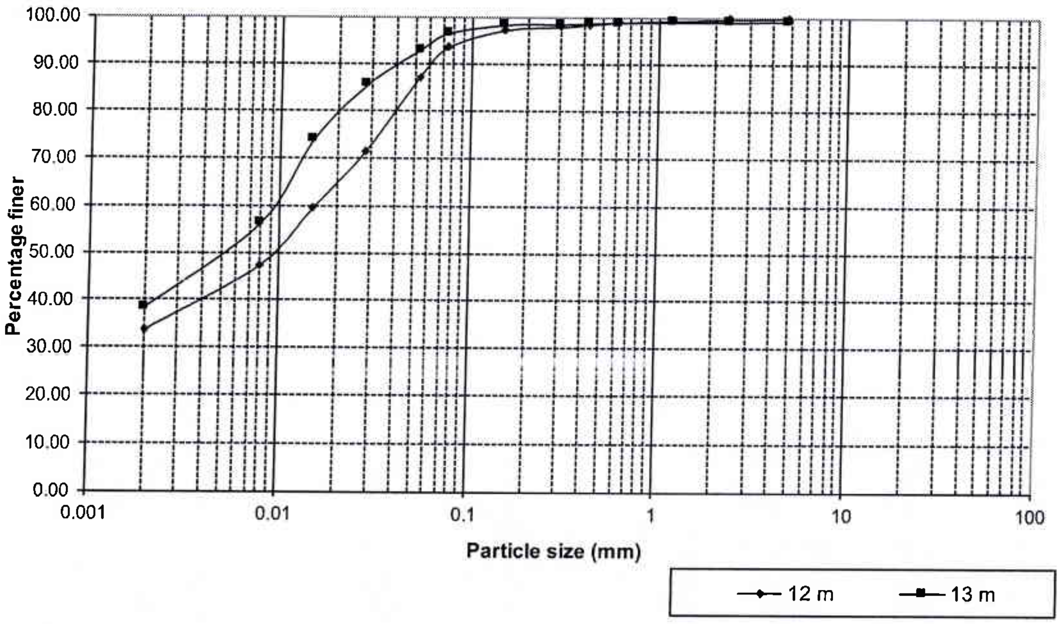
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## PARTICLE SIZE DISTRIBUTION CURVES

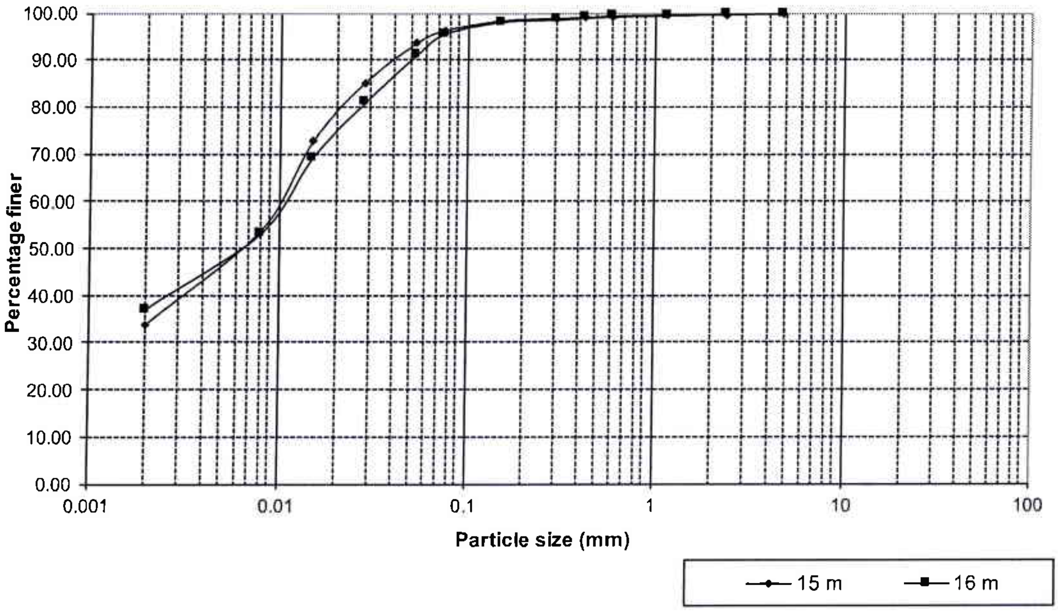



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P165 | 9 m | 34.68 | 60.47 | 4.85 | 0.00 | |
| P165 | 10 m | 36.11 | 58.47 | 5.42 | 0.00 | |

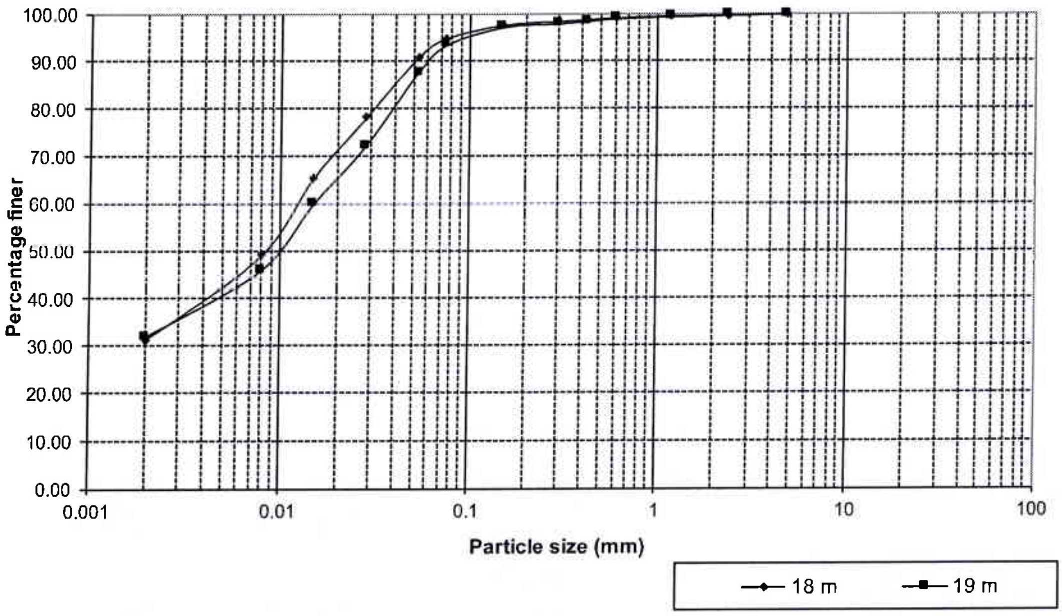



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P165 | 12 m | 33.50 | 60.25 | 6.25 | 0.00 | |
| P165 | 13 m | 38.44 | 58.22 | 2.58 | 0.76 | |

PARTICLE SIZE DISTRIBUTION CURVES




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P165 | 15 m | 33.84 | 62.41 | 3.54 | 0.21 | |
| P165 | 16 m | 37.00 | 58.66 | 4.34 | 0.00 | |

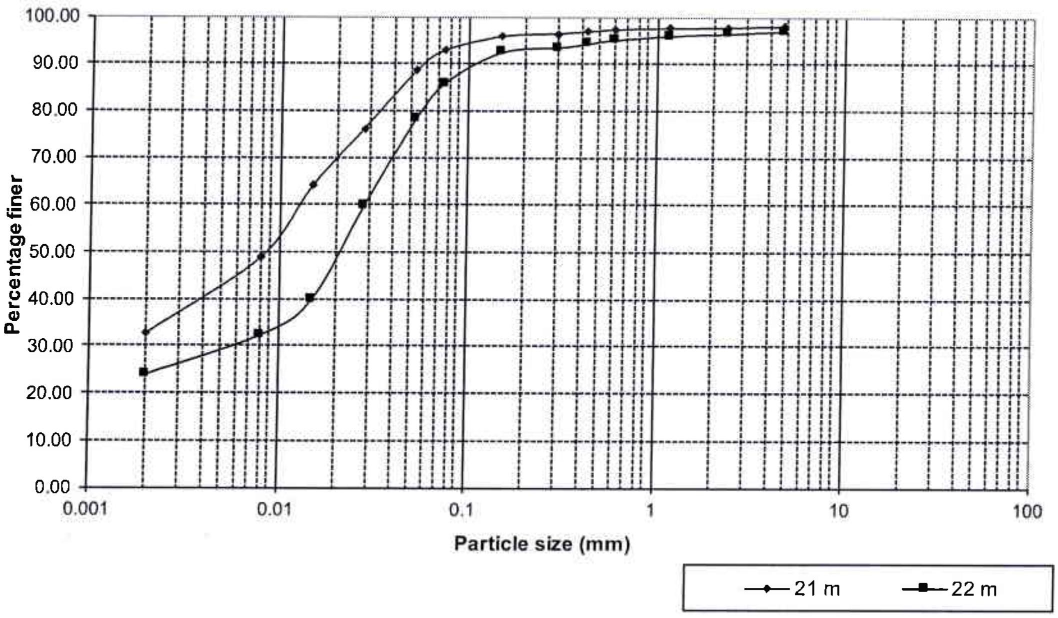



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P165 | 18 m | 31.29 | 63.52 | 5.04 | 0.15 | |
| P165 | 19 m | 31.75 | 61.80 | 6.45 | 0.00 | |

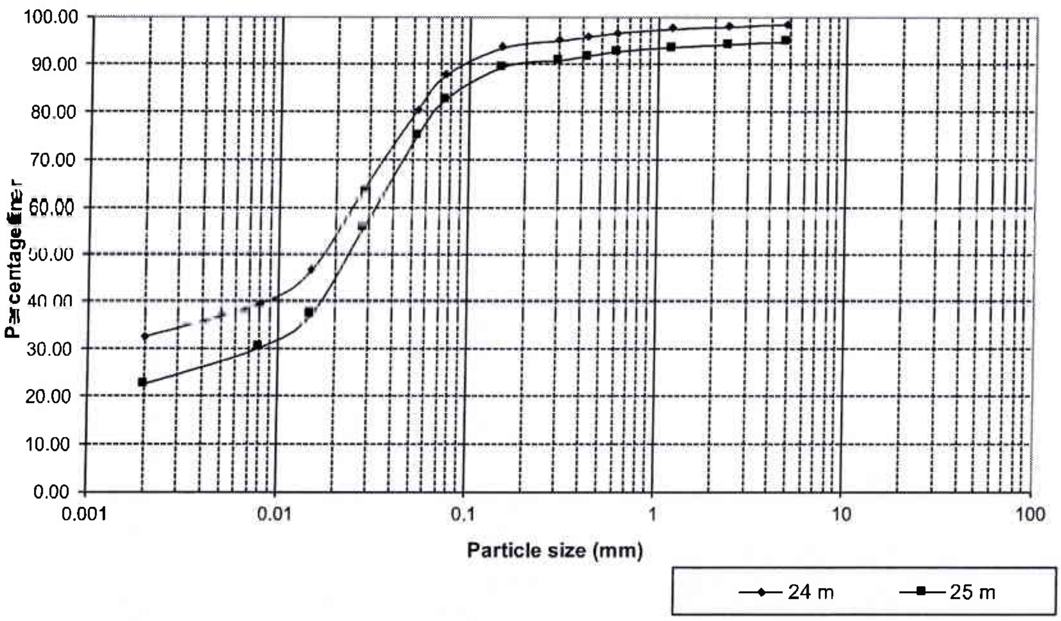
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P165 | 21 m | 32.74 | 60.14 | 5.08 | 2.04 | |
| P165 | 22 m | 24.13 | 61.77 | 11.12 | 2.98 | |



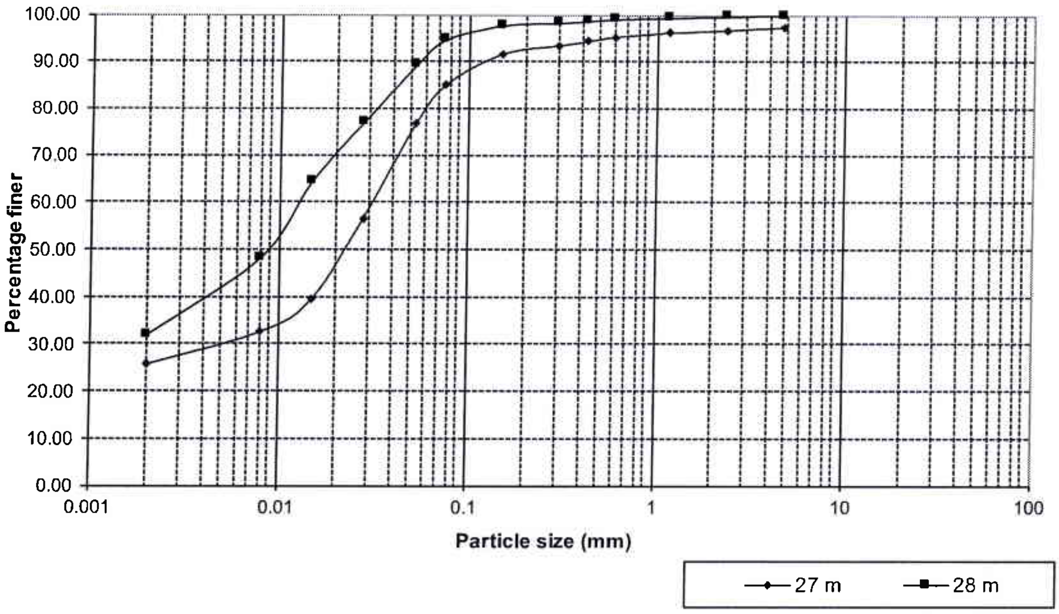

| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P165 | 24 m | 32.43 | 55.48 | 10.58 | 1.51 | |
| P165 | 25 m | 22.46 | 60.14 | 12.09 | 5.31 | |

ANAND RAJ INFRATECH PVT. LTD.

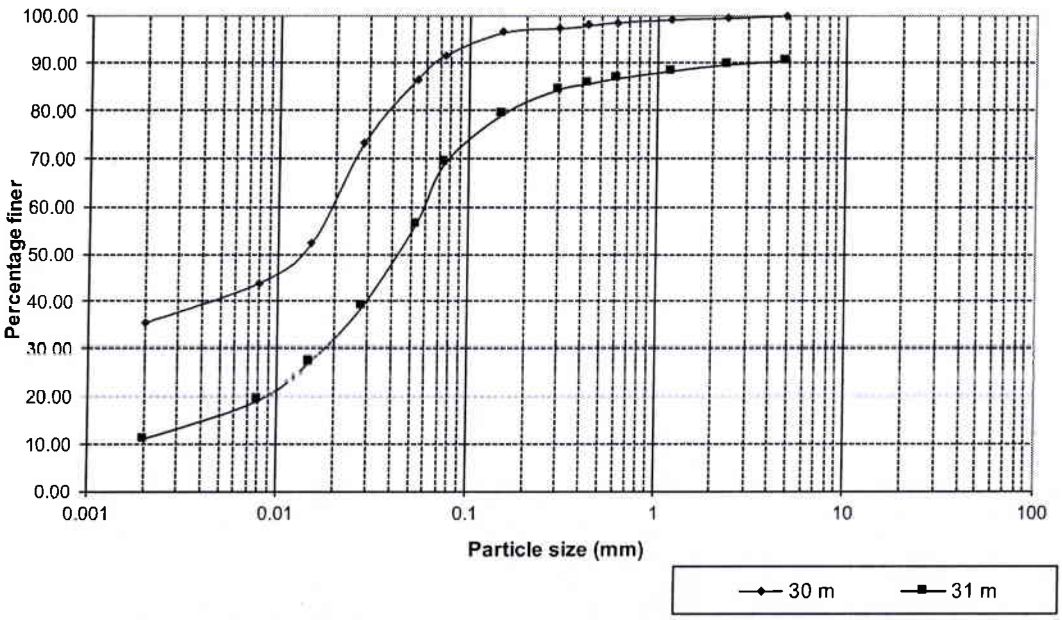
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## PARTICLE SIZE DISTRIBUTION CURVES




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P165 | 27 m | 25.69 | 59.25 | 12.41 | 2.65 | |
| P165 | 28 m | 32.12 | 62.55 | 5.33 | 0.00 | |

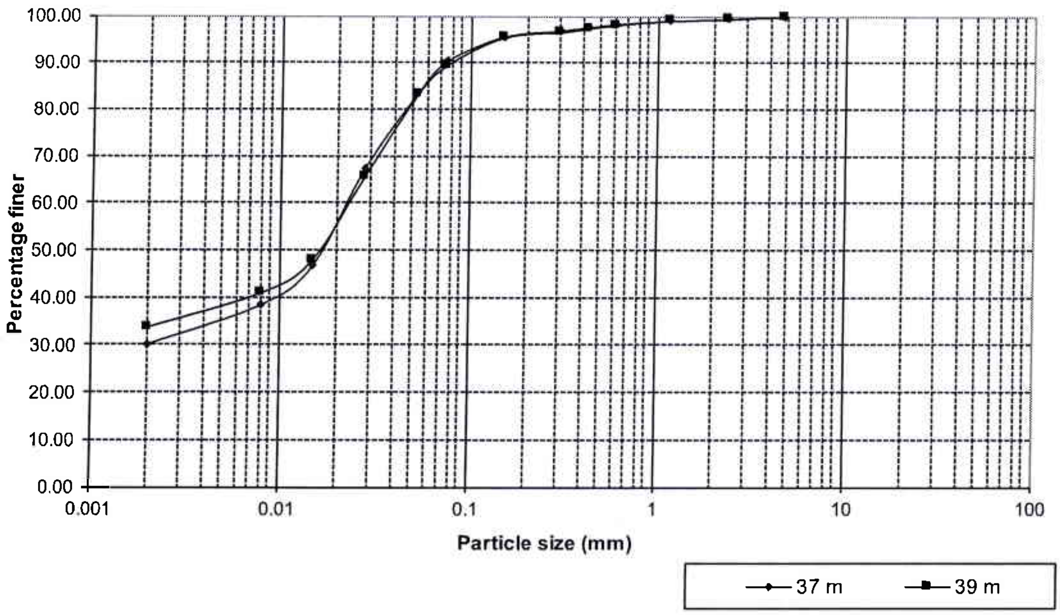



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P165 | 30 m | 35.47 | 56.25 | 8.14 | 0.14 | |
| P165 | 31 m | 10.99 | 58.14 | 21.42 | 9.45 | |

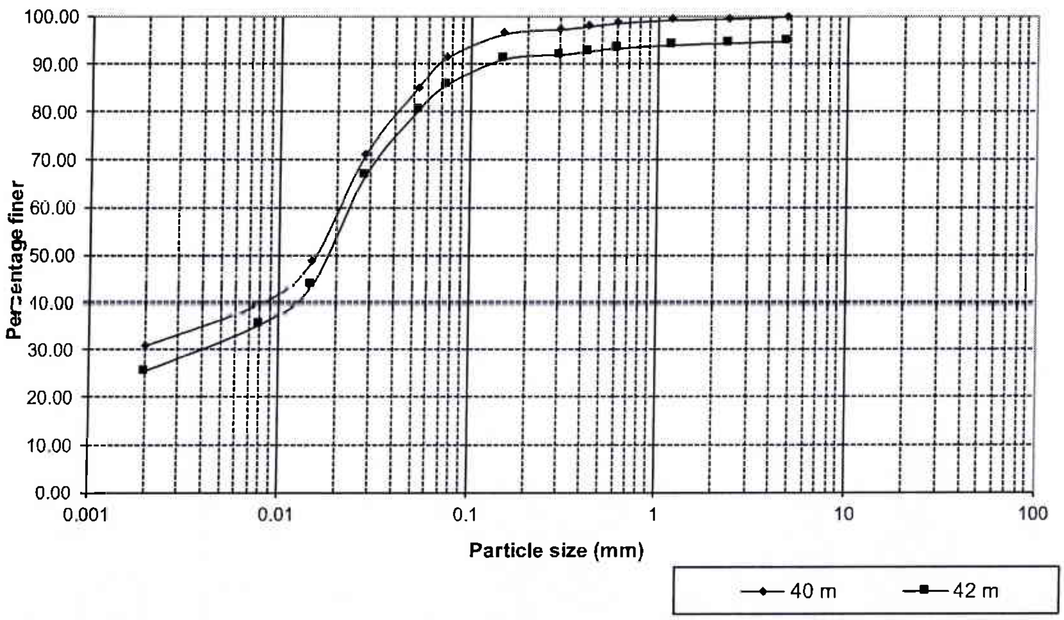
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## PARTICLE SIZE DISTRIBUTION CURVES

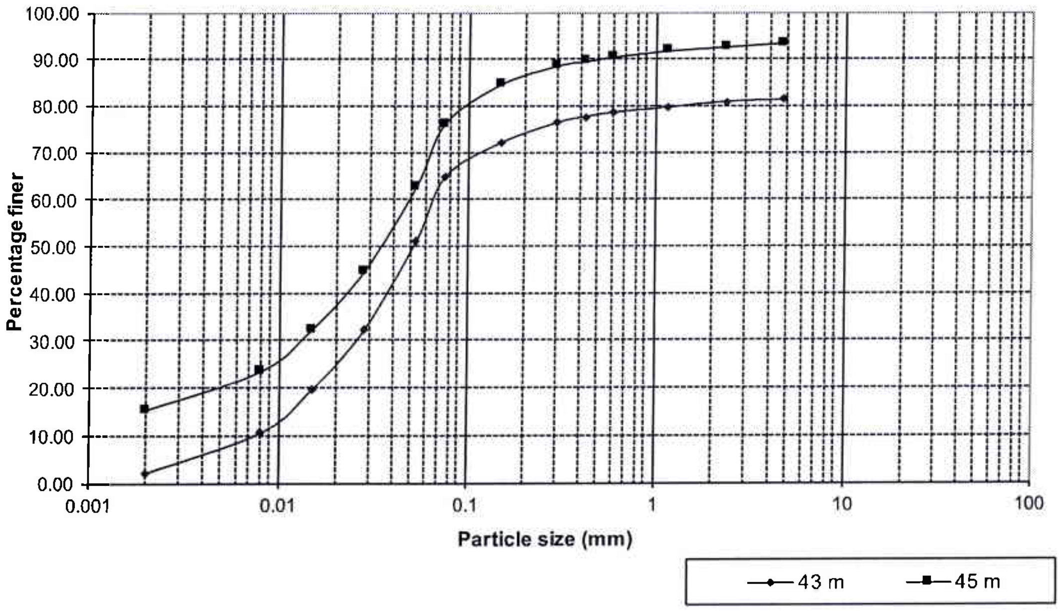



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P165 | 37 m | 30.23 | 60.14 | 9.63 | 0.00 | |
| P165 | 39 m | 33.67 | 55.81 | 10.52 | 0.00 | |

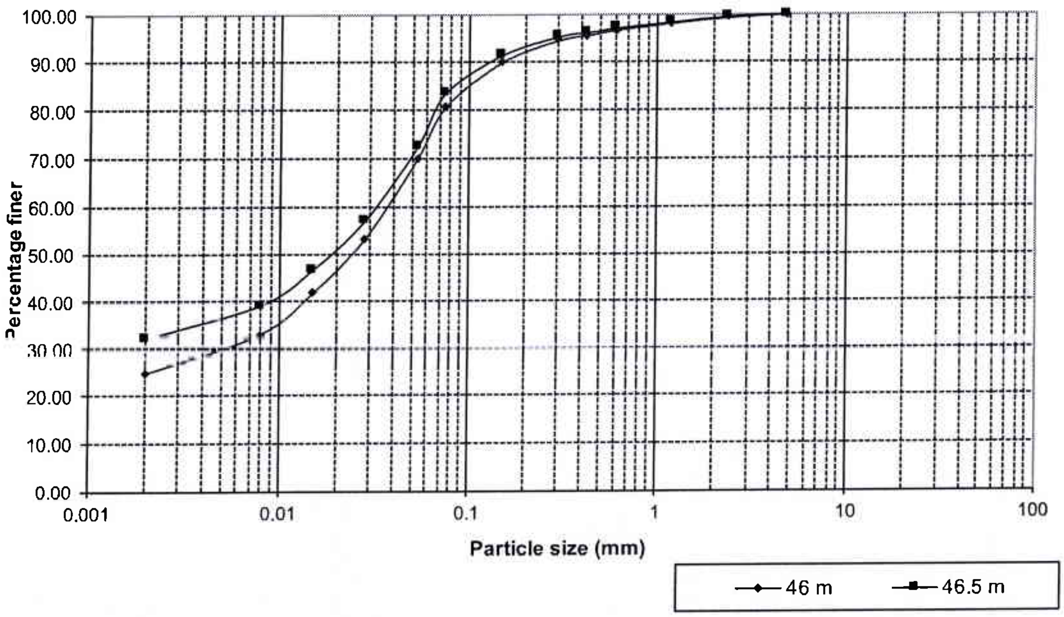



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P165 | 40 m | 30.90 | 60.58 | 8.52 | 0.00 | |
| P165 | 42 m | 25.41 | 60.47 | 9.06 | 5.06 | |

## PARTICLE SIZE DISTRIBUTION CURVES




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P165 | 43 m | 2.05 | 62.58 | 16.63 | 18.74 | |
| P165 | 45 m | 15.31 | 60.85 | 17.26 | 6.58 | |

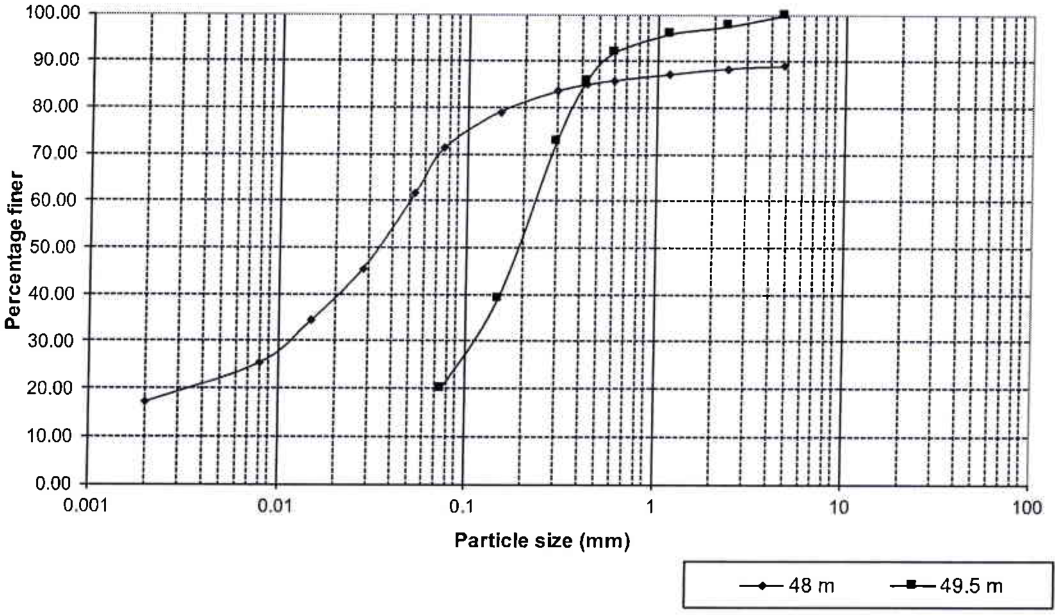



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P165 | 46 m | 24.60 | 56.25 | 19.15 | 0.00 | |
| P165 | 46.5 m | 32.17 | 51.58 | 16.25 | 0.00 | |

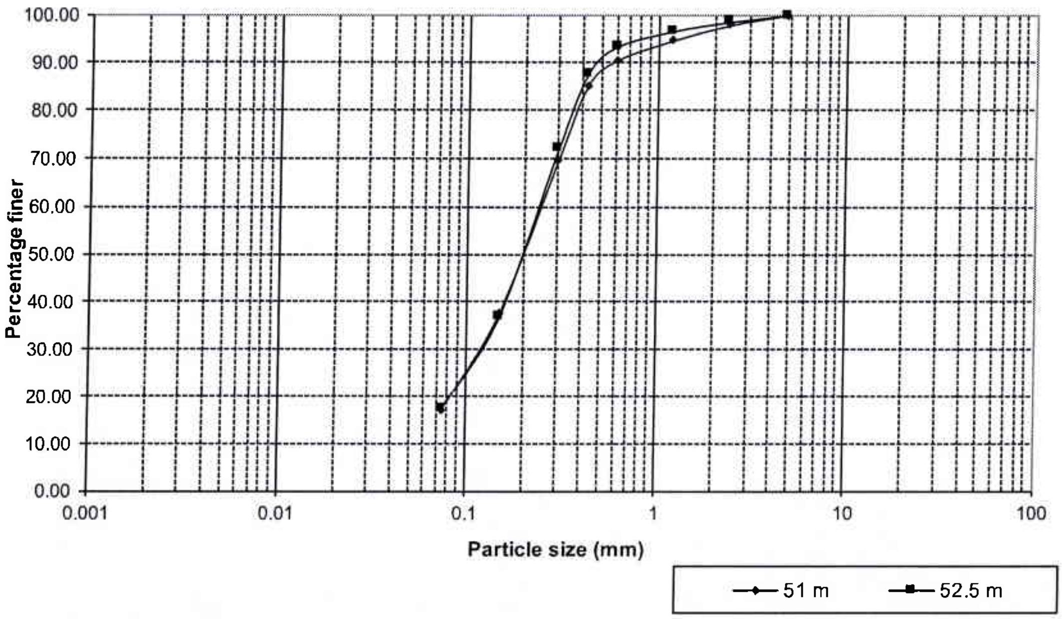
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P165 | 48 m | 17.02 | 54.22 | 17.68 | 11.08 | |
| P165 | 49.5 m | 0.00 | 19.94 | 80.06 | 0.00 | 1.06 |

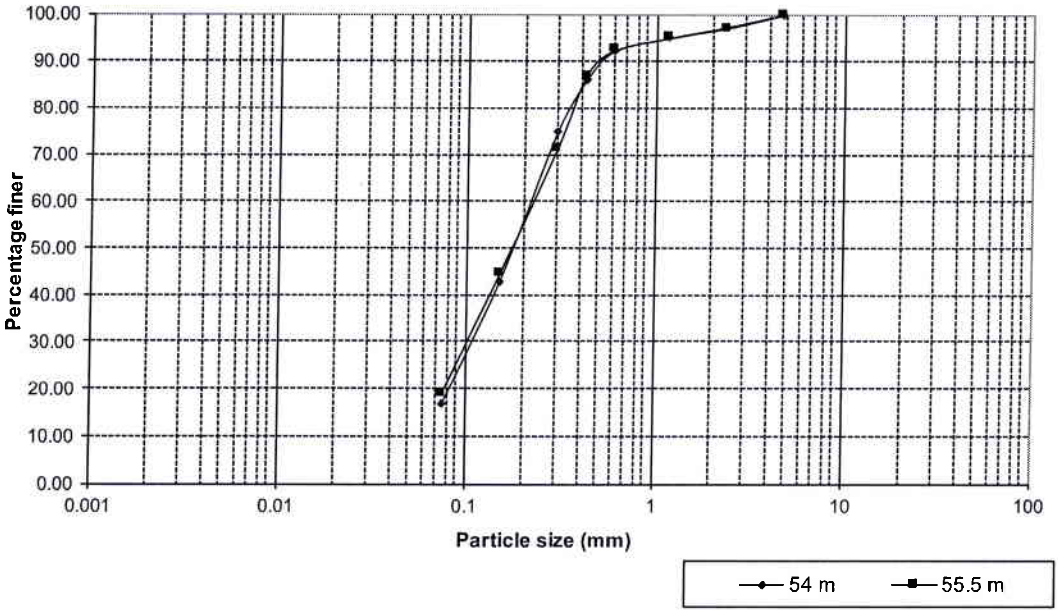



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P165 | 51 m | 0.00 | 17.17 | 82.83 | 0.00 | 1.08 |
| P165 | 52.5 m | 0.00 | 17.53 | 82.47 | 0.00 | 1.01 |

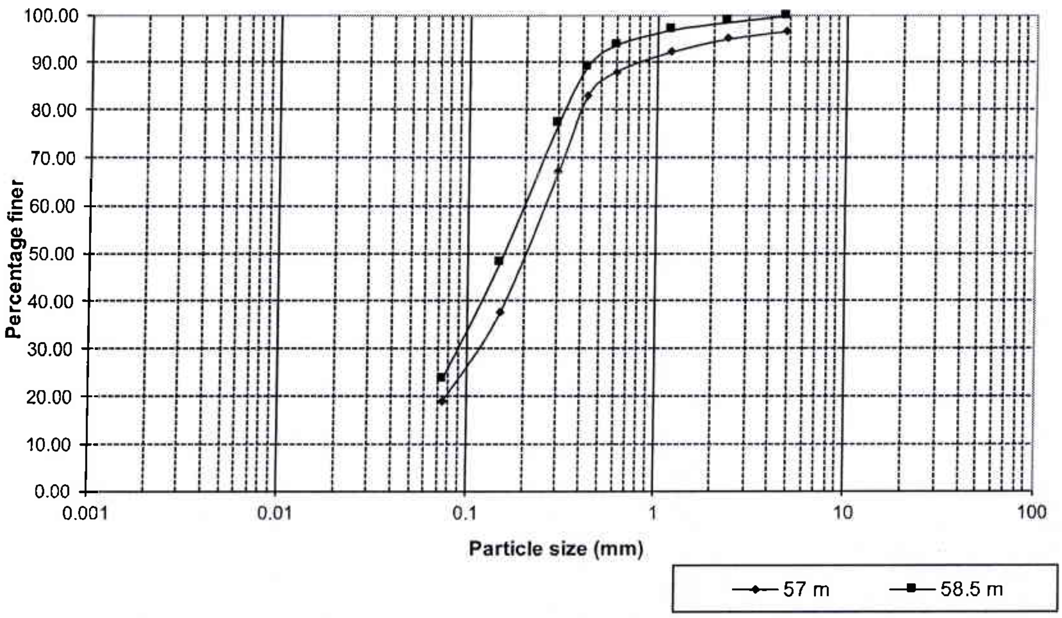
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P165 | 54 m | 0.00 | 16.86 | 83.14 | 0.00 | 1.07 |
| P165 | 55.5 m | 0.00 | 19.05 | 80.95 | 0.00 | 1.06 |

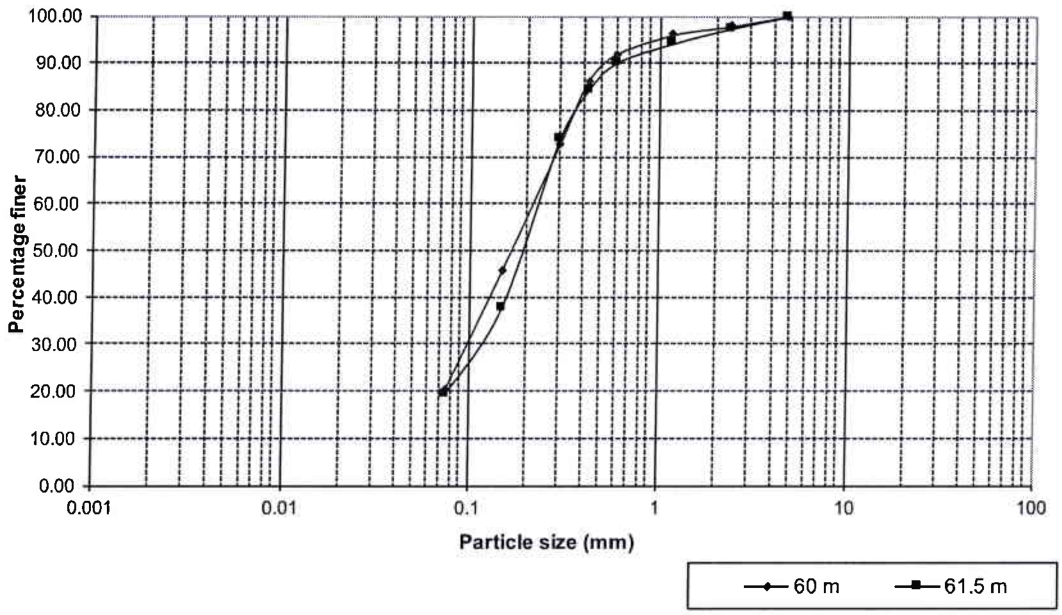



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P165 | 57 m | 0.00 | 18.87 | 77.73 | 3.40 | 1.03 |
| P165 | 58.5 m | 0.00 | 23.41 | 76.59 | 0.00 | 0.96 |

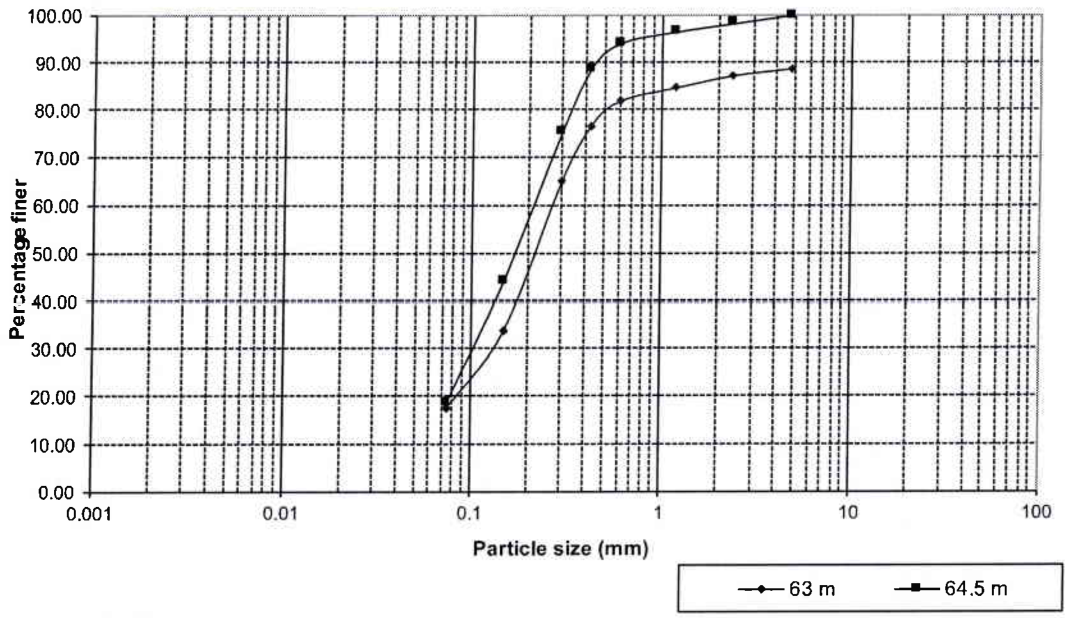
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**PARTICLE SIZE DISTRIBUTION CURVES**




| *Grain size (mm)* | | *< 0.002* | *0.002 - 0.075* | *0.075 - 4.75* | *> 4.75* | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| **Bore Hole** | **Sample** | **Clay (%)** | **Silt (%)** | **Sand (%)** | **Gravel (%)** | |
| P165 | 60 m | 0.00 | 20.51 | 79.49 | 0.00 | 1.02 |
| P165 | 61.5 m | 0.00 | 19.26 | 80.74 | 0.00 | 1.10 |




| *Grain size (mm)* | | *< 0.002* | *0.002 - 0.075* | *0.075 - 4.75* | *> 4.75* | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| **Bore Hole** | **Sample** | **Clay (%)** | **Silt (%)** | **Sand (%)** | **Gravel (%)** | |
| P165 | 63 m | 0.00 | 17.40 | 71.30 | 11.30 | 0.98 |
| P165 | 64.5 m | 0.00 | 18.53 | 81.47 | 0.00 | 0.99 |

ANAND RAJ INFRATECH PVT. LTD.

**M/s Anand Raj Infratech Pvt. Ltd.**

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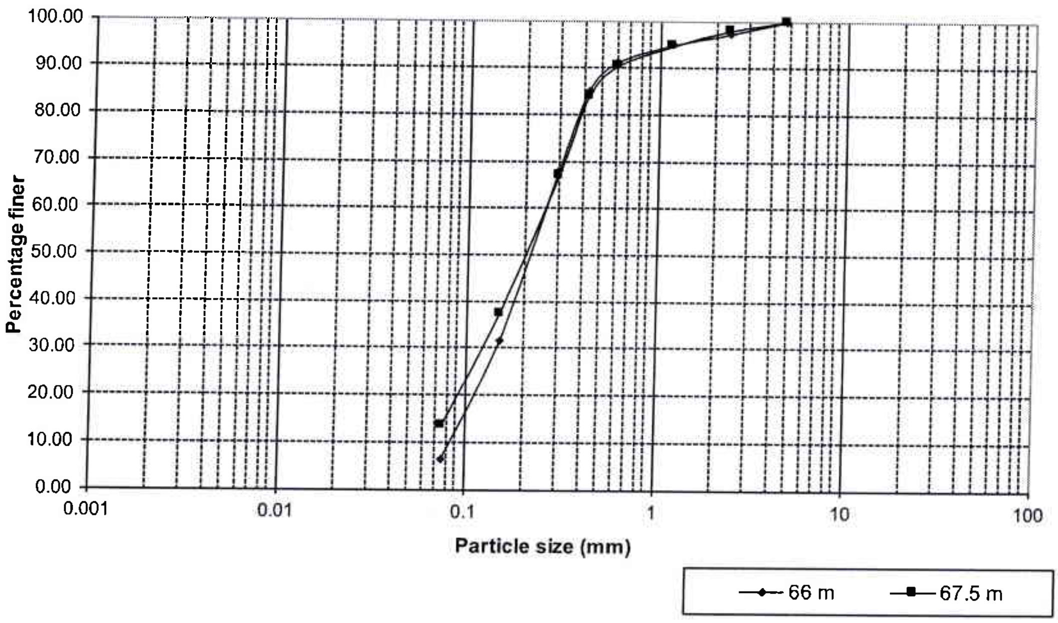
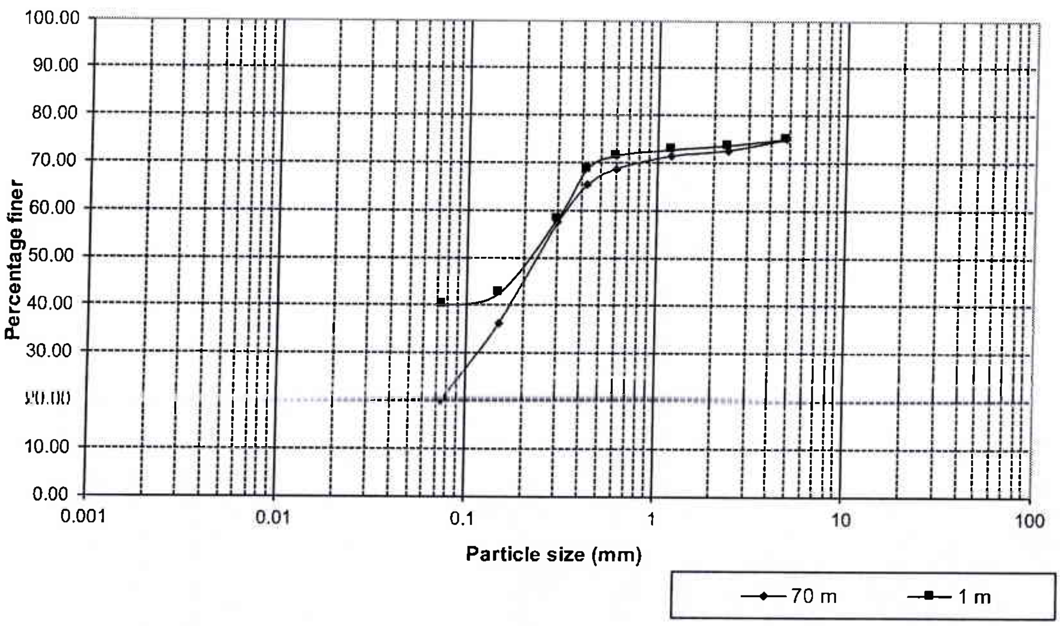
## PARTICLE SIZE DISTRIBUTION CURVES




| *Grain size (mm)* | | *< 0.002* | *0.002 - 0.075* | *0.075 - 4.75* | *> 4.75* | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| **Bore Hole** | **Sample** | **Clay (%)** | **Silt (%)** | **Sand (%)** | **Gravel (%)** | |
| P165 | 66 m | 0.00 | 6.29 | 93.71 | 0.00 | 1.11 |
| P165 | 67.5 m | 0.00 | 13.46 | 86.54 | 0.00 | 1.09 |




| *Grain size (mm)* | | *< 0.002* | *0.002 - 0.075* | *0.075 - 4.75* | *> 4.75* | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| **Bore Hole** | **Sample** | **Clay (%)** | **Silt (%)** | **Sand (%)** | **Gravel (%)** | |
| P165 | 70 m | 0.00 | 19.95 | 55.03 | 25.02 | 0.90 |
| P166 | 1 m | 0.00 | 40.00 | 35.00 | 25.00 | 0.77 |

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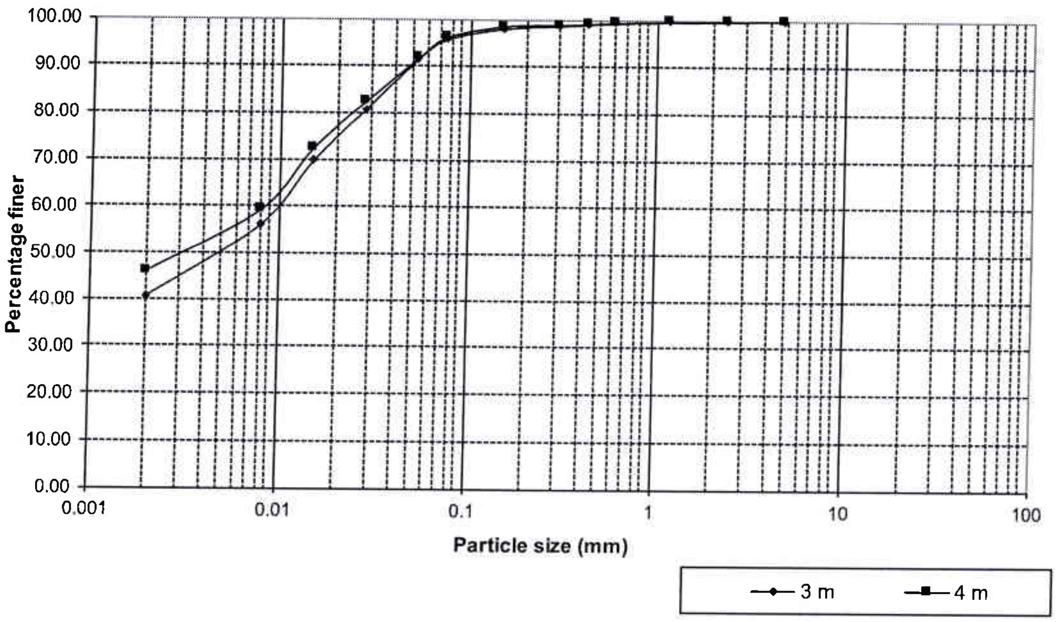
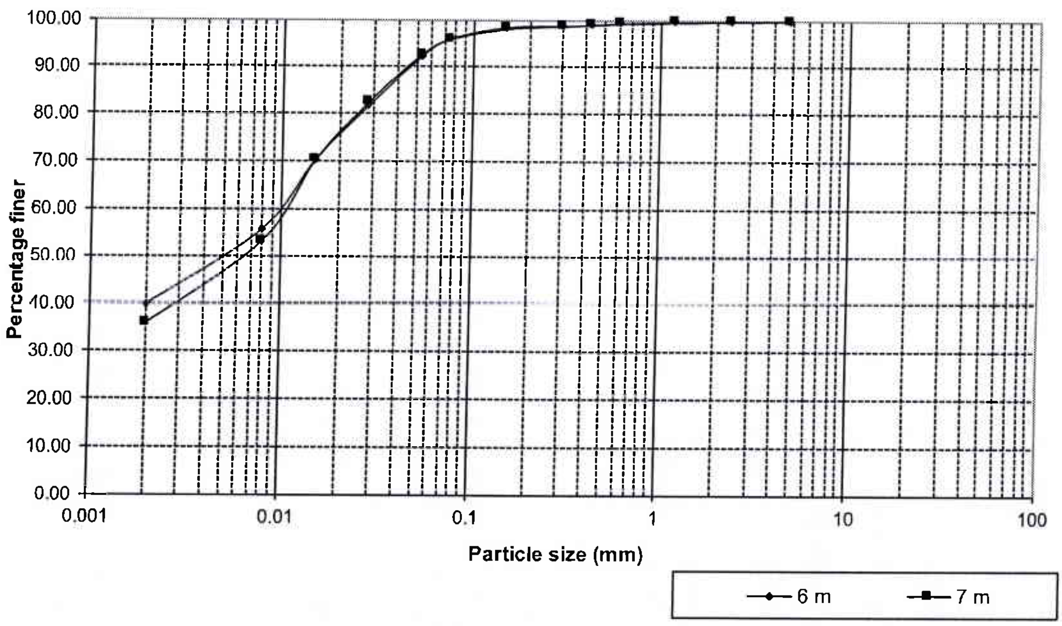
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## PARTICLE SIZE DISTRIBUTION CURVES




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P166 | 3 m | 40.69 | 55.05 | 4.26 | 0.00 | |
| P166 | 4 m | 46.07 | 50.15 | 3.78 | 0.00 | |



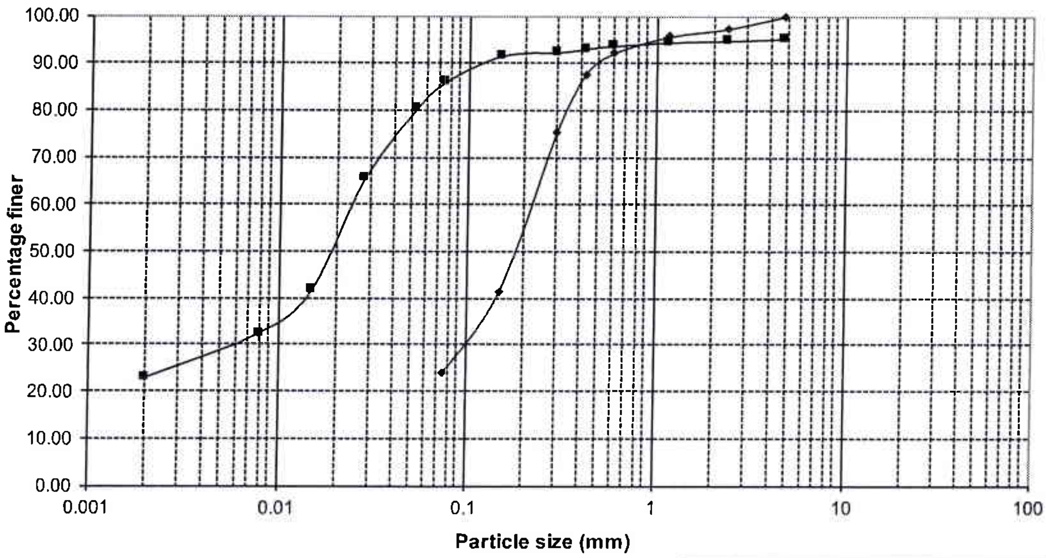

| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P166 | 6 m | 39.83 | 56.25 | 3.92 | 0.00 | |
| P166 | 7 m | 35.68 | 60.25 | 4.07 | 0.00 | |

RAJ INFRATECH PVT. LTD.

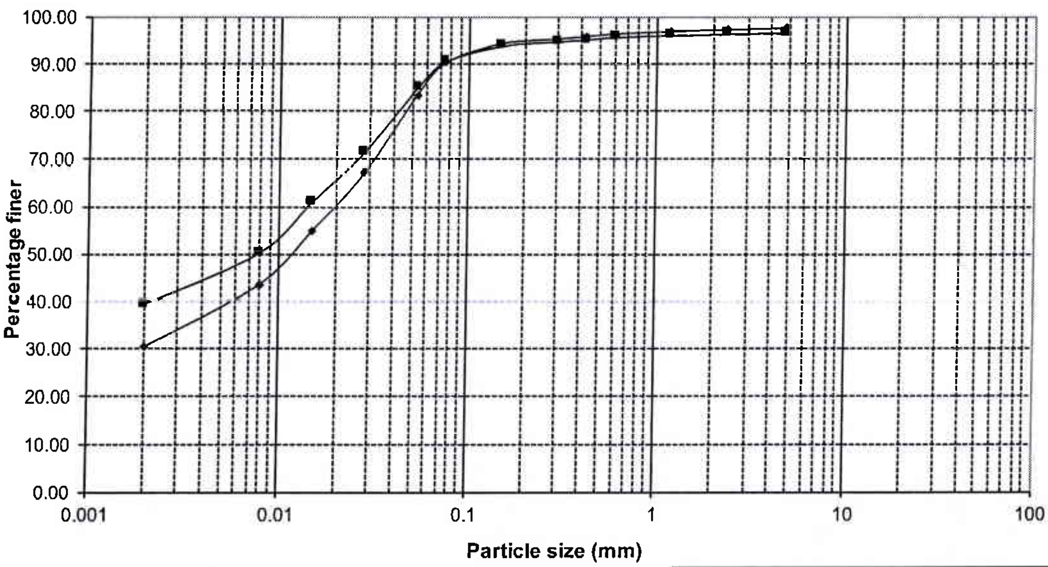
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P166 | 9 m | 0.00 | 24.00 | 76.00 | 0.00 | 1.04 |
| P166 | 10.5 m | 22.75 | 63.25 | 9.30 | 4.70 | |

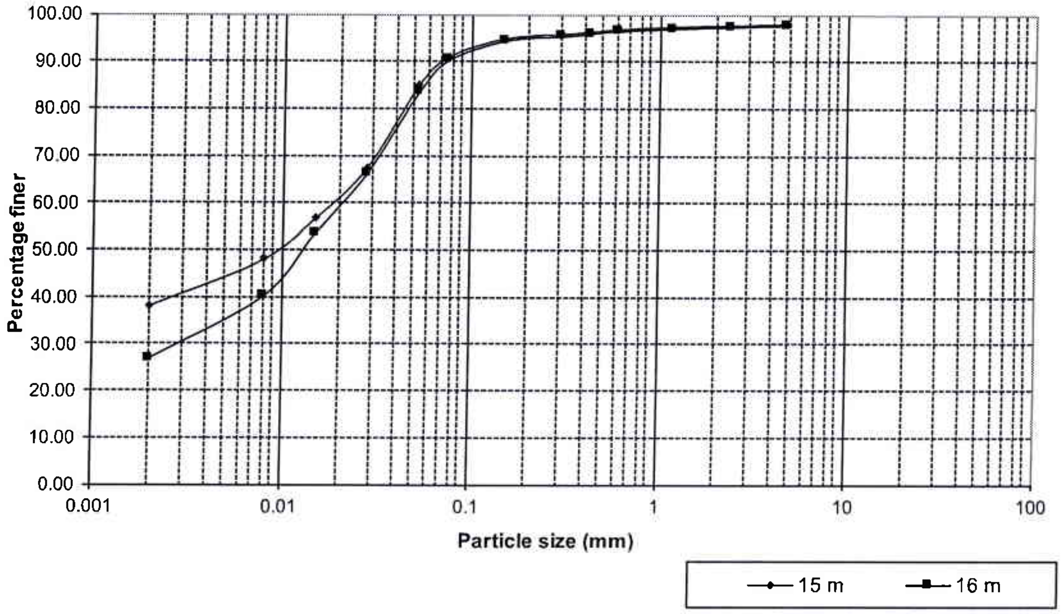



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P166 | 12 m | 30.26 | 60.14 | 7.20 | 2.40 | |
| P166 | 13 m | 39.22 | 51.48 | 6.04 | 3.26 | |

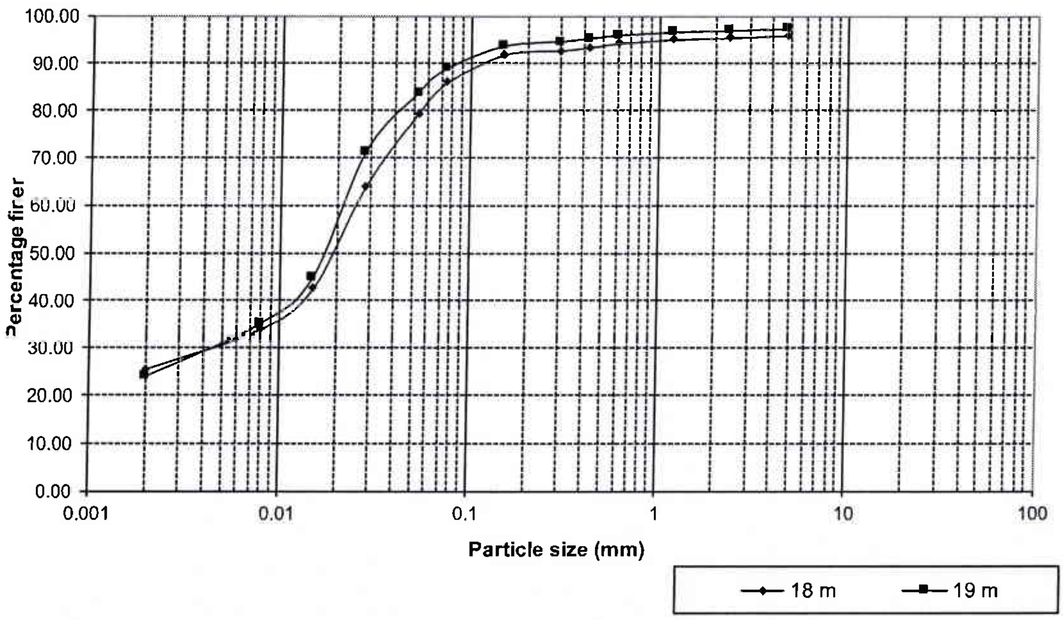
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## PARTICLE SIZE DISTRIBUTION CURVES

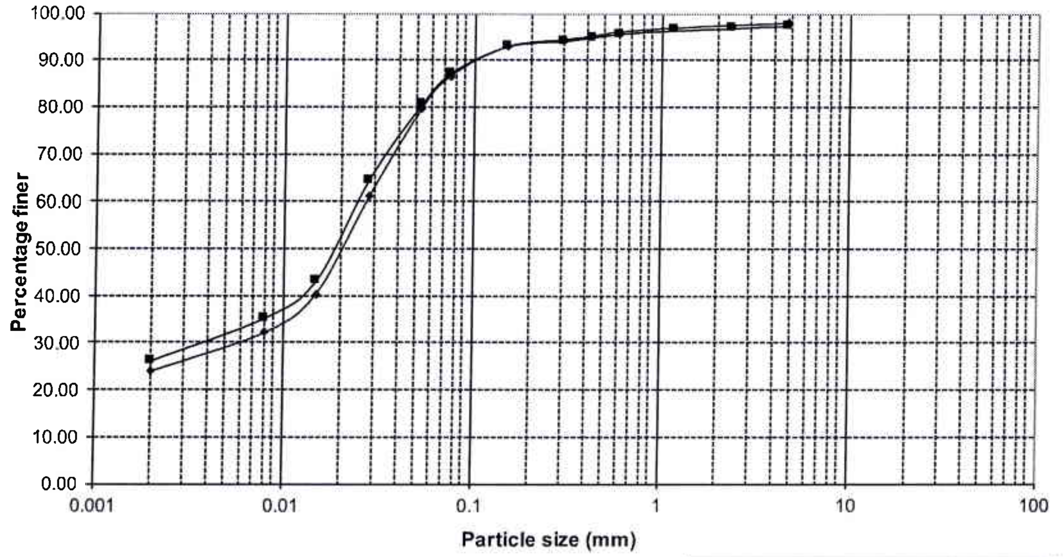



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P166 | 15 m | 38.24 | 52.66 | 7.10 | 2.00 | |
| P166 | 16 m | 27.05 | 63.25 | 7.50 | 2.20 | |

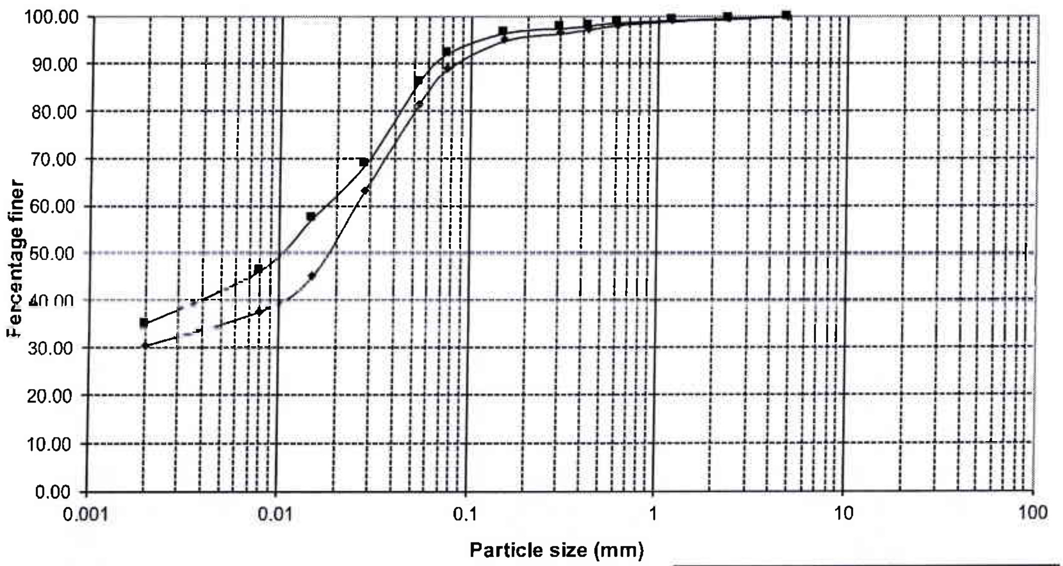



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P166 | 18 m | 25.42 | 60.58 | 10.00 | 4.00 | |
| P166 | 19 m | 23.75 | 65.25 | 8.20 | 2.80 | |

## PARTICLE SIZE DISTRIBUTION CURVES




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P166 | 21 m | 23.95 | 62.65 | 11.30 | 2.10 | |
| P166 | 22 m | 26.20 | 61.05 | 10.15 | 2.60 | |




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P166 | 24 m | 30.37 | 58.59 | 11.04 | 0.00 | |
| P166 | 25 m | 35.20 | 57.15 | 7.65 | 0.00 | |

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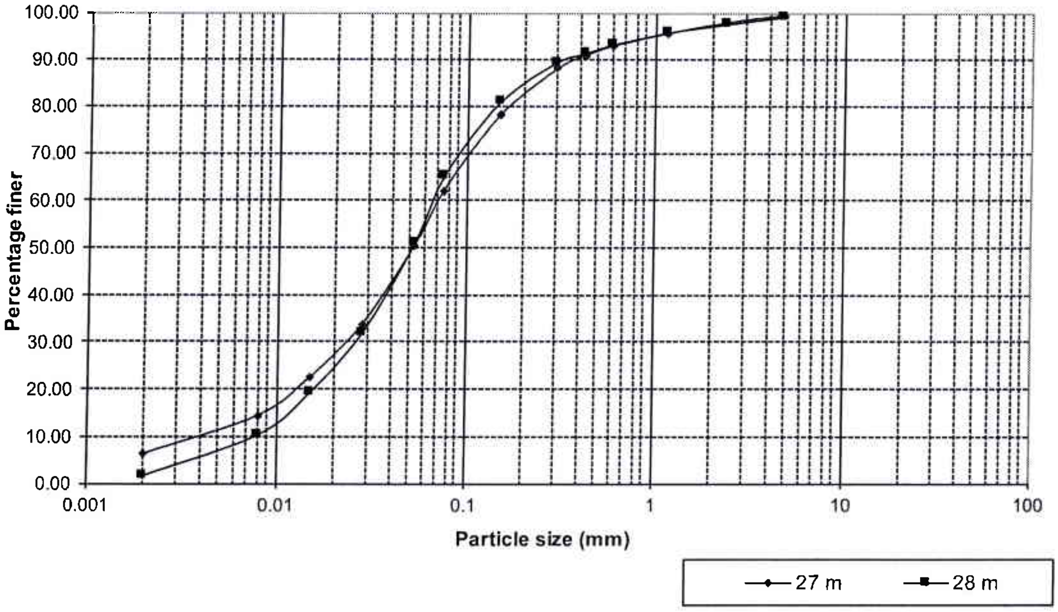
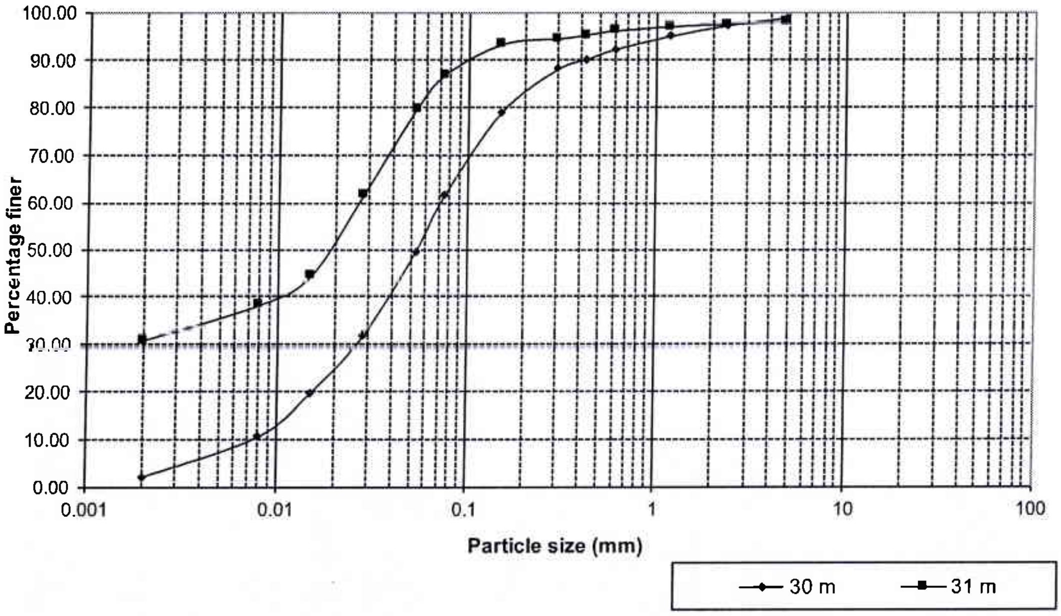
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## PARTICLE SIZE DISTRIBUTION CURVES




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P166 | 27 m | 6.16 | 55.84 | 37.40 | 0.60 | |
| P166 | 28 m | 1.76 | 63.24 | 34.20 | 0.80 | |



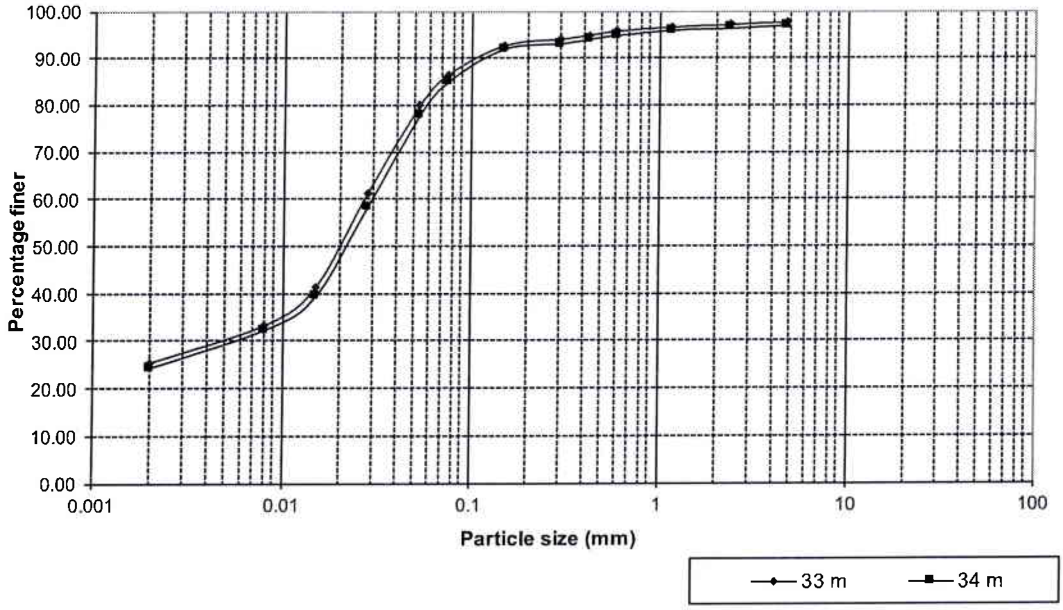

| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P166 | 30 m | 2.08 | 59.57 | 37.15 | 1.20 | |
| P166 | 31 m | 30.75 | 56.25 | 11.00 | 2.00 | |

ANAND RAJ INFRATECH PVT. LTD. PATNA

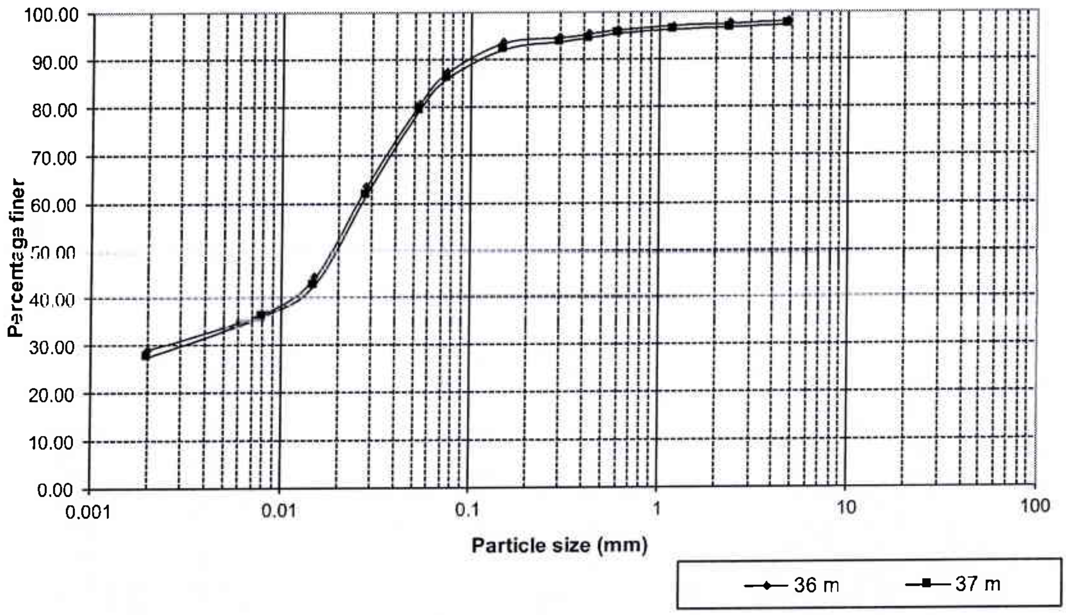
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P166 | 33 m | 25.45 | 61.05 | 11.20 | 2.30 | |
| P166 | 34 m | 24.53 | 60.47 | 12.00 | 3.00 | |

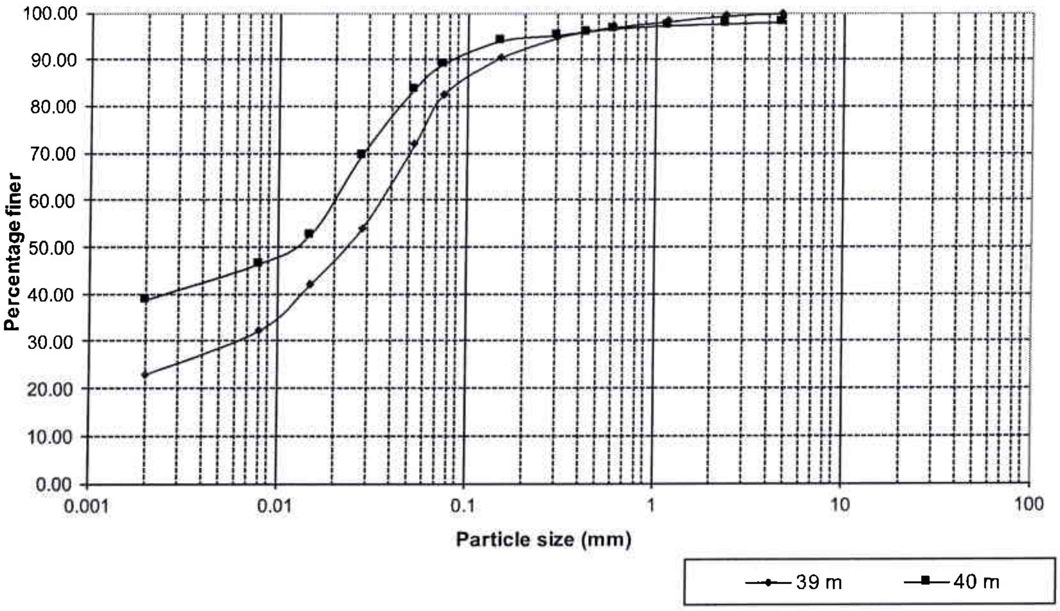



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P166 | 36 m | 29.09 | 58.36 | 10.65 | 1.90 | |
| P166 | 37 m | 27.50 | 58.65 | 11.10 | 2.75 | |

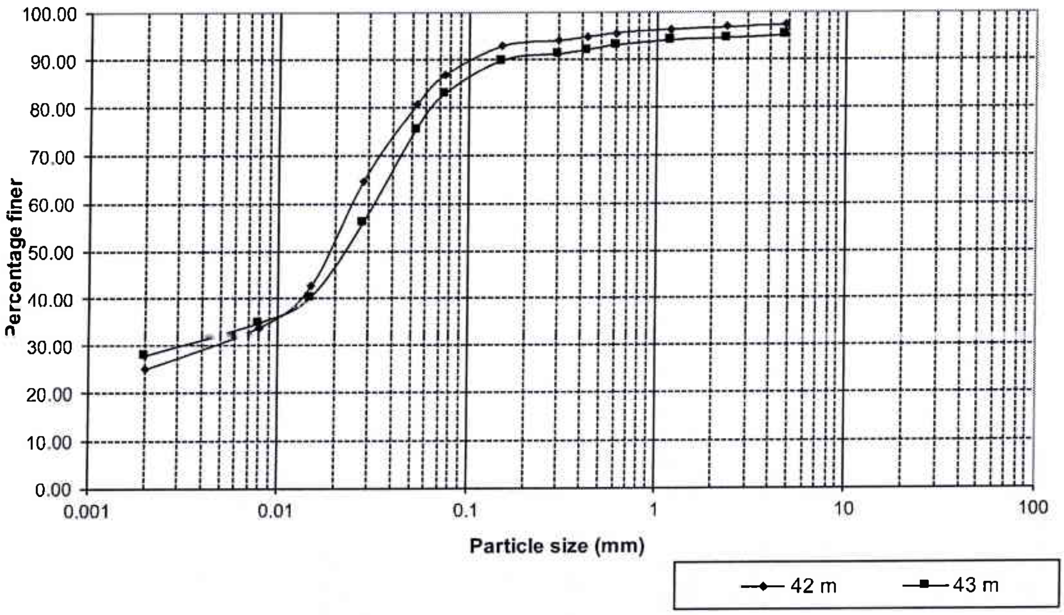
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## PARTICLE SIZE DISTRIBUTION CURVES




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P166 | 39 m | 23.08 | 59.57 | 17.35 | 0.00 | |
| P166 | 40 m | 38.74 | 50.26 | 9.00 | 2.00 | |




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P166 | 42 m | 24.86 | 62.14 | 10.30 | 2.70 | |
| P166 | 43 m | 27.74 | 55.26 | 12.00 | 5.00 | |

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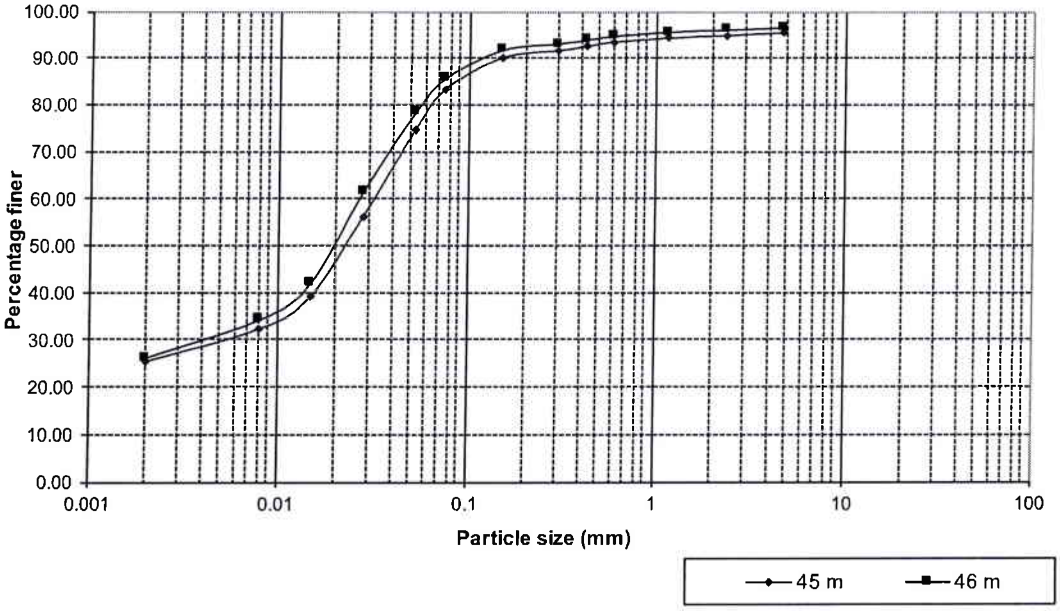
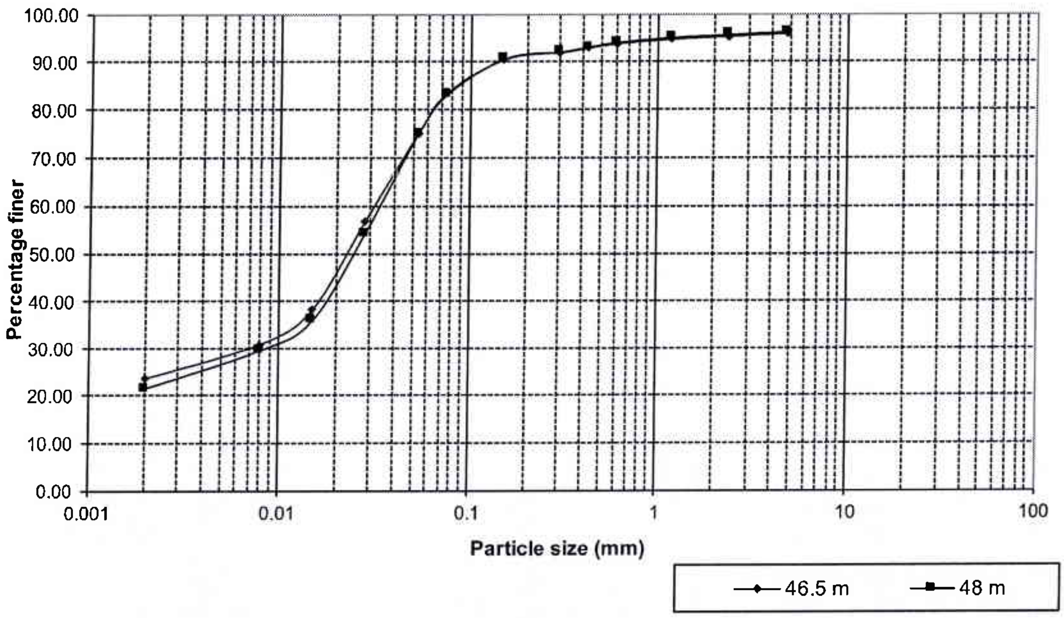
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P166 | 45 m | 25.35 | 57.85 | 12.20 | 4.60 | |
| P166 | 46 m | 26.35 | 59.25 | 11.05 | 3.35 | |




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P166 | 46.5 m | 23.49 | 60.14 | 12.30 | 4.07 | |
| P166 | 48 m | 21.45 | 61.85 | 13.05 | 3.65 | |

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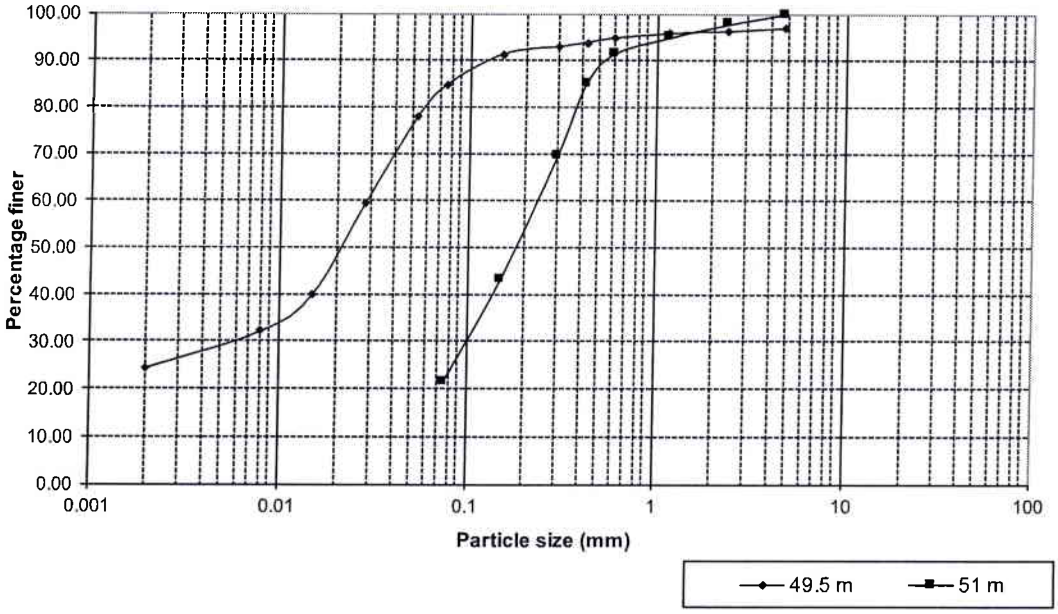
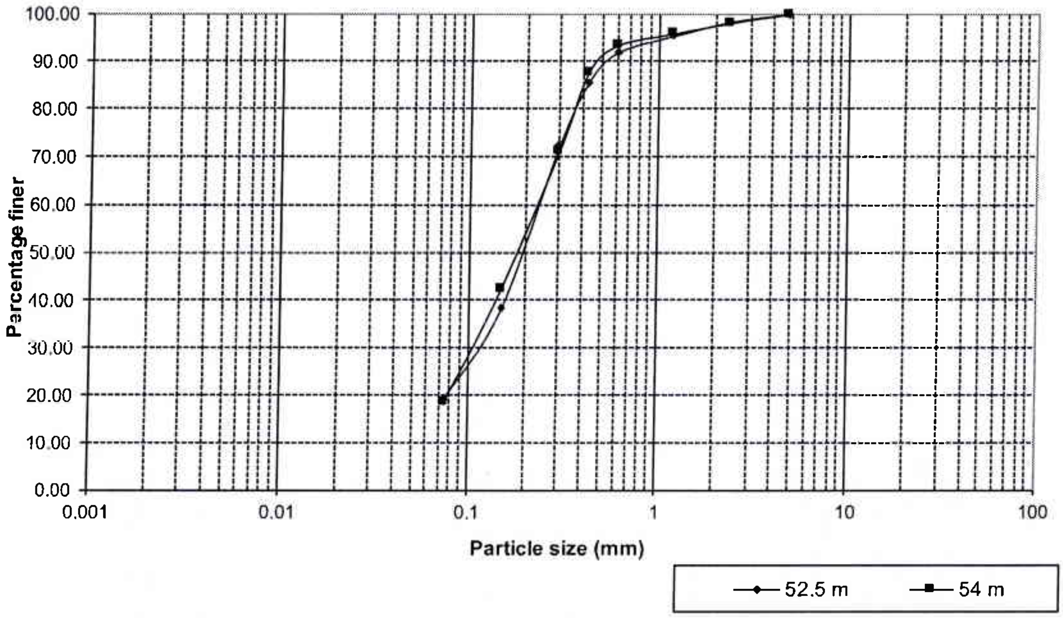
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## PARTICLE SIZE DISTRIBUTION CURVES




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P166 | 49.5 m | 24.54 | 60.24 | 12.01 | 3.21 | |
| P166 | 51 m | 0.00 | 21.45 | 78.55 | 0.00 | 1.05 |




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P166 | 52.5 m | 0.00 | 19.40 | 80.60 | 0.00 | 1.05 |
| P166 | 54 m | 0.00 | 18.55 | 81.45 | 0.00 | 1.02 |

**M/s Anand Raj Infratech Pvt. Ltd.**

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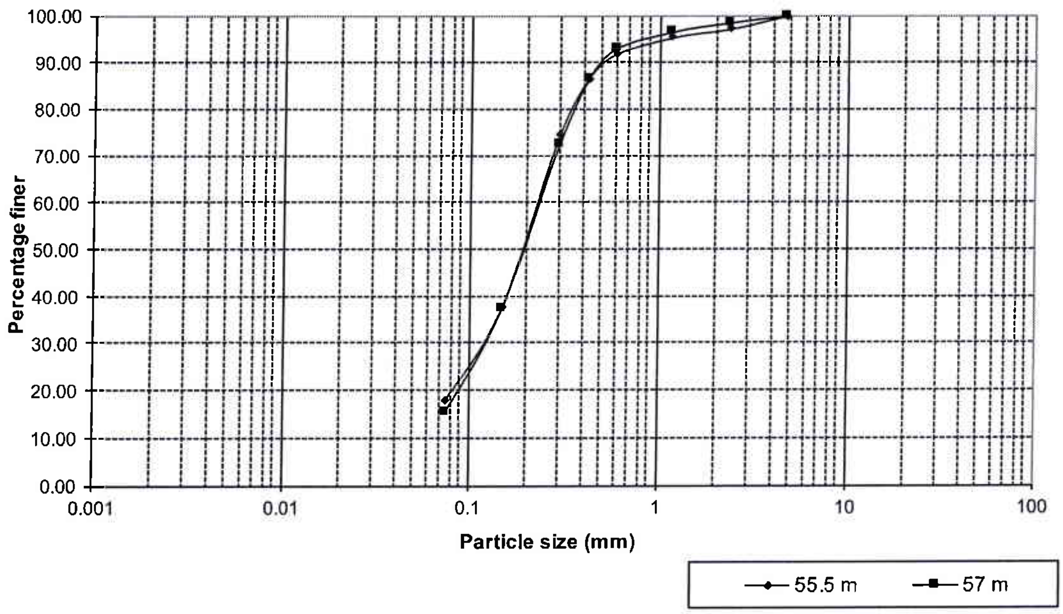
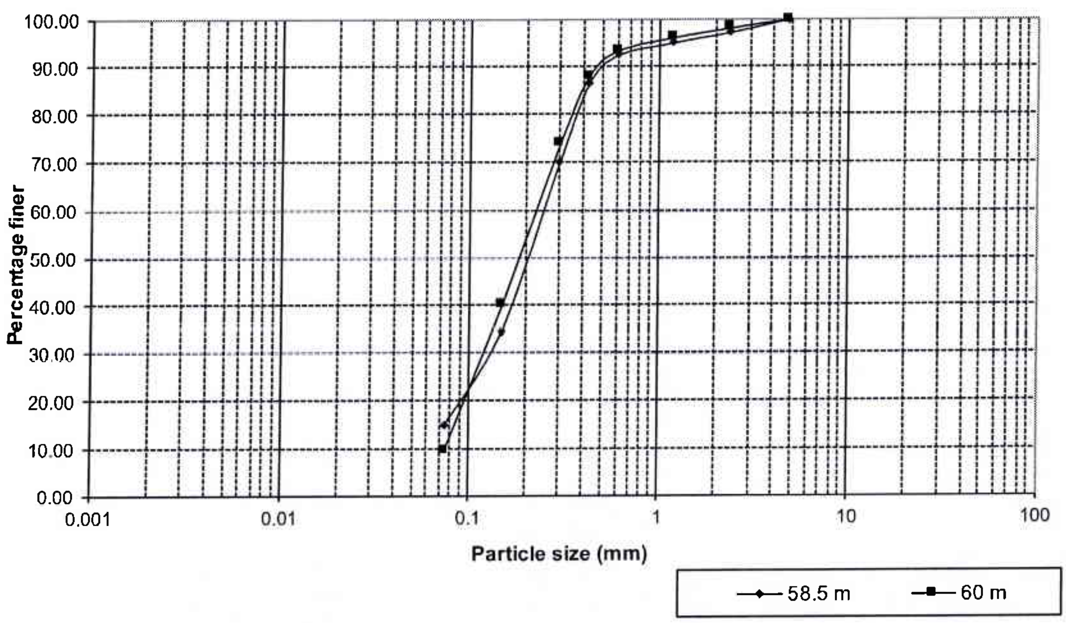
**PARTICLE SIZE DISTRIBUTION CURVES**



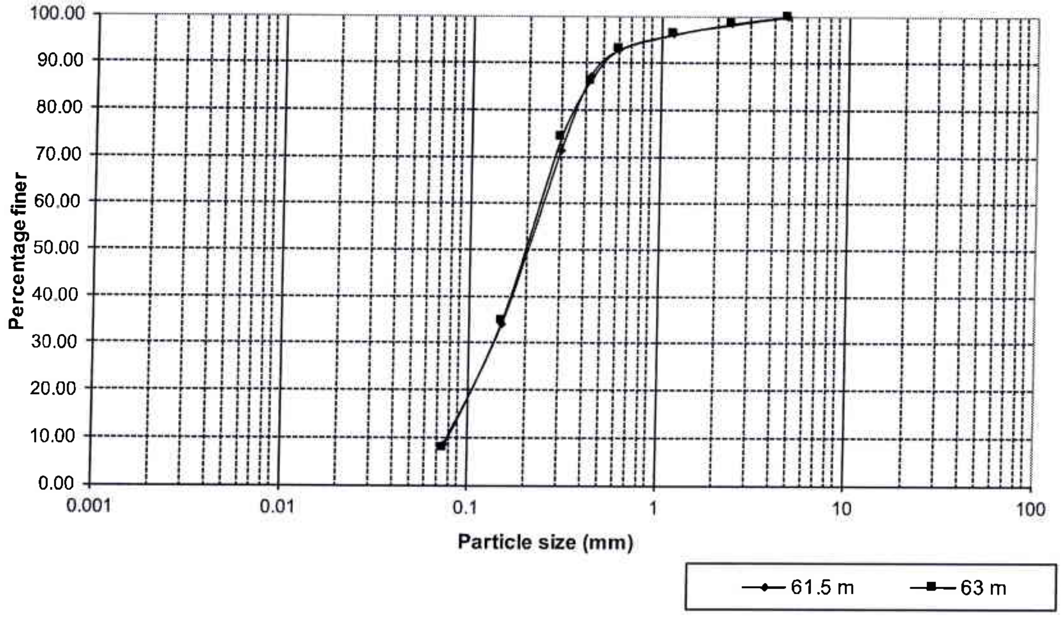

| *Grain size (mm)* | | *< 0.002* | *0.002 - 0.075* | *0.075 - 4.75* | *> 4.75* | **Silt factor (for sands)** |
|---|---|---|---|---|---|---|
| **Bore Hole** | **Sample** | **Clay (%)** | **Silt (%)** | **Sand (%)** | **Gravel (%)** | |
| P166 | 55.5 m | 0.00 | 18.00 | 82.00 | 0.00 | 1.07 |
| P166 | 57 m | 0.00 | 15.30 | 84.70 | 0.00 | 1.03 |



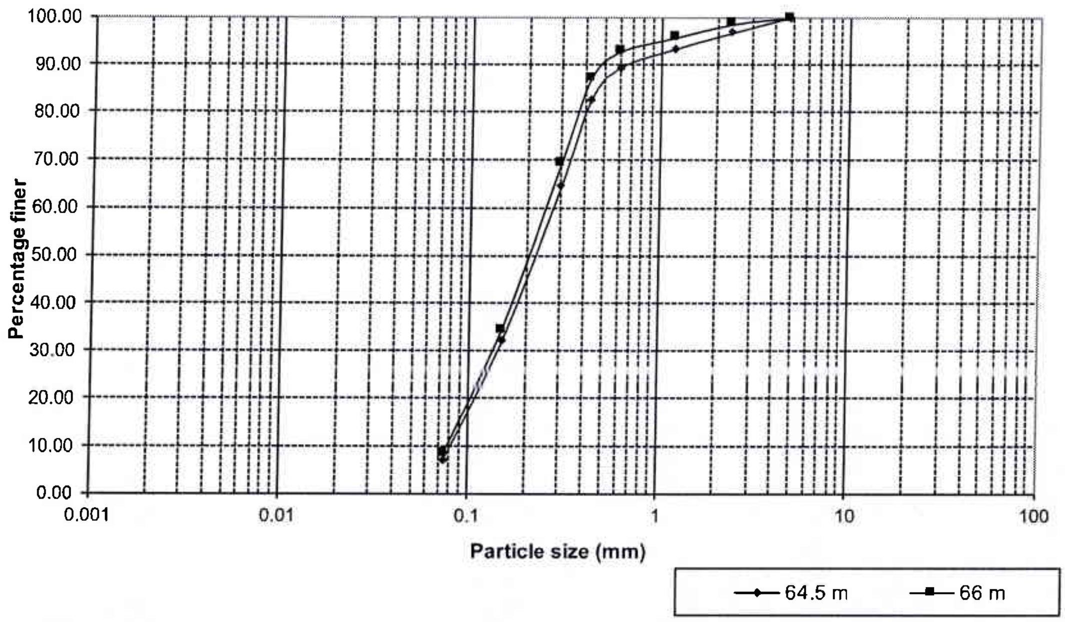

| *Grain size (mm)* | | *< 0.002* | *0.002 - 0.075* | *0.075 - 4.75* | *> 4.75* | **Silt factor (for sands)** |
|---|---|---|---|---|---|---|
| **Bore Hole** | **Sample** | **Clay (%)** | **Silt (%)** | **Sand (%)** | **Gravel (%)** | |
| P166 | 58.5 m | 0.00 | 14.82 | 85.18 | 0.00 | 1.09 |
| P166 | 60 m | 0.00 | 9.65 | 90.35 | 0.00 | 1.03 |

ANAND RAJ INFRATECH PVT. LTD. PATNA

PARTICLE SIZE DISTRIBUTION CURVES




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P166 | 61.5 m | 0.00 | 8.33 | 91.67 | 0.00 | 1.05 |
| P166 | 63 m | 0.00 | 7.84 | 92.16 | 0.00 | 1.06 |

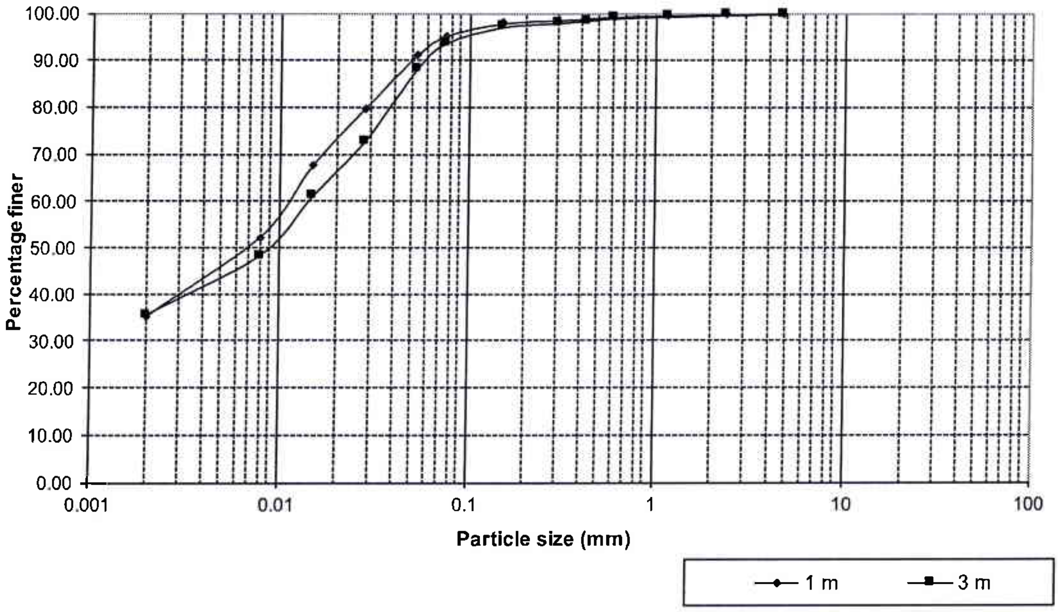



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P166 | 64.5 m | 0.00 | 7.12 | 92.88 | 0.00 | 1.16 |
| P166 | 66 m | 0.00 | 8.35 | 91.65 | 0.00 | 1.04 |

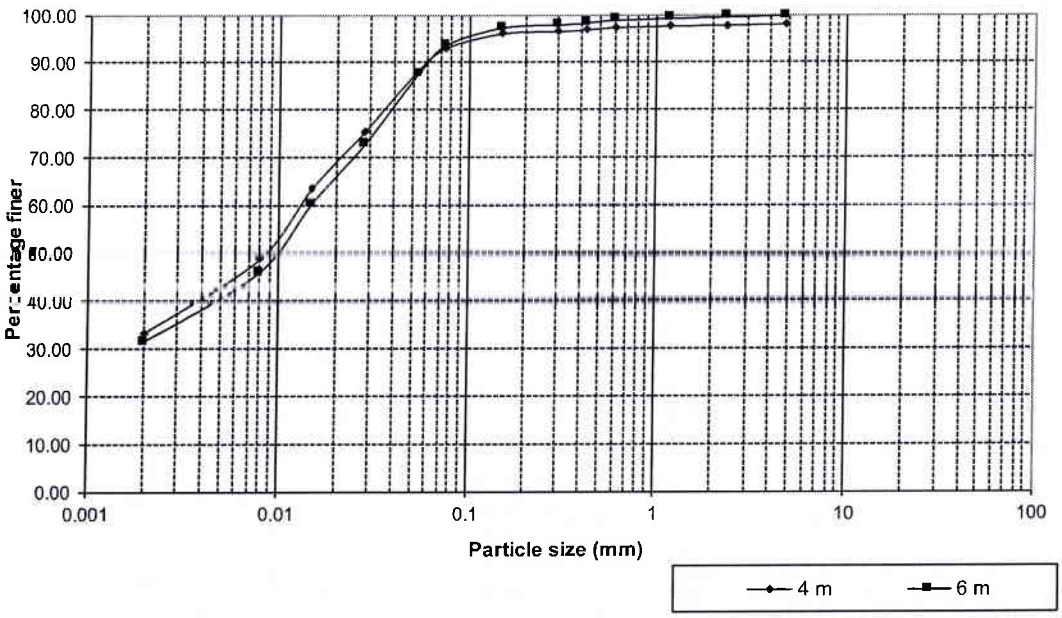
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P167 | 1 m | 35.10 | 60.14 | 4.76 | 0.00 | |
| P167 | 3 m | 35.52 | 58.26 | 6.22 | 0.00 | |

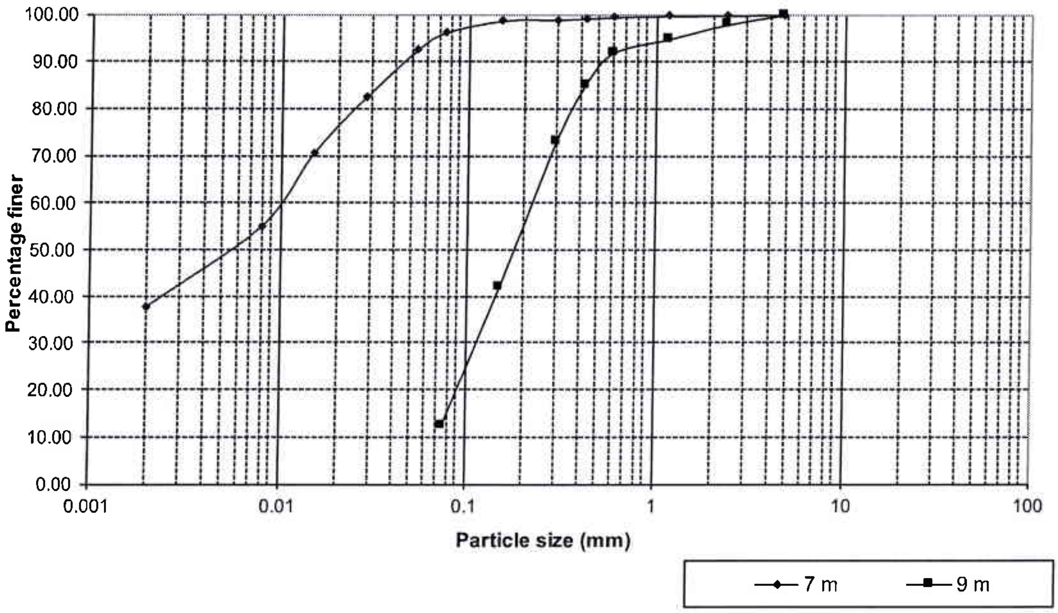



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P167 | 4 m | 33.34 | 59.62 | 5.04 | 2.00 | |
| P167 | 6 m | 31.44 | 62.41 | 6.15 | 0.00 | |

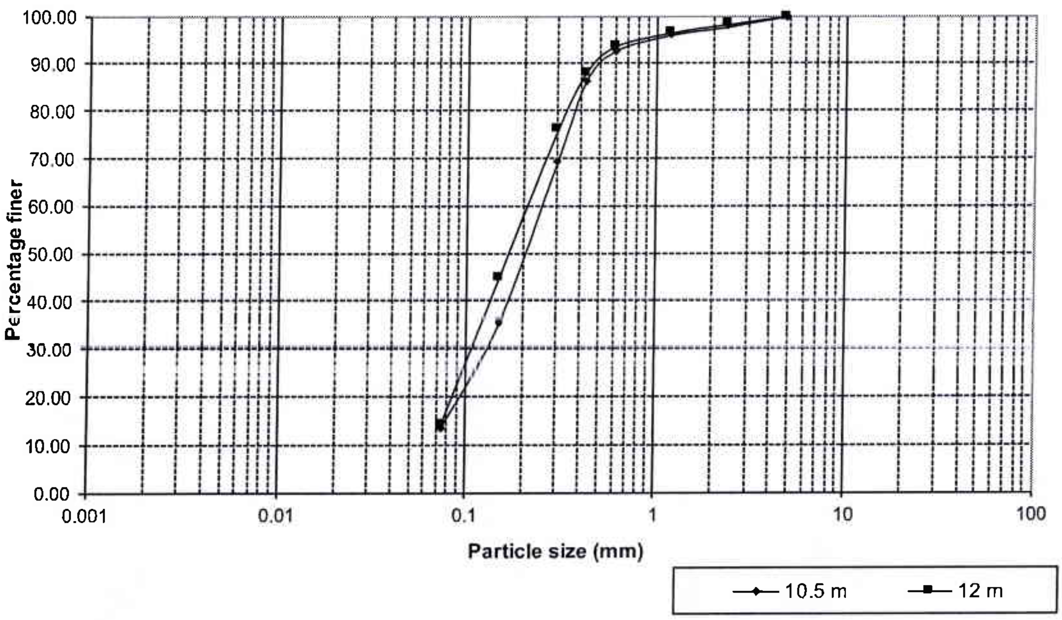
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## PARTICLE SIZE DISTRIBUTION CURVES




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P167 | 7 m | 37.60 | 58.60 | 3.80 | 0.00 | |
| P167 | 9 m | 0.00 | 12.45 | 87.55 | 0.00 | 1.07 |




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P167 | 10.5 m | 0.00 | 13.60 | 86.40 | 0.00 | 1.06 |
| P167 | 12 m | 0.00 | 14.22 | 85.78 | 0.00 | 1.00 |

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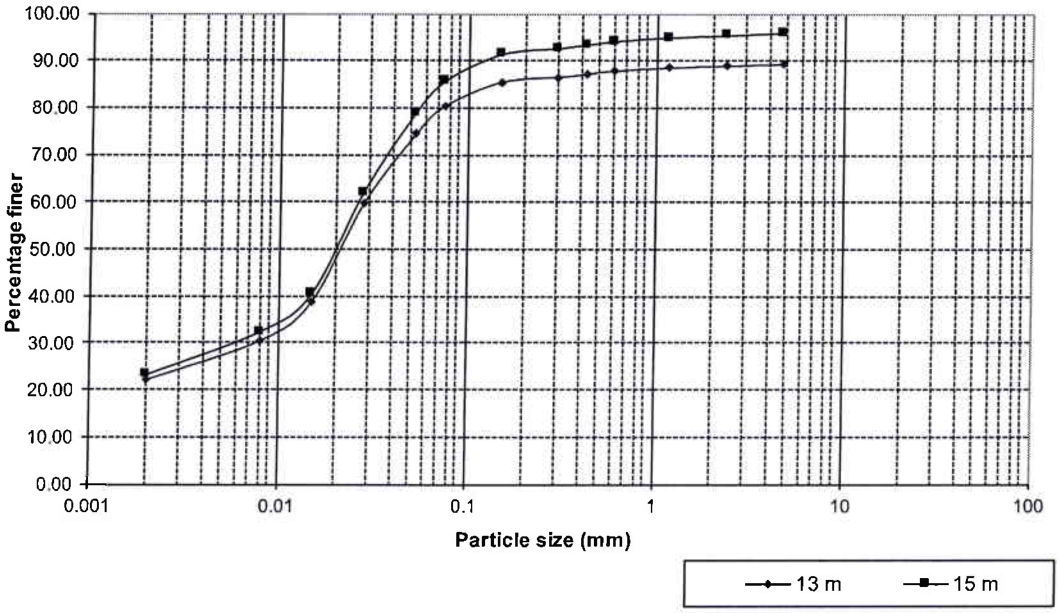
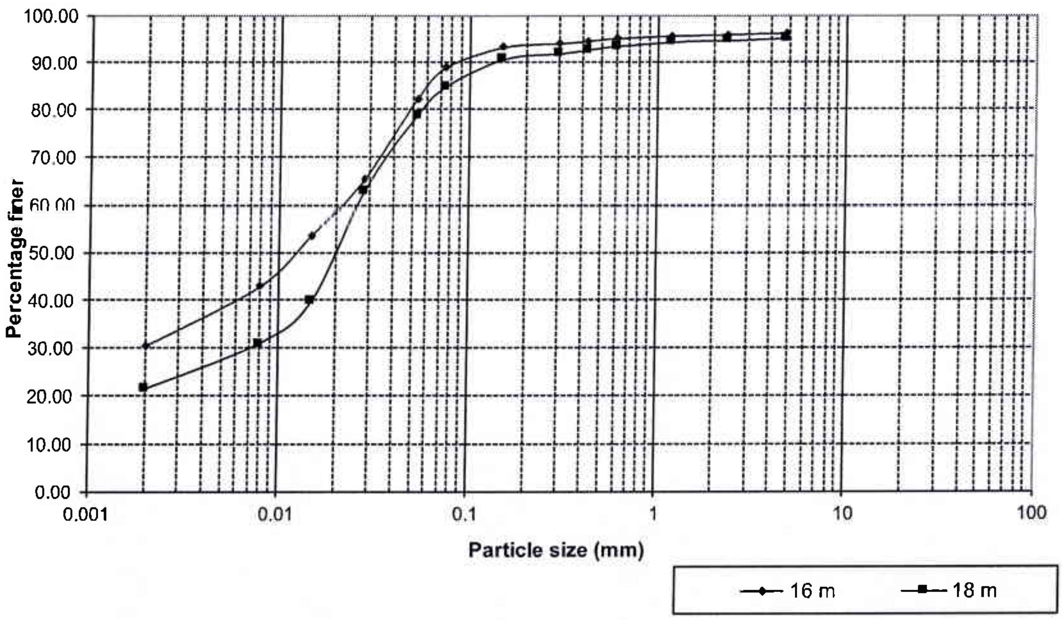
**PARTICLE SIZE DISTRIBUTION CURVES**

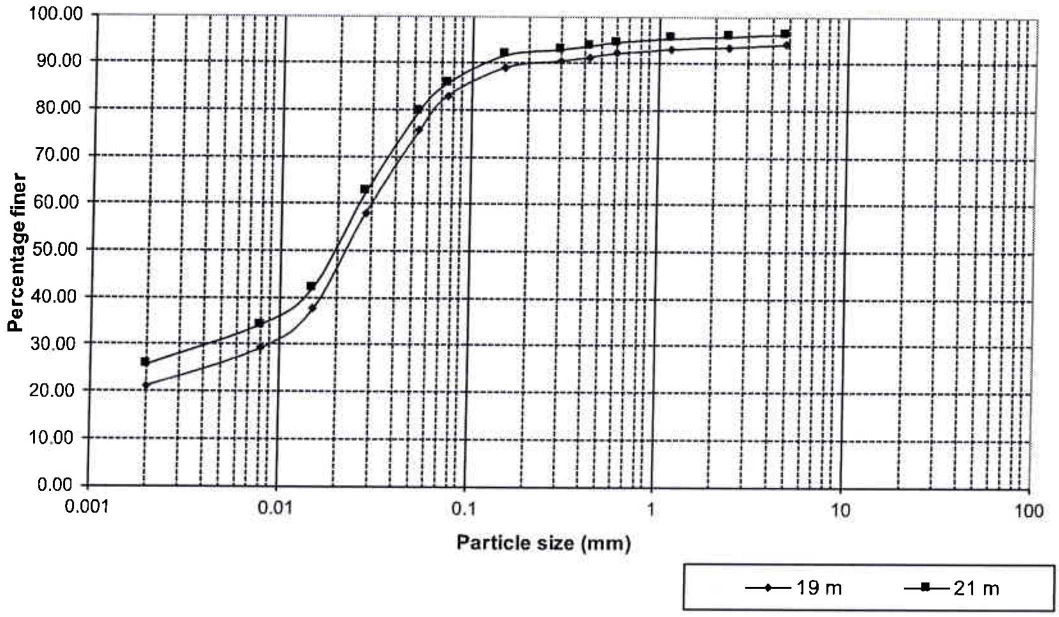



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P167 | 13 m | 22.08 | 58.22 | 9.05 | 10.65 | |
| P167 | 15 m | 23.24 | 62.41 | 10.20 | 4.15 | |

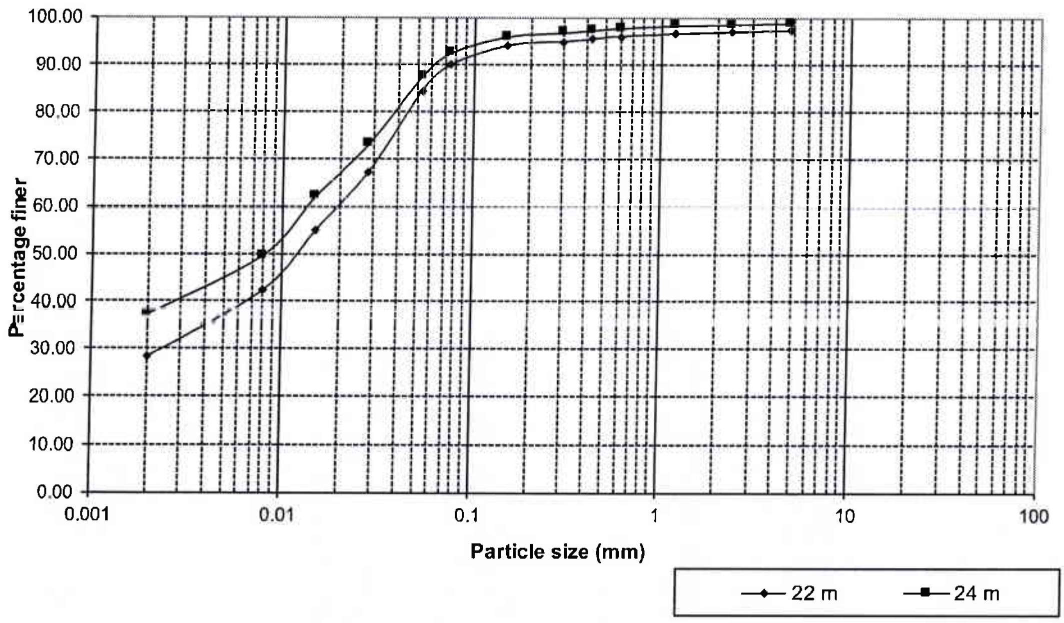



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P167 | 16 m | 30.39 | 58.66 | 7.25 | 3.70 | |
| P167 | 18 m | 21.31 | 63.52 | 10.30 | 4.87 | |

**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P167 | 19 m | 21.20 | 61.80 | 11.00 | 6.00 | |
| P167 | 21 m | 25.71 | 60.14 | 10.50 | 3.65 | |

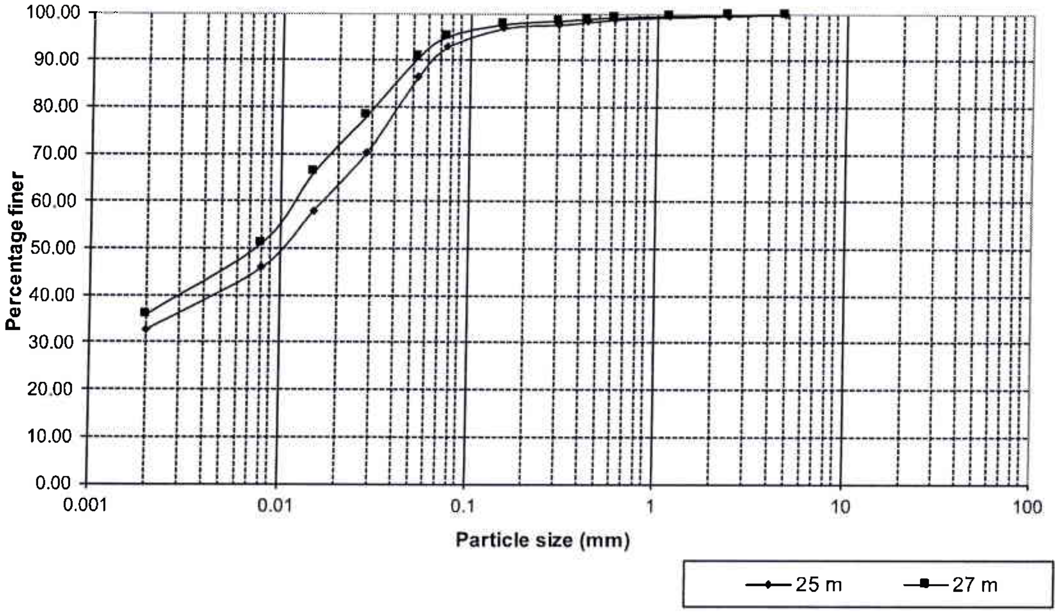



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P167 | 22 m | 28.28 | 61.77 | 7.15 | 2.80 | |
| P167 | 24 m | 37.07 | 55.48 | 6.30 | 1.15 | |

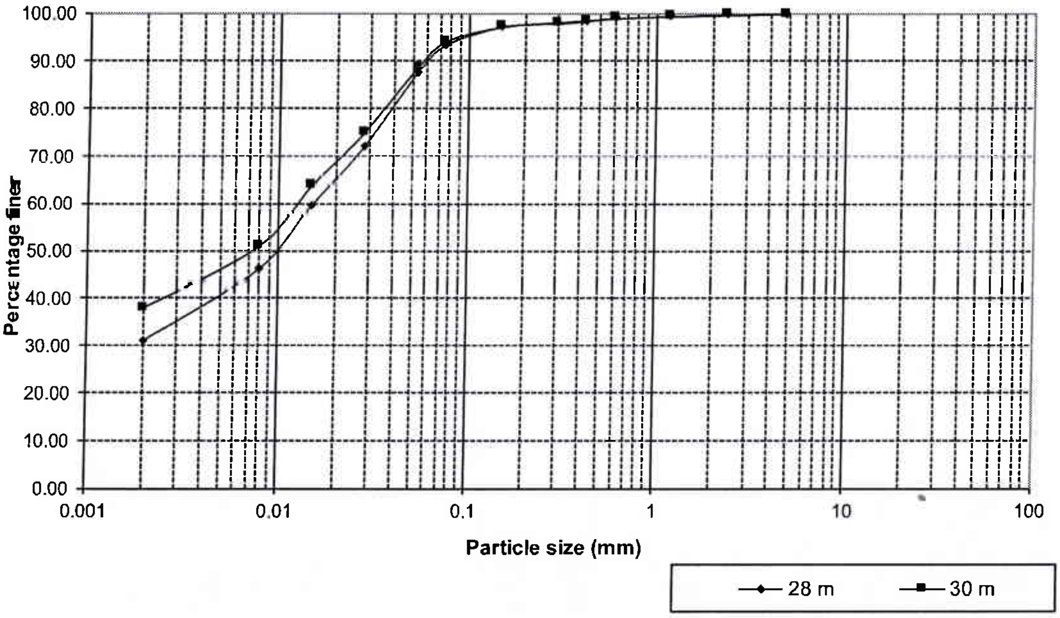
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## PARTICLE SIZE DISTRIBUTION CURVES




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P167 | 25 m | 32.64 | 60.14 | 7.22 | 0.00 | |
| P167 | 27 m | 35.85 | 59.25 | 4.90 | 0.00 | |




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P167 | 28 m | 30.97 | 62.55 | 6.48 | 0.00 | |
| P167 | 30 m | 37.95 | 56.25 | 5.80 | 0.00 | |

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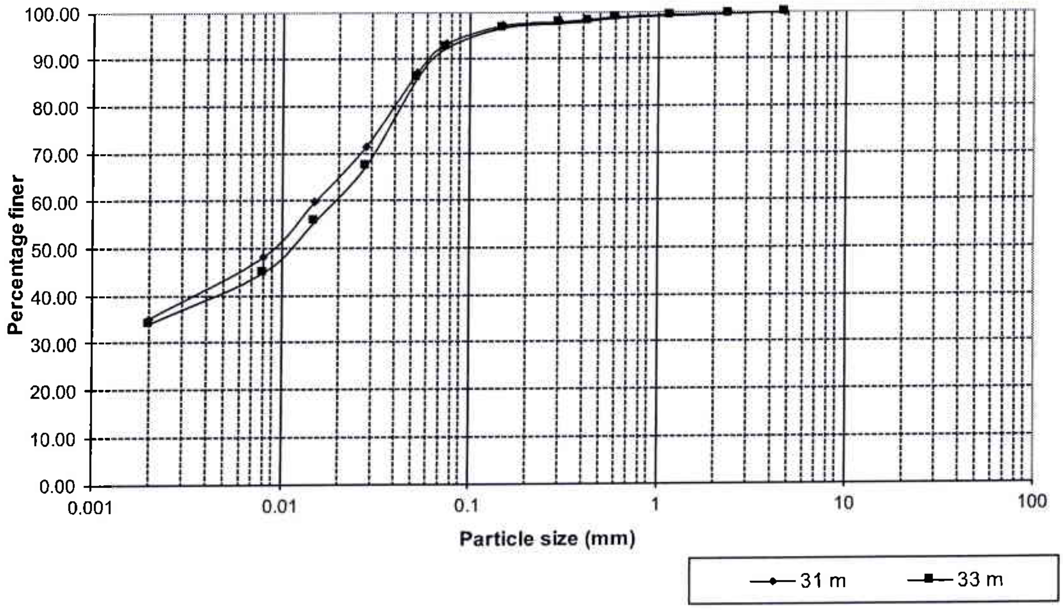
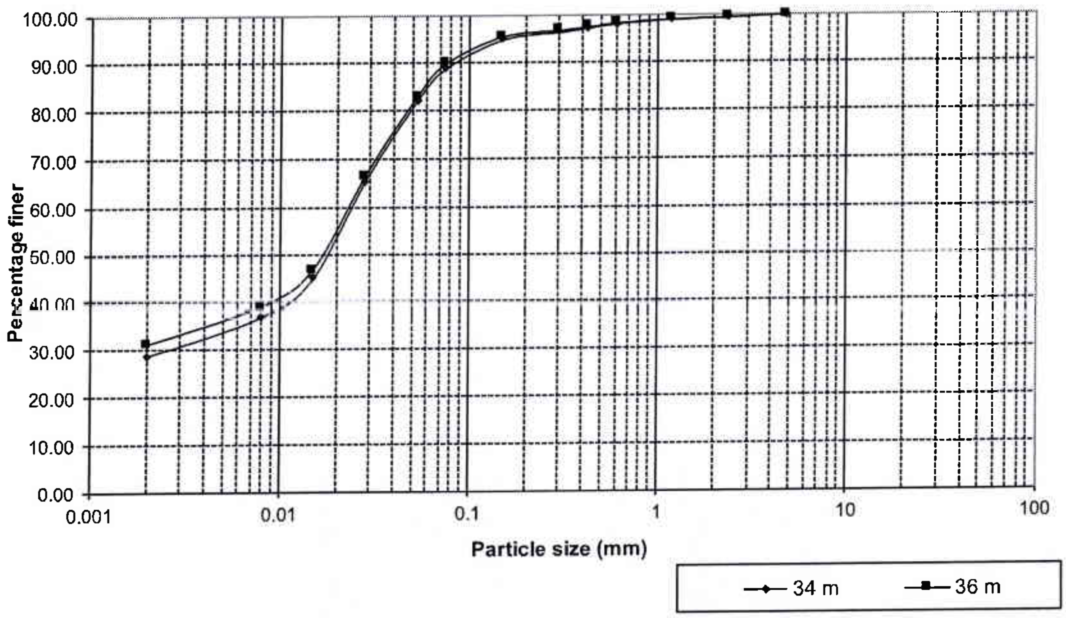
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**PARTICLE SIZE DISTRIBUTION CURVES**




| *Grain size (mm)* | | *< 0.002* | *0.002 - 0.075* | *0.075 - 4.75* | *> 4.75* | **Silt factor (for sands)** |
|---|---|---|---|---|---|---|
| **Bore Hole** | **Sample** | **Clay (%)** | **Silt (%)** | **Sand (%)** | **Gravel (%)** | |
| P167 | 31 m | 35.21 | 58.14 | 6.65 | 0.00 | |
| P167 | 33 m | 34.00 | 58.42 | 7.58 | 0.00 | |

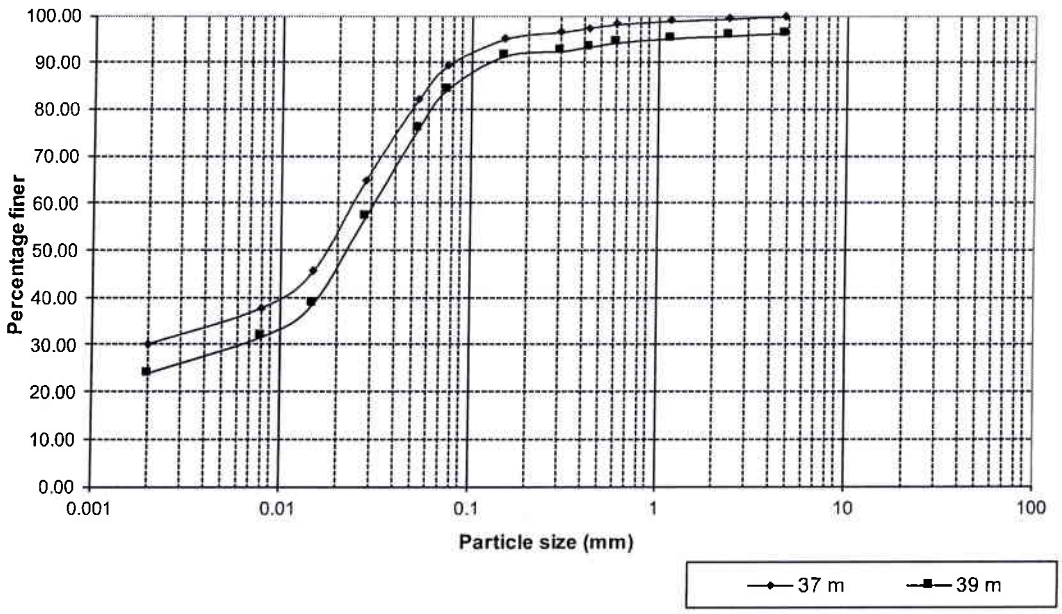



| *Grain size (mm)* | | *< 0.002* | *0.002 - 0.075* | *0.075 - 4.75* | *> 4.75* | **Silt factor (for sands)** |
|---|---|---|---|---|---|---|
| **Bore Hole** | **Sample** | **Clay (%)** | **Silt (%)** | **Sand (%)** | **Gravel (%)** | |
| P167 | 34 m | 28.73 | 60.22 | 11.05 | 0.00 | |
| P167 | 36 m | 30.99 | 59.06 | 9.95 | 0.00 | |

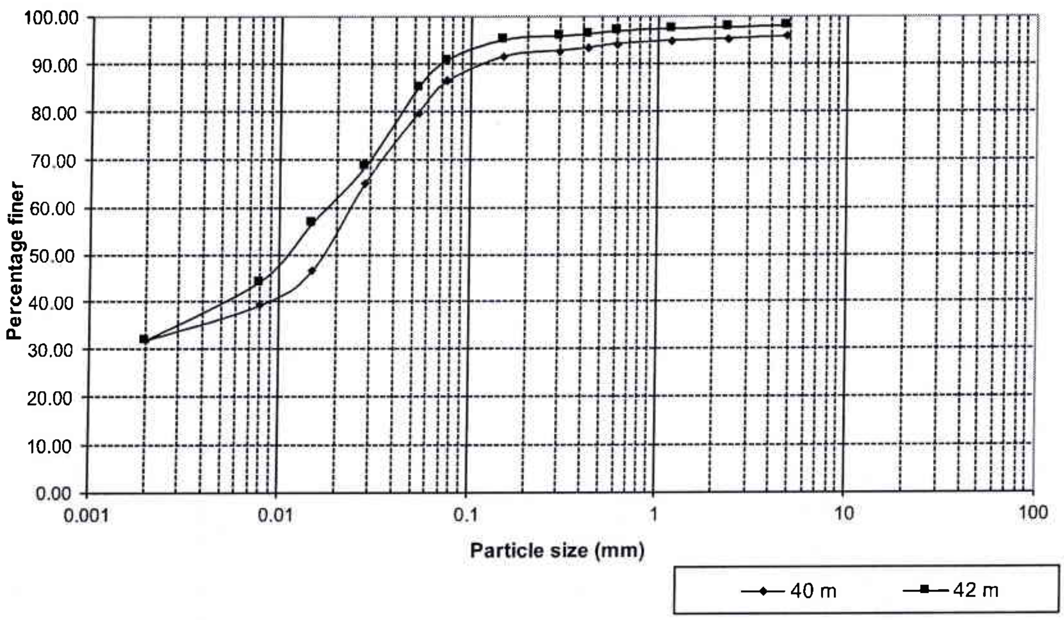
M/s Anand Raj Infratech Pvt. Ltd.

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## PARTICLE SIZE DISTRIBUTION CURVES




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P167 | 37 m | 30.08 | 59.25 | 10.67 | 0.00 | |
| P167 | 39 m | 24.16 | 60.14 | 12.00 | 3.70 | |



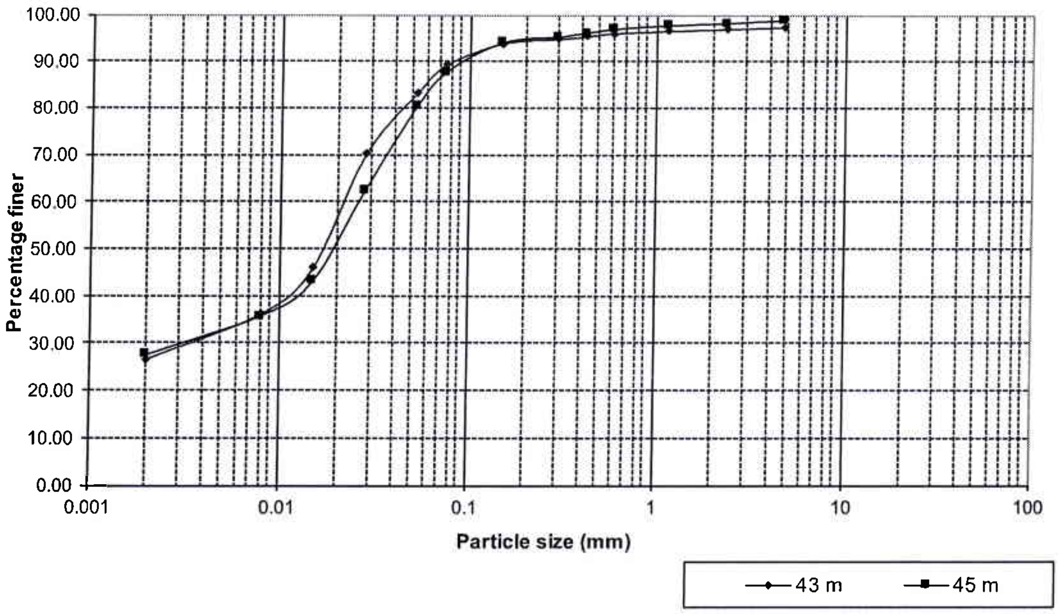

| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P167 | 40 m | 31.87 | 54.58 | 9.30 | 4.25 | |
| P167 | 42 m | 31.75 | 59.25 | 7.00 | 2.00 | |

ANAND RAJ INFRATECH PVT. LTD. PATNA

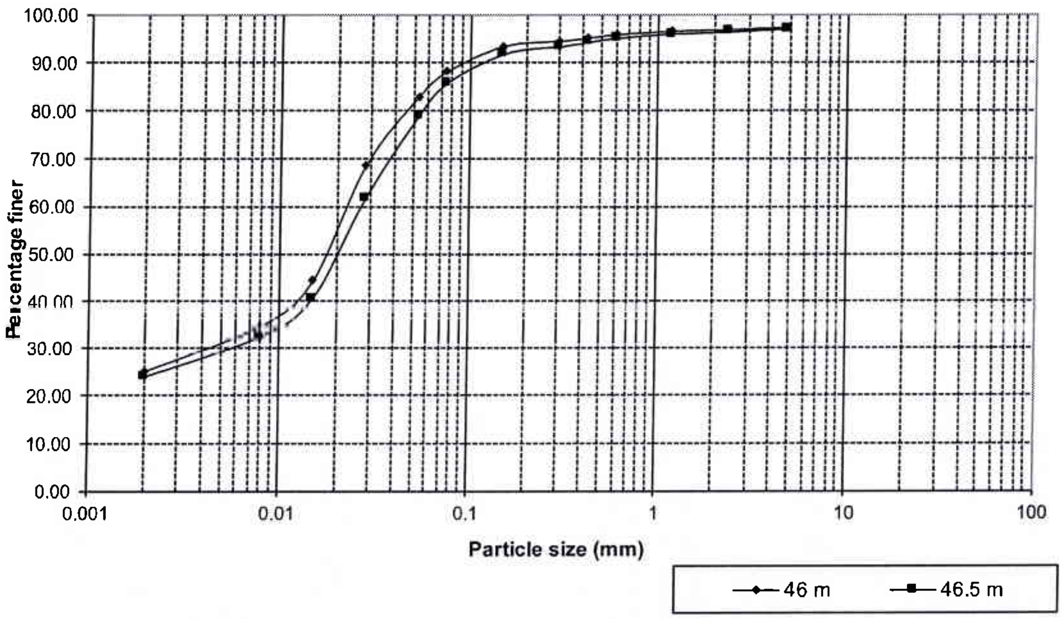
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**PARTICLE SIZE DISTRIBUTION CURVES**

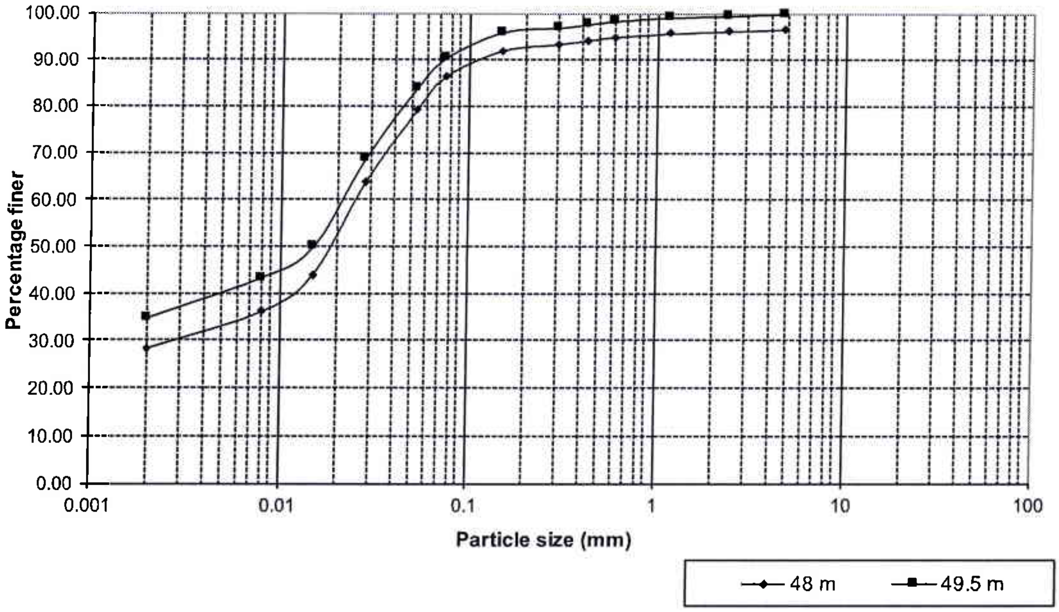



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P167 | 43 m | 26.71 | 62.54 | 8.15 | 2.60 | |
| P167 | 45 m | 27.46 | 60.14 | 11.05 | 1.35 | |

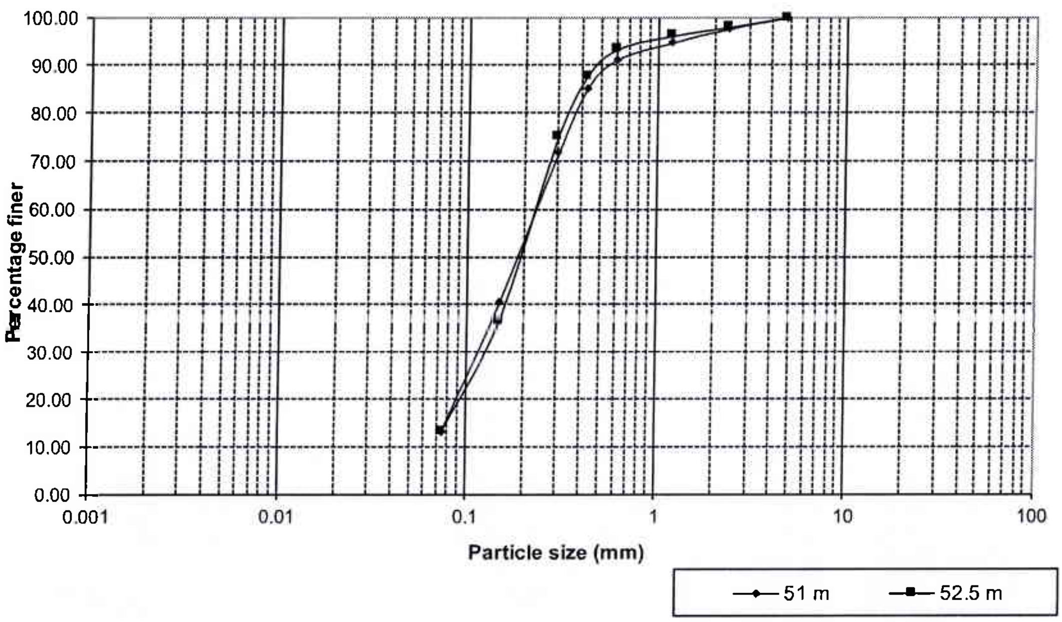



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P167 | 46 m | 25.00 | 63.25 | 9.10 | 2.65 | |
| P167 | 46.5 m | 23.75 | 62.05 | 11.20 | 3.00 | |

## PARTICLE SIZE DISTRIBUTION CURVES




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P167 | 48 m | 28.34 | 58.16 | 10.20 | 3.30 | |
| P167 | 49.5 m | 34.80 | 55.60 | 9.60 | 0.00 | |



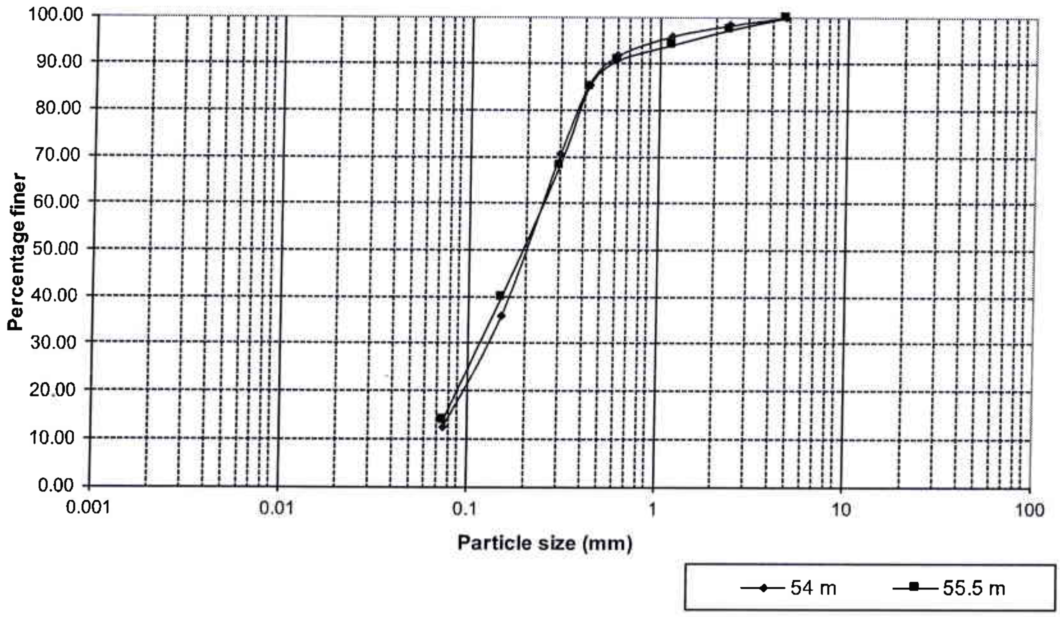

| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P167 | 51 m | 0.00 | 13.30 | 86.70 | 0.00 | 1.08 |
| P167 | 52.5 m | 0.00 | 12.95 | 87.05 | 0.00 | 1.04 |

ANAND RAJ INFRATECH PVT. LTD. PATNA

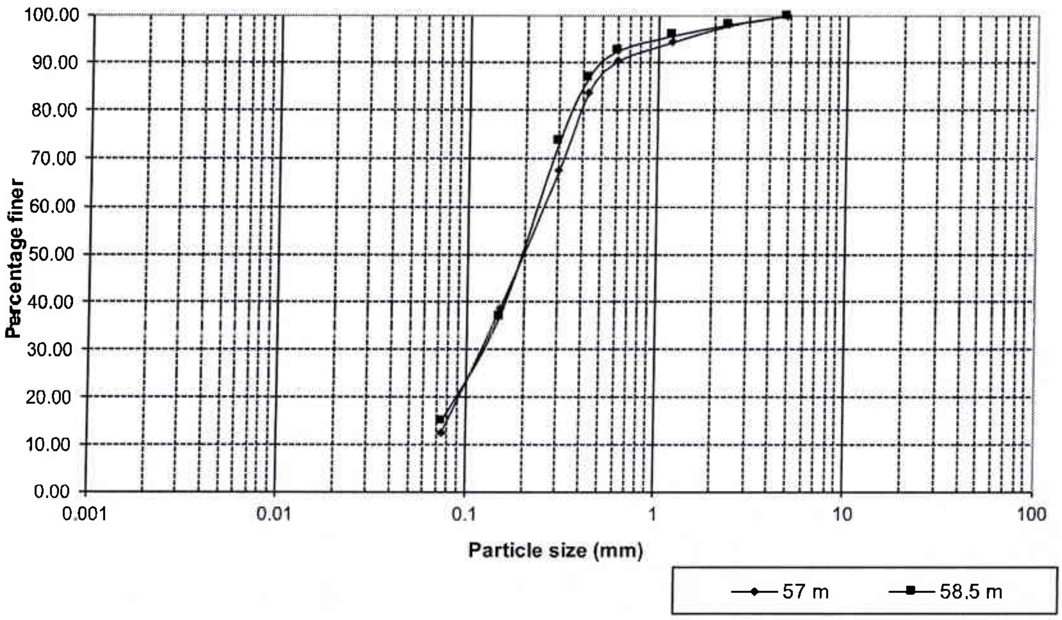
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**PARTICLE SIZE DISTRIBUTION CURVES**



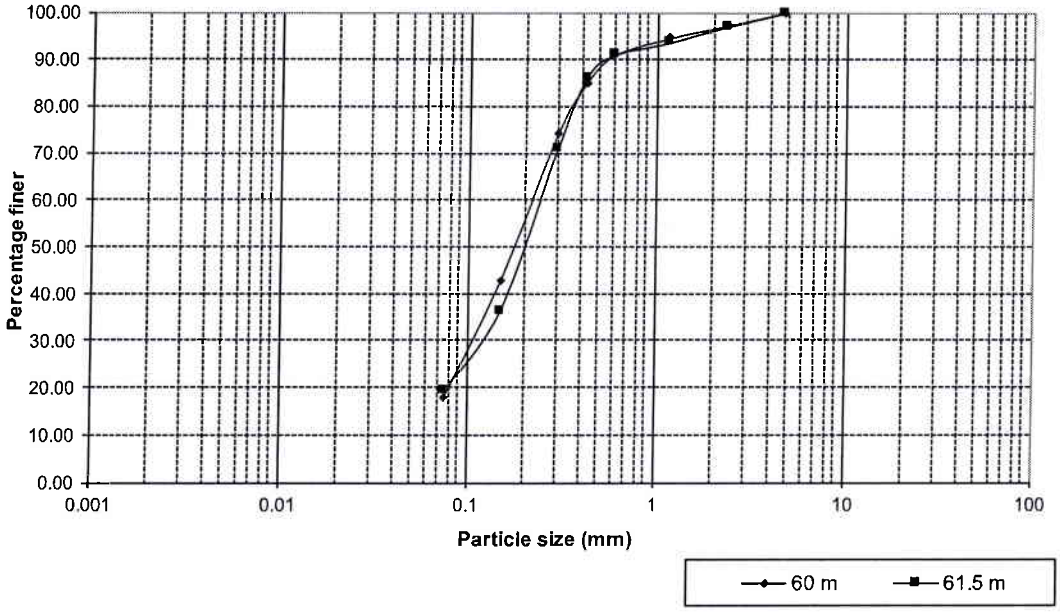

| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P167 | 54 m | 0.00 | 12.34 | 87.66 | 0.00 | 1.06 |
| P167 | 55.5 m | 0.00 | 13.80 | 86.20 | 0.00 | 1.10 |



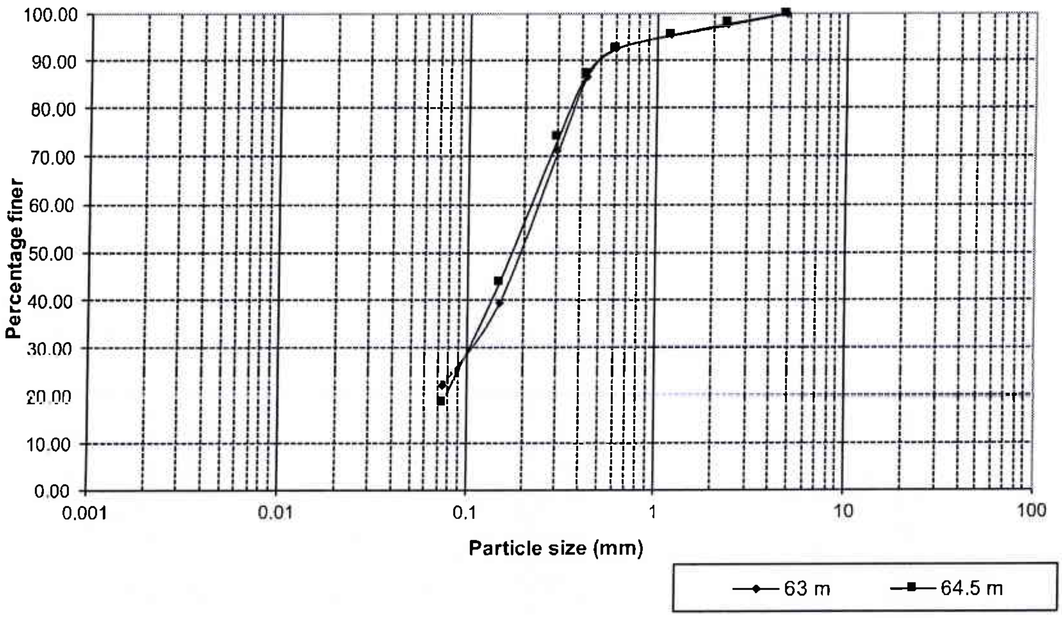

| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P167 | 57 m | 0.00 | 12.55 | 87.45 | 0.00 | 1.09 |
| P167 | 58.5 m | 0.00 | 14.85 | 85.15 | 0.00 | 1.05 |

ANAND RAJ INFRATECH PVT. LTD.

**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P167 | 60 m | 0.00 | 17.92 | 82.08 | 0.00 | 1.08 |
| P167 | 61.5 m | 0.00 | 19.22 | 80.78 | 0.00 | 1.11 |

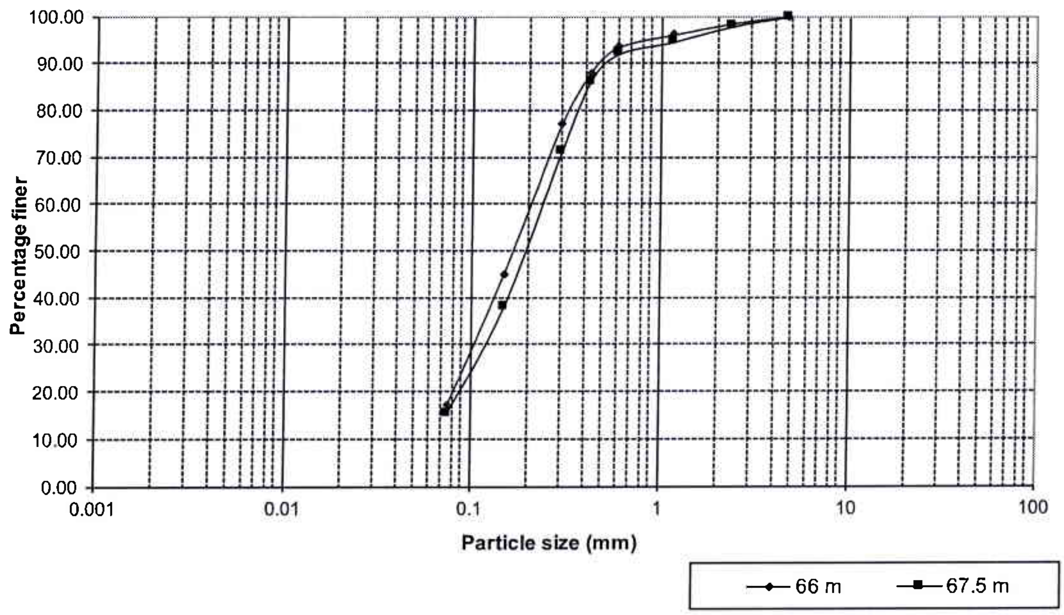



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P167 | 63 m | 0.00 | 22.00 | 78.00 | 0.00 | 1.05 |
| P167 | 64.5 m | 0.00 | 18.40 | 81.60 | 0.00 | 1.03 |

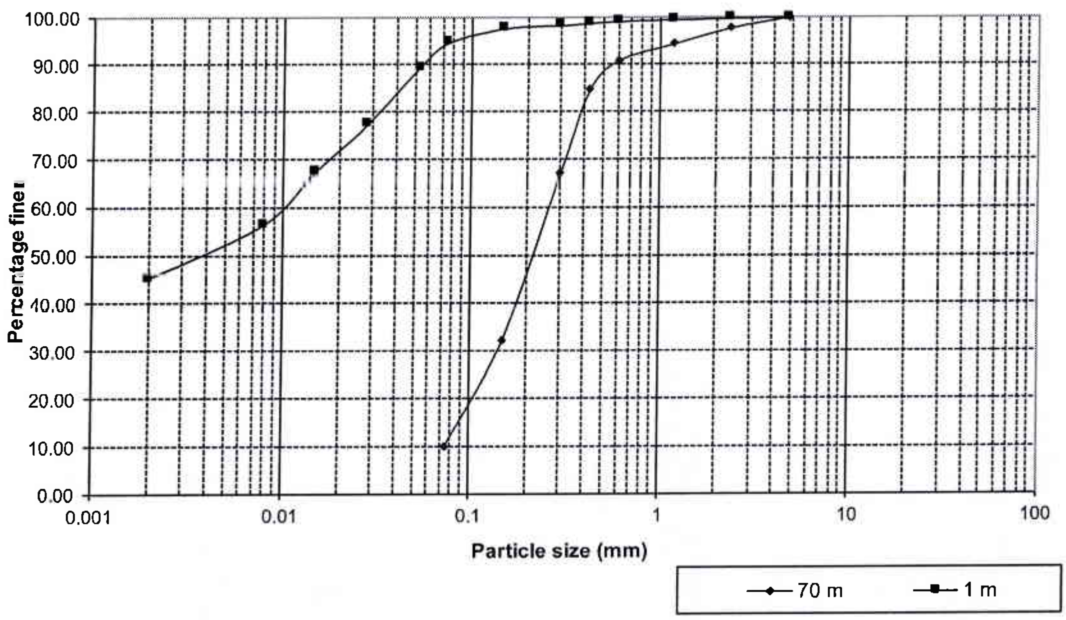
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P167 | 66 m | 0.00 | 17.00 | 83.00 | 0.00 | 1.00 |
| P167 | 67.5 m | 0.00 | 15.50 | 84.50 | 0.00 | 1.07 |




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P167 | 70 m | 0.00 | 10.00 | 90.00 | 0.00 | 1.11 |
| P168 | 1 m | 44.98 | 49.65 | 5.37 | 0.00 | |

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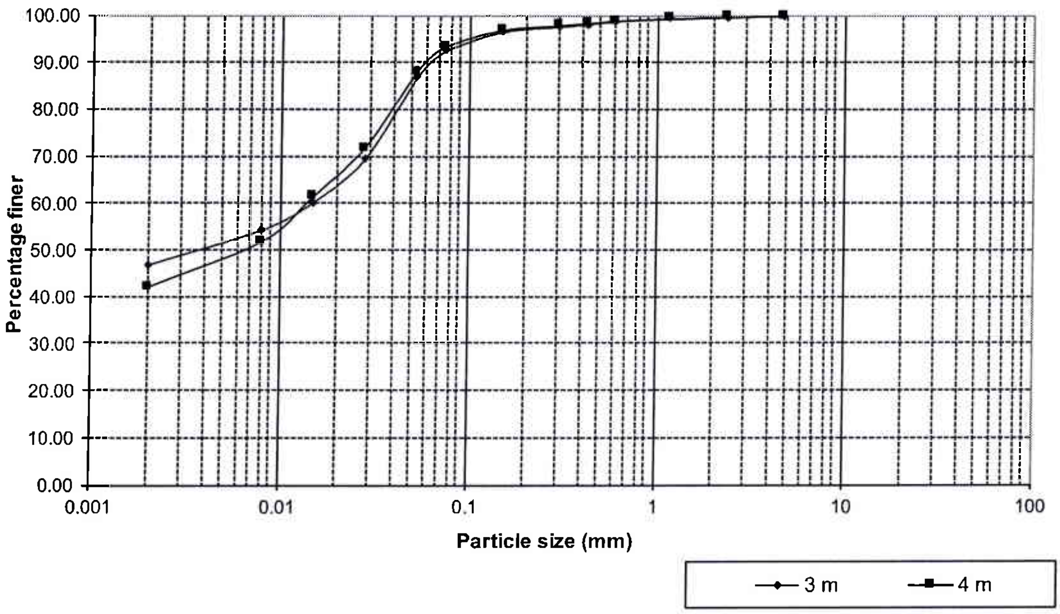
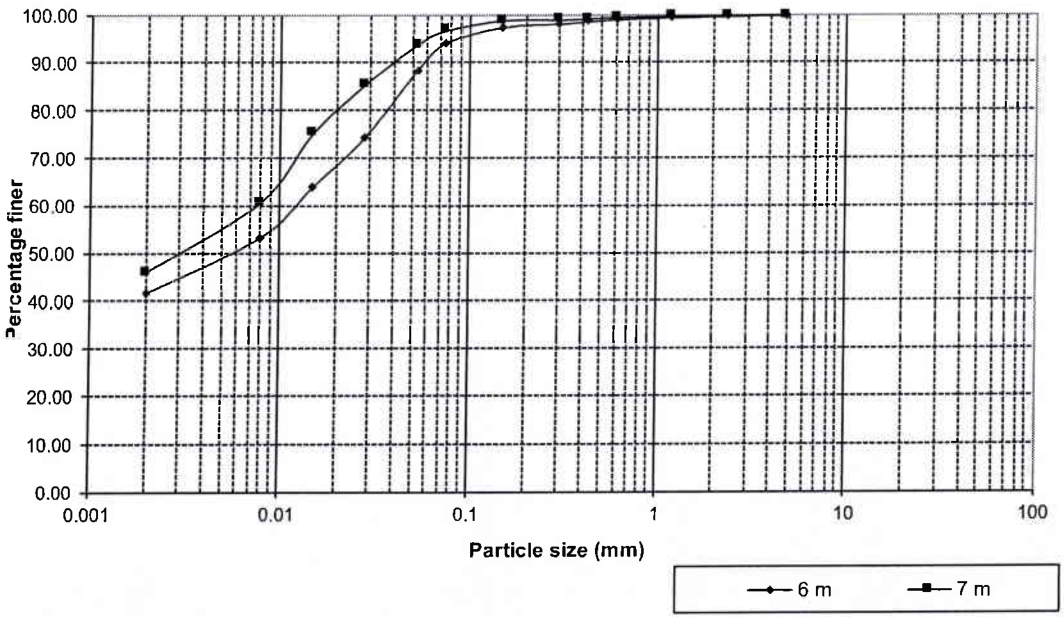
**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P168 | 3 m | 46.77 | 45.68 | 7.55 | 0.00 | |
| P168 | 4 m | 41.96 | 51.44 | 6.60 | 0.00 | |

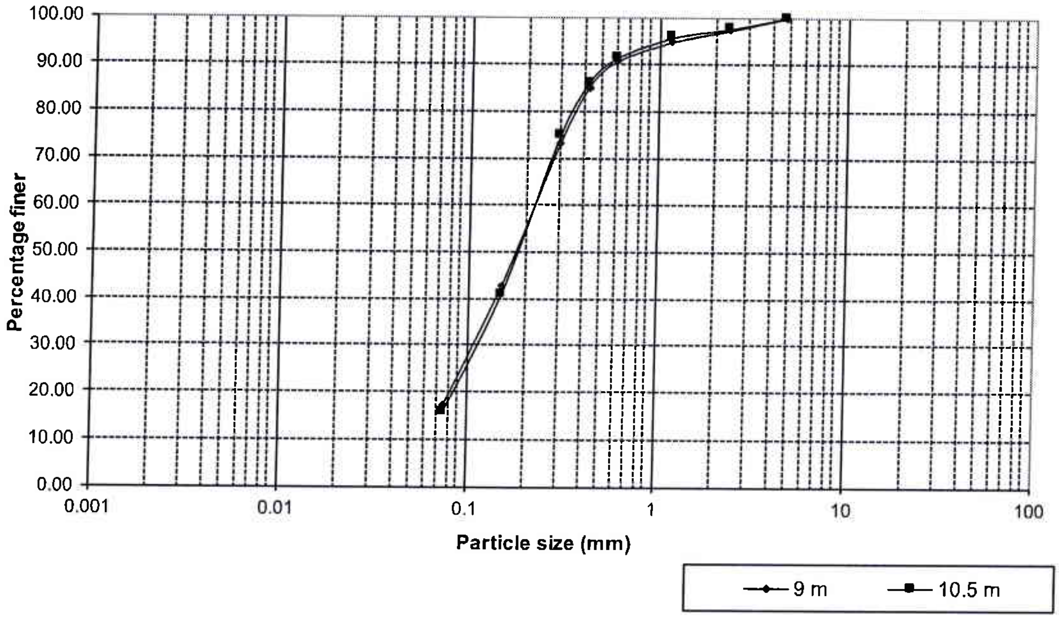



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P168 | 6 m | 41.55 | 52.65 | 5.80 | 0.00 | |
| P168 | 7 m | 45.70 | 51.08 | 3.22 | 0.00 | |

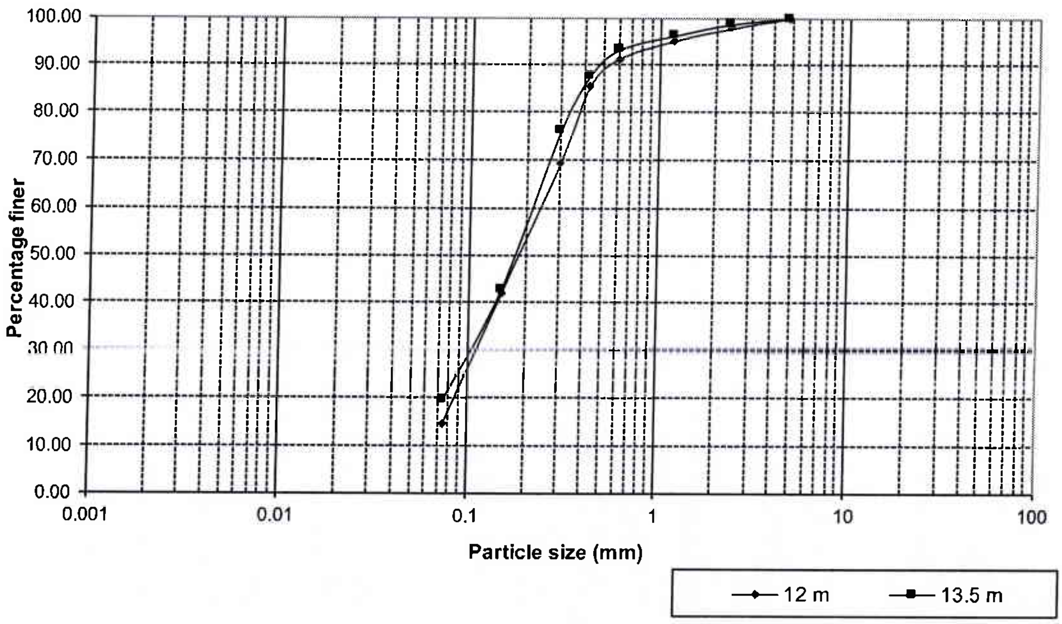
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P168 | 9 m | 0.00 | 17.30 | 82.70 | 0.00 | 1.08 |
| P168 | 10.5 m | 0.00 | 15.73 | 84.27 | 0.00 | 1.06 |




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P168 | 12 m | 0.00 | 14.50 | 85.50 | 0.00 | 1.06 |
| P168 | 13.5 m | 0.00 | 19.45 | 80.55 | 0.00 | 1.00 |

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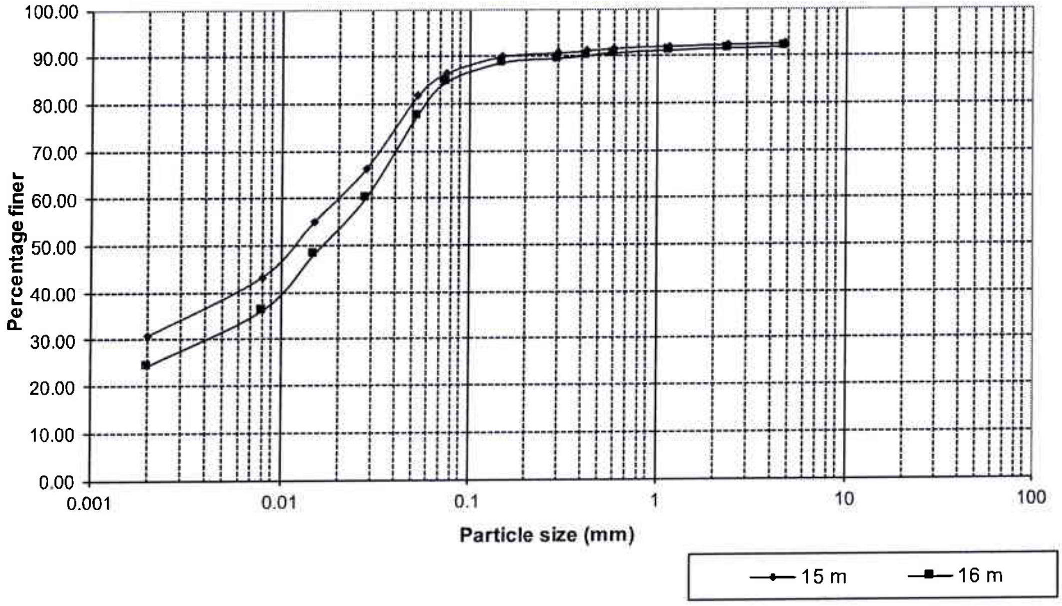
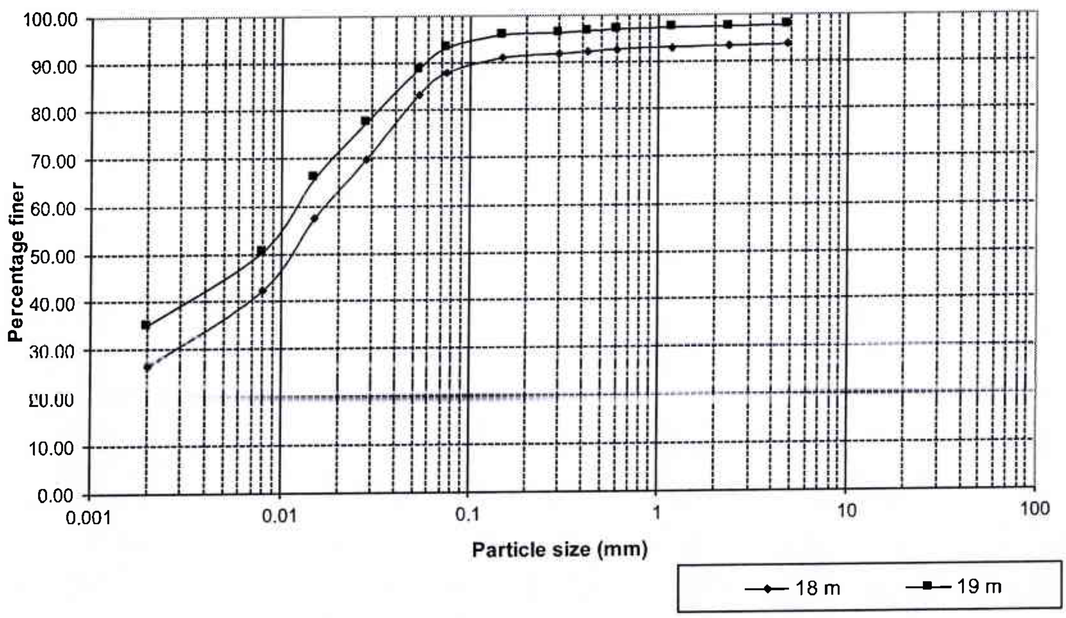
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## PARTICLE SIZE DISTRIBUTION CURVES




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P168 | 15 m | 30.73 | 55.65 | 6.27 | 7.35 | |
| P168 | 16 m | 24.25 | 60.25 | 7.30 | 8.20 | |




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P168 | 18 m | 26.48 | 61.52 | 5.60 | 6.40 | |
| P168 | 19 m | 35.09 | 58.25 | 4.30 | 2.36 | |

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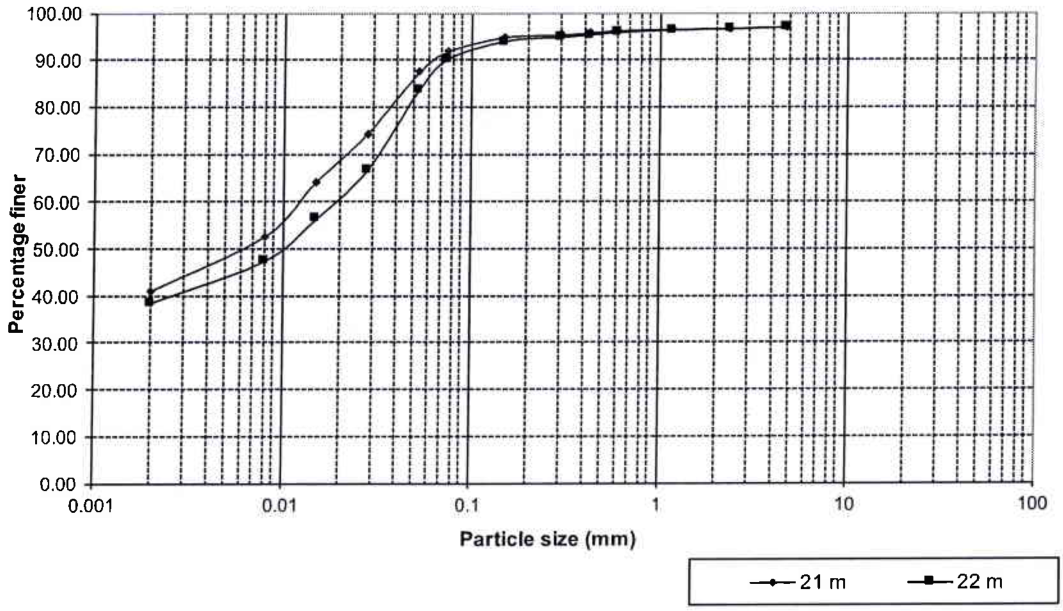
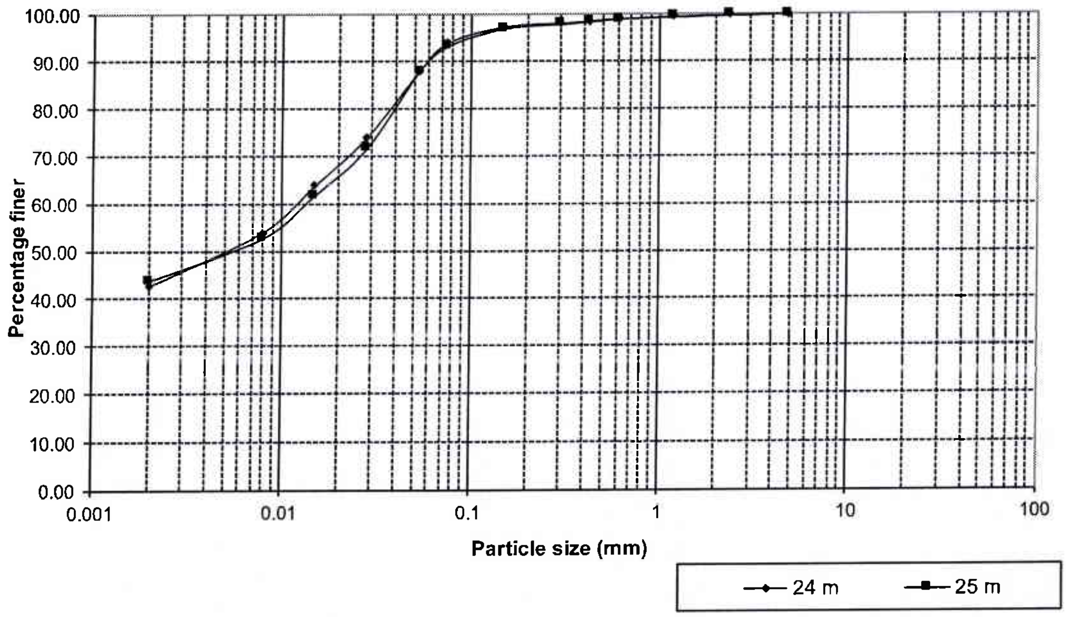
**PARTICLE SIZE DISTRIBUTION CURVES**




| *Grain size (mm)* | | *< 0.002* | *0.002 - 0.075* | *0.075 - 4.75* | *> 4.75* | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P168 | 21 m | 41.08 | 50.65 | 5.27 | 3.00 | |
| P168 | 22 m | 38.58 | 51.47 | 6.80 | 3.15 | |

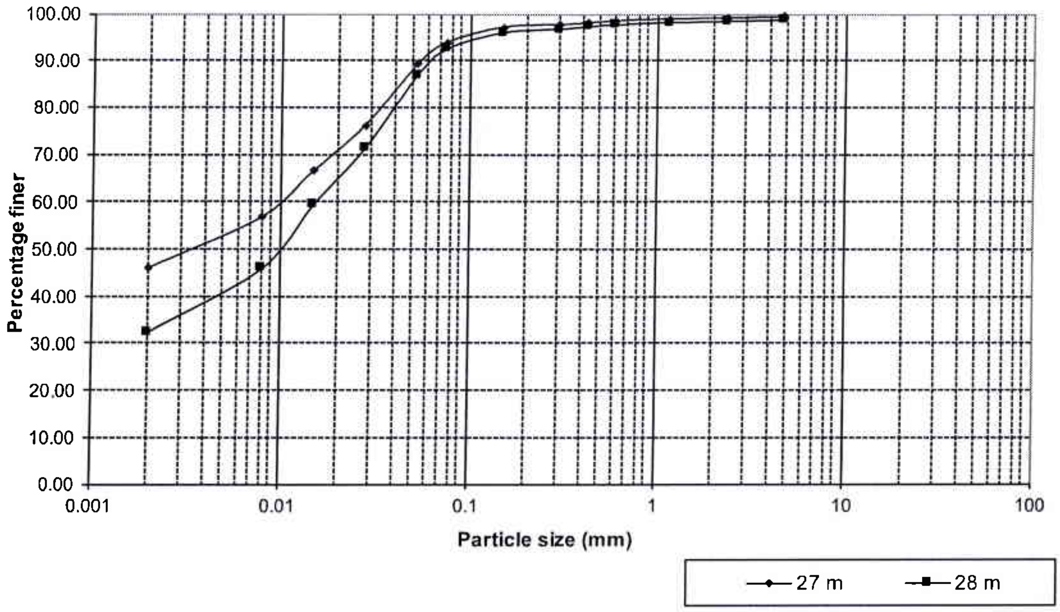



| *Grain size (mm)* | | *< 0.002* | *0.002 - 0.075* | *0.075 - 4.75* | *> 4.75* | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P168 | 24 m | 42.61 | 51.44 | 5.95 | 0.00 | |
| P168 | 25 m | 43.85 | 49.58 | 6.57 | 0.00 | |

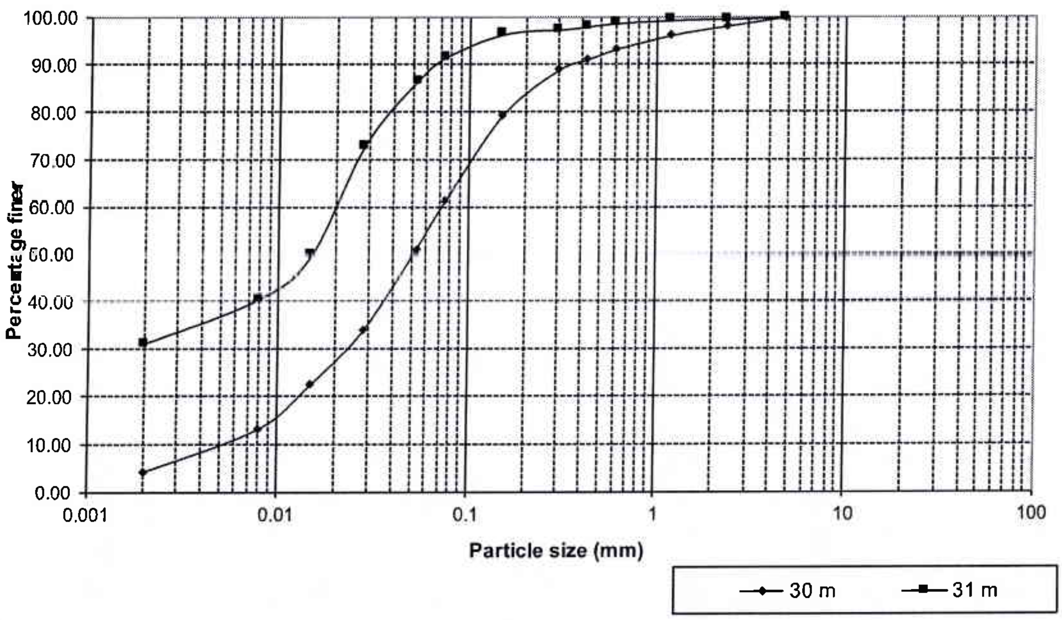
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## PARTICLE SIZE DISTRIBUTION CURVES

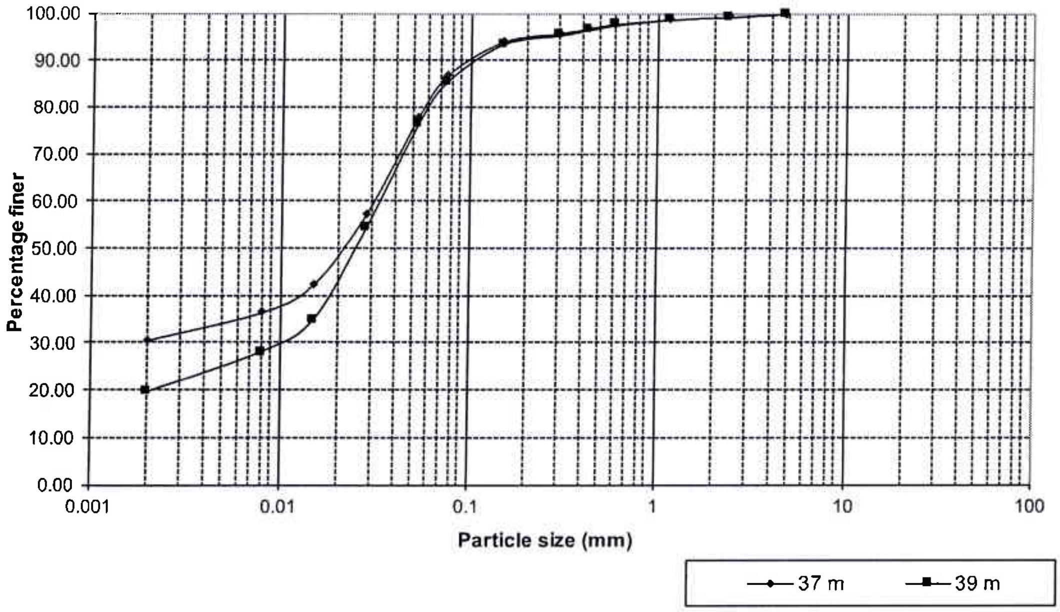



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P168 | 27 m | 45.88 | 47.94 | 5.48 | 0.70 | |
| P168 | 28 m | 32.34 | 60.14 | 6.20 | 1.32 | |

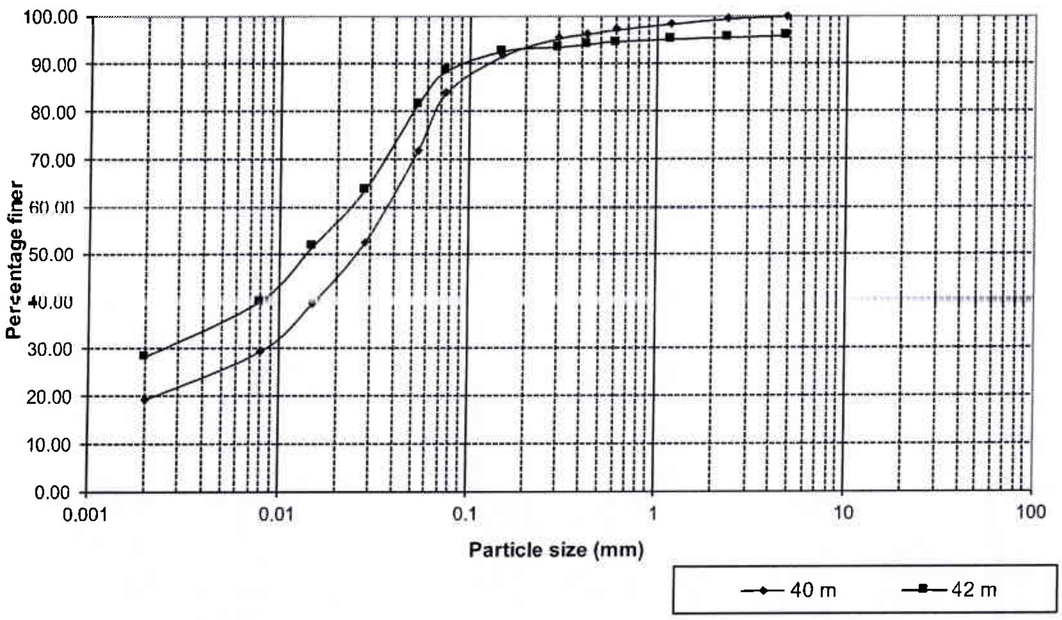



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P168 | 30 m | 4.12 | 57.18 | 38.70 | 0.00 | |
| P168 | 31 m | 31.24 | 60.41 | 8.35 | 0.00 | |

**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P168 | 37 m | 30.57 | 56.25 | 13.18 | 0.00 | |
| P168 | 39 m | 19.55 | 65.95 | 14.50 | 0.00 | |




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P168 | 40 m | 19.11 | 64.89 | 16.00 | 0.00 | |
| P168 | 42 m | 28.25 | 60.25 | 7.30 | 4.20 | |

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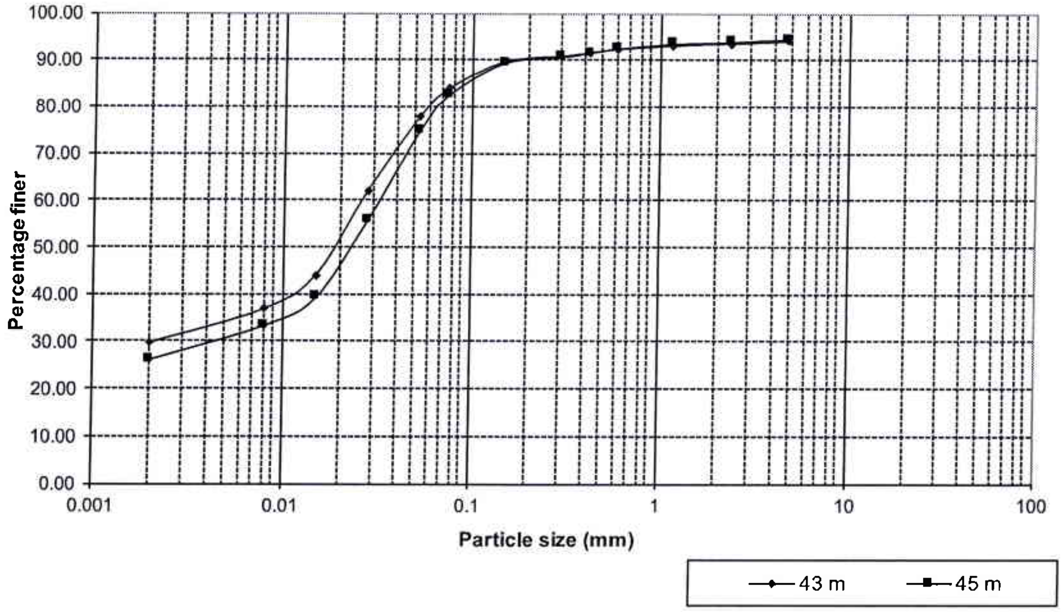
PATNA

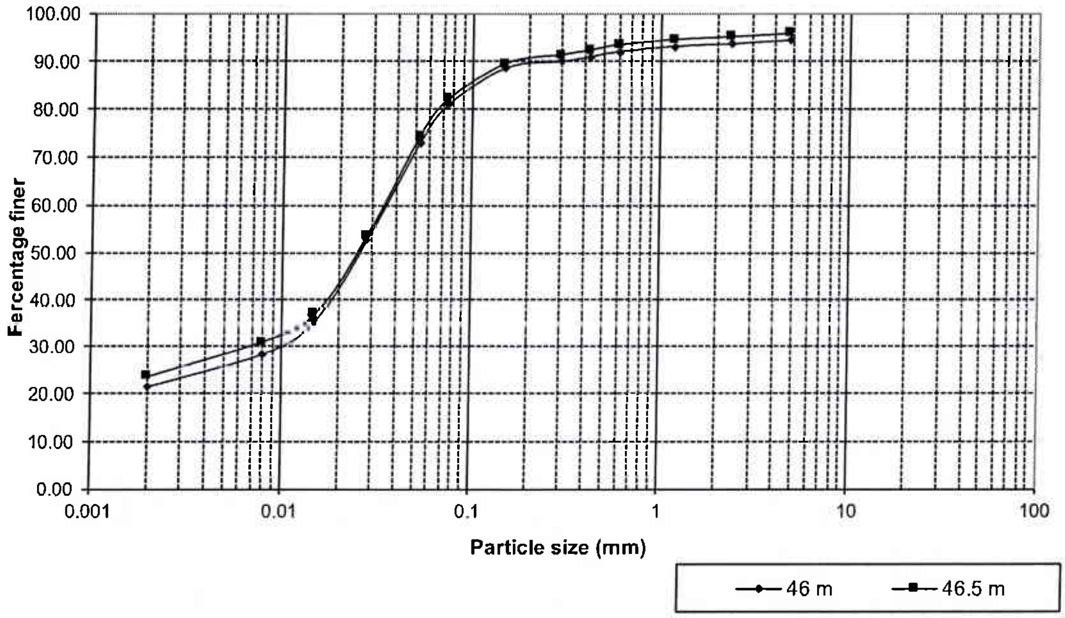
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P168 | 43 m | 29.62 | 54.18 | 10.20 | 6.00 | |
| P168 | 45 m | 26.25 | 56.25 | 12.05 | 5.45 | |




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P168 | 46 m | 21.42 | 59.58 | 13.30 | 5.70 | |
| P168 | 46.5 m | 23.41 | 58.74 | 13.55 | 4.30 | |

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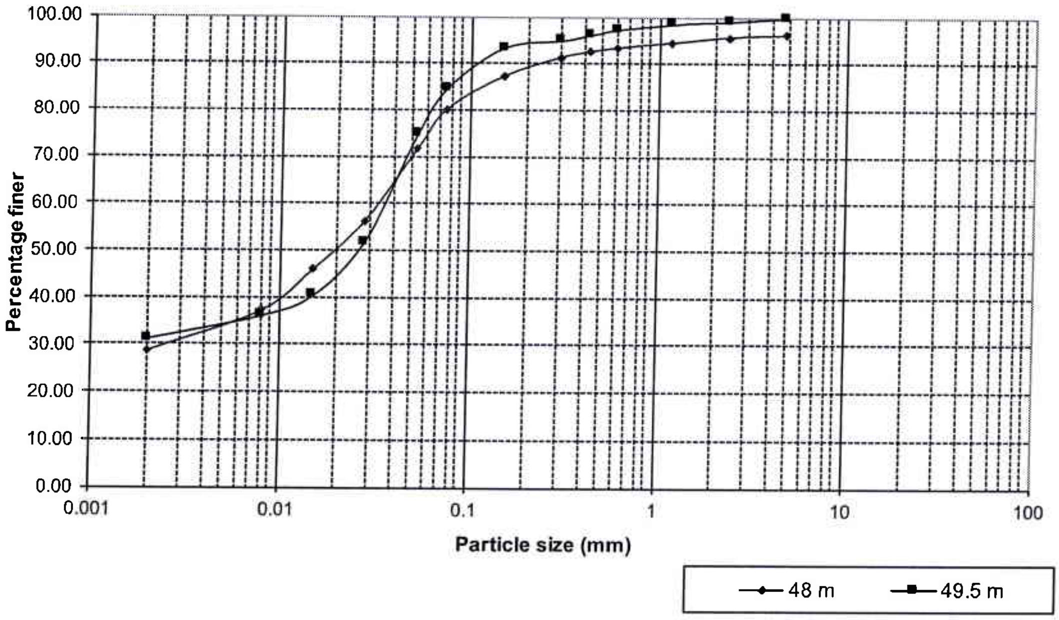
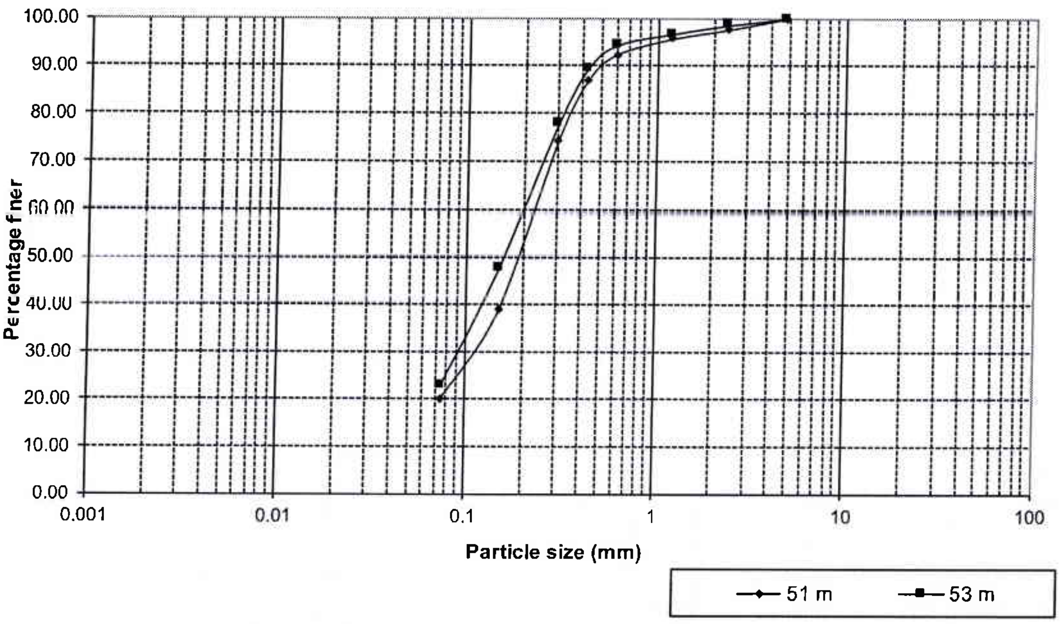
**PARTICLE SIZE DISTRIBUTION CURVES**




| *Grain size (mm)* | | *< 0.002* | *0.002 - 0.075* | *0.075 - 4.75* | *> 4.75* | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P168 | 48 m | 28.63 | 51.47 | 16.05 | 3.85 | |
| P168 | 49.5 m | 31.39 | 53.26 | 15.35 | 0.00 | |

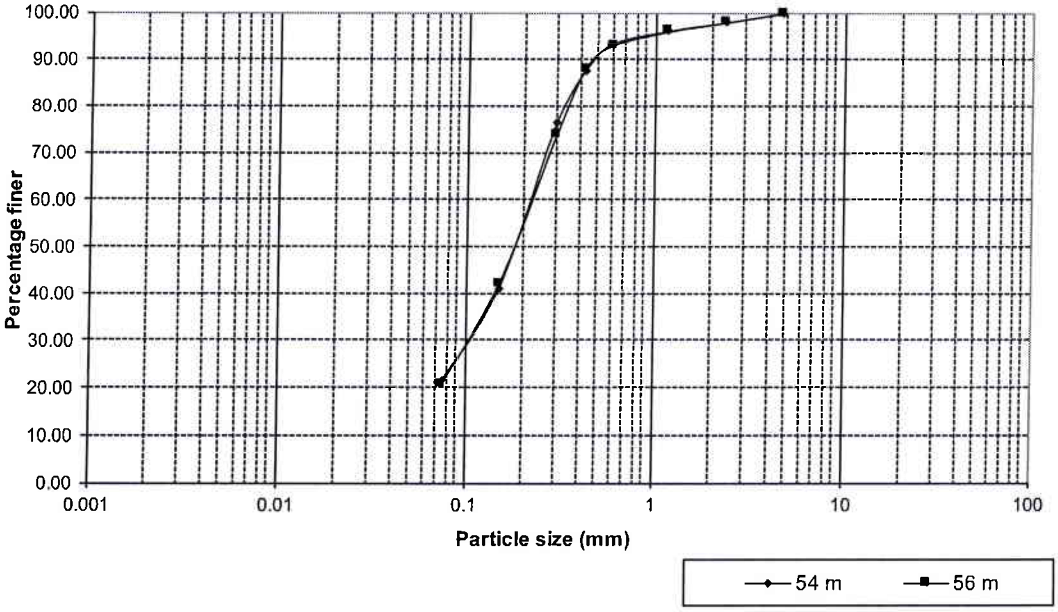



| *Grain size (mm)* | | *< 0.002* | *0.002 - 0.075* | *0.075 - 4.75* | *> 4.75* | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P168 | 51 m | 0.00 | 20.00 | 80.00 | 0.00 | 1.05 |
| P168 | 53 m | 0.00 | 22.75 | 77.25 | 0.00 | 0.96 |

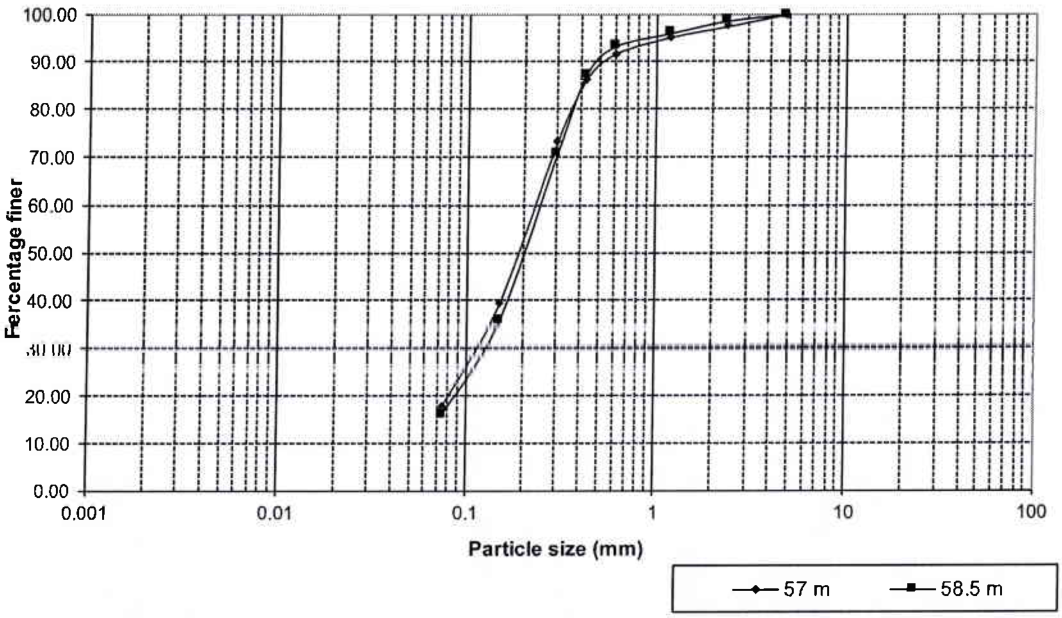
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## PARTICLE SIZE DISTRIBUTION CURVES

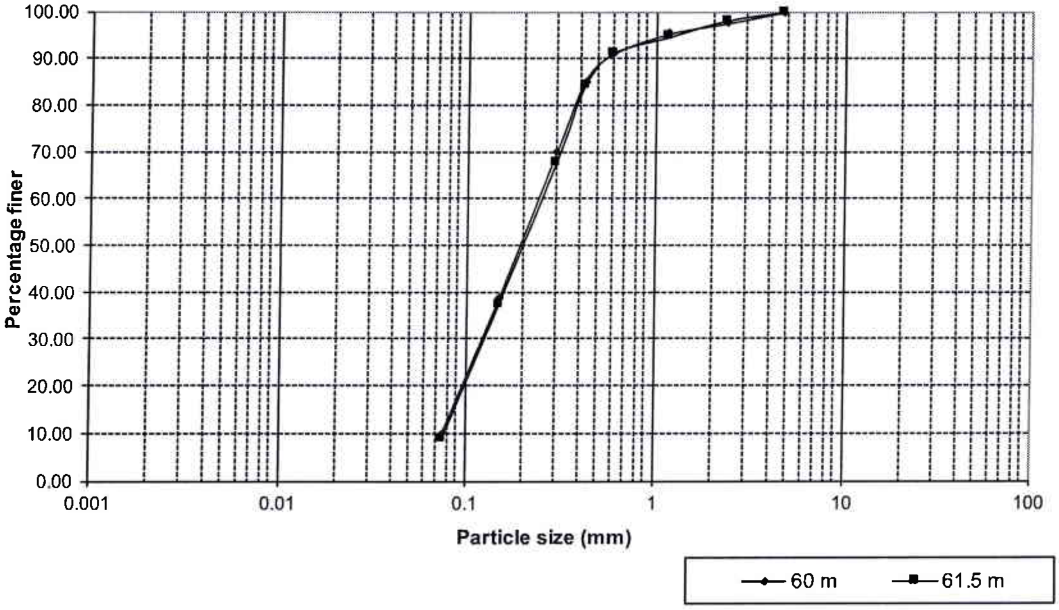



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P168 | 54 m | 0.00 | 21.35 | 78.65 | 0.00 | 1.02 |
| P168 | 56 m | 0.00 | 20.69 | 79.31 | 0.00 | 1.02 |

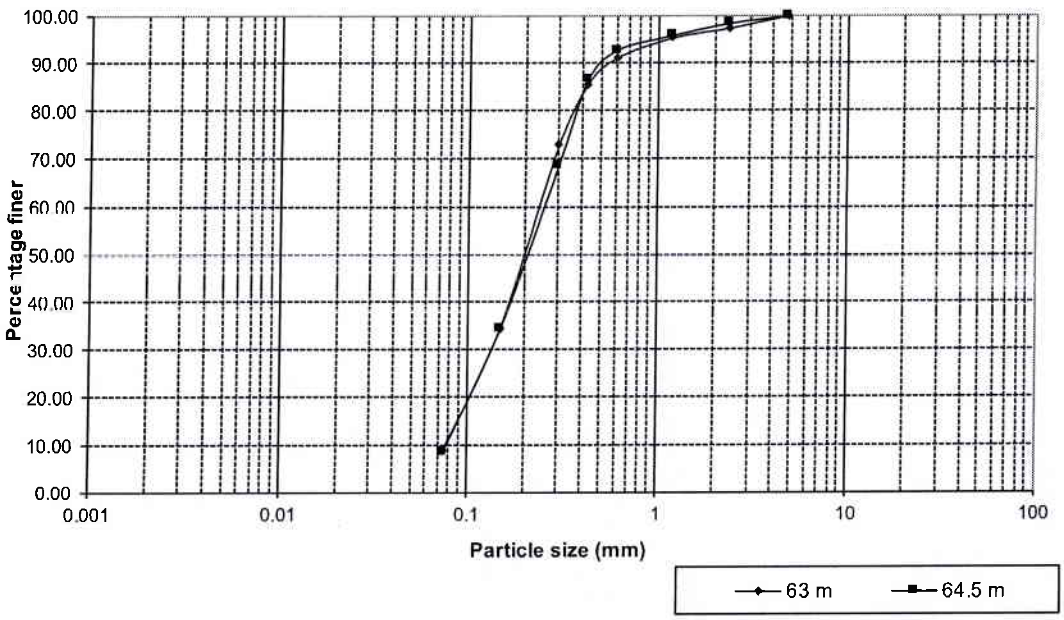



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P168 | 57 m | 0.00 | 17.85 | 82.15 | 0.00 | 1.07 |
| P168 | 58.5 m | 0.00 | 16.10 | 83.90 | 0.00 | 1.03 |

## PARTICLE SIZE DISTRIBUTION CURVES




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P168 | 60 m | 0.00 | 9.90 | 90.10 | 0.00 | 1.08 |
| P168 | 61.5 m | 0.00 | 8.80 | 91.20 | 0.00 | 1.09 |

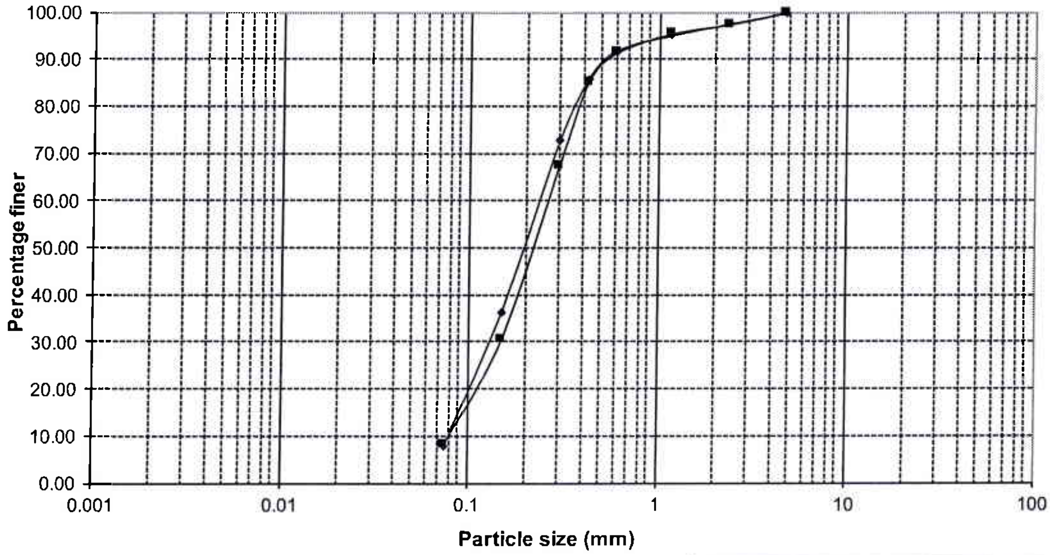



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P168 | 63 m | 0.00 | 8.65 | 91.35 | 0.00 | 1.09 |
| P168 | 64.5 m | 0.00 | 8.30 | 91.70 | 0.00 | 1.05 |

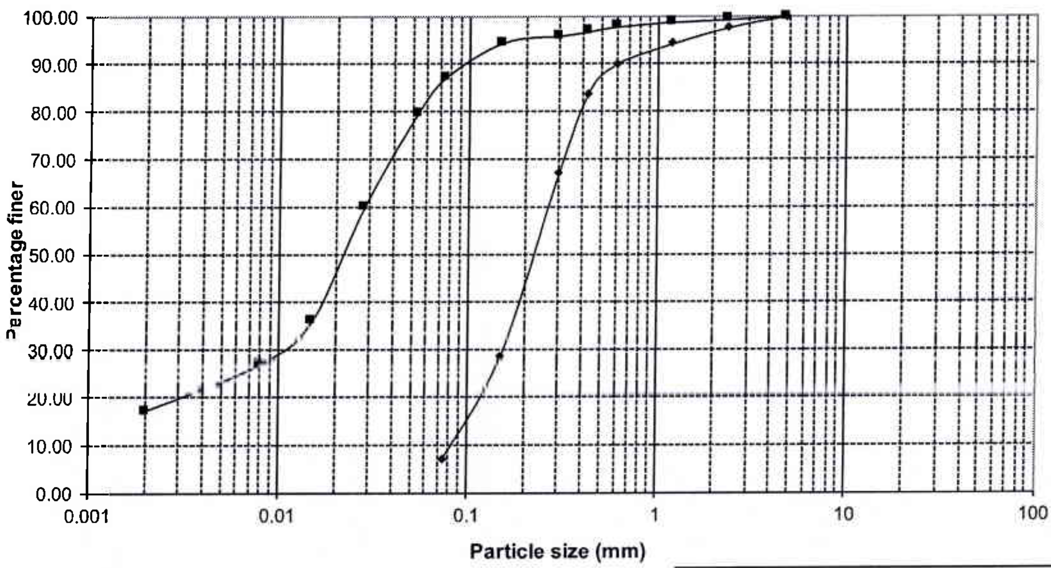
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P168 | 66 m | 0.00 | 7.60 | 92.40 | 0.00 | 1.09 |
| P168 | 67.5 m | 0.00 | 8.15 | 91.85 | 0.00 | 1.10 |

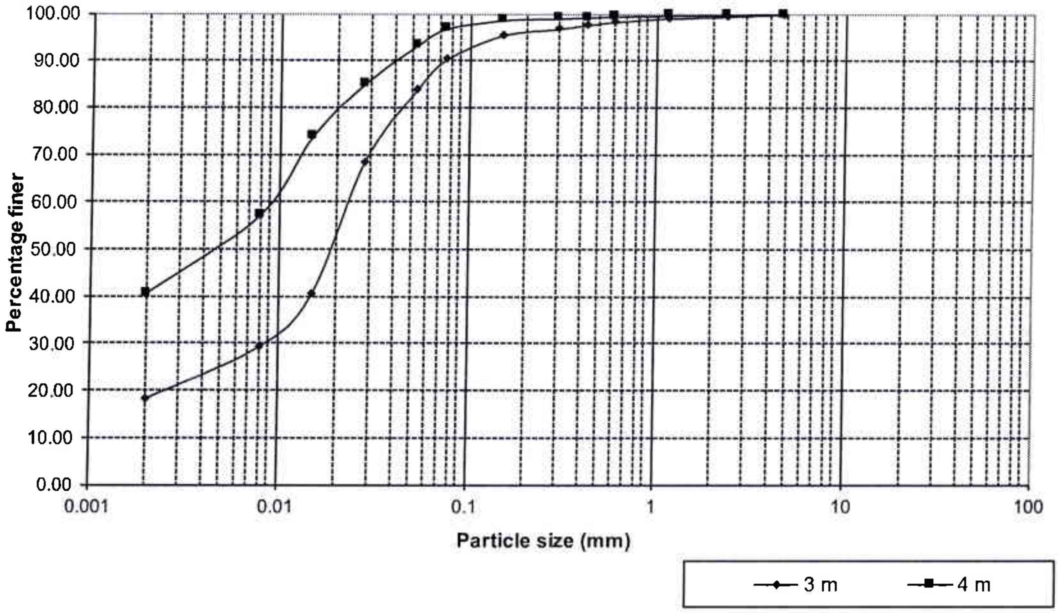



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P168 | 70 m | 0.00 | 6.90 | 93.10 | 0.00 | 1.13 |
| P169 | 1 m | 17.21 | 70.14 | 12.65 | 0.00 | |

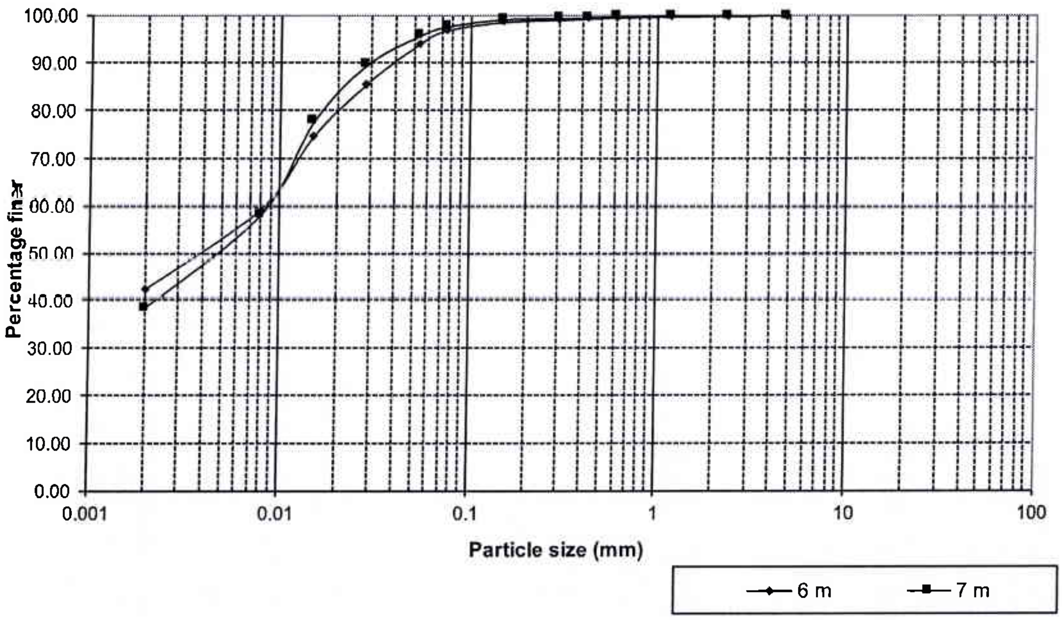
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## PARTICLE SIZE DISTRIBUTION CURVES




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P169 | 3 m | 18.15 | 72.15 | 9.70 | 0.00 | |
| P169 | 4 m | 40.60 | 56.25 | 3.15 | 0.00 | |

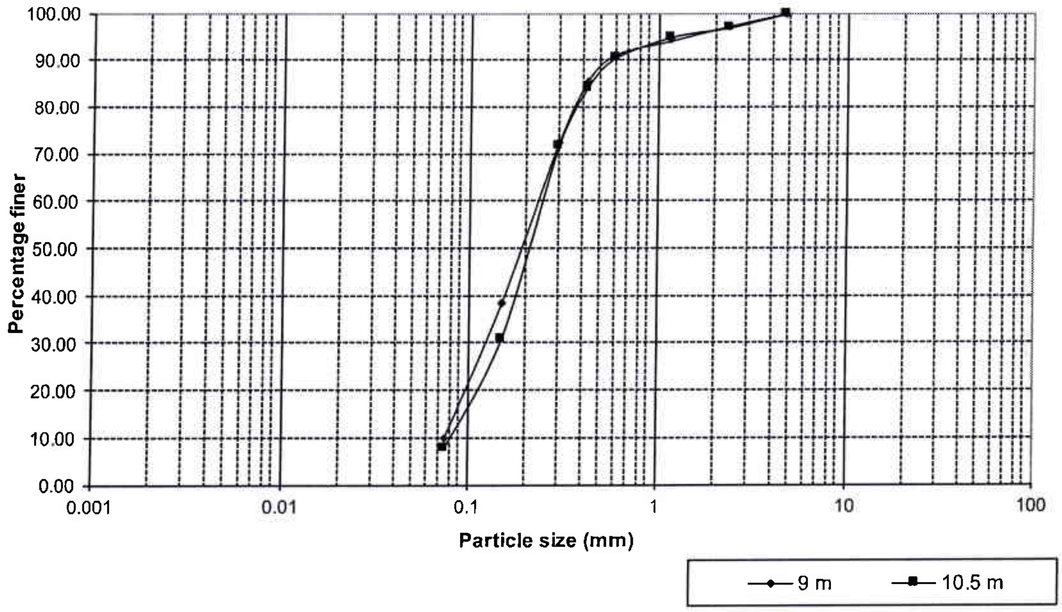



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P169 | 6 m | 42.10 | 54.85 | 3.05 | 0.00 | |
| P169 | 7 m | 38.48 | 59.25 | 2.27 | 0.00 | |

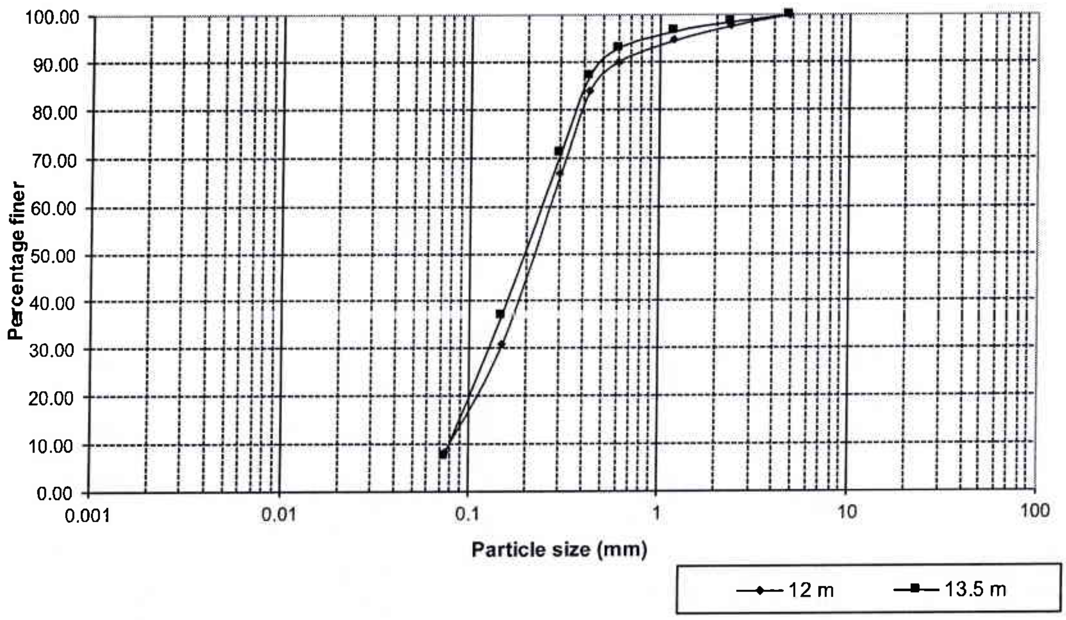
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P169 | 9 m | 0.00 | 9.90 | 90.10 | 0.00 | 1.10 |
| P169 | 10.5 m | 0.00 | 7.70 | 92.30 | 0.00 | 1.13 |

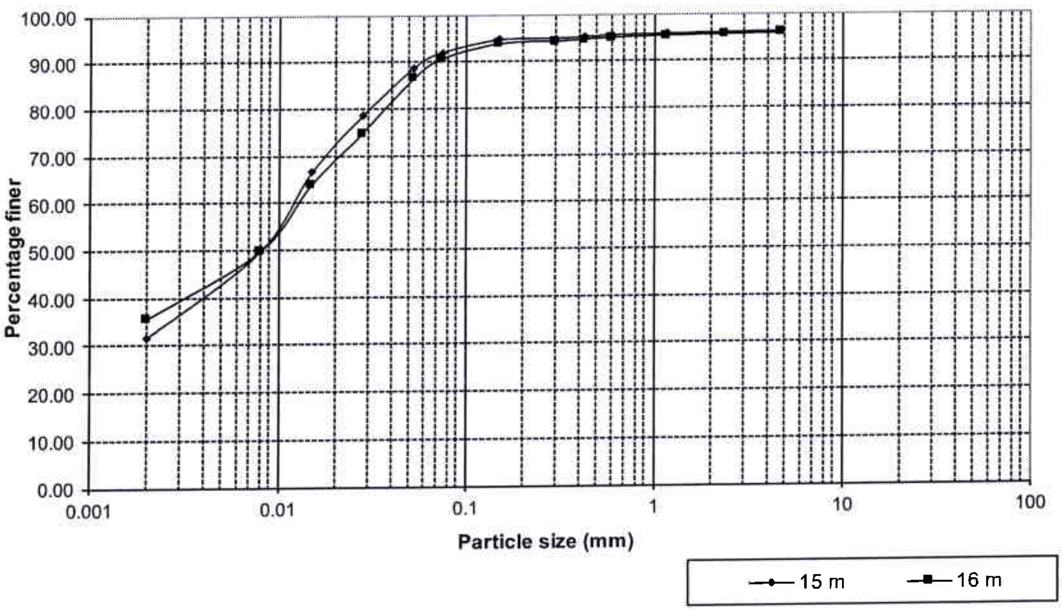



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P169 | 12 m | 0.00 | 8.25 | 91.75 | 0.00 | 1.12 |
| P169 | 13.5 m | 0.00 | 7.33 | 92.67 | 0.00 | 1.03 |

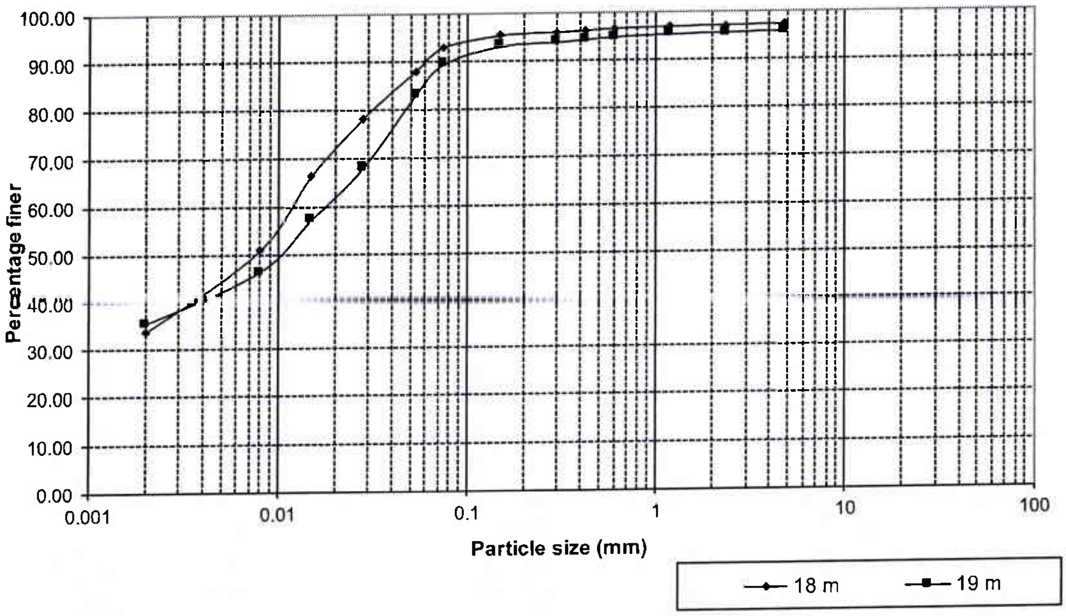
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P169 | 15 m | 31.75 | 60.25 | 4.20 | 3.80 | |
| P169 | 16 m | 35.45 | 55.15 | 5.12 | 4.28 | |

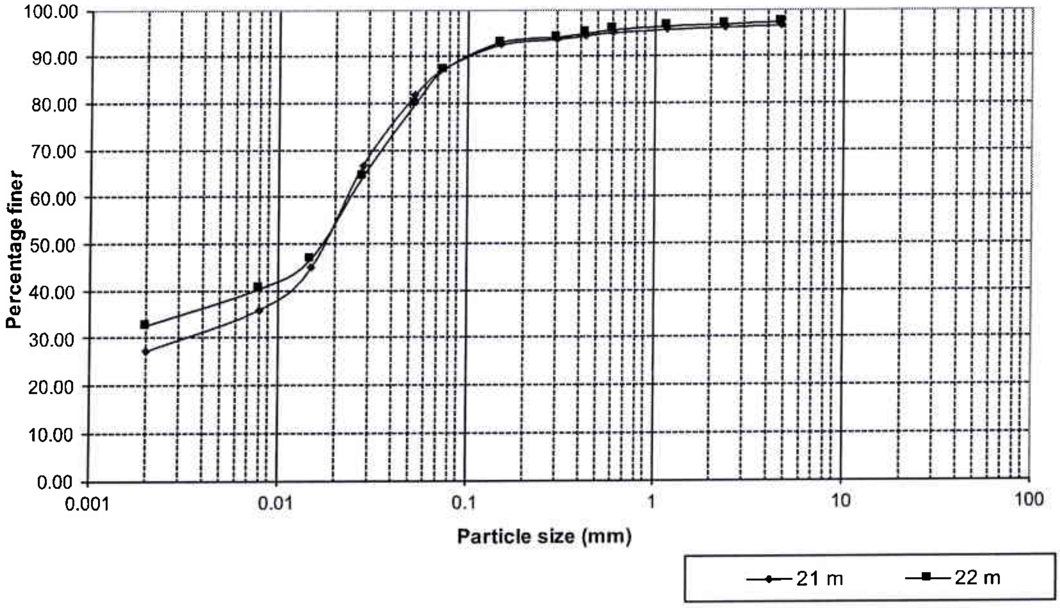



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P169 | 18 m | 33.75 | 59.25 | 4.30 | 2.70 | |
| P169 | 19 m | 35.50 | 54.15 | 6.35 | 4.00 | |

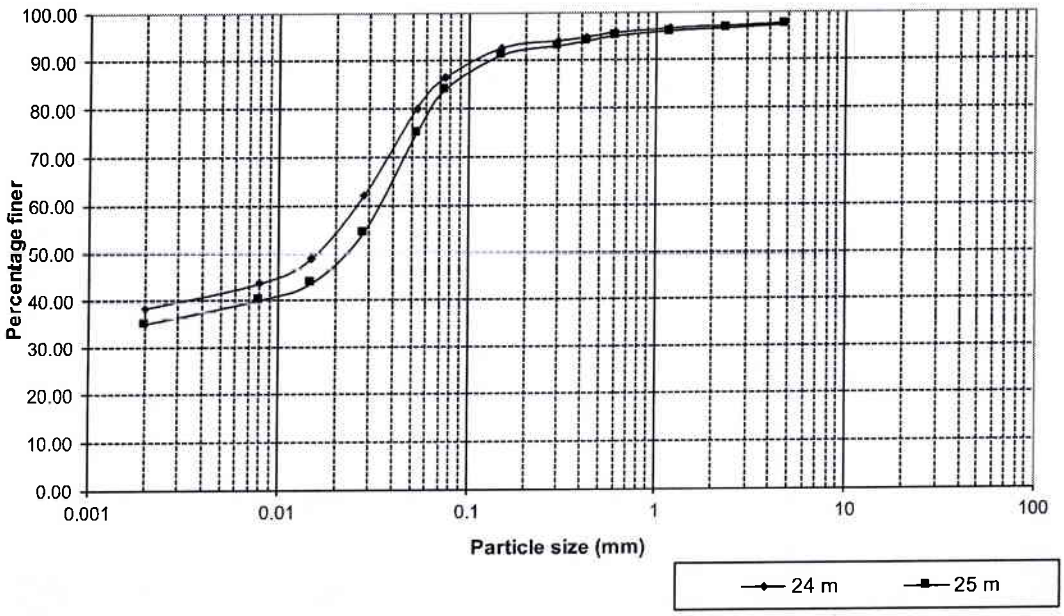
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**PARTICLE SIZE DISTRIBUTION CURVES**

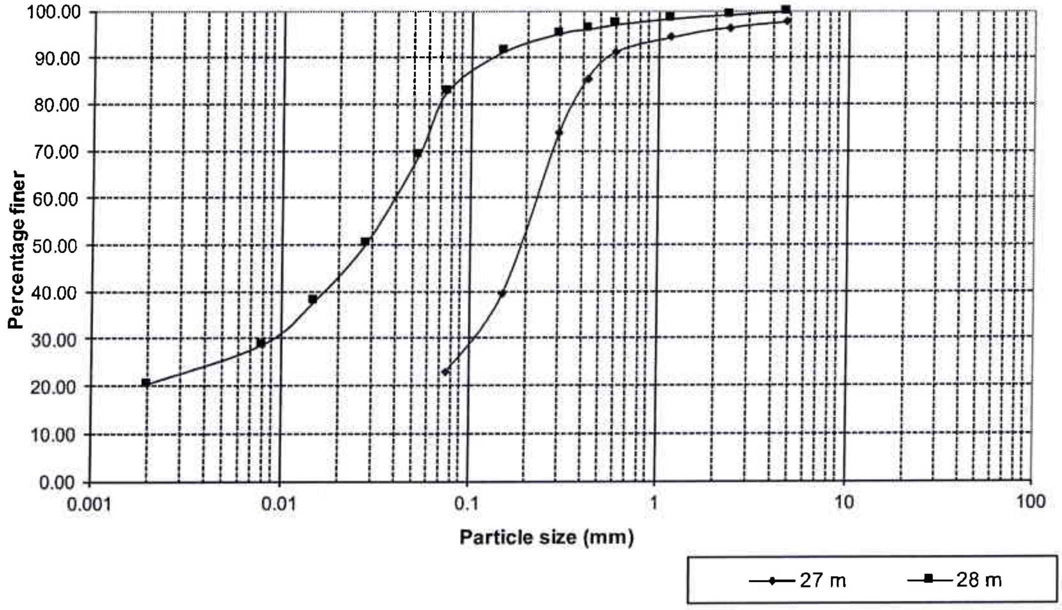



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P169 | 21 m | 27.20 | 60.25 | 9.30 | 3.25 | |
| P169 | 22 m | 32.77 | 54.48 | 10.15 | 2.60 | |

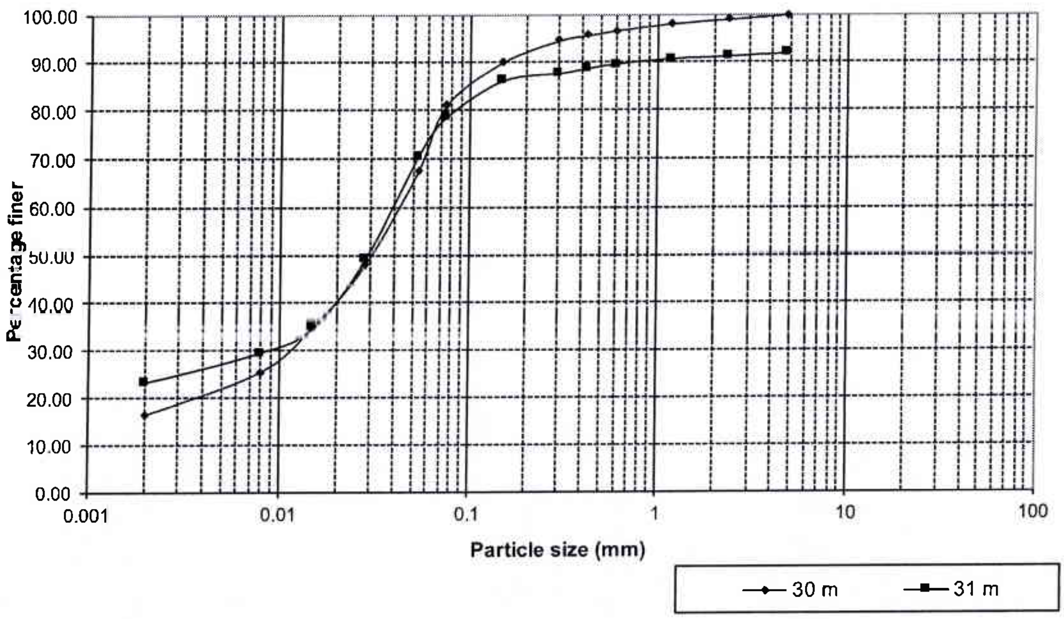



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P169 | 24 m | 38.35 | 48.25 | 11.05 | 2.35 | |
| P169 | 25 m | 35.05 | 48.95 | 13.20 | 2.80 | |

**PARTICLE SIZE DISTRIBUTION CURVES**



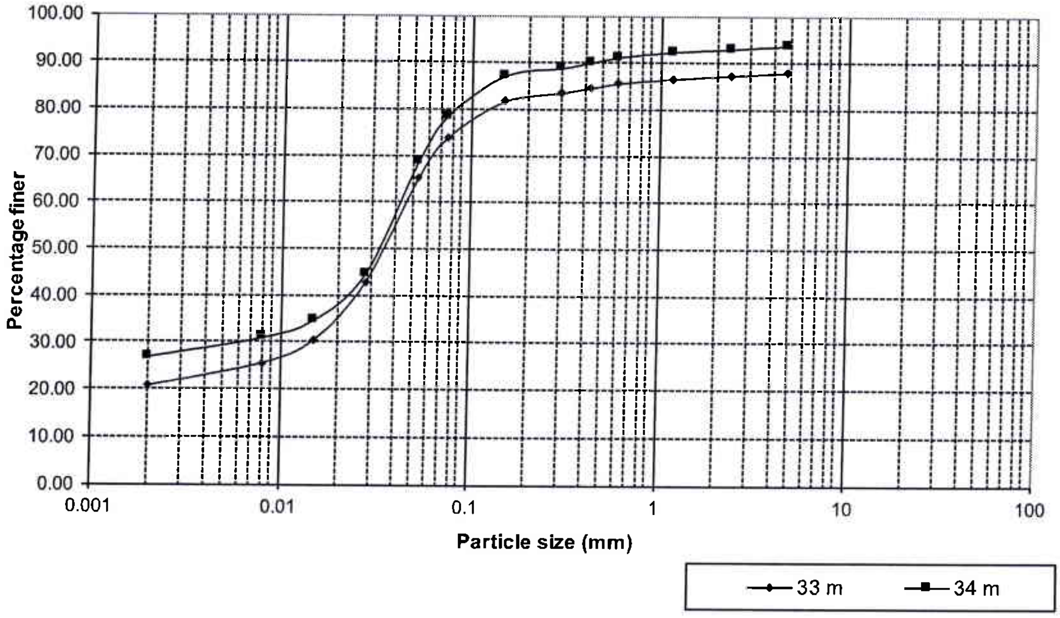

| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P169 | 27 m | 0.00 | 23.04 | 74.55 | 2.41 | 0.98 |
| P169 | 28 m | 20.46 | 62.54 | 17.00 | 0.00 | |



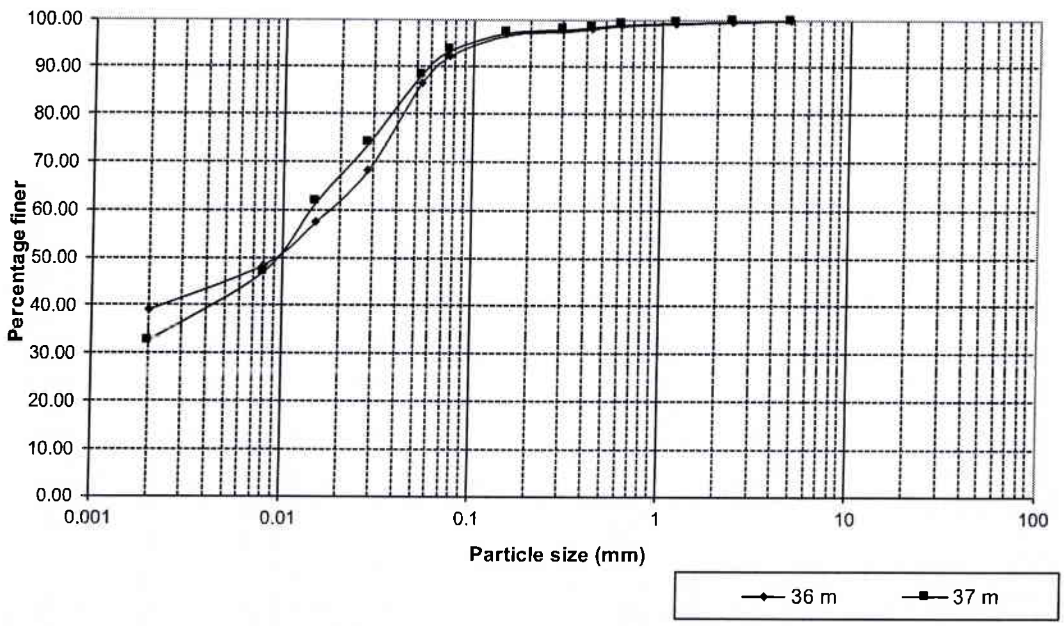

| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P169 | 30 m | 16.40 | 64.85 | 18.75 | 0.00 | |
| P169 | 31 m | 23.24 | 55.26 | 13.30 | 8.20 | |

ANAND RAJ INFRATECH PVT. LTD.

## PARTICLE SIZE DISTRIBUTION CURVES




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P169 | 33 m | 20.60 | 53.25 | 14.15 | 12.00 | |
| P169 | 34 m | 26.96 | 51.47 | 15.32 | 6.25 | |



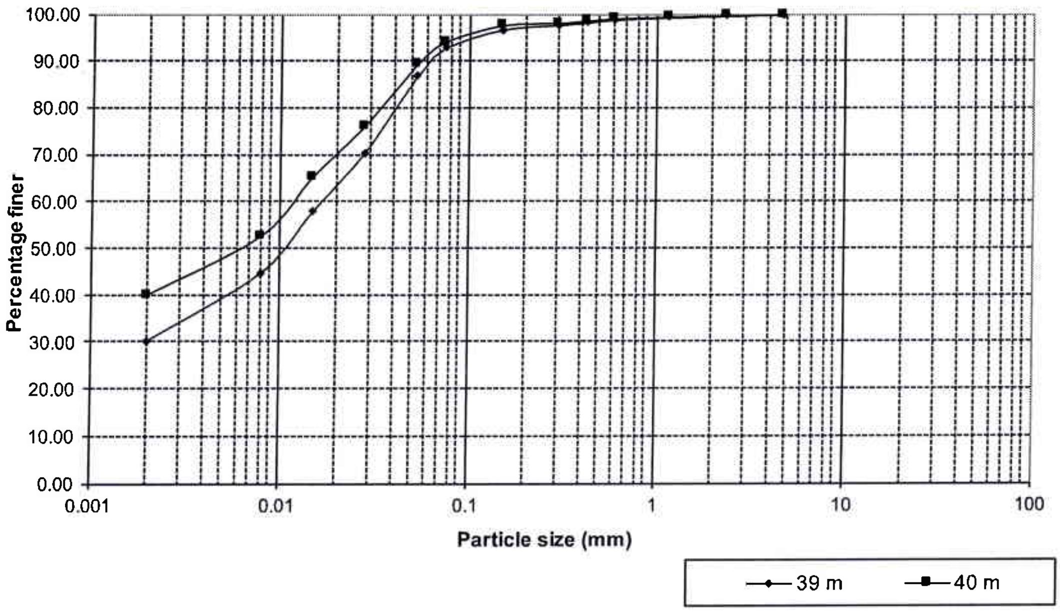

| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P169 | 36 m | 39.14 | 53.28 | 7.58 | 0.00 | |
| P169 | 37 m | 32.50 | 61.05 | 6.45 | 0.00 | |

ANAND RAJ INFRATECH PVT. LTD.

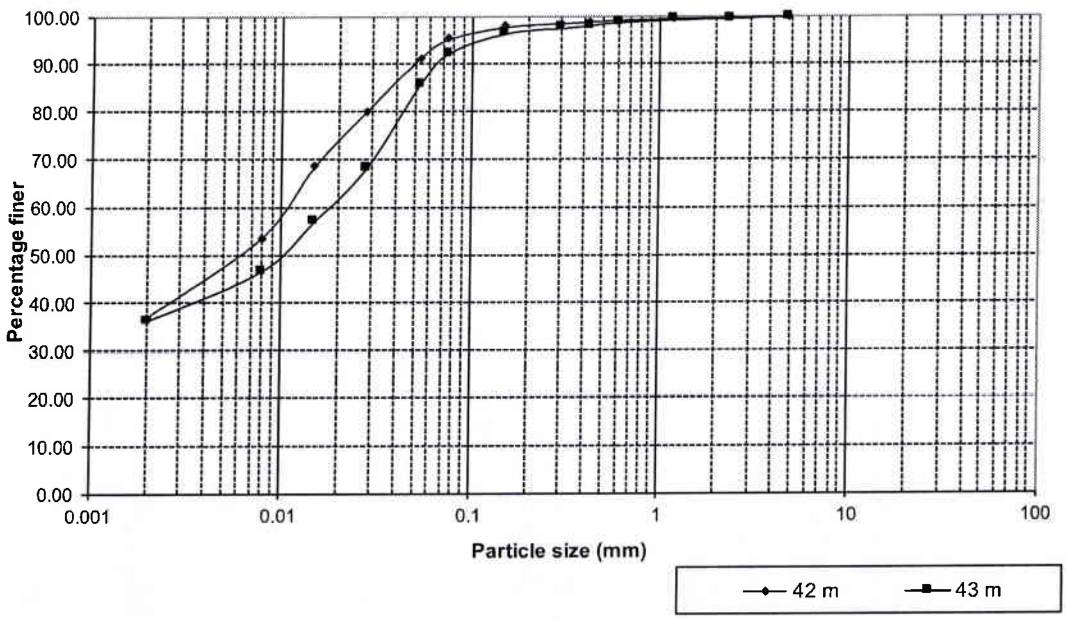
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## PARTICLE SIZE DISTRIBUTION CURVES




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P169 | 39 m | 30.17 | 62.65 | 7.18 | 0.00 | |
| P169 | 40 m | 40.05 | 54.15 | 5.80 | 0.00 | |




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P169 | 42 m | 36.75 | 58.59 | 4.66 | 0.00 | |
| P169 | 43 m | 36.19 | 56.25 | 7.56 | 0.00 | |

ANAND RAJ INFRATECH PVT. LTD.

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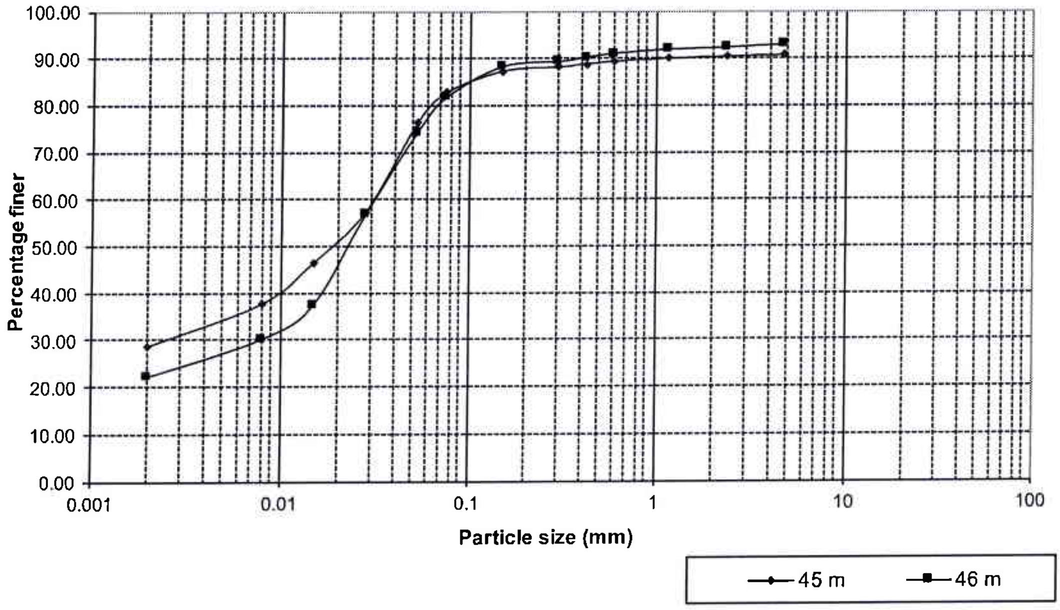
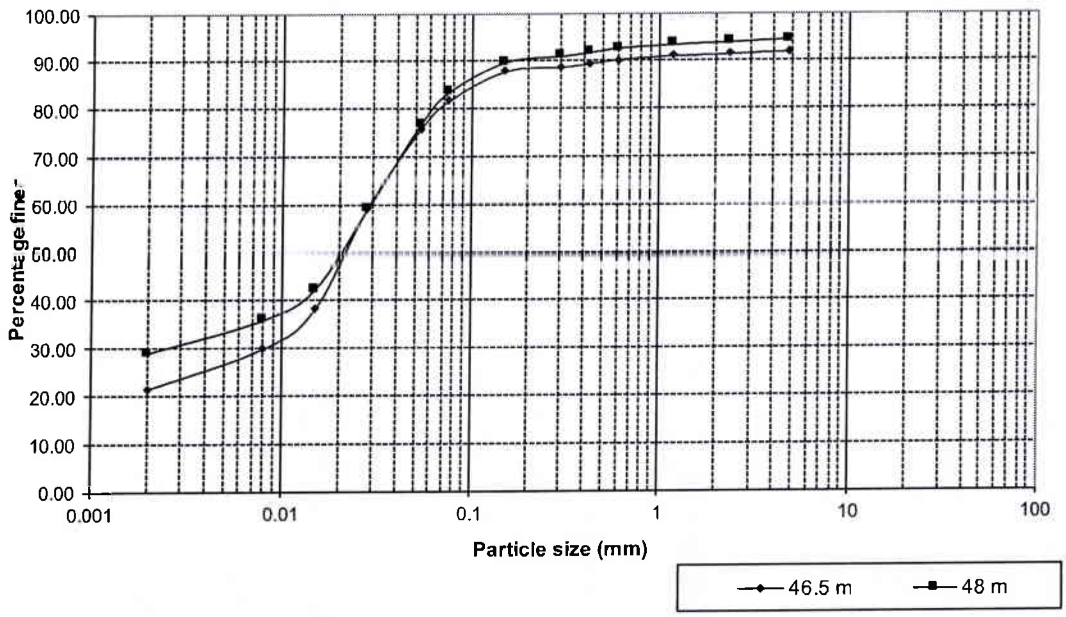
**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P169 | 45 m | 28.55 | 54.15 | 8.00 | 9.30 | |
| P169 | 46 m | 22.10 | 59.55 | 11.20 | 7.15 | |

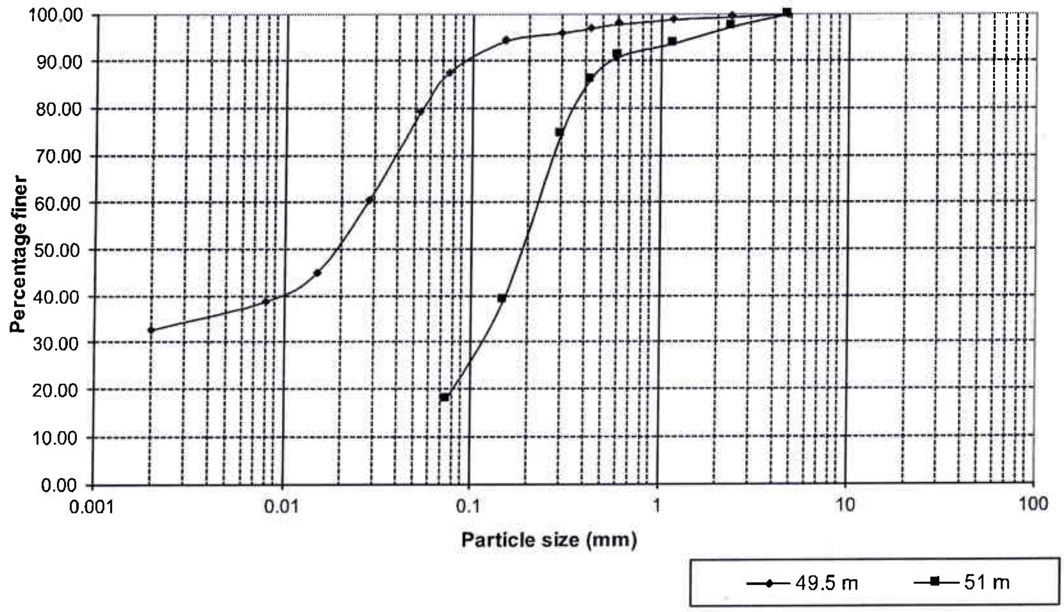



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P169 | 46.5 m | 21.50 | 60.20 | 10.30 | 8.00 | |
| P169 | 48 m | 29.13 | 54.47 | 11.00 | 5.40 | |

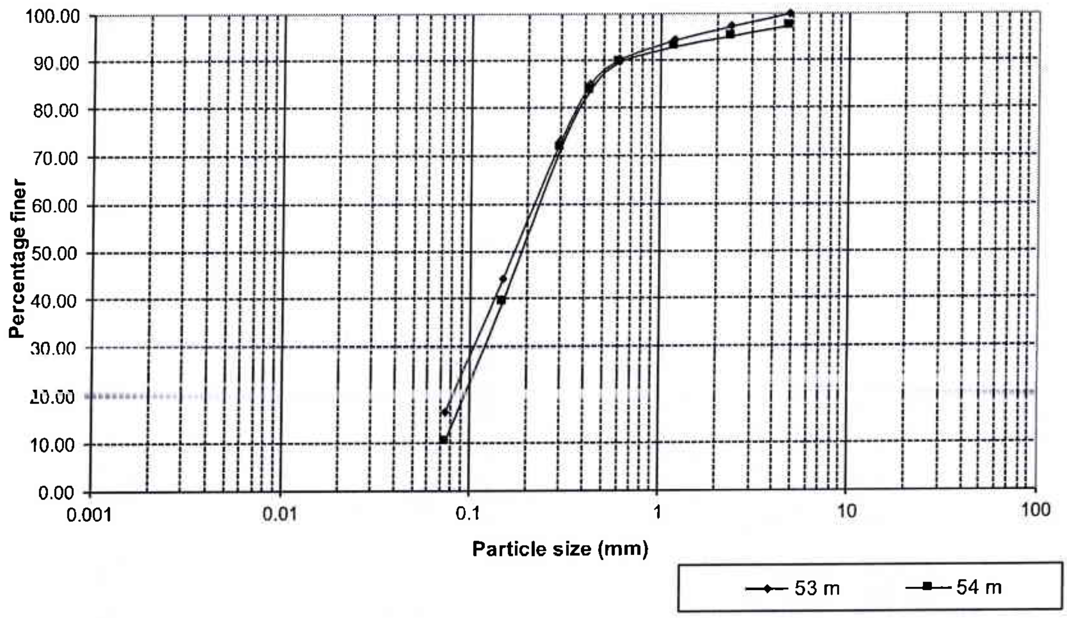
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**PARTICLE SIZE DISTRIBUTION CURVES**




| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P169 | 49.5 m | 32.81 | 54.89 | 12.30 | 0.00 | |
| P169 | 51 m | 0.00 | 18.00 | 82.00 | 0.00 | 1.09 |



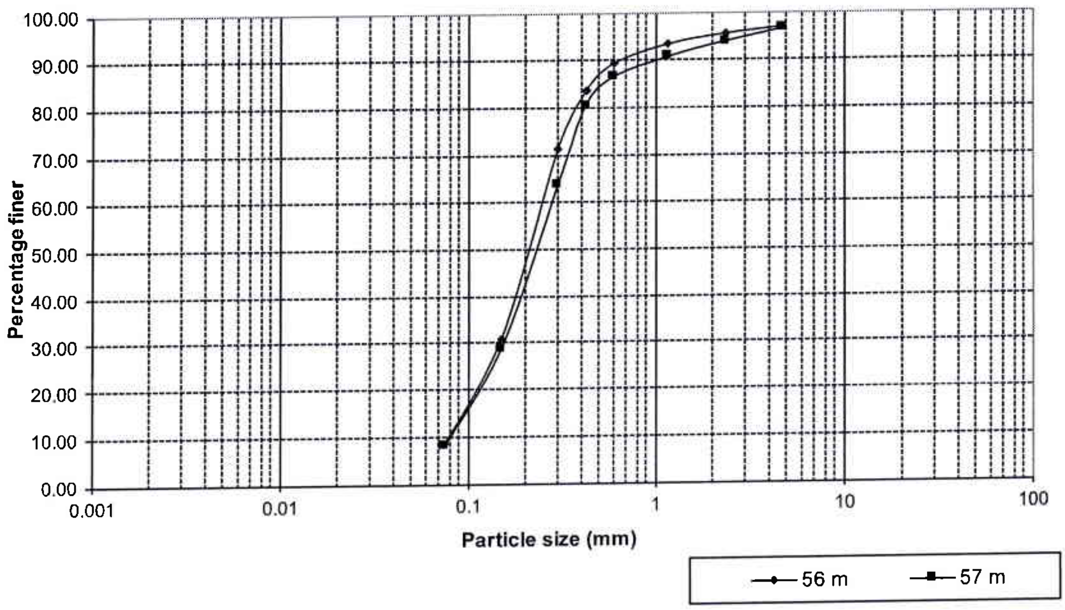

| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P169 | 53 m | 0.00 | 16.35 | 83.65 | 0.00 | 1.08 |
| P169 | 54 m | 0.00 | 10.30 | 87.05 | 2.65 | 1.05 |

ANAND INFRATECH PVT. LTD. PATNA

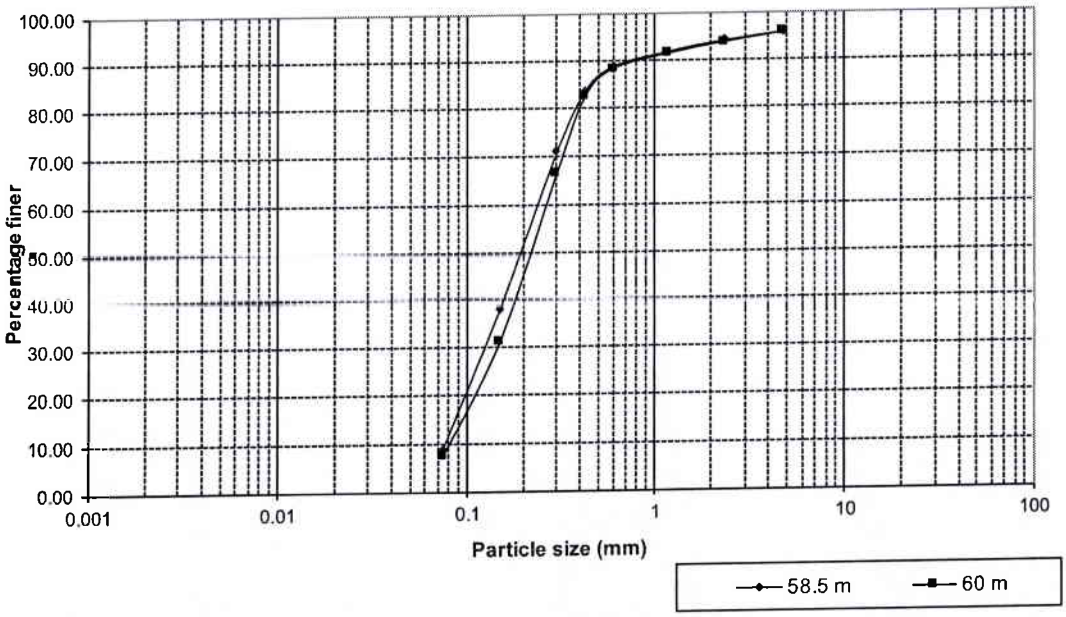
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## PARTICLE SIZE DISTRIBUTION CURVES

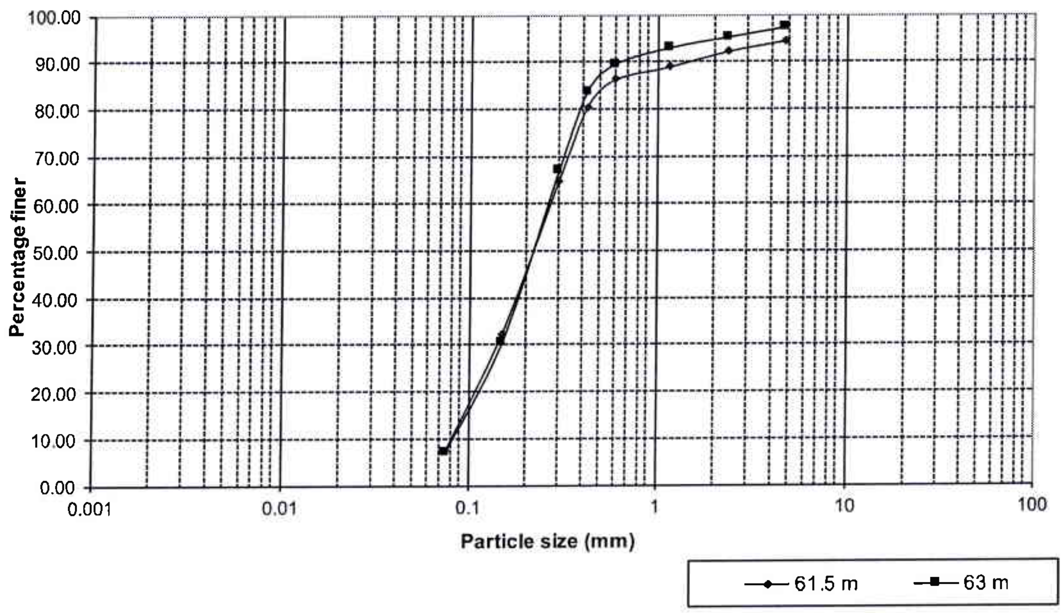



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P169 | 56 m | 0.00 | 8.50 | 88.40 | 3.10 | 1.04 |
| P169 | 57 m | 0.00 | 8.05 | 88.35 | 3.60 | 1.12 |

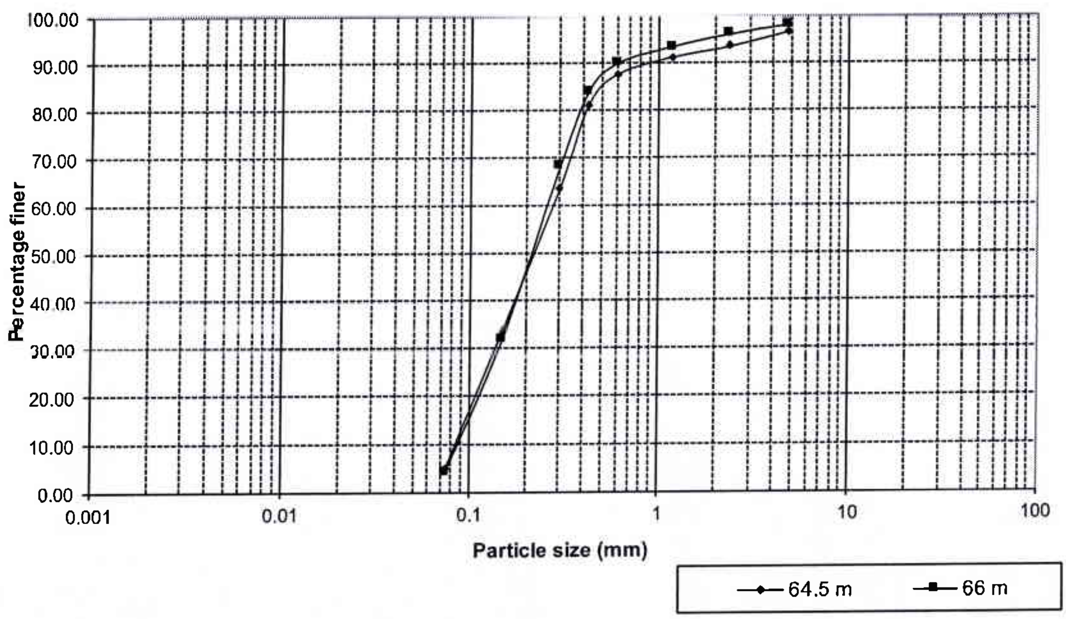



| Grain size (mm) | | < 0.002 | 0.002 - 0.075 | 0.075 - 4.75 | > 4.75 | Silt factor (for sands) |
|---|---|---|---|---|---|---|
| Bore Hole | Sample | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | |
| P169 | 58.5 m | 0.00 | 8.90 | 87.10 | 4.00 | 1.02 |
| P169 | 60 m | 0.00 | 7.55 | 88.15 | 4.30 | 1.06 |

## PARTICLE SIZE DISTRIBUTION CURVES




| *Grain size (mm)* | | *< 0.002* | *0.002 - 0.075* | *0.075 - 4.75* | *> 4.75* | **Silt factor (for sands)** |
|---|---|---|---|---|---|---|
| **Bore Hole** | **Sample** | **Clay (%)** | **Silt (%)** | **Sand (%)** | **Gravel (%)** | |
| P169 | 61.5 m | 0.00 | 7.50 | 87.05 | 5.45 | 1.08 |
| P169 | 63 m | 0.00 | 7.05 | 90.10 | 2.85 | 1.07 |

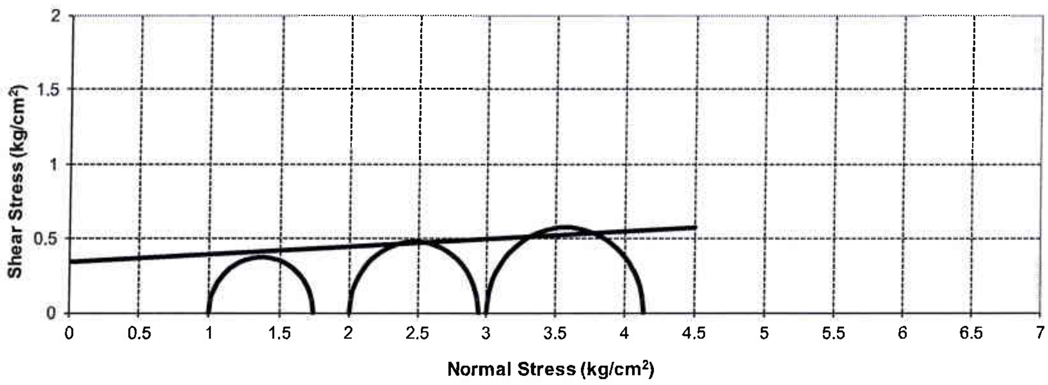



| *Grain size (mm)* | | *< 0.002* | *0.002 - 0.075* | *0.075 - 4.75* | *> 4.75* | **Silt factor (for sands)** |
|---|---|---|---|---|---|---|
| **Bore Hole** | **Sample** | **Clay (%)** | **Silt (%)** | **Sand (%)** | **Gravel (%)** | |
| P169 | 64.5 m | 0.00 | 4.90 | 91.75 | 3.35 | 1.11 |
| P169 | 66 m | 0.00 | 4.30 | 93.70 | 2.00 | 1.07 |

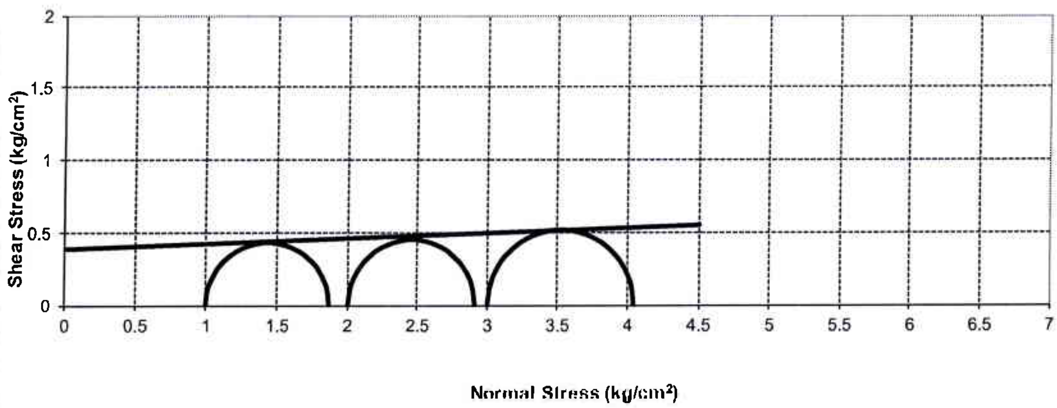
## GRAPHICAL REPRESENTATION OF TRIAXIAL TEST RESULTS

**TEST TYPE : UNCONSOLIDATED UNDRAINED**

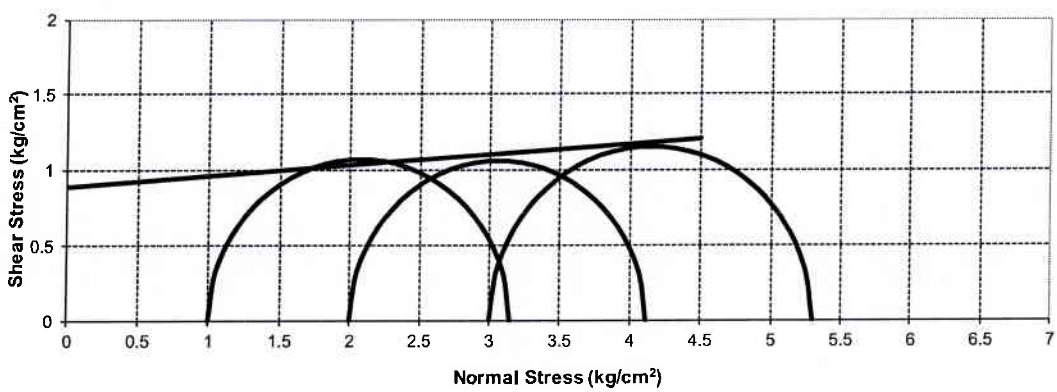
| Bore Hole P164 | Depth | 4.00 m | C = | 0.34 kg/cm2 | Ø = | 3 | degree |
|---|---|---|---|---|---|---|---|




| Bore Hole P164 | Depth | 7.00 m | C = | 0.39 kg/cm2 | Ø = | 2 | degree |
|---|---|---|---|---|---|---|---|




| Bore Hole P164 | Depth | 13.00 m | C = | 0.89 kg/cm2 | Ø = | 4 | degree |
|---|---|---|---|---|---|---|---|



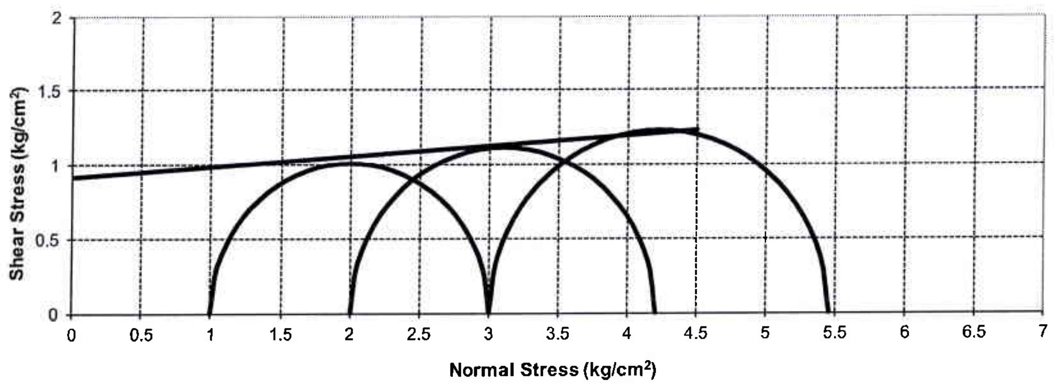
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

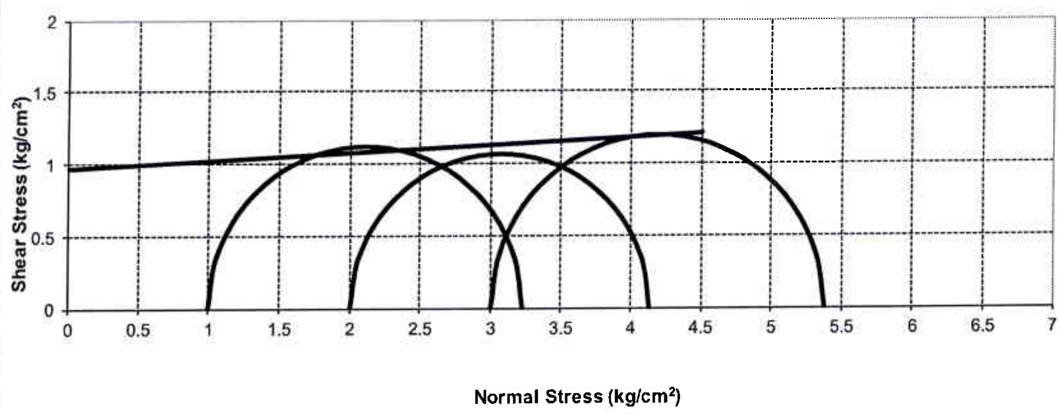
## GRAPHICAL REPRESENTATION OF TRIAXIAL TEST RESULTS

TEST TYPE : UNCONSOLIDATED UNDRAINED

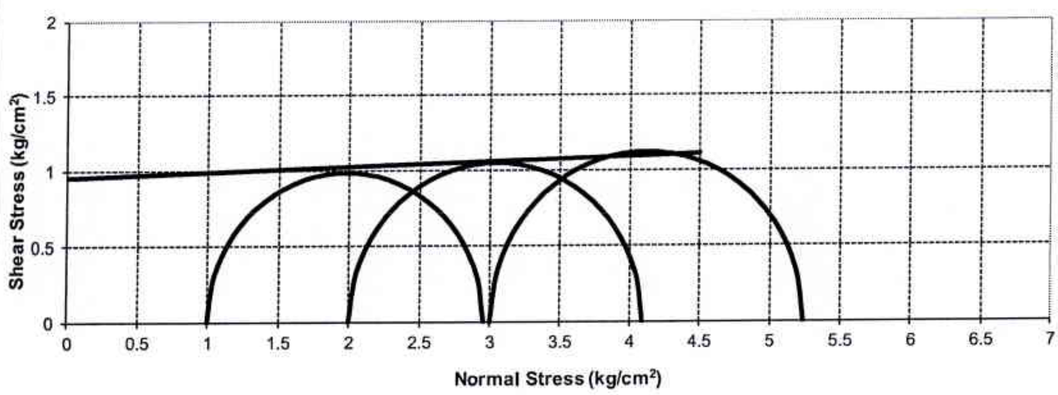
Bore Hole P164 Depth 16.00 m C = 0.91 kg/cm2 Ø = 4 degree




Bore Hole P164 Depth 19.00 m C = 0.97 kg/cm2 Ø = 3 degree



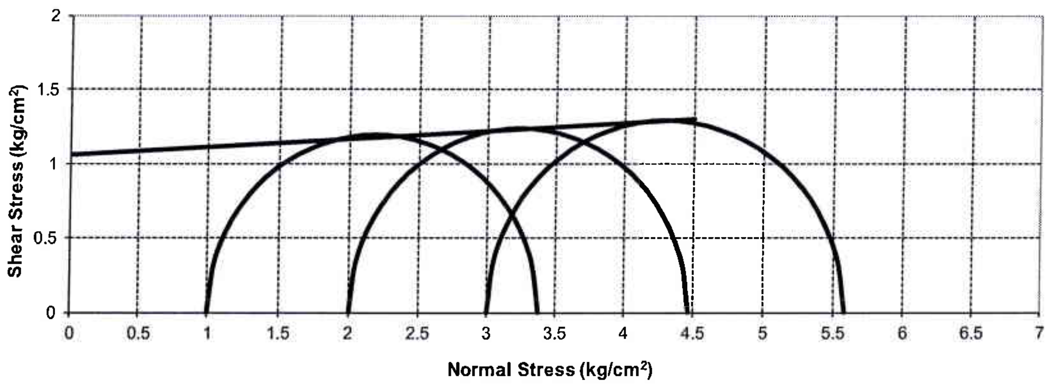

Bore Hole P164 Depth 22.00 m C = 0.95 kg/cm2 Ø = 2 degree



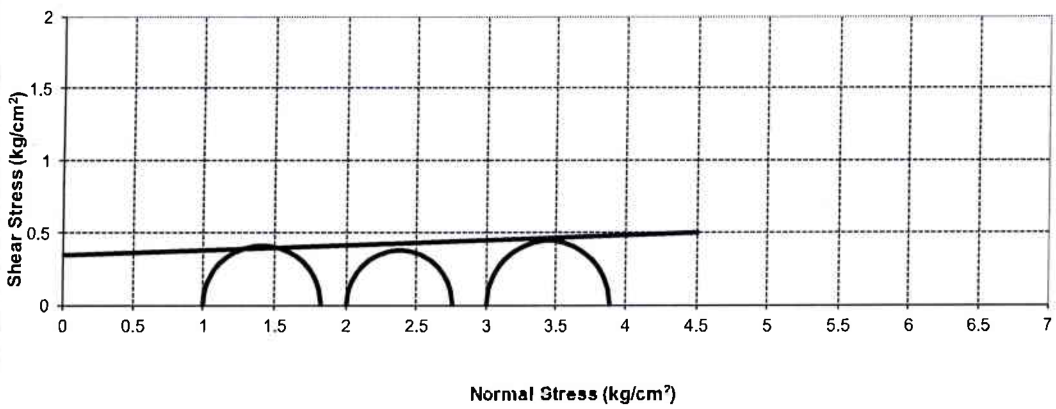
## GRAPHICAL REPRESENTATION OF TRIAXIAL TEST RESULTS

**TEST TYPE : UNCONSOLIDATED UNDRAINED**

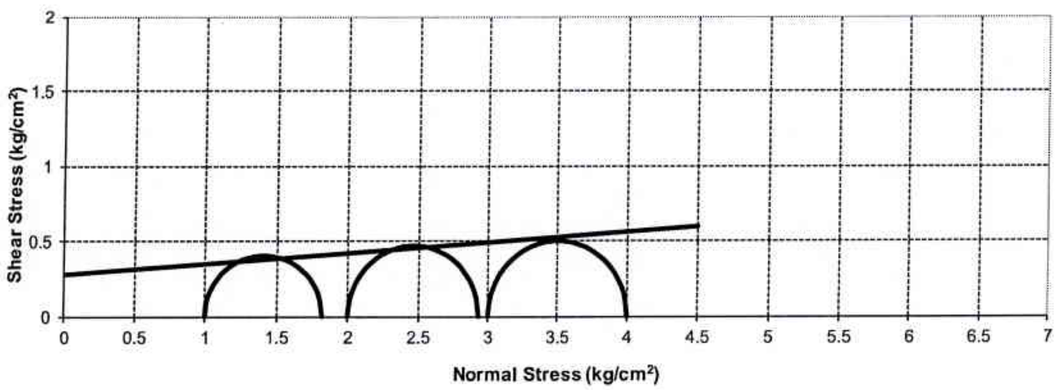
| Bore Hole P164 | Depth | 25.00 m | C = | 1.06 kg/cm2 | Ø = | 3 | degree |
|---|---|---|---|---|---|---|---|




| Bore Hole P165 | Depth | 4.00 m | C = | 0.34 kg/cm2 | Ø = | 2 | degree |
|---|---|---|---|---|---|---|---|




| Bore Hole P165 | Depth | 7.00 m | C = | 0.28 kg/cm2 | Ø = | 4 | degree |
|---|---|---|---|---|---|---|---|



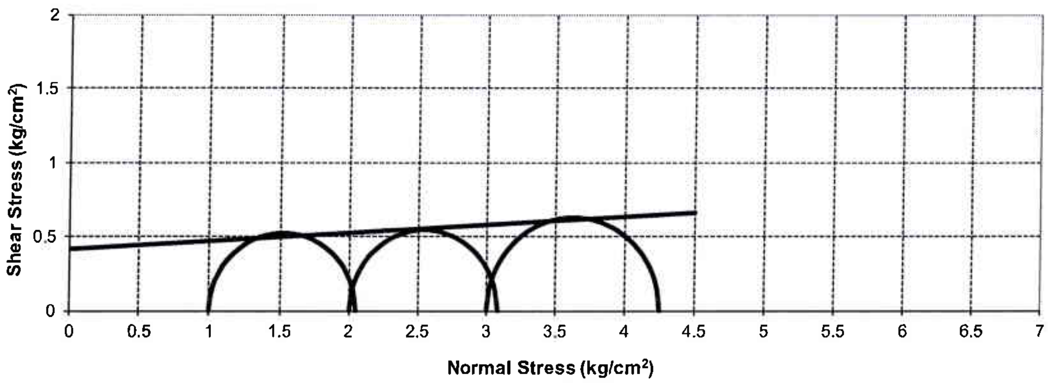
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

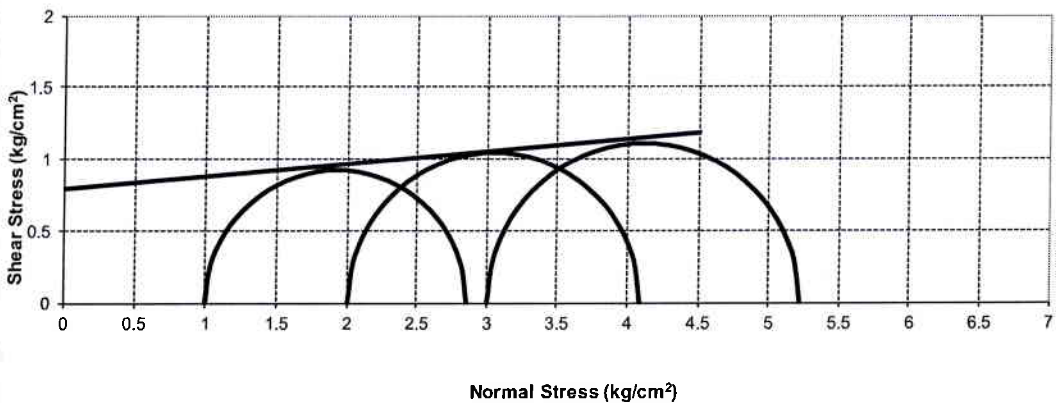
## GRAPHICAL REPRESENTATION OF TRIAXIAL TEST RESULTS

**TEST TYPE : UNCONSOLIDATED UNDRAINED**

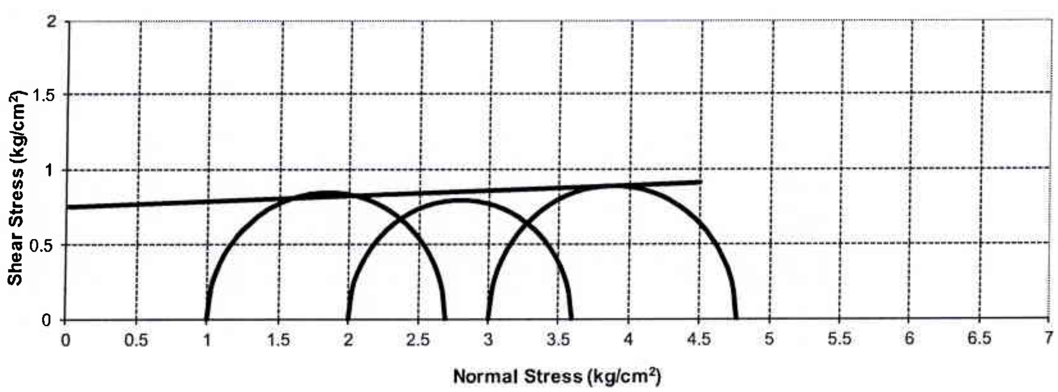
| Bore Hole P165 | Depth | 10.00 m | C = | 0.42 kg/cm2 | Ø = | 3 | degree |
|---|---|---|---|---|---|---|---|




| Bore Hole P165 | Depth | 13.00 m | C = | 0.79 kg/cm2 | Ø = | 5 | degree |
|---|---|---|---|---|---|---|---|




| Bore Hole P165 | Depth | 16.00 m | C = | 0.75 kg/cm2 | Ø = | 2 | degree |
|---|---|---|---|---|---|---|---|



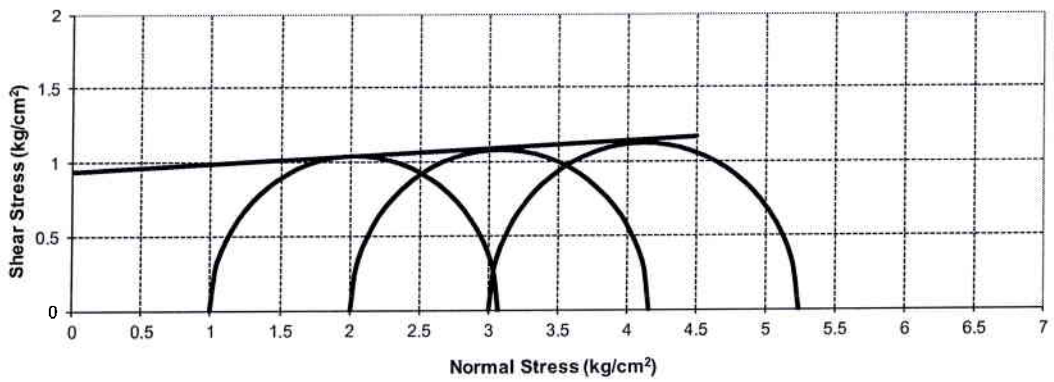
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

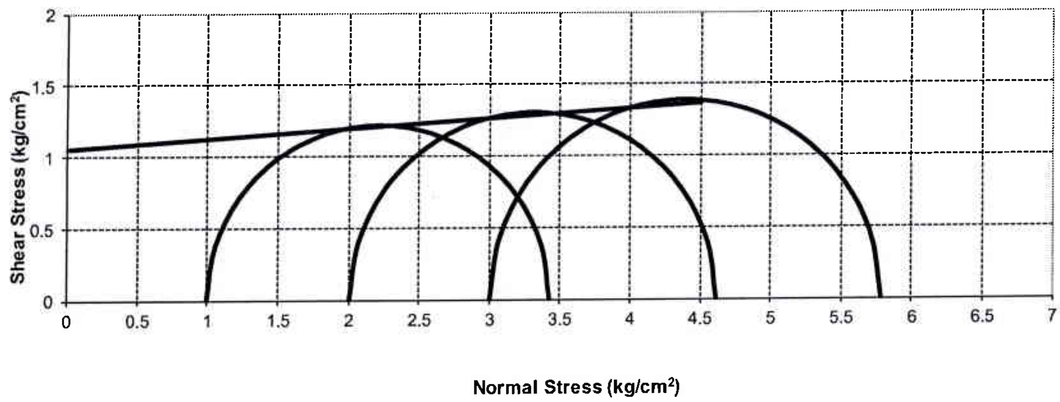
## GRAPHICAL REPRESENTATION OF TRIAXIAL TEST RESULTS

**TEST TYPE : UNCONSOLIDATED UNDRAINED**

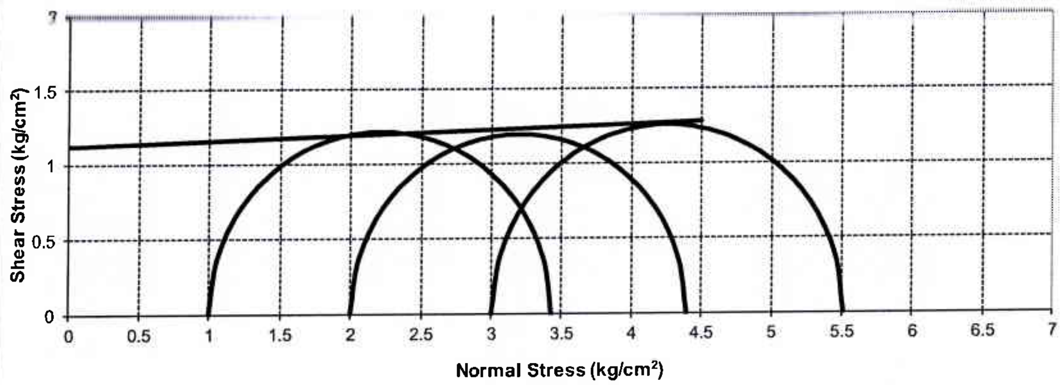
| Bore Hole P165 | Depth | 19.00 m | C = | 0.93 kg/cm2 | Ø = | 3 | degree |
|---|---|---|---|---|---|---|---|




| Bore Hole P165 | Depth | 22.00 m | C = | 1.06 kg/cm2 | Ø = | 4 | degree |
|---|---|---|---|---|---|---|---|



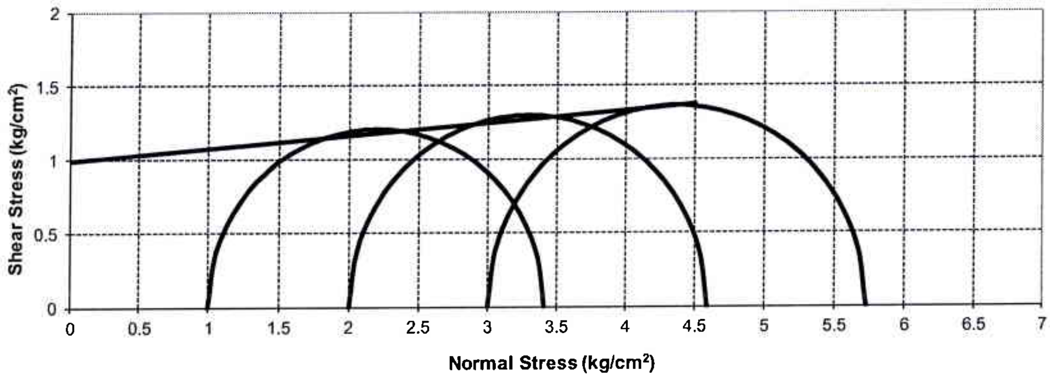

| Bore Hole P165 | Depth | 25.00 m | C = | 1.12 kg/cm2 | Ø = | 2 | degree |
|---|---|---|---|---|---|---|---|



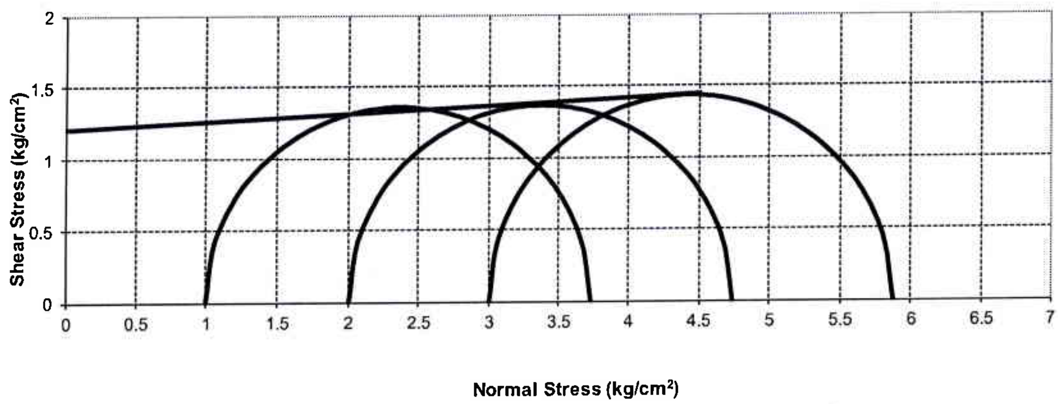
## GRAPHICAL REPRESENTATION OF TRIAXIAL TEST RESULTS

TEST TYPE : UNCONSOLIDATED UNDRAINED

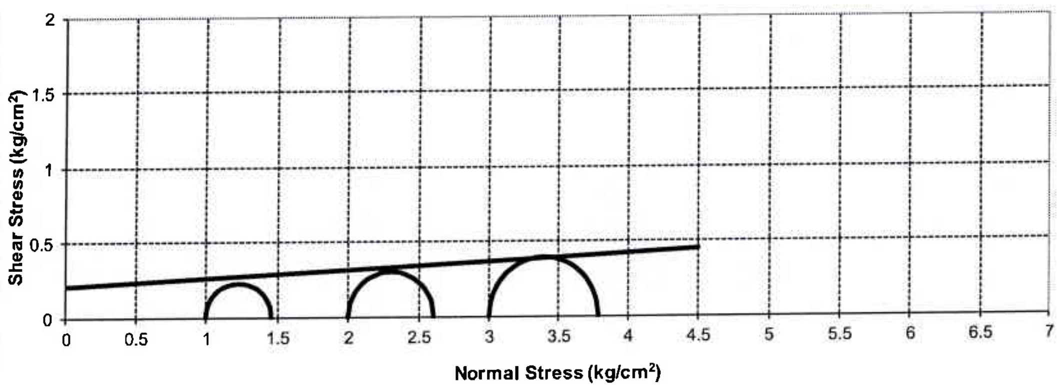
| Bore Hole P165 | Depth | 28.00 m | C = | 0.98 kg/cm2 | Ø = | 5 | degree |
|---|---|---|---|---|---|---|---|




| Bore Hole P165 | Depth | 31.00 m | C = | 1.21 kg/cm2 | Ø = | 3 | degree |
|---|---|---|---|---|---|---|---|




| Bore Hole P166 | Depth | 4.00 m | C = | 0.21 kg/cm2 | Ø = | 3 | degree |
|---|---|---|---|---|---|---|---|



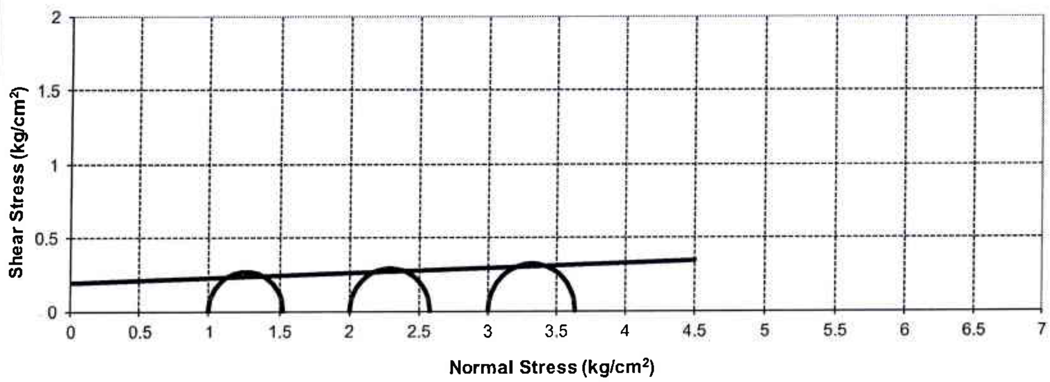
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

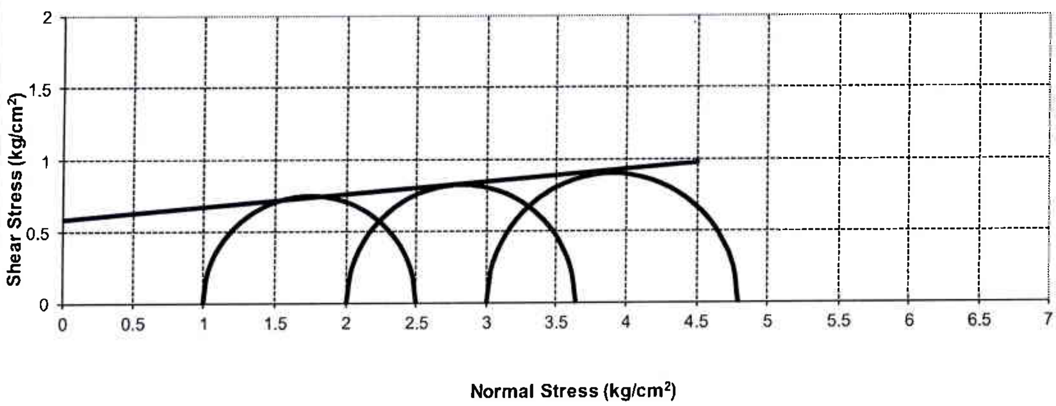
## GRAPHICAL REPRESENTATION OF TRIAXIAL TEST RESULTS

**TEST TYPE : UNCONSOLIDATED UNDRAINED**

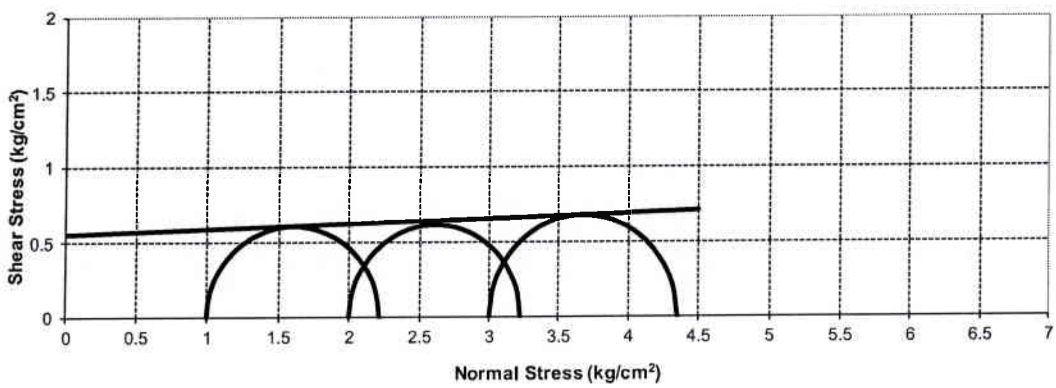
| Bore Hole P166 | Depth | 7.00 m | C = | 0.19 kg/cm2 | ø = | 2 | degree |
|---|---|---|---|---|---|---|---|




| Bore Hole P166 | Depth | 10.50 m | C = | 0.59 kg/cm2 | ø = | 5 | degree |
|---|---|---|---|---|---|---|---|




| Bore Hole P166 | Depth | 13.00 m | C = | 0.55 kg/cm2 | ø = | 2 | degree |
|---|---|---|---|---|---|---|---|



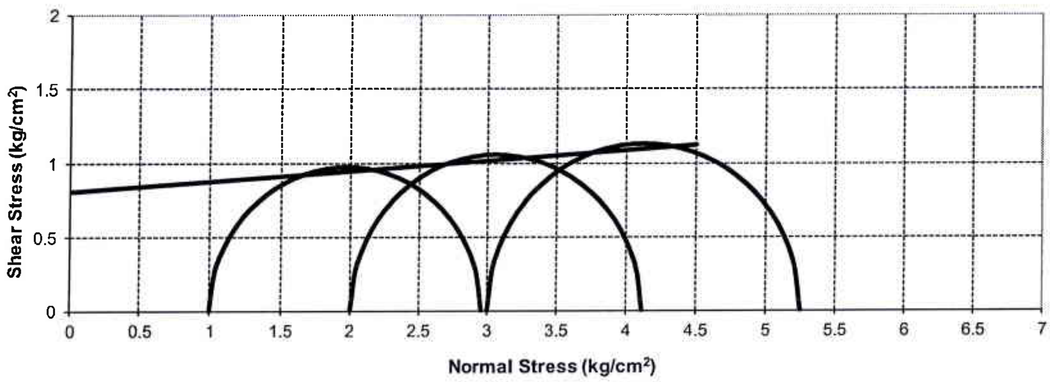
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

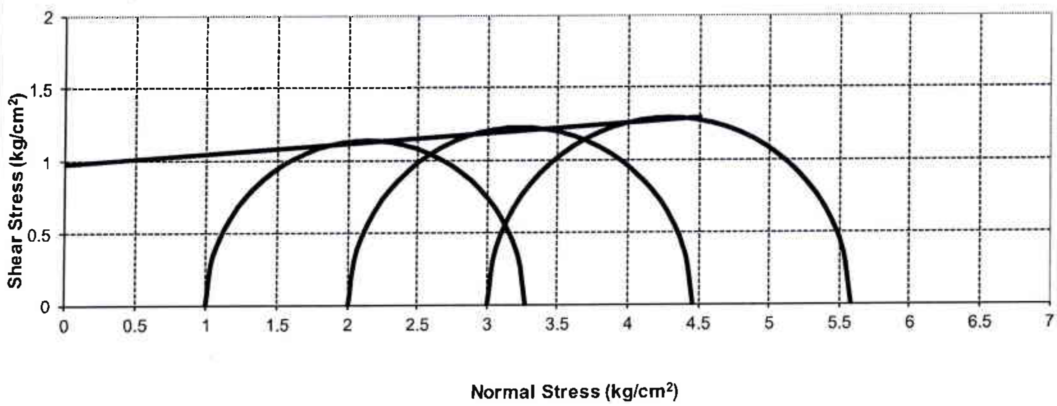
## GRAPHICAL REPRESENTATION OF TRIAXIAL TEST RESULTS

TEST TYPE : UNCONSOLIDATED UNDRAINED

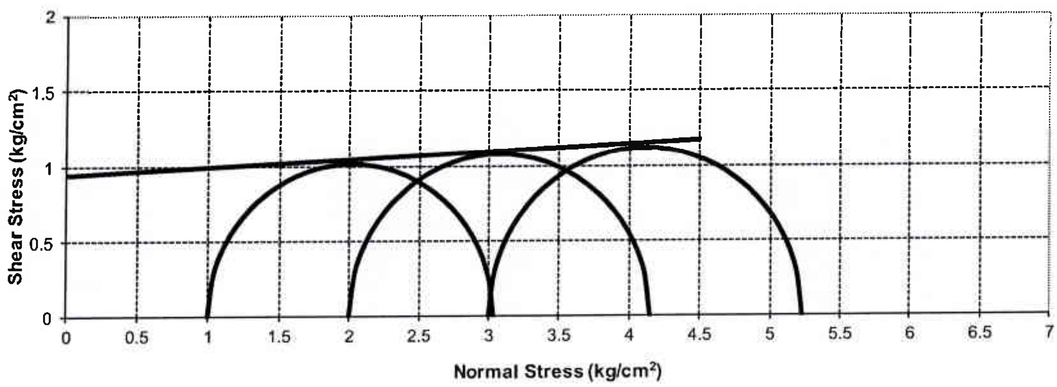
**Bore Hole P166 Depth 16.00 m C = 0.81 kg/cm2 ∅ = 4 degree**




**Bore Hole P166 Depth 19.00 m C = 0.98 kg/cm2 ∅ = 4 degree**




**Bore Hole P166 Depth 22.00 m C = 0.94 kg/cm2 ∅ = 3 degree**



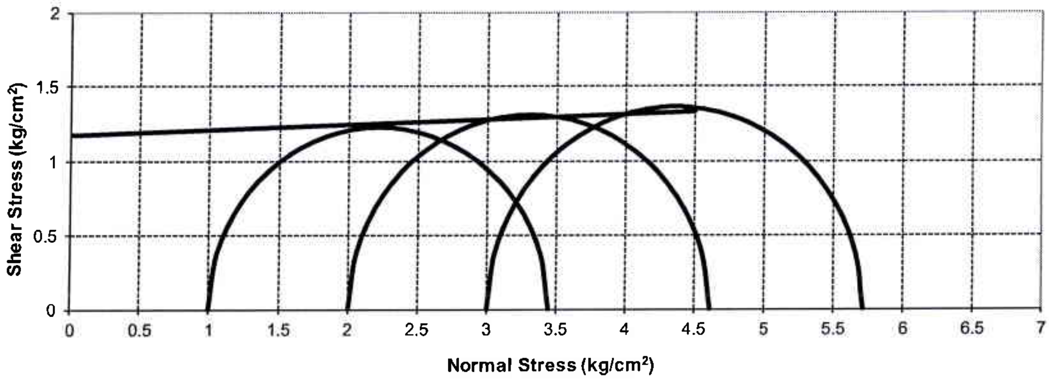
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

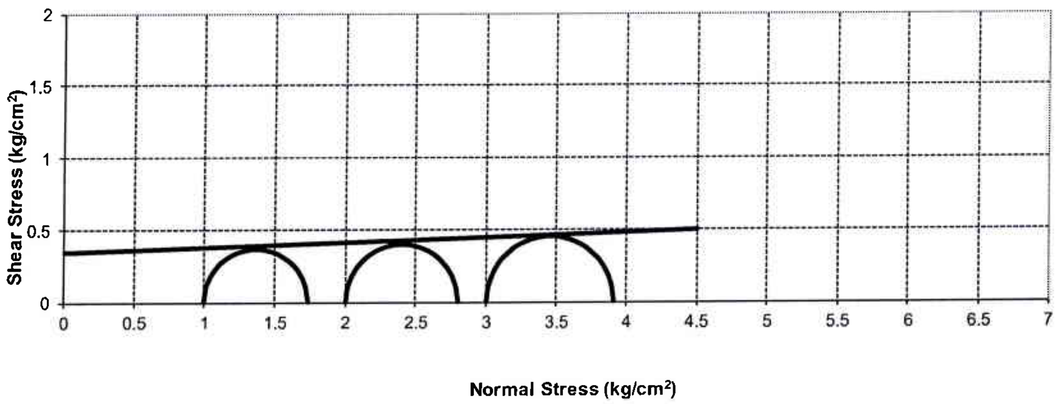
## GRAPHICAL REPRESENTATION OF TRIAXIAL TEST RESULTS

**TEST TYPE : UNCONSOLIDATED UNDRAINED**

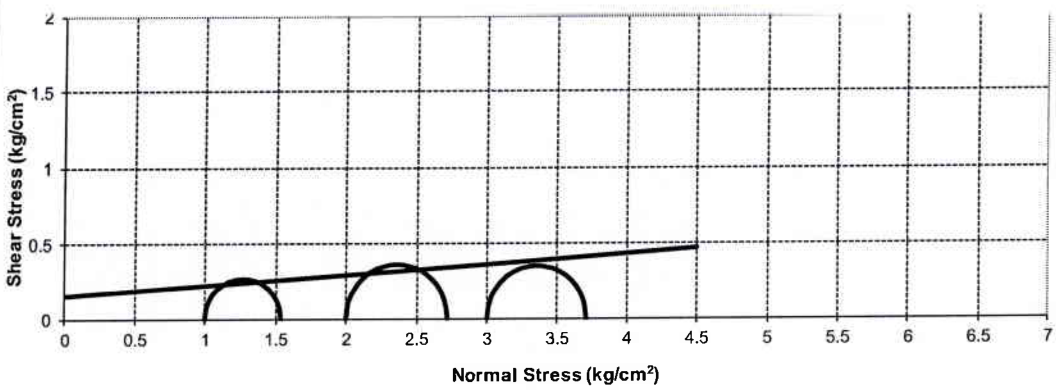
| Bore Hole P166 | Depth | 25.00 m | C = | 1.17 kg/cm2 | Ø = | 2 | degree |
|---|---|---|---|---|---|---|---|




| Bore Hole P167 | Depth | 4.00 m | C = | 0.34 kg/cm2 | Ø = | 2 | degree |
|---|---|---|---|---|---|---|---|



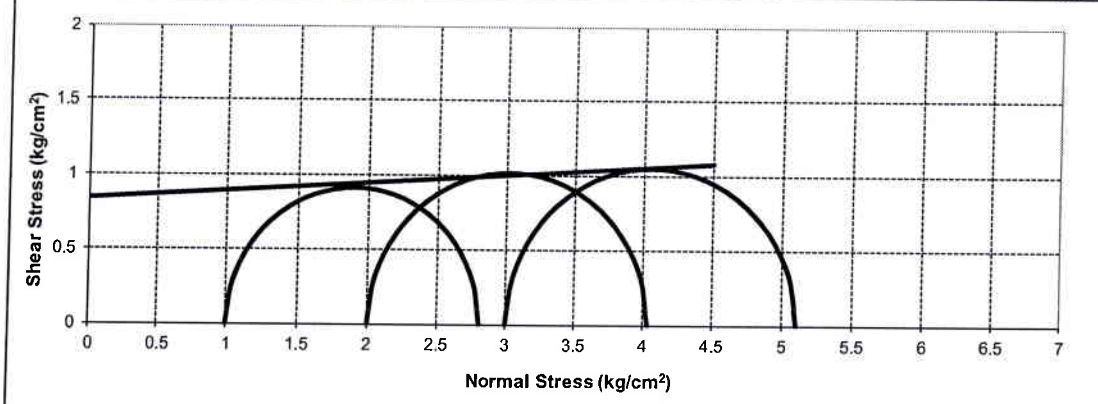

| Bore Hole P167 | Depth | 7.00 m | C = | 0.15 kg/cm2 | Ø = | 4 | degree |
|---|---|---|---|---|---|---|---|



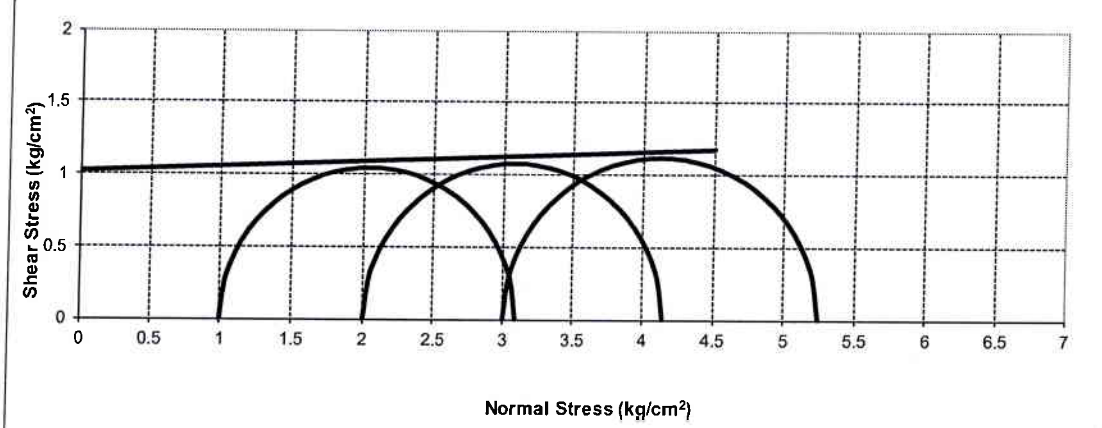
## GRAPHICAL REPRESENTATION OF TRIAXIAL TEST RESULTS

**TEST TYPE : UNCONSOLIDATED UNDRAINED**

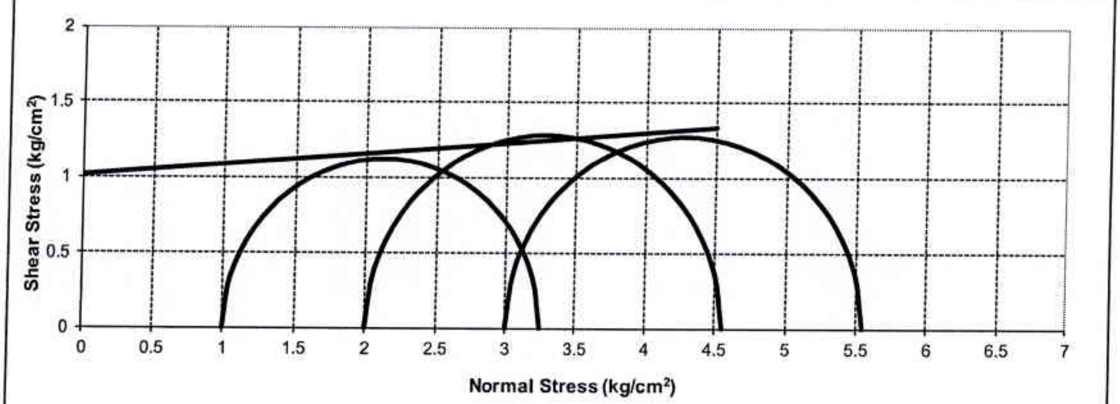
**Bore Hole P167 Depth 13.00 m C = 0.84 kg/cm2 Ø = 3 degree**




**Bore Hole P167 Depth 16.00 m C = 1.02 kg/cm2 Ø = 2 degree**



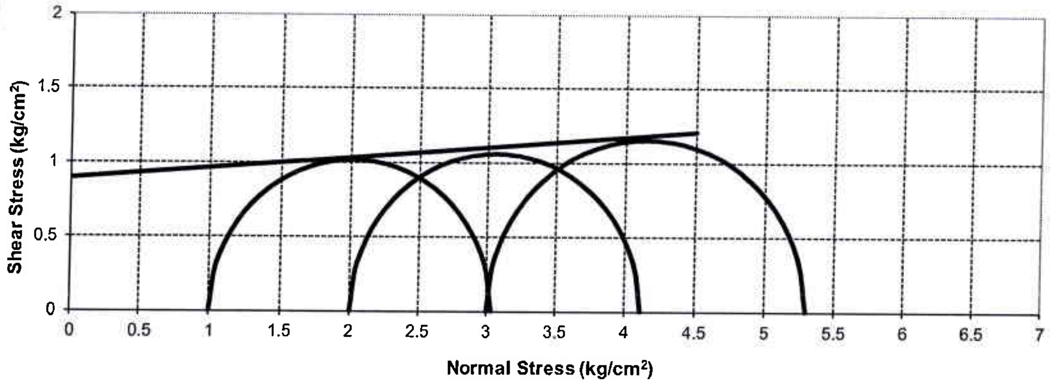

**Bore Hole P167 Depth 19.00 m C = 1.02 kg/cm2 Ø = 4 degree**



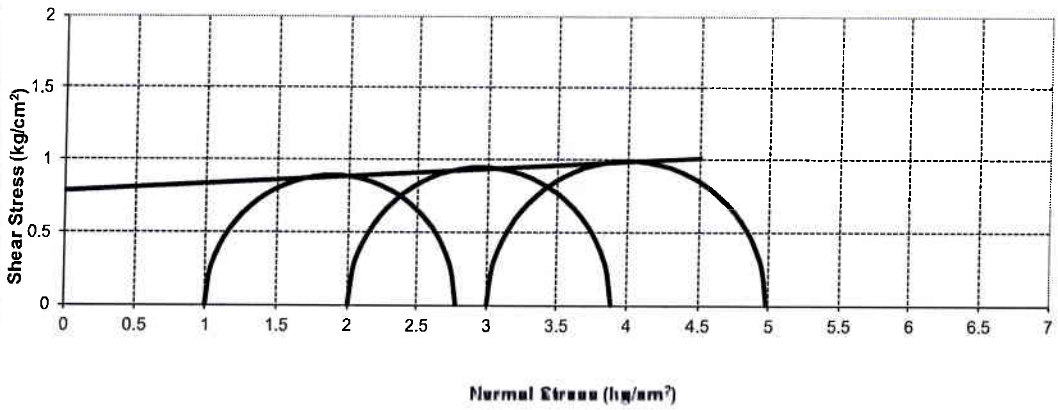
## GRAPHICAL REPRESENTATION OF TRIAXIAL TEST RESULTS

**TEST TYPE : UNCONSOLIDATED UNDRAINED**

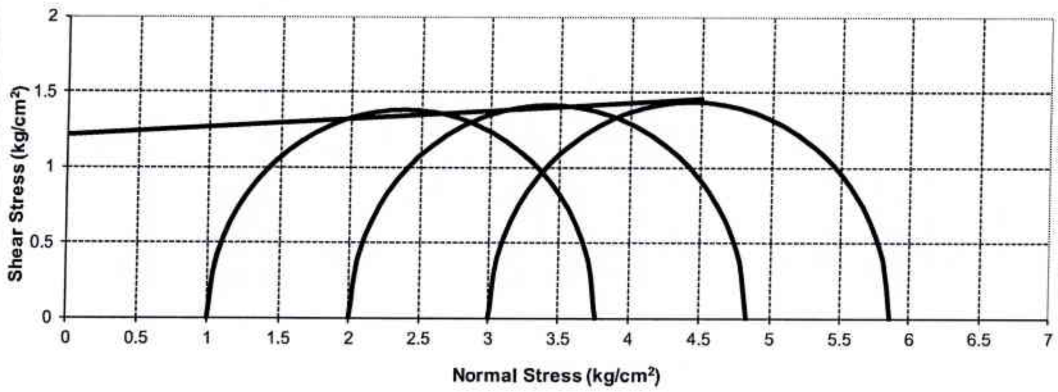
| Bore Hole P167 | Depth | 22.00 m | C = | 0.89 kg/cm2 | ∅ = | 4 | degree |
|---|---|---|---|---|---|---|---|




| Bore Hole P167 | Depth | 25.00 m | C = | 0.78 kg/cm2 | ∅ = | 3 | degree |
|---|---|---|---|---|---|---|---|




| Bore Hole P167 | Depth | 28.00 m | C = | 1.22 kg/cm2 | ∅ = | 3 | degree |
|---|---|---|---|---|---|---|---|



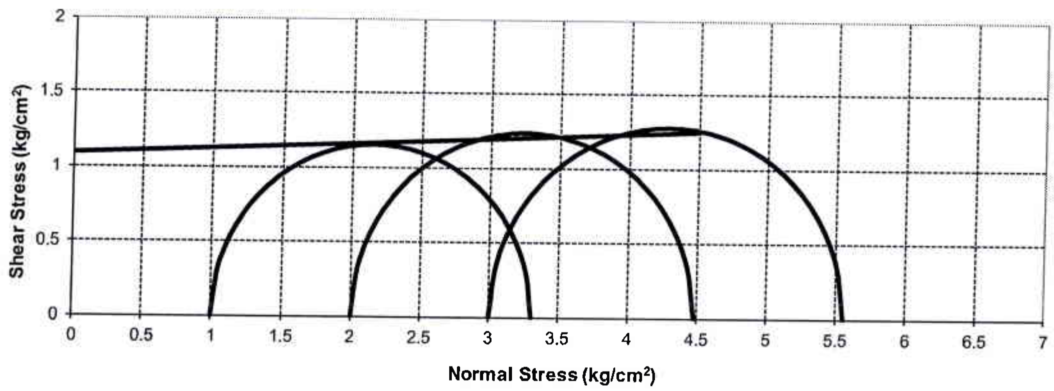
M/s Anand Raj Infratech Pvt. Ltd.

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

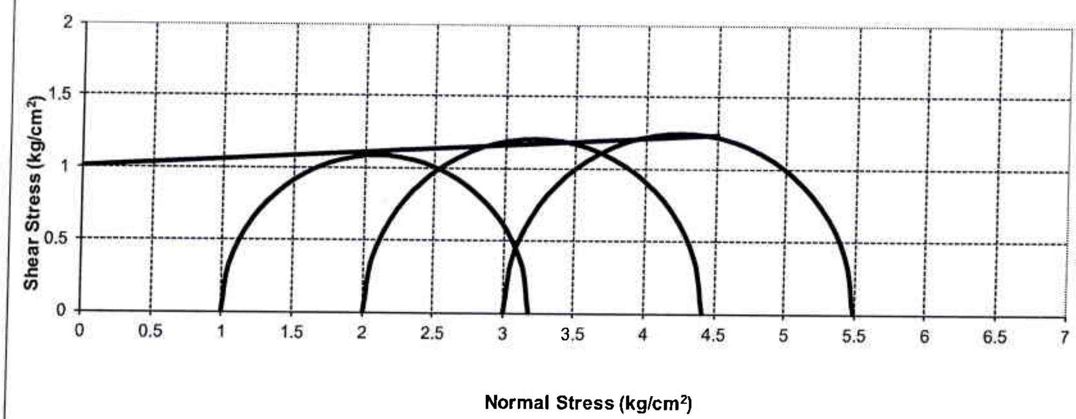
## GRAPHICAL REPRESENTATION OF TRIAXIAL TEST RESULTS

TEST TYPE : UNCONSOLIDATED UNDRAINED

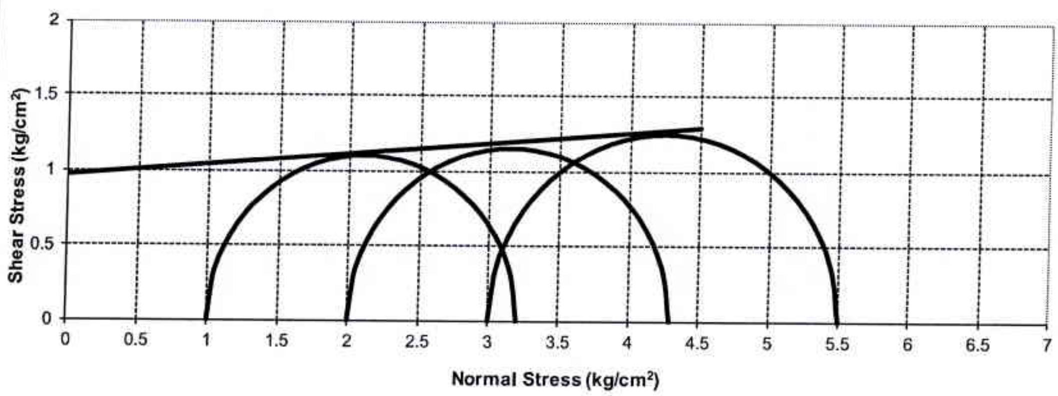
Bore Hole P168 Depth 16.00 m C = 1.09 kg/cm2 ∅ = 2 degree




Bore Hole P168 Depth 19.00 m C = 1.01 kg/cm2 ∅ = 3 degree



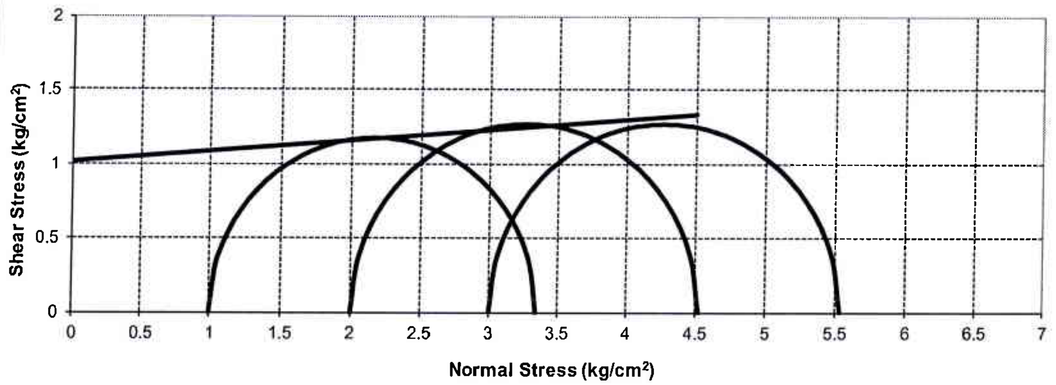

Bore Hole P168 Depth 22.00 m C = 0.97 kg/cm2 ∅ = 4 degree



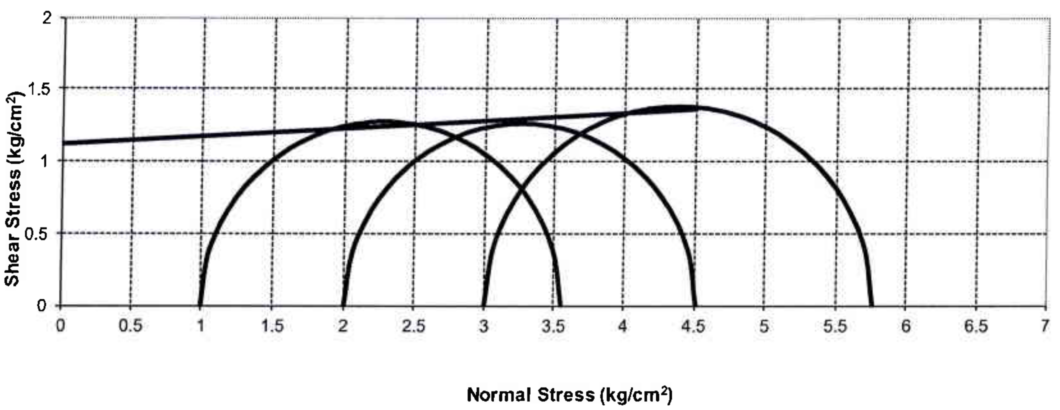
## GRAPHICAL REPRESENTATION OF TRIAXIAL TEST RESULTS

**TEST TYPE : UNCONSOLIDATED UNDRAINED**

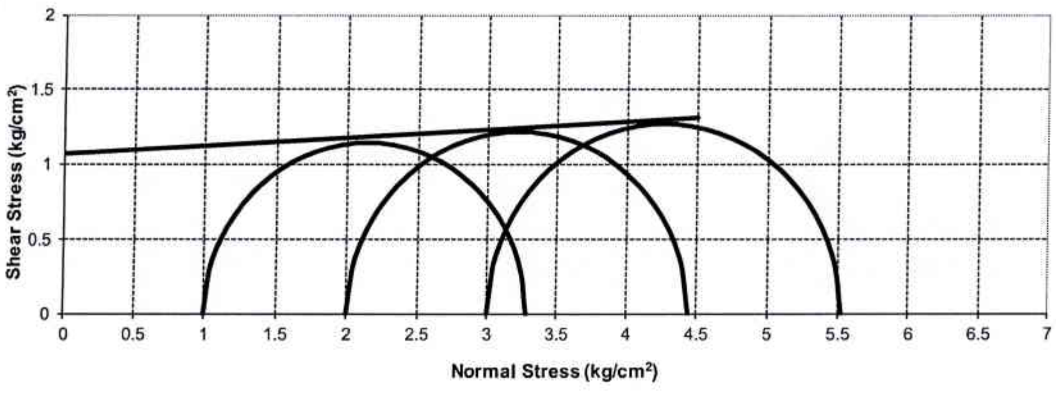
| Bore Hole P168 | Depth | 25.00 m | C = | 1.02 kg/cm2 | Ø = | 4 | degree |
|---|---|---|---|---|---|---|---|




| Bore Hole P168 | Depth | 28.00 m | C = | 1.12 kg/cm2 | Ø = | 3 | degree |
|---|---|---|---|---|---|---|---|




| Bore Hole P168 | Depth | 31.00 m | C = | 1.07 kg/cm2 | Ø = | 3 | degree |
|---|---|---|---|---|---|---|---|



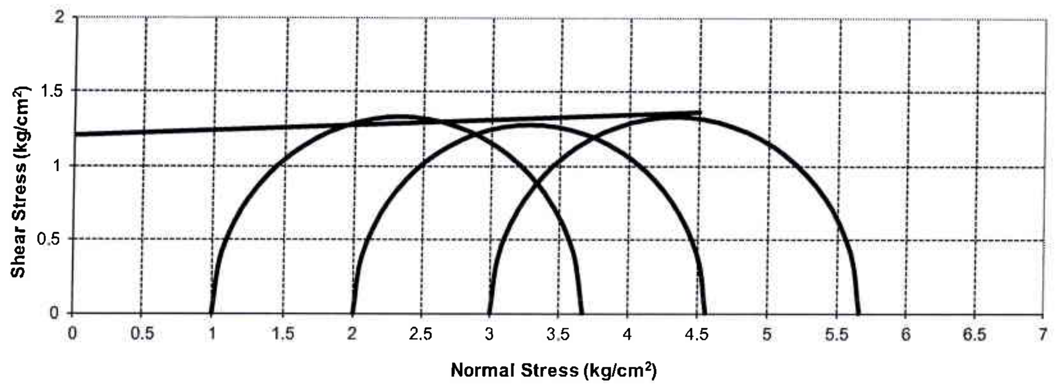
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

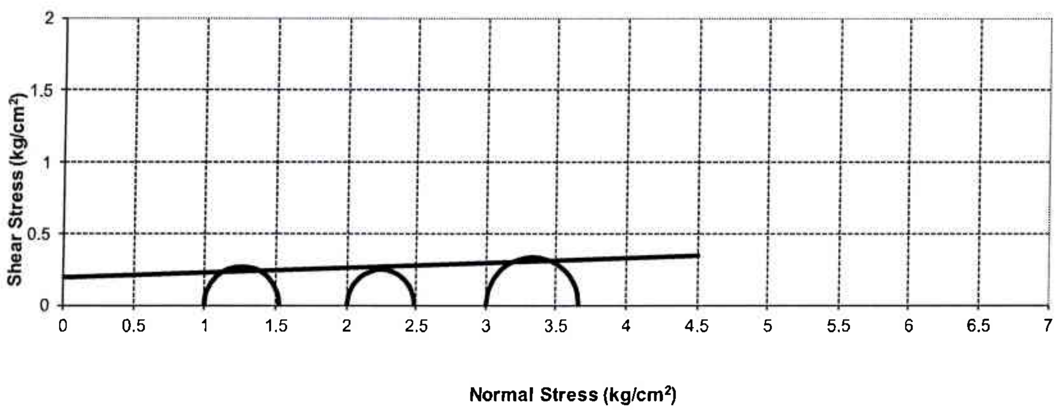
## GRAPHICAL REPRESENTATION OF TRIAXIAL TEST RESULTS

TEST TYPE : UNCONSOLIDATED UNDRAINED

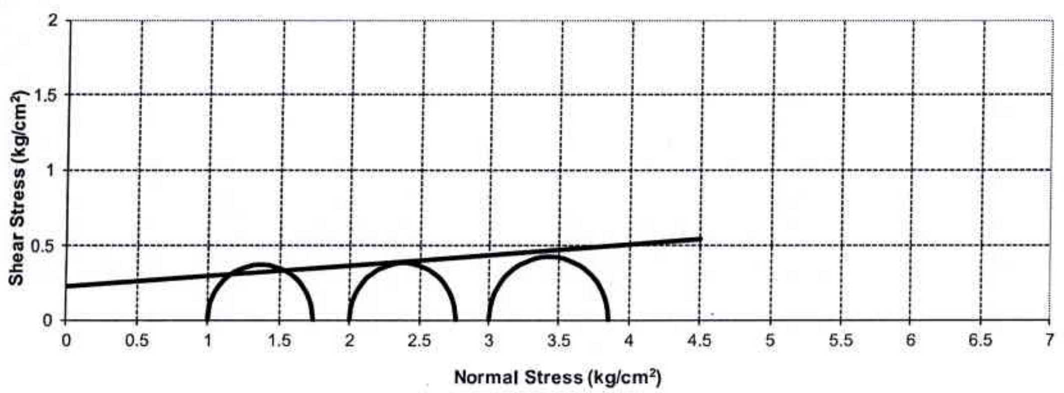
| Bore Hole P168 | Depth | 37.00 m | C = | 1.21 kg/cm2 | ø = | 2 | degree |
|---|---|---|---|---|---|---|---|




| Bore Hole P169 | Depth | 4.00 m | C = | 0.19 kg/cm2 | ø = | 2 | degree |
|---|---|---|---|---|---|---|---|




| Bore Hole P169 | Depth | 7.00 m | C = | 0.23 kg/cm2 | ø = | 4 | degree |
|---|---|---|---|---|---|---|---|



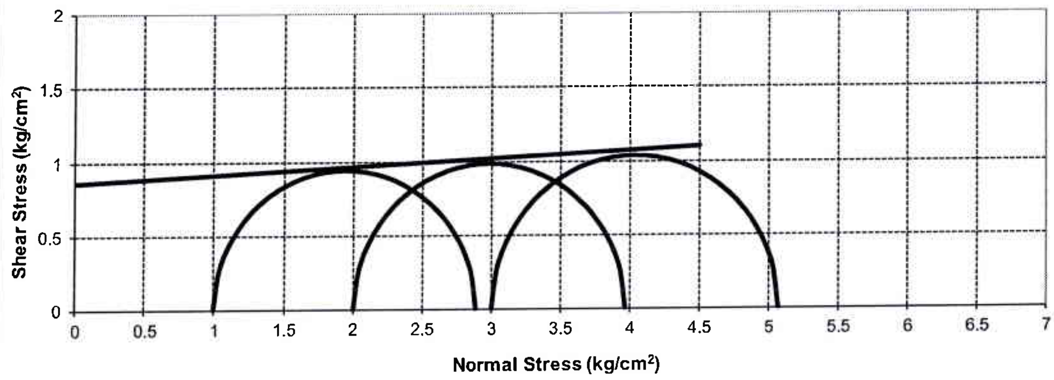
**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

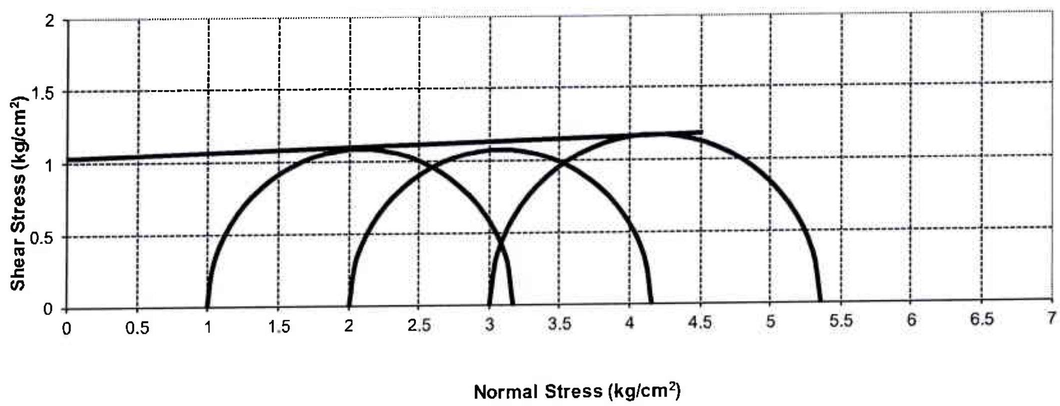
## GRAPHICAL REPRESENTATION OF TRIAXIAL TEST RESULTS

**TEST TYPE : UNCONSOLIDATED UNDRAINED**

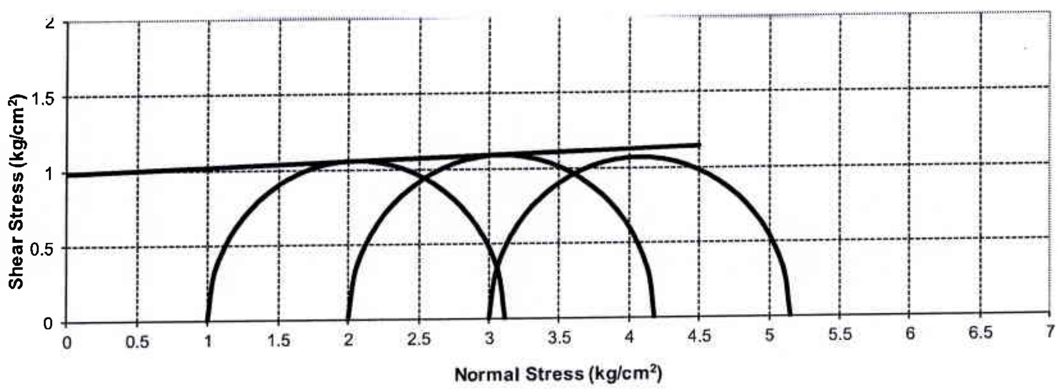
| Bore Hole P169 | Depth | 16.00 m | C = | 0.86 kg/cm2 | Ø = | 3 | degree |
|---|---|---|---|---|---|---|---|




| Bore Hole P169 | Depth | 19.00 m | C = | 1.03 kg/cm2 | Ø = | 2 | degree |
|---|---|---|---|---|---|---|---|




| Bore Hole P169 | Depth | 22.00 m | C = | 0.98 kg/cm2 | Ø = | 2 | degree |
|---|---|---|---|---|---|---|---|



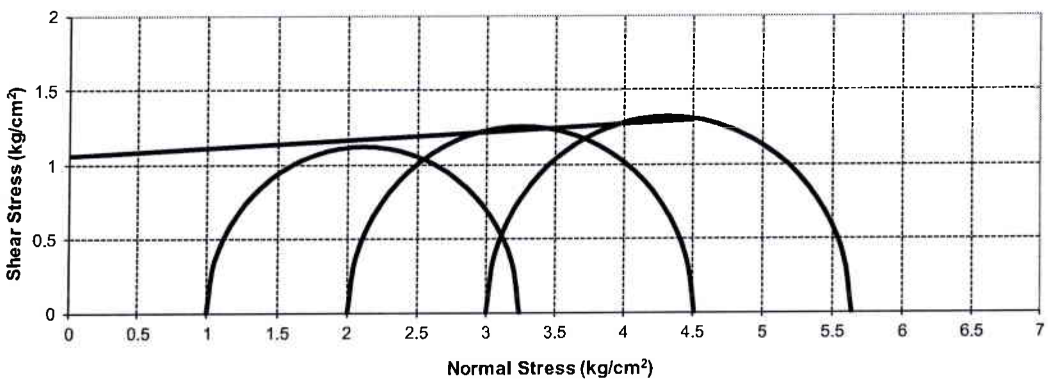

M/s Anand Raj Infratech Pvt. Ltd.

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

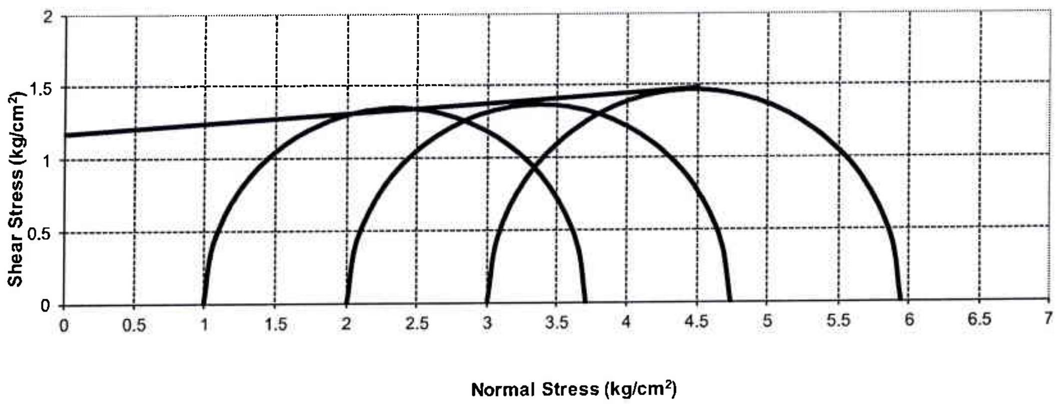
## GRAPHICAL REPRESENTATION OF TRIAXIAL TEST RESULTS

TEST TYPE : UNCONSOLIDATED UNDRAINED

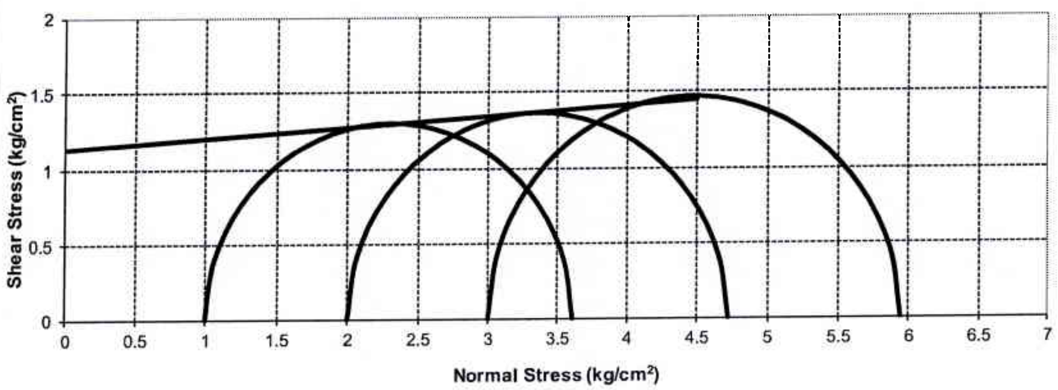
Bore Hole P169 Depth 25.00 m C = 1.06 kg/cm2 ∅ = 3 degree




Bore Hole P169 Depth 28.00 m C = 1.17 kg/cm2 ∅ = 4 degree



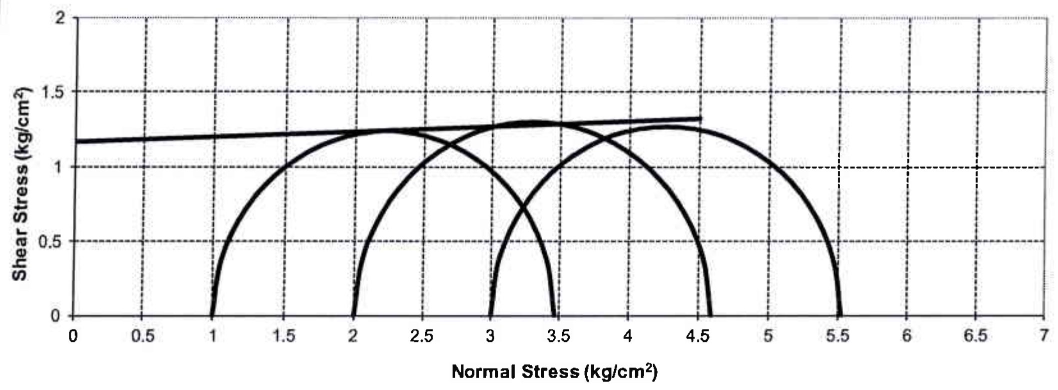

Bore Hole P169 Depth 31.00 m C = 1.13 kg/cm2 ∅ = 4 degree



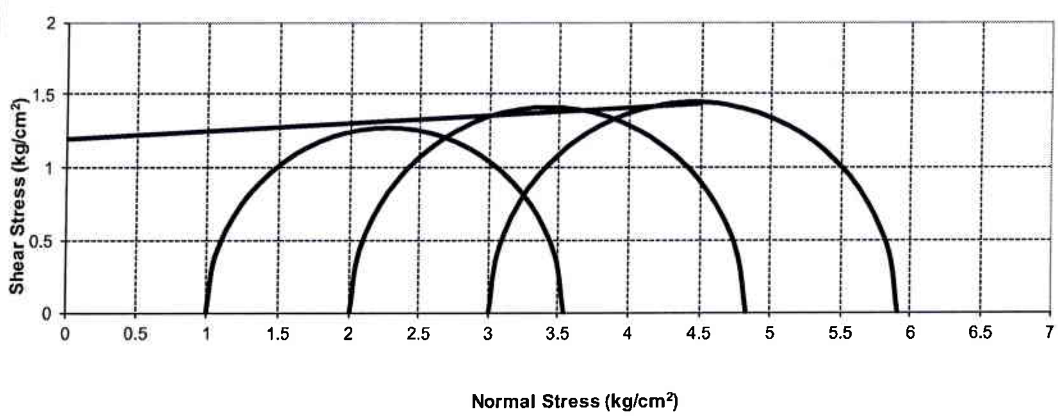
## GRAPHICAL REPRESENTATION OF TRIAXIAL TEST RESULTS

**TEST TYPE : UNCONSOLIDATED UNDRAINED**

| Bore Hole P169 | Depth | 37.00 m | C = | 1.16 kg/cm2 | ø = | 2 | degree |
|---|---|---|---|---|---|---|---|




| Bore Hole P169 | Depth | 40.00 m | C = | 1.20 kg/cm2 | ø = | 3 | degree |
|---|---|---|---|---|---|---|---|

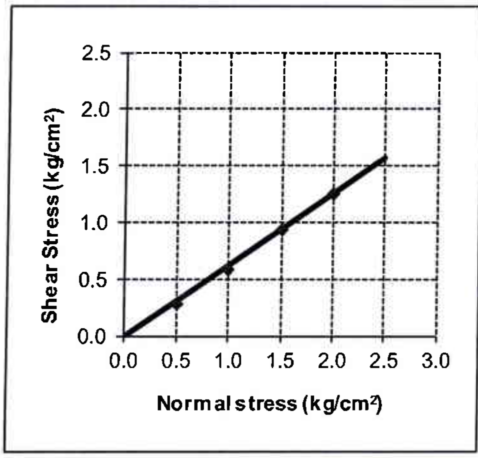


**M/s Anand Raj Infratech Pvt. Ltd.**

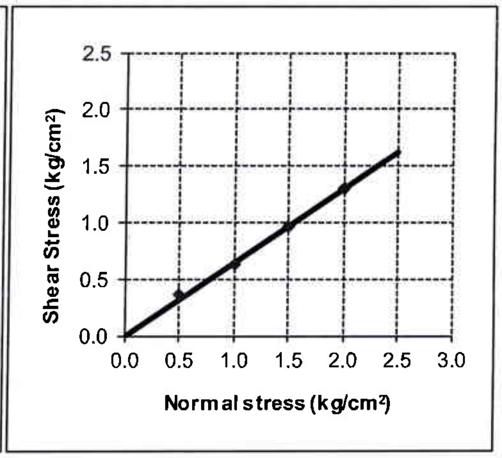
*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## GRAPHICAL REPRESENTATION OF DIRECT SHEAR TEST RESULTS

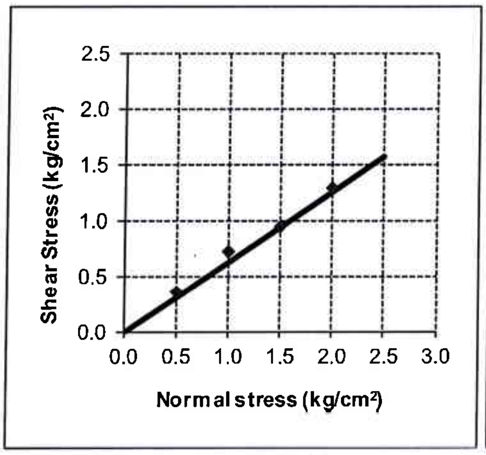
BH No. P164 Depth 10.00 m
C = 0 kg/cm$^2$
ø = 32 degree



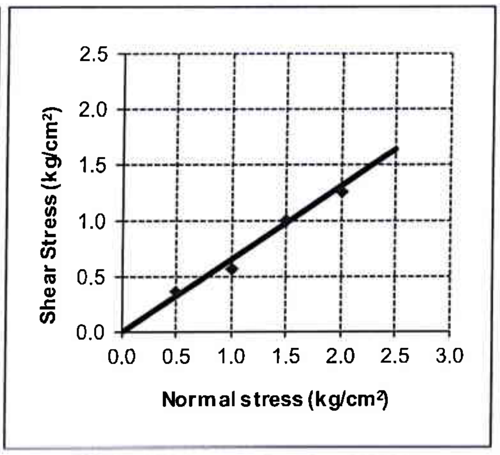

BH No. P164 Depth 28.00 m
C = 0 kg/cm$^2$
ø = 33 degree



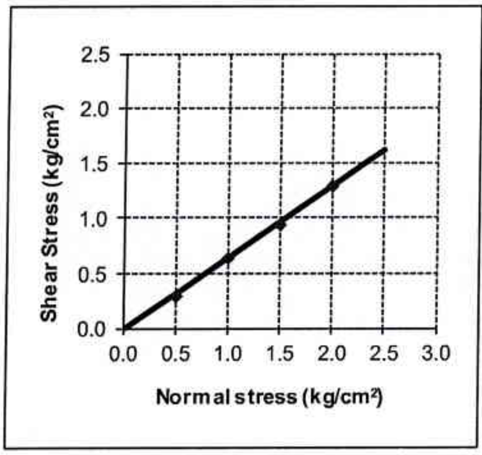

BH No. P164 Depth 40.00 m
C = 0 kg/cm$^2$
ø = 32 degree



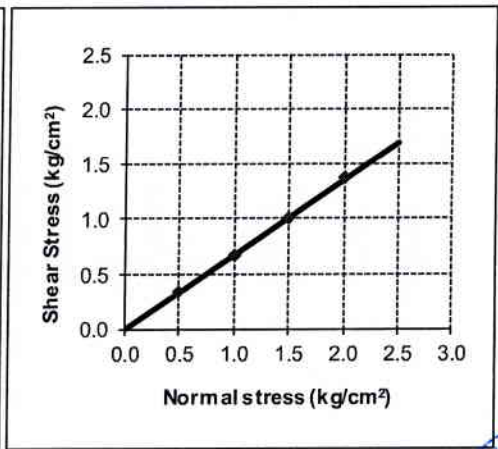

BH No. P164 Depth 51.00 m
C = 0 kg/cm$^2$
ø = 33 degree




BH No. P164 Depth 54.00 m
C = 0 kg/cm$^2$
ø = 33 degree




BH No. P164 Depth 57.00 m
C = 0 kg/cm$^2$
ø = 34 degree

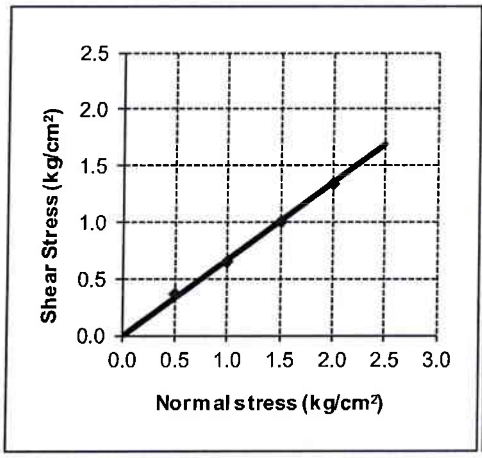


## GRAPHICAL REPRESENTATION OF DIRECT SHEAR TEST RESULTS

BH No. P164 Depth 60.00 m

C = 0 kg/cm$^2$

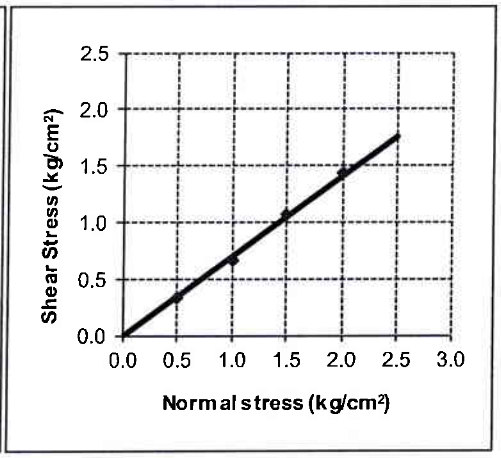
ø = 34 degree




BH No. P164 Depth 63.00 m

C = 0 kg/cm$^2$

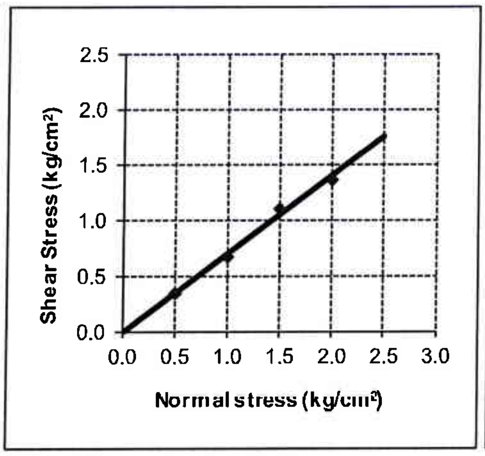
ø = 35 degree




BH No. P164 Depth 66.00 m

C = 0 kg/cm$^2$

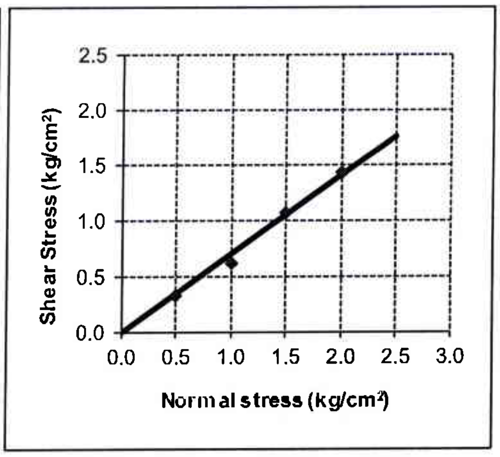
ø = 35 degree




BH No. P164 Depth 70.00 m

C = 0 kg/cm$^2$

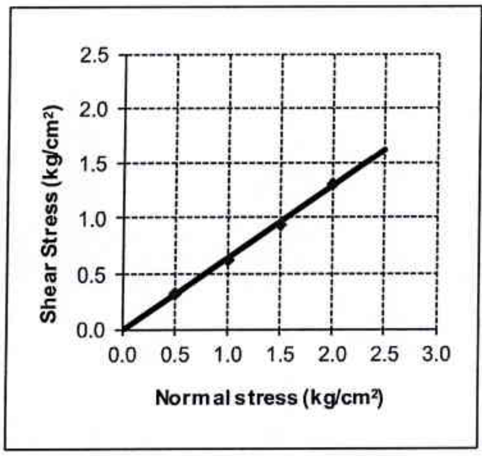
ø = 35 degree




BH No. P165 Depth 51.00 m

C = 0 kg/cm$^2$

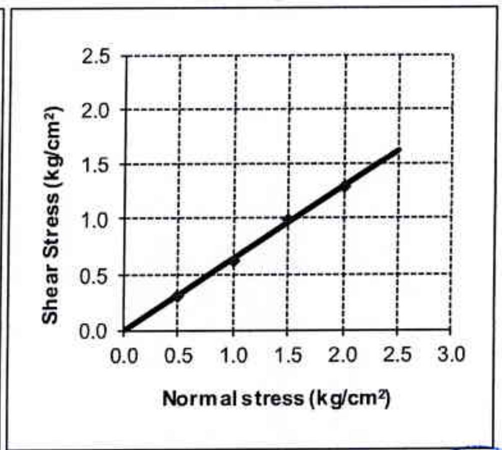
ø = 33 degree




BH No. P165 Depth 54.00 m

C = 0 kg/cm$^2$

ø = 33 degree

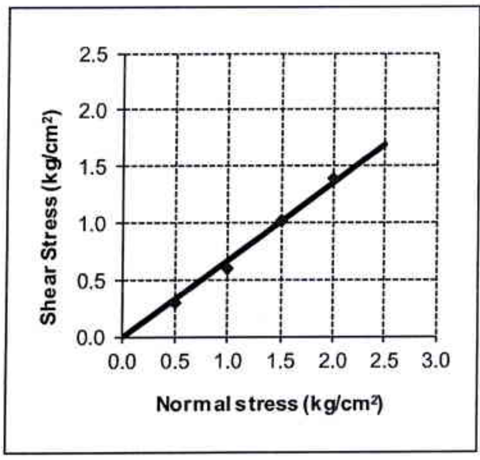


## GRAPHICAL REPRESENTATION OF DIRECT SHEAR TEST RESULTS

**BH No. P165 Depth 57.00 m**

**C = 0 kg/cm$^2$**

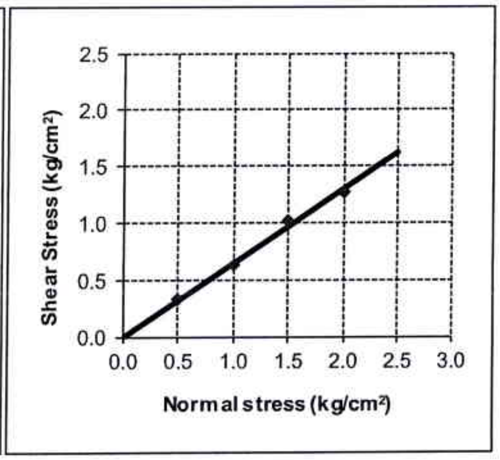
**ø = 34 degree**




**BH No. P165 Depth 60.00 m**

**C = 0 kg/cm$^2$**

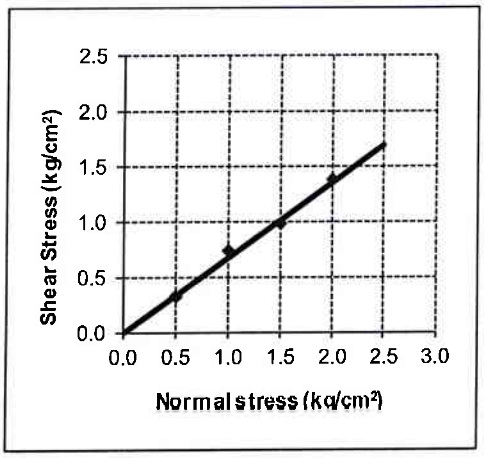
**ø = 33 degree**




**BH No. P165 Depth 63.00 m**

**C = 0 kg/cm$^2$**

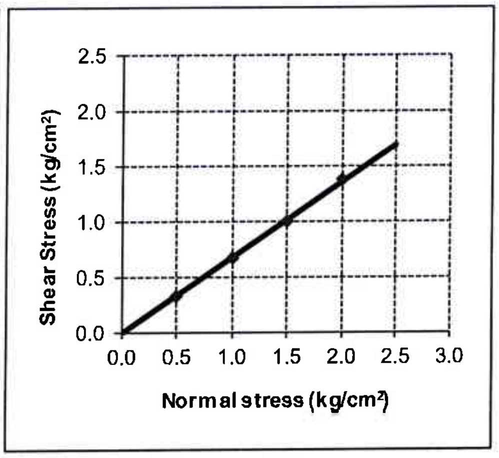
**ø = 34 degree**




**BH No. P165 Depth 66.00 m**

**C = 0 kg/cm$^2$**

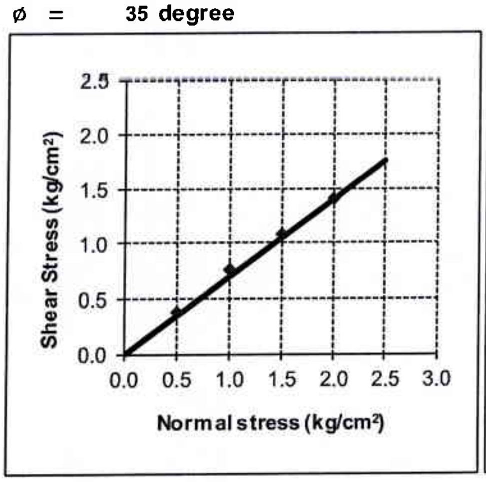
**ø = 34 degree**




**BH No. P165 Depth 70.00 m**

**C = 0 kg/cm$^2$**

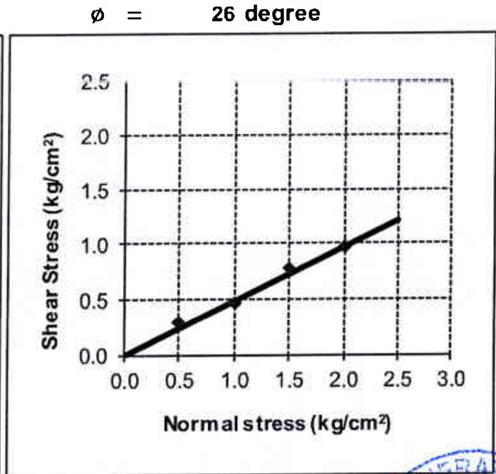
**ø = 35 degree**




**BH No. P166 Depth 1.00 m**

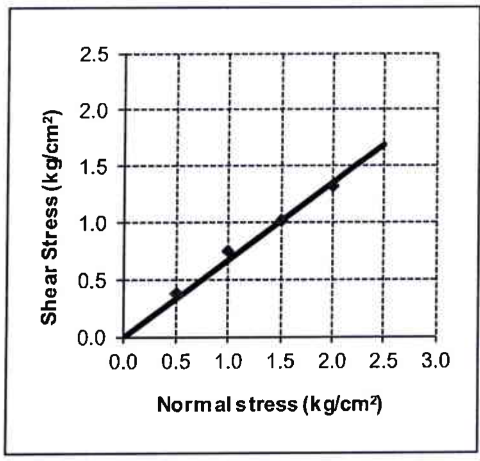
**C = 0 kg/cm$^2$**

**ø = 26 degree**

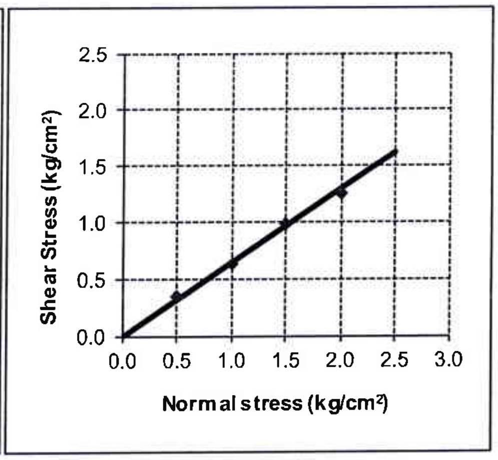


## GRAPHICAL REPRESENTATION OF DIRECT SHEAR TEST RESULTS

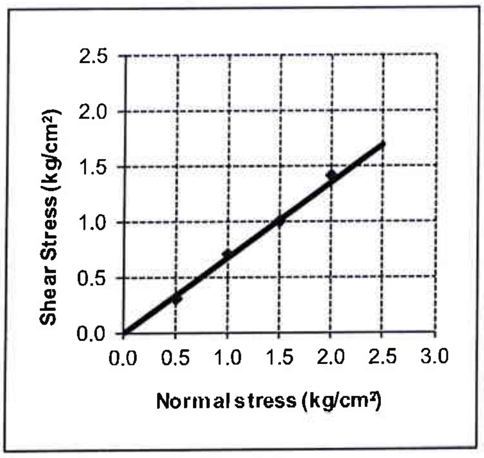
**BH No. P166 Depth 51.00 m**
**C = 0 kg/cm$^2$**
**Ø = 34 degree**



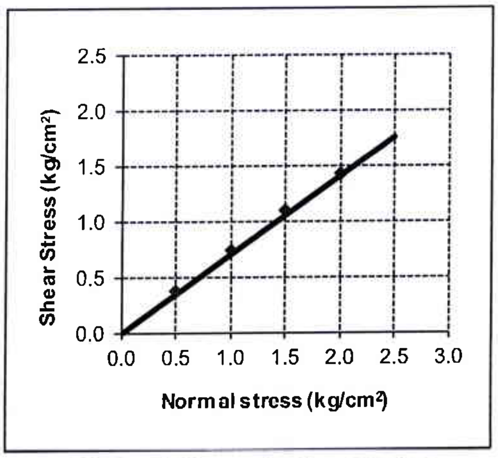

**BH No. P166 Depth 54.00 m**
**C = 0 kg/cm$^2$**
**Ø = 33 degree**



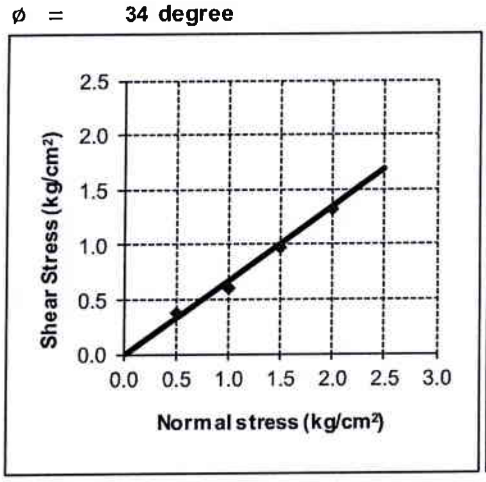

**BH No. P166 Depth 57.00 m**
**C = 0 kg/cm$^2$**
**Ø = 34 degree**



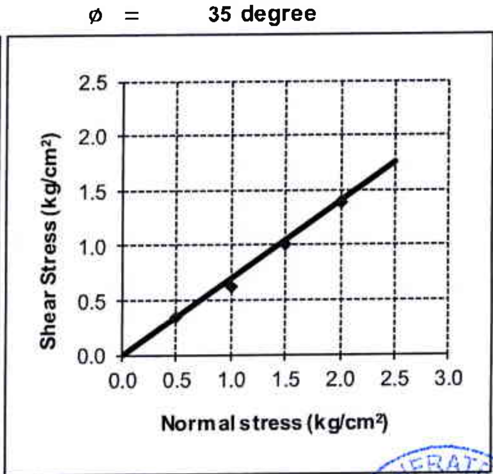

**BH No. P166 Depth 60.00 m**
**C = 0 kg/cm$^2$**
**Ø = 35 degree**




**BH No. P166 Depth 63.00 m**
**C = 0 kg/cm$^2$**
**Ø = 34 degree**




**BH No. P166 Depth 66.00 m**
**C = 0 kg/cm$^2$**
**Ø = 35 degree**



**M/s Anand Raj Infratech Pvt. Ltd.**

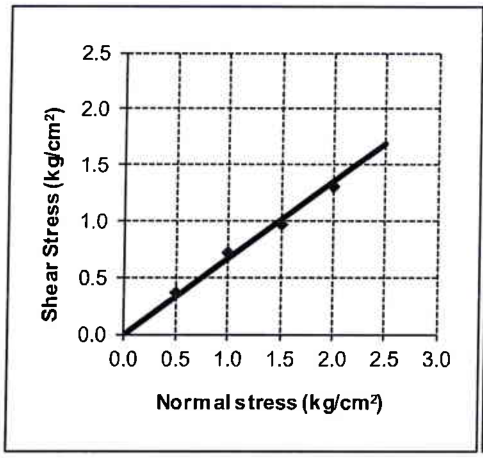
*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## GRAPHICAL REPRESENTATION OF DIRECT SHEAR TEST RESULTS

BH No. P167 Depth 63.00 m

C = 0 kg/cm$^2$

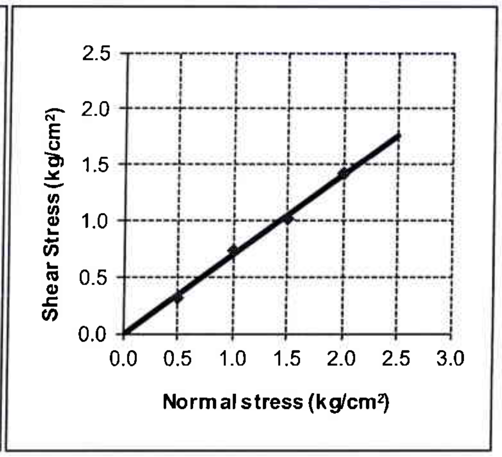
ø = 34 degree




BH No. P167 Depth 66.00 m

C = 0 kg/cm$^2$

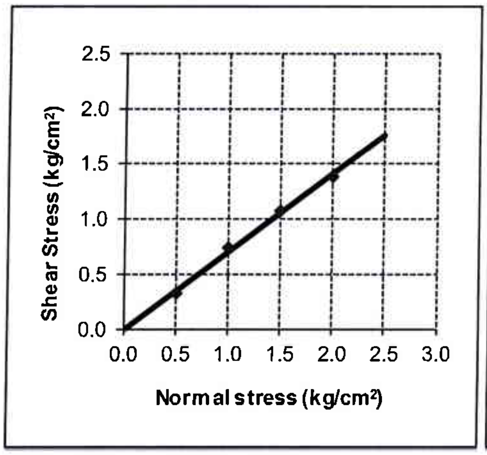
ø = 35 degree




BH No. P167 Depth 70.00 m

C = 0 kg/cm$^2$

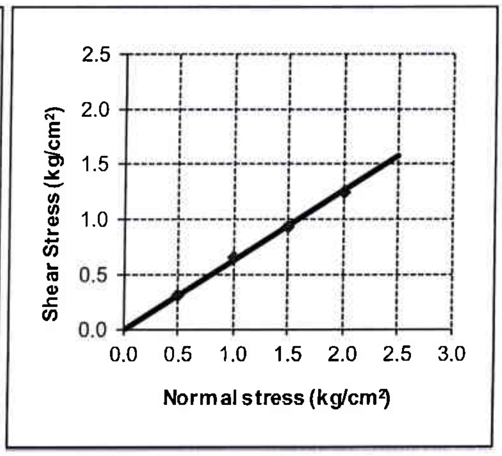
ø = 35 degree




BH No. P168 Depth 10.50 m

C = 0 kg/cm$^2$

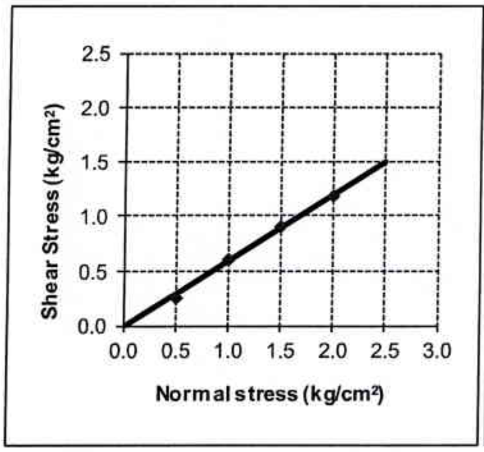
ø = 32 degree




BH No. P168 Depth 13.50 m

C = 0 kg/cm$^2$

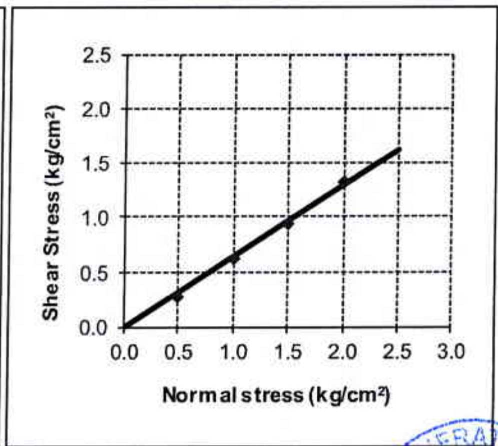
ø = 31 degree




BH No. P168 Depth 51.00 m

C = 0 kg/cm$^2$

ø = 33 degree

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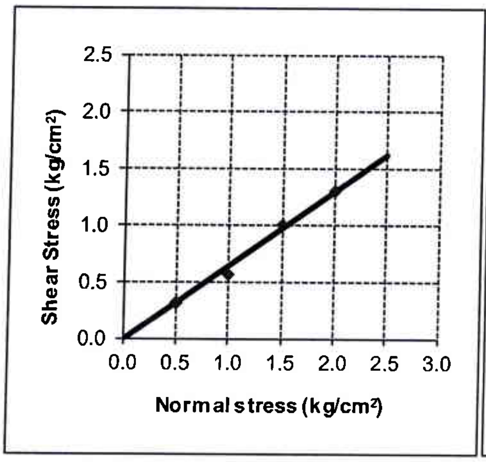
**M/s Anand Raj Infratech Pvt. Ltd.**

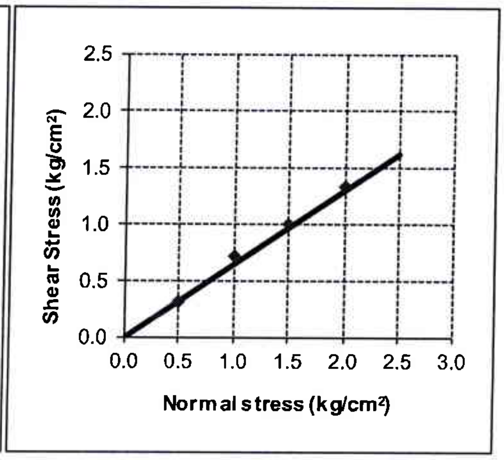
*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## GRAPHICAL REPRESENTATION OF DIRECT SHEAR TEST RESULTS

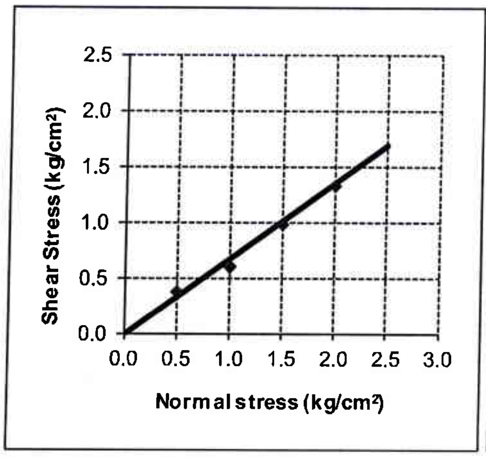
**BH No. P168 Depth 54.00 m**
**C = 0 kg/cm$^2$**
**Ø = 33 degree**



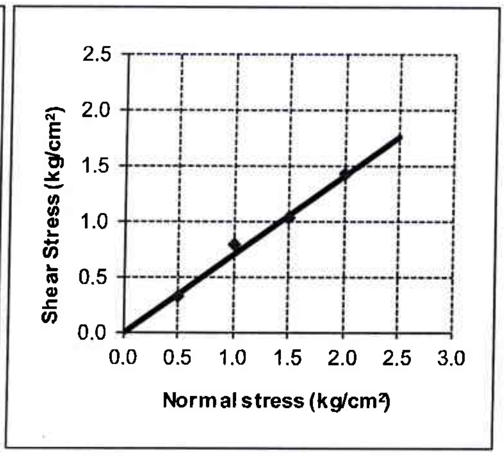

**BH No. P168 Depth 57.00 m**
**C = 0 kg/cm$^2$**
**Ø = 33 degree**



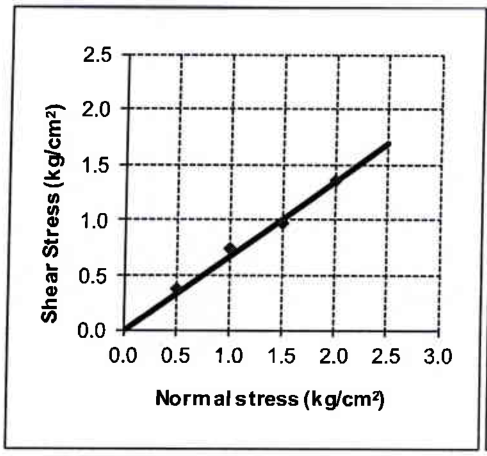

**BH No. P168 Depth 60.00 m**
**C = 0 kg/cm$^2$**
**Ø = 34 degree**



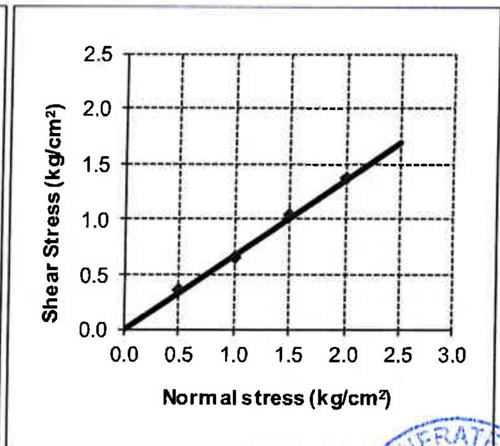

**BH No. P168 Depth 63.00 m**
**C = 0 kg/cm$^2$**
**Ø = 35 degree**




**BH No. P168 Depth 66.00 m**
**C = 0 kg/cm$^2$**
**Ø = 34 degree**




**BH No. P168 Depth 70.00 m**
**C = 0 kg/cm$^2$**
**Ø = 34 degree**



**M/s Anand Raj Infratech Pvt. Ltd.**

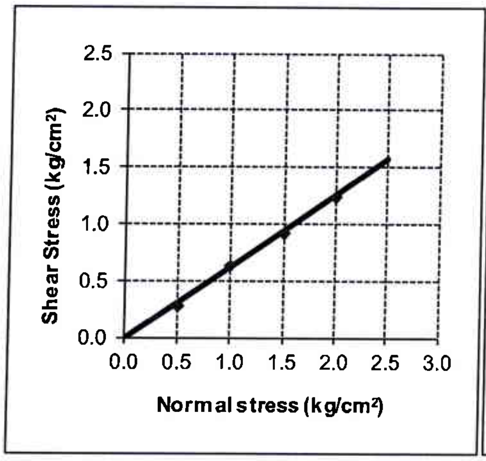
*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## GRAPHICAL REPRESENTATION OF DIRECT SHEAR TEST RESULTS

BH No. P169 Depth 10.50 m

C = 0 kg/cm$^2$

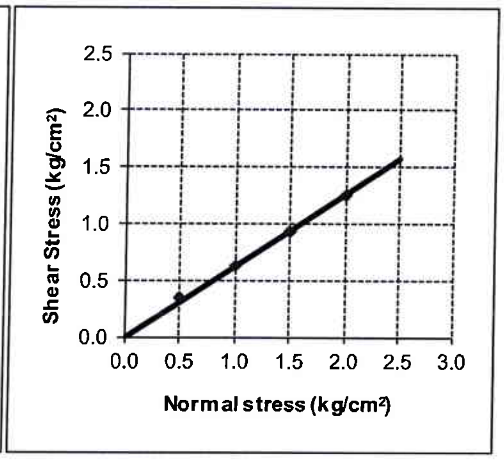
ø = 32 degree




BH No. P169 Depth 13.50 m

C = 0 kg/cm$^2$

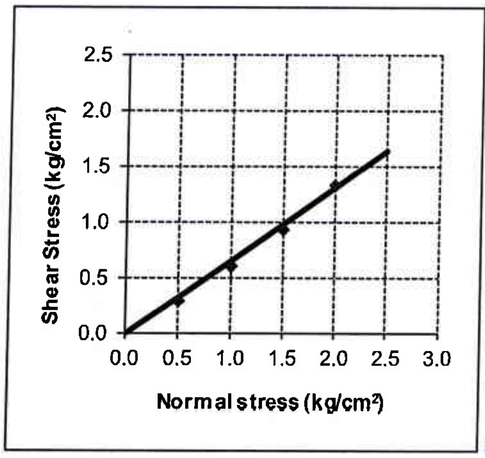
ø = 32 degree




BH No. P169 Depth 51.00 m

C = 0 kg/cm$^2$

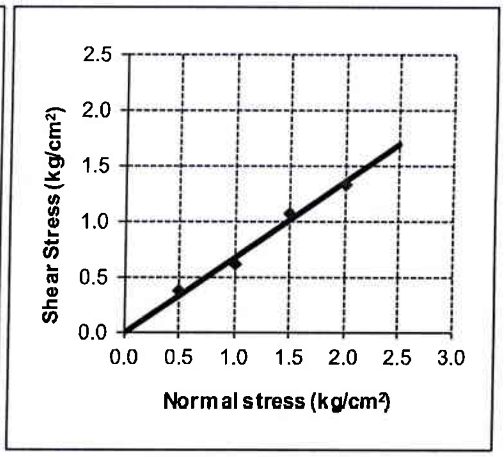
ø = 33 degree




BH No. P169 Depth 54.00 m

C = 0 kg/cm$^2$

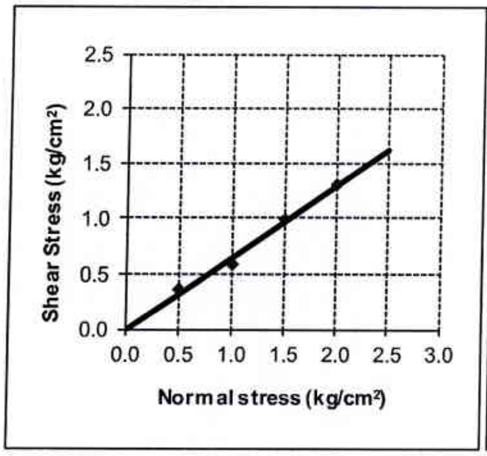
ø = 34 degree




BH No. P169 Depth 57.00 m

C = 0 kg/cm$^2$

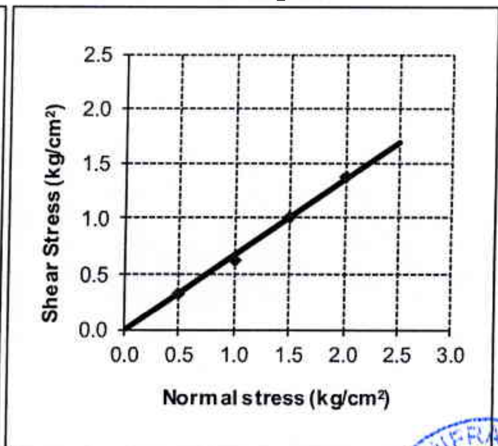
ø = 33 degree




BH No. P169 Depth 60.00 m

C = 0 kg/cm$^2$

ø = 34 degree

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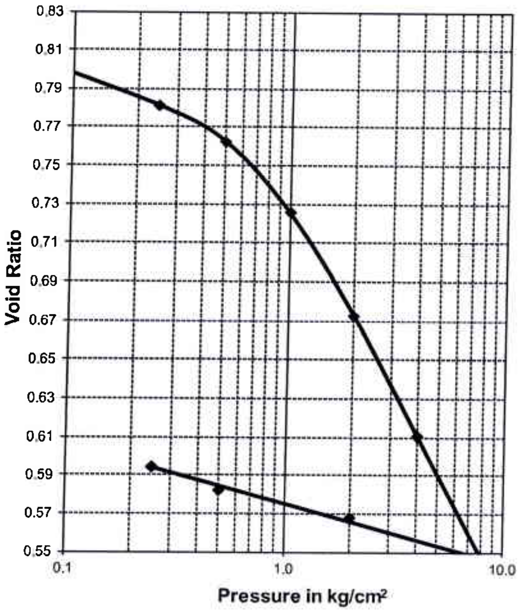
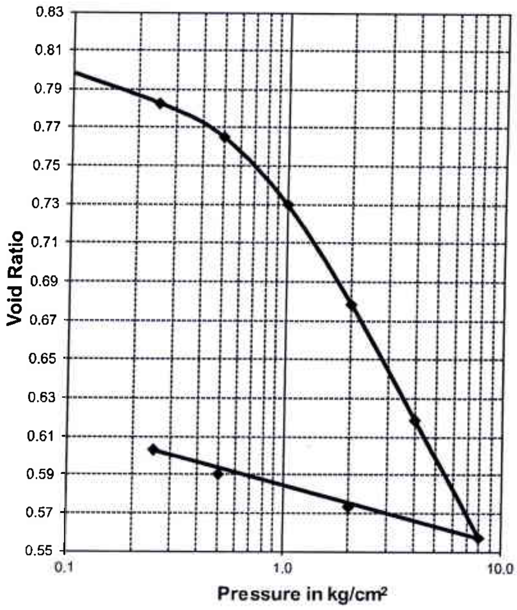
## e - log p curve

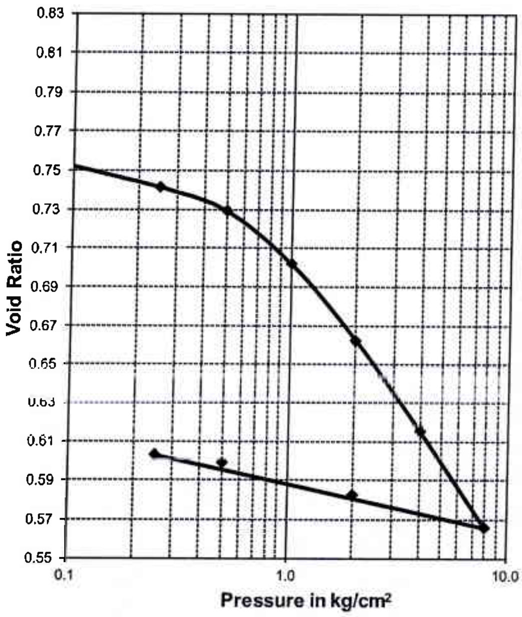
| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P164 | 4.00 | 0.81 | 0.212 |



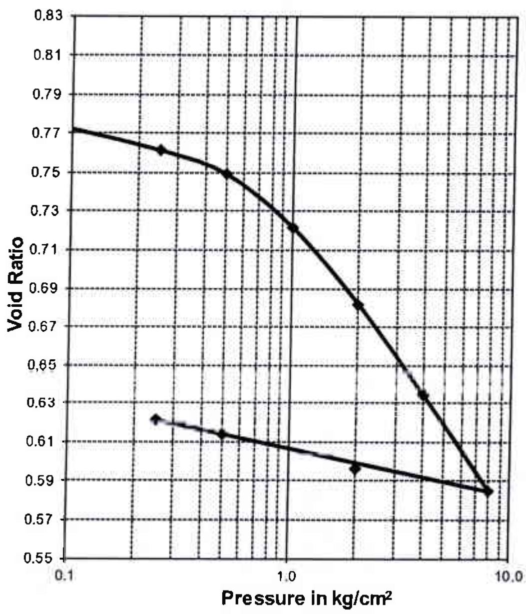

| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P164 | 7.00 | 0.81 | 0.205 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P164 | 13.00 | 0.76 | 0.163 |

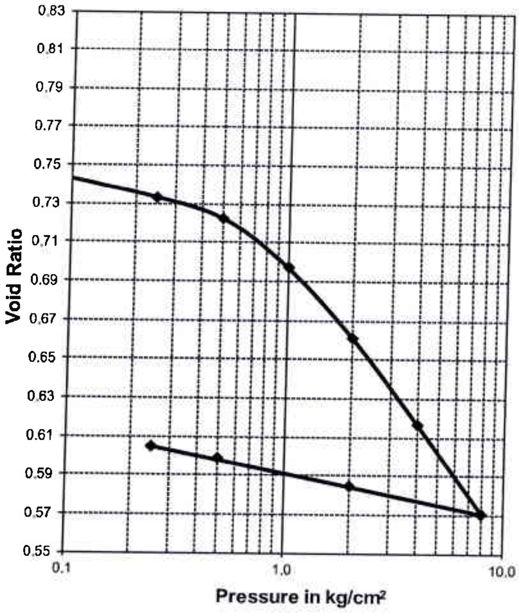



| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P164 | 16.00 | 0.78 | 0.164 |

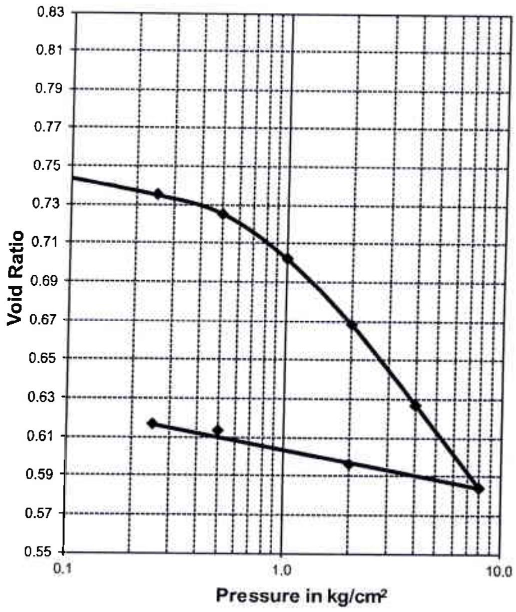


## e - log p curve

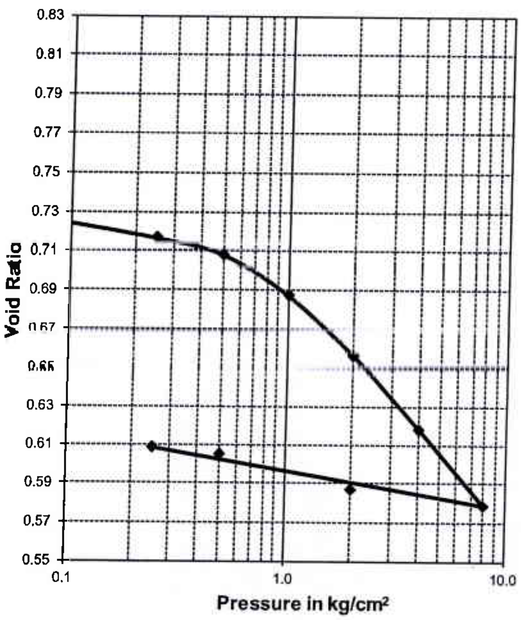
| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P164 | 19.00 | 0.75 | 0.152 |



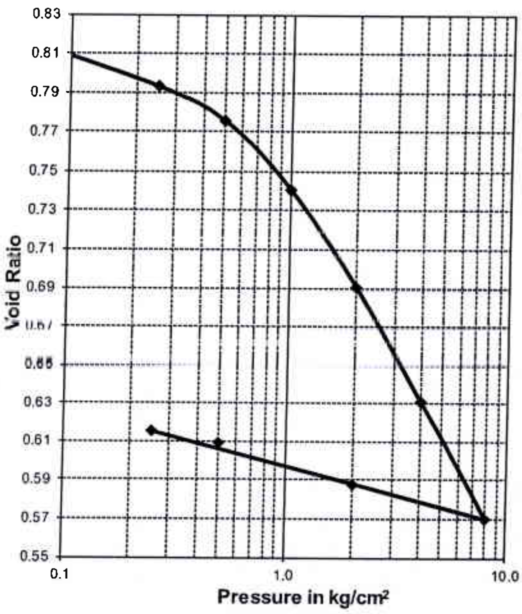

| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P164 | 22.00 | 0.75 | 0.142 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P164 | 25.00 | 0.73 | 0.131 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P165 | 4.00 | 0.82 | 0.203 |

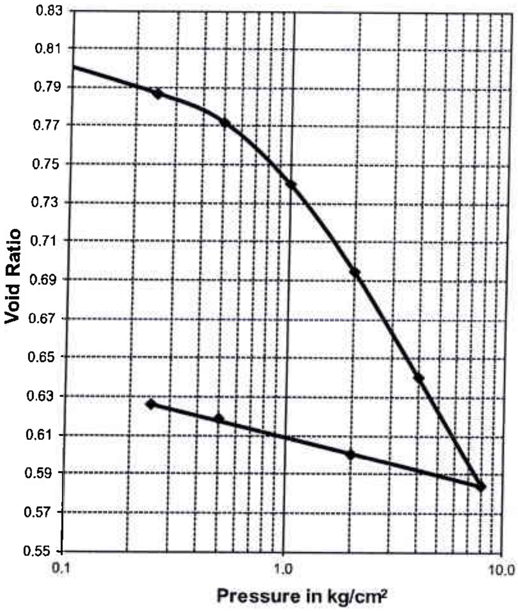


**M/s Anand Raj Infratech Pvt. Ltd.**

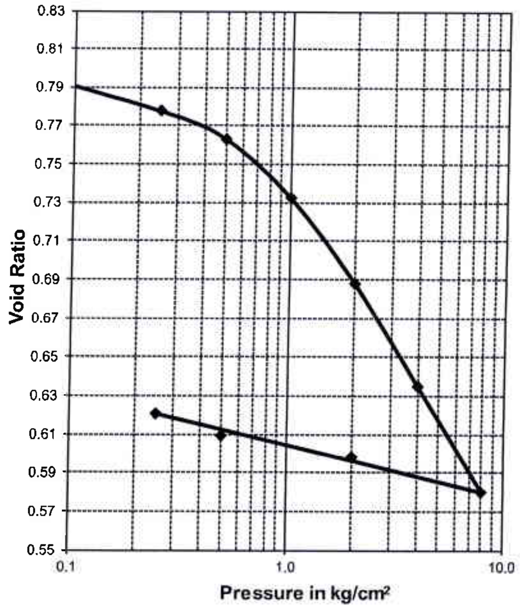
*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## e - log p curve

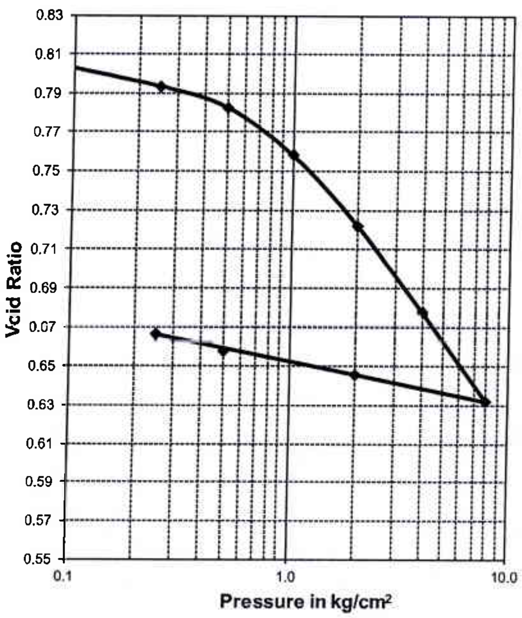
| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P165 | 7.00 | 0.81 | 0.186 |



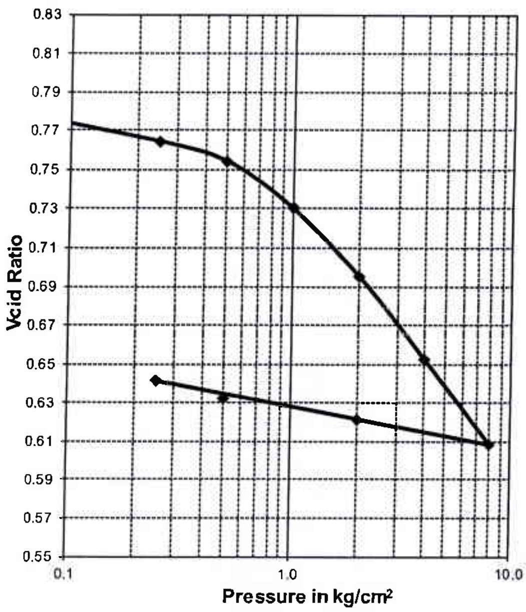

| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P165 | 10.00 | 0.8 | 0.182 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P165 | 13.00 | 0.81 | 0.151 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P165 | 16.00 | 0.78 | 0.146 |

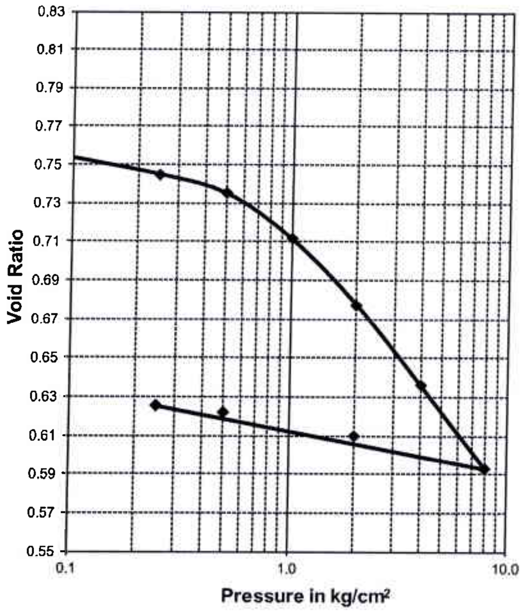


**M/s Anand Raj Infratech Pvt. Ltd.**

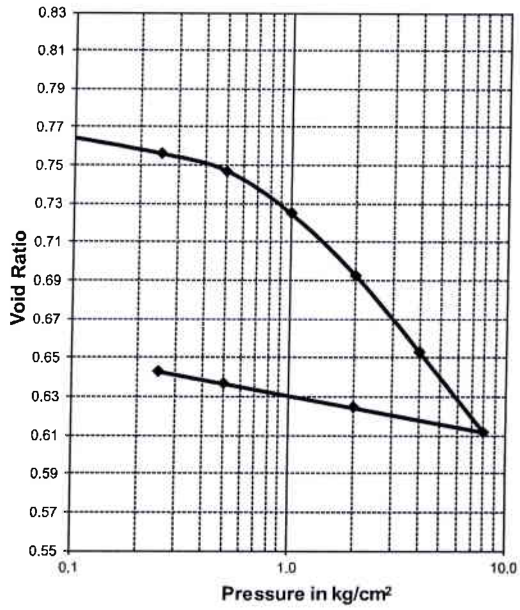
*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**e - log p curve**

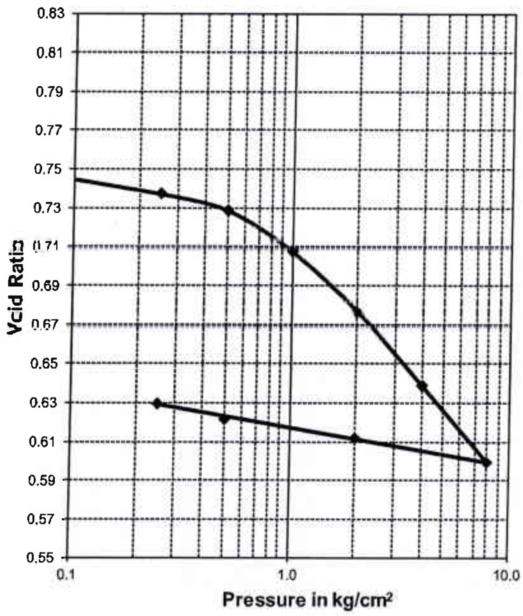
| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P165 | 19.00 | 0.76 | 0.143 |



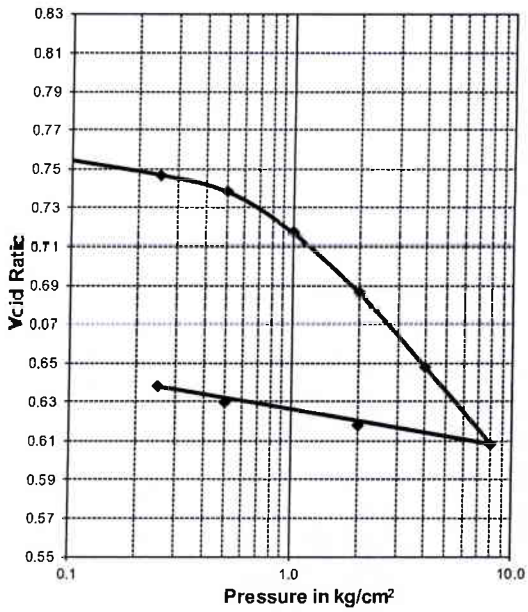

| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P165 | 22.00 | 0.77 | 0.136 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P165 | 25.00 | 0.75 | 0.13 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P165 | 28.00 | 0.76 | 0.131 |

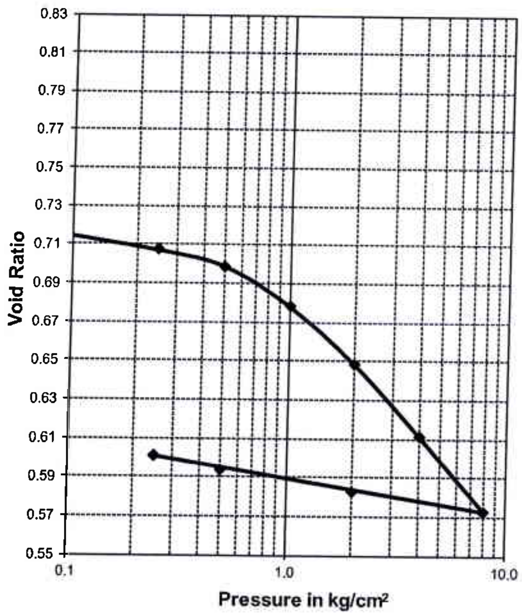



**M/s Anand Raj Infratech Pvt. Ltd.**

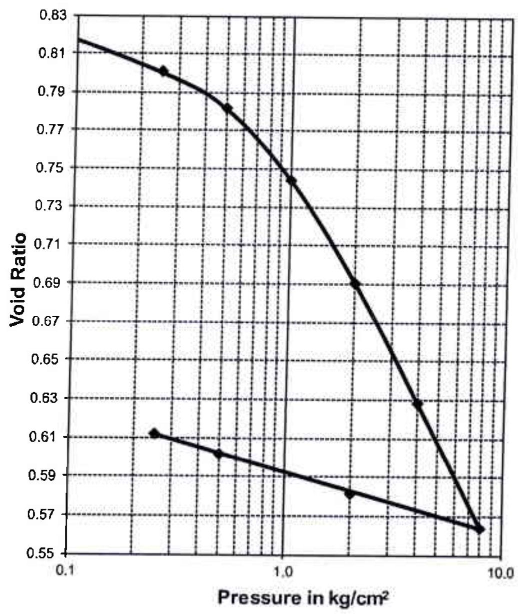
*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**e - log p curve**

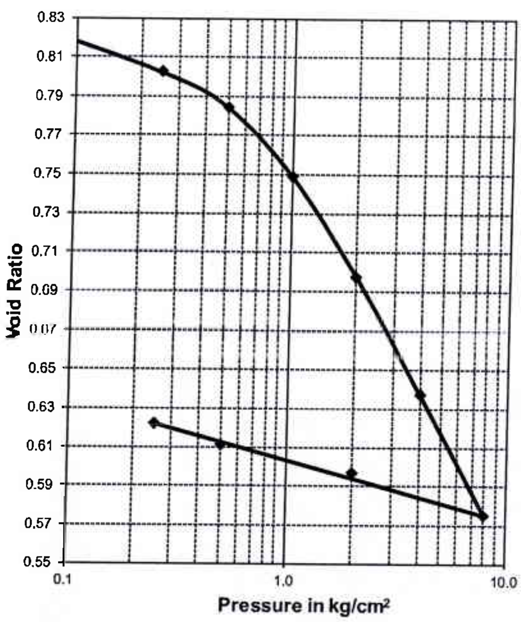
| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P165 | 31.00 | 0.72 | 0.128 |



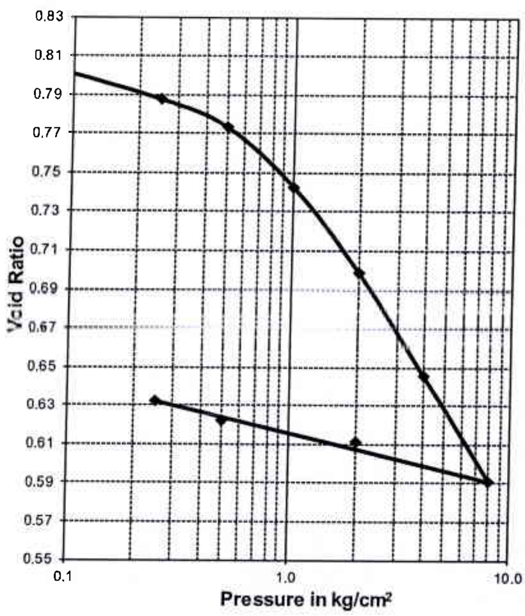

| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P166 | 4.00 | 0.83 | 0.214 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P166 | 7.00 | 0.83 | 0.206 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P166 | 10.50 | 0.81 | 0.181 |

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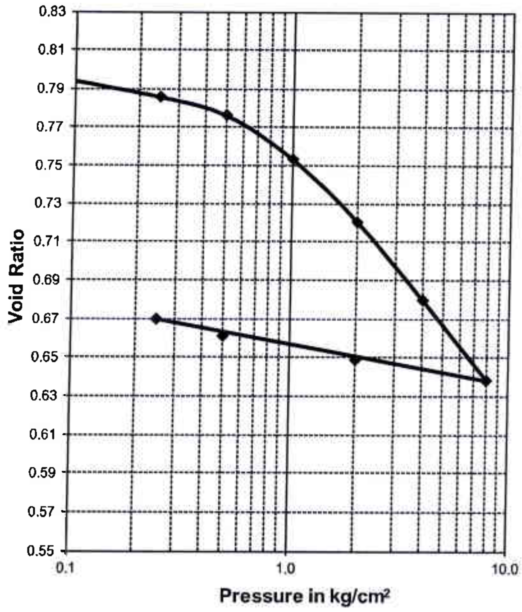
**M/s Anand Raj Infratech Pvt. Ltd.**

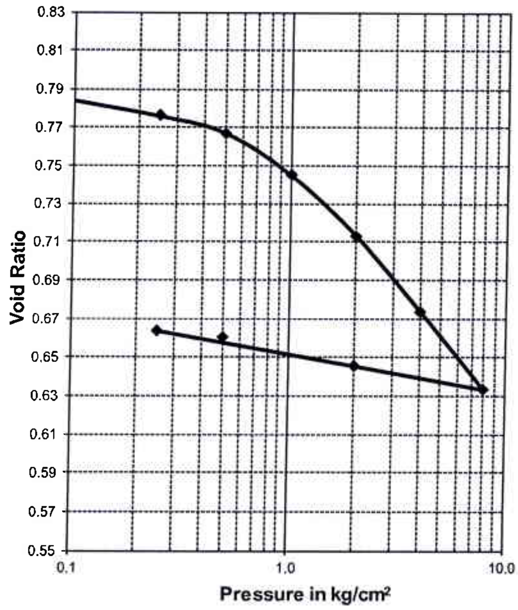
*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## e - log p curve

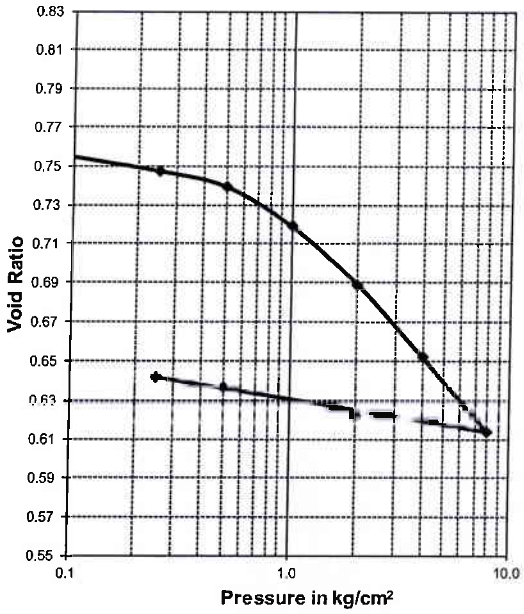
| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P166 | 13.00 | 0.8 | 0.139 |



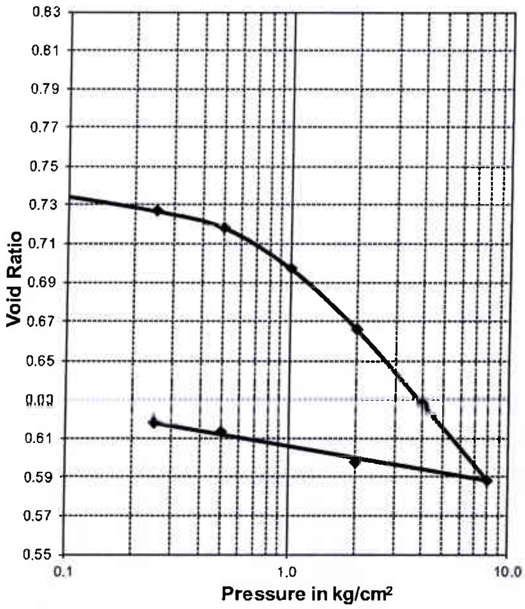

| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P166 | 16.00 | 0.79 | 0.135 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P166 | 19.00 | 0.76 | 0.127 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P166 | 22.00 | 0.74 | 0.131 |

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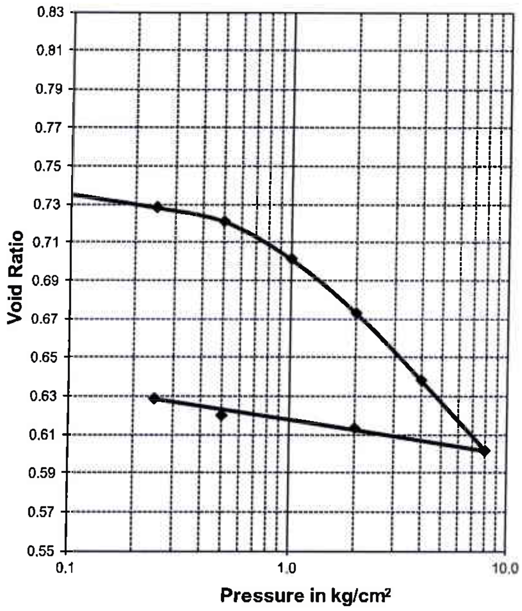
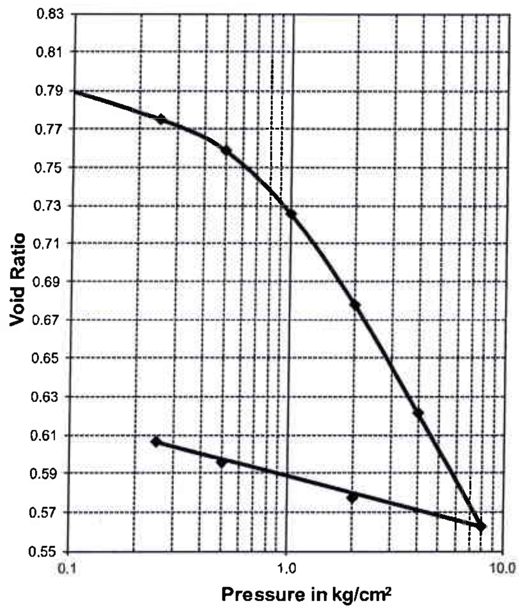
**e - log p curve**

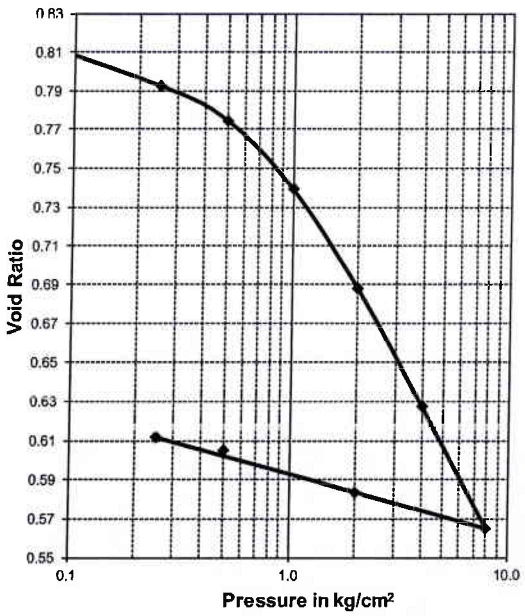
| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P166 | 25.00 | 0.74 | 0.121 |



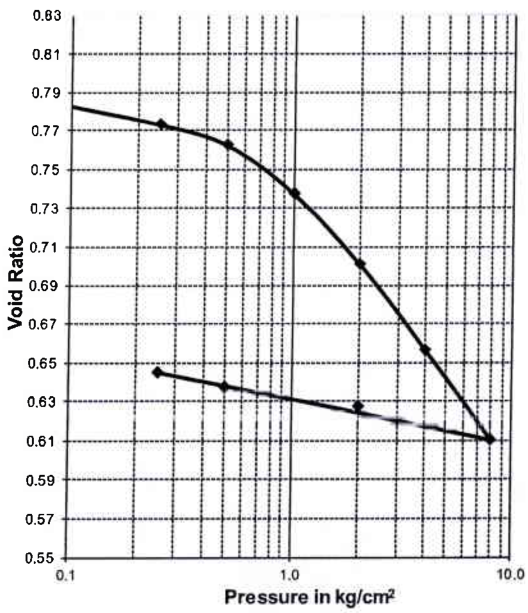

| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P167 | 4.00 | 0.8 | 0.194 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P167 | 7.00 | 0.82 | 0.206 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P167 | 13.00 | 0.79 | 0.152 |

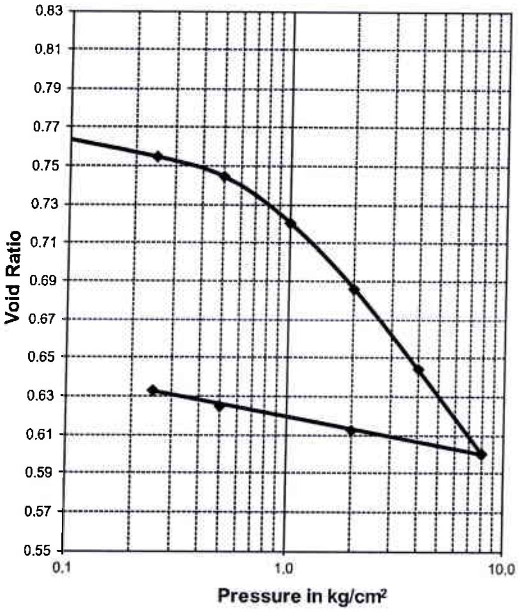



**M/s Anand Raj Infratech Pvt. Ltd.**

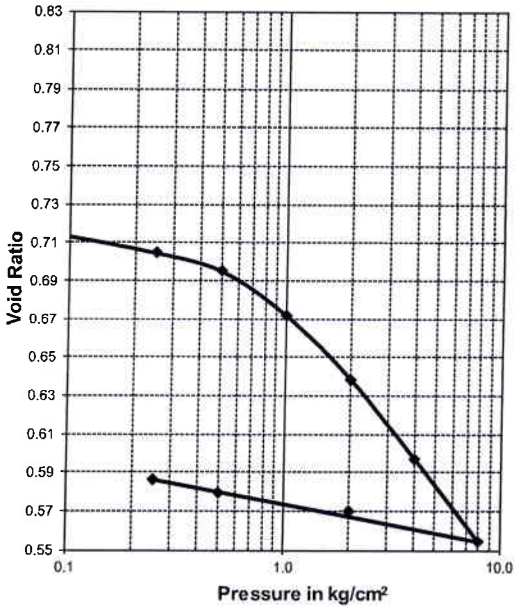
*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## e - log p curve

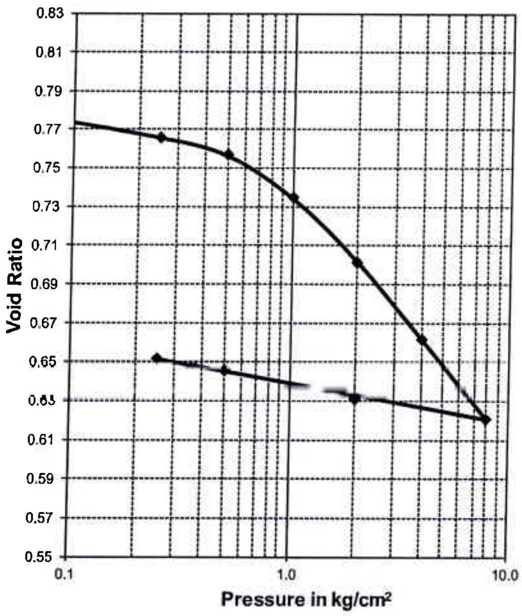
| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P167 | 16.00 | 0.77 | 0.145 |



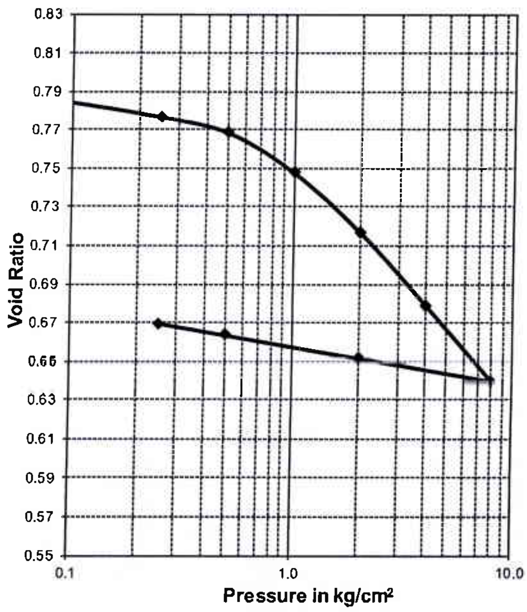

| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P167 | 19.00 | 0.72 | 0.142 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P167 | 22.00 | 0.78 | 0.137 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P167 | 25.00 | 0.79 | 0.13 |

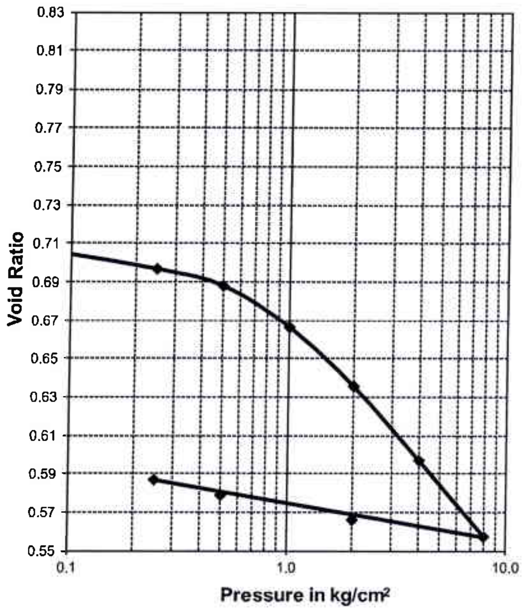


**M/s Anand Raj Infratech Pvt. Ltd.**

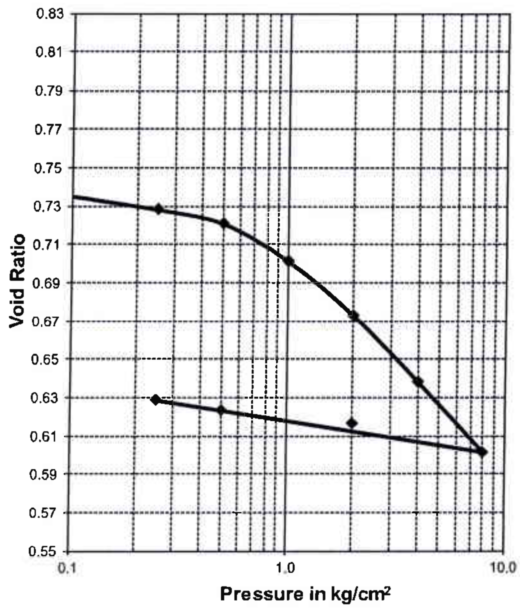
*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**e - log p curve**

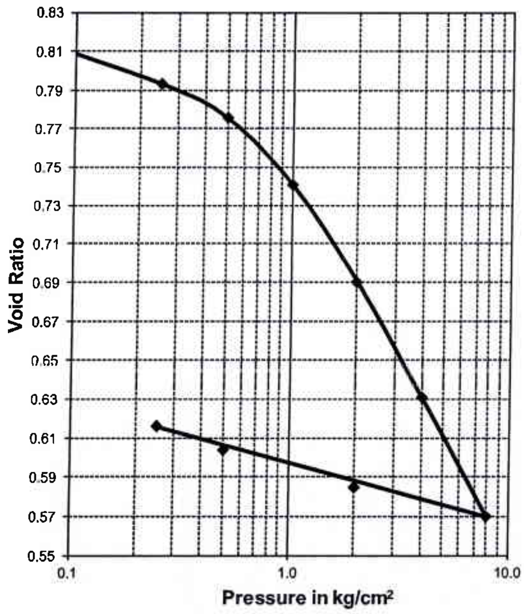
| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P167 | 28.00 | 0.71 | 0.132 |



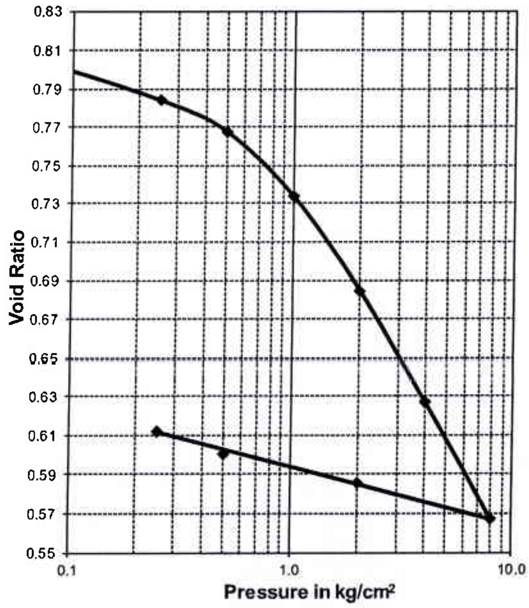

| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P167 | 37.00 | 0.74 | 0.121 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P168 | 4.00 | 0.82 | 0.203 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P168 | 7.00 | 0.81 | 0.198 |

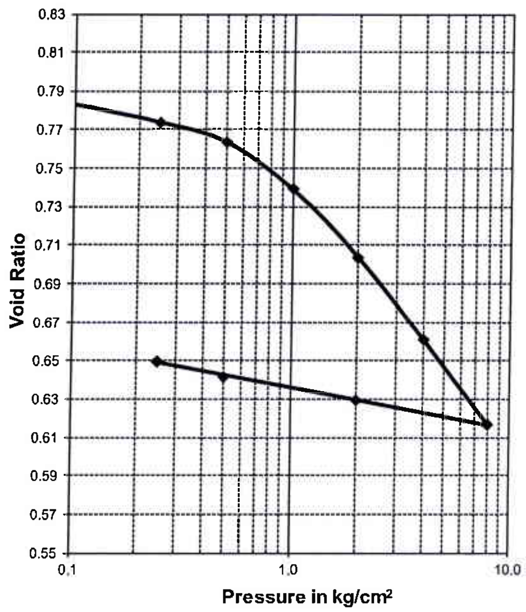


**M/s Anand Raj Infratech Pvt. Ltd.**

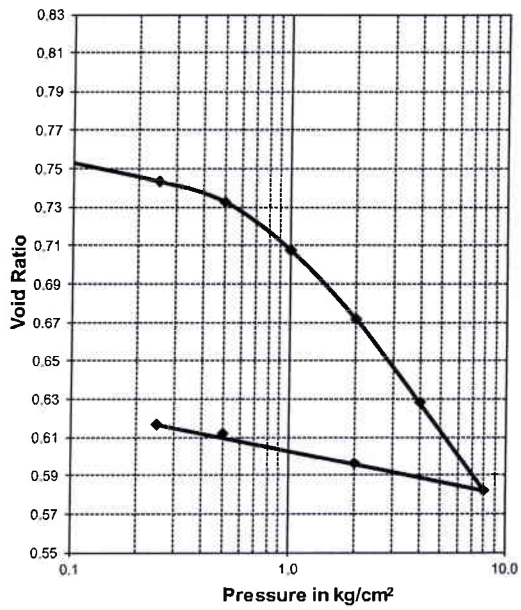
*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**e - log p curve**

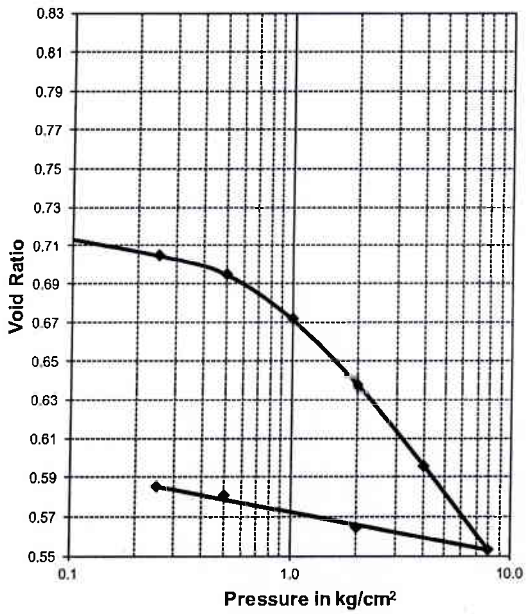
| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P168 | 16.00 | 0.79 | 0.148 |



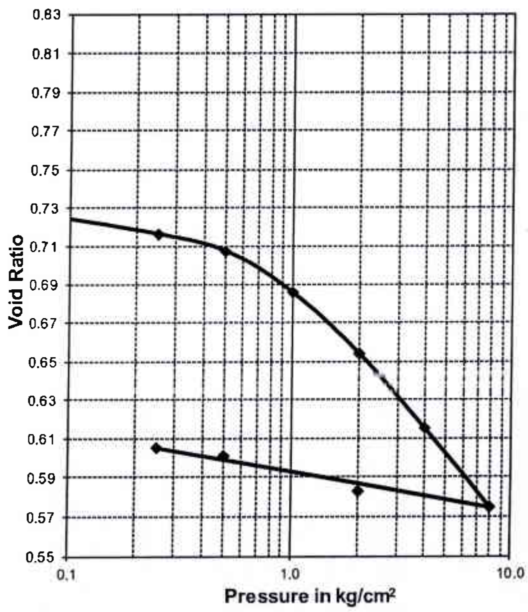

| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P168 | 19.00 | 0.76 | 0.151 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P168 | 22.00 | 0.72 | 0.143 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P168 | 25.00 | 0.73 | 0.134 |

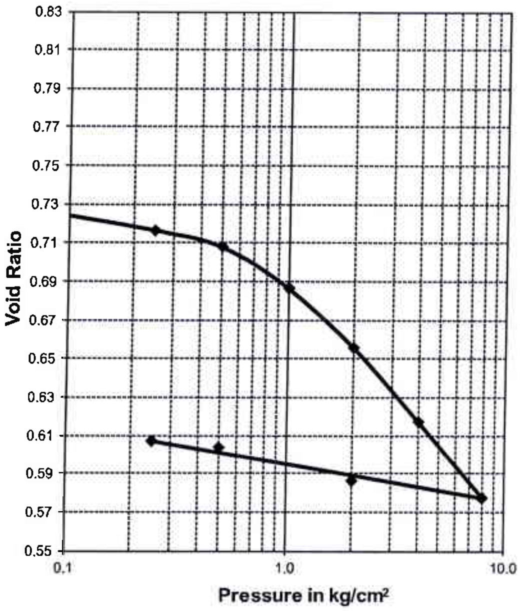


**M/s Anand Raj Infratech Pvt. Ltd.**

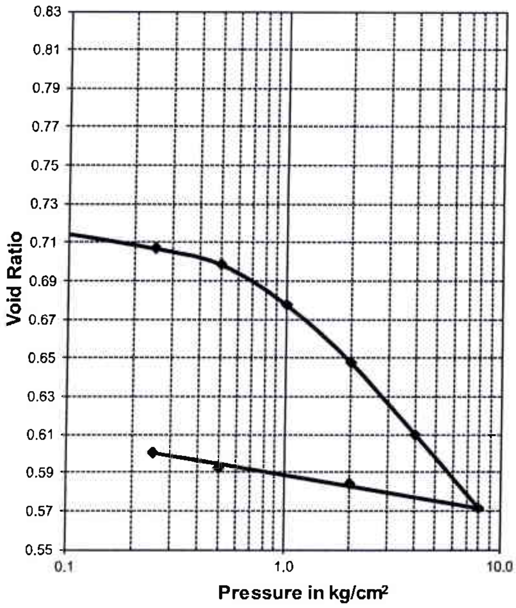
*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**e - log p curve**

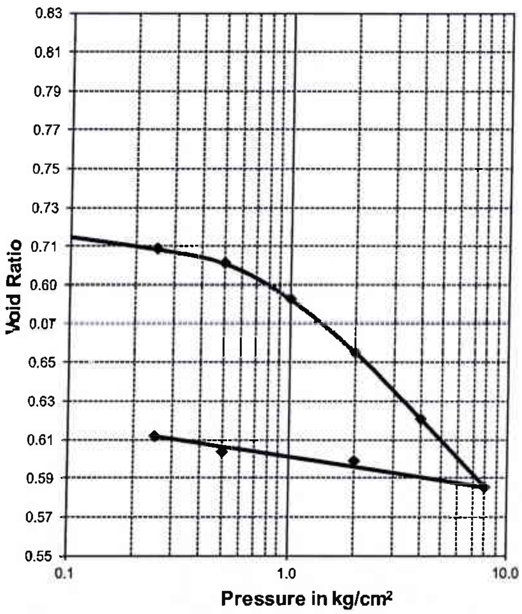
| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P168 | 28.00 | 0.73 | 0.132 |



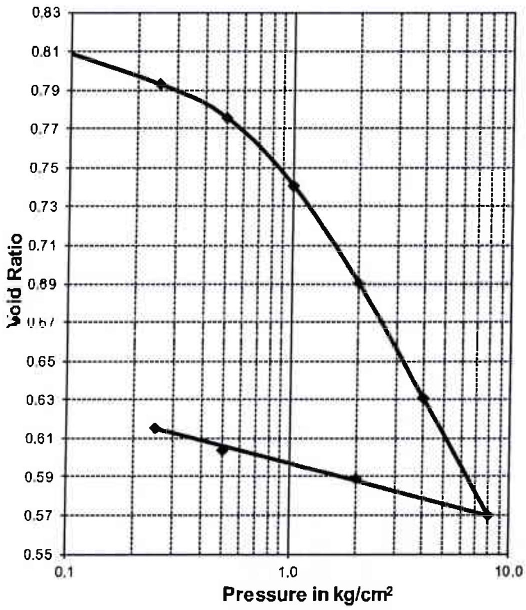

| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P168 | 31.00 | 0.72 | 0.129 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P168 | 37.00 | 0.72 | 0.118 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P169 | 4.00 | 0.82 | 0.203 |

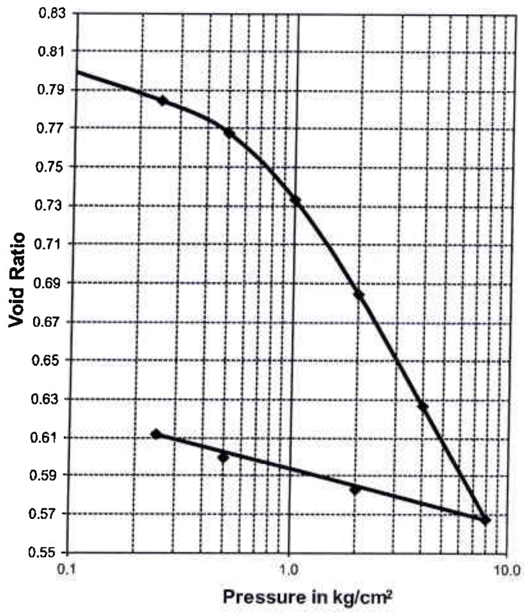


**M/s Anand Raj Infratech Pvt. Ltd.**

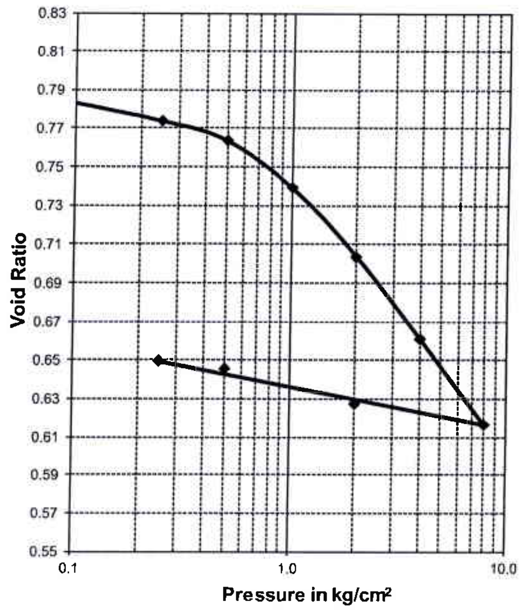
*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**e - log p curve**

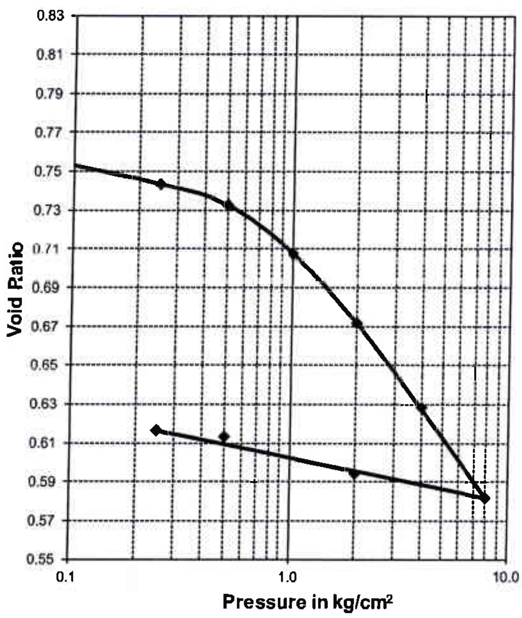
| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P169 | 7.00 | 0.81 | 0.198 |



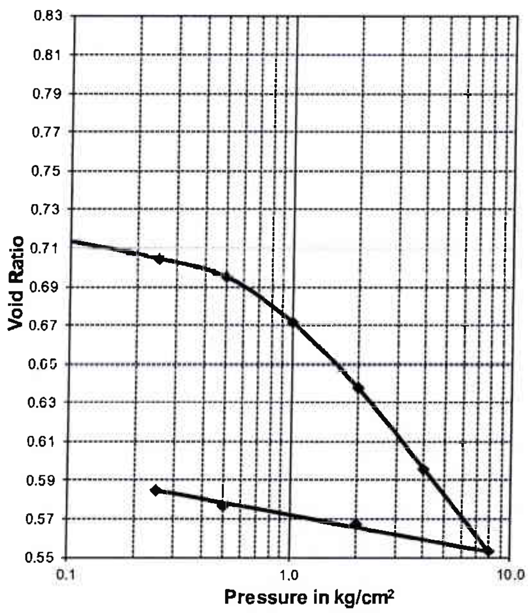

| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P169 | 16.00 | 0.79 | 0.148 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P169 | 19.00 | 0.76 | 0.151 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P169 | 22.00 | 0.72 | 0.143 |

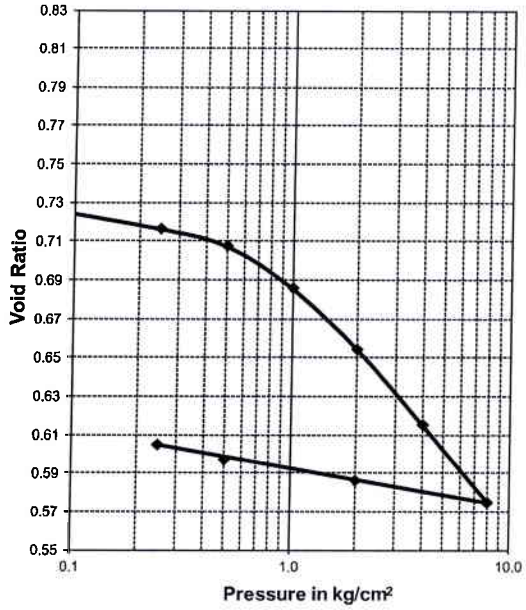


**M/s Anand Raj Infratech Pvt. Ltd.**

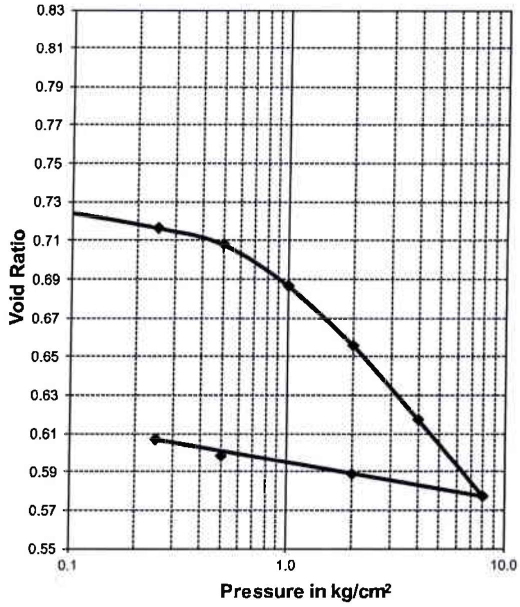
*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

**e - log p curve**

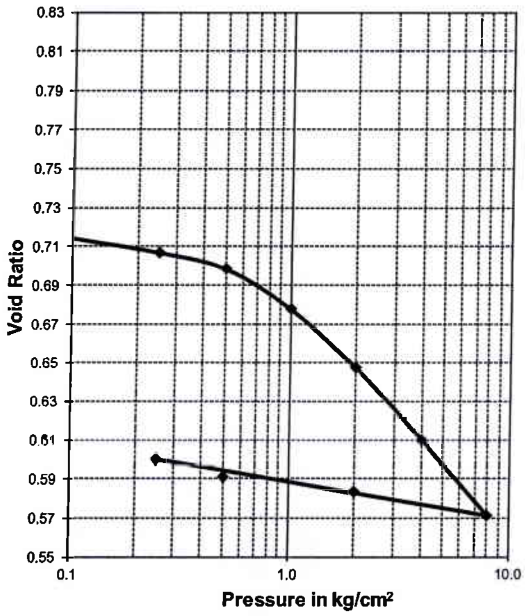
| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P169 | 25.00 | 0.73 | 0.134 |



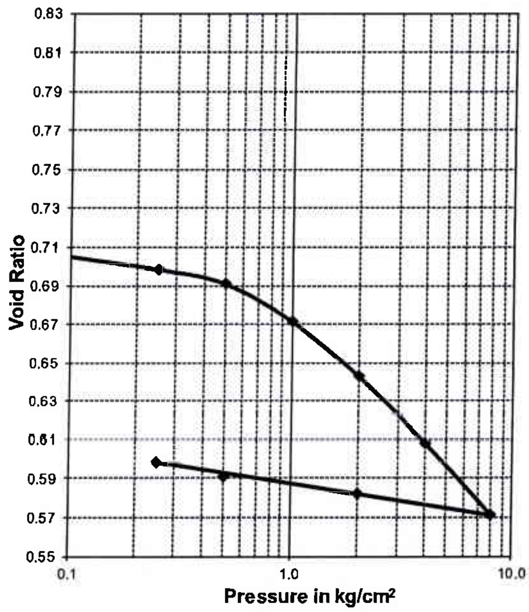

| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P169 | 28.00 | 0.73 | 0.132 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P169 | 31.00 | 0.72 | 0.129 |




| B.H. No. | Depth (m) | eo | Cc |
|---|---|---|---|
| P169 | 37.00 | 0.71 | 0.121 |




**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## Determination of Pile Capacity (P164 new) for 60 m pile length

GL = 48.181 m

Pile tip level = -16.450 m

Max. Scour Level = 7.100 m

Cut off level = 43.55 m

Effective shaft length 23.55 m

Pile type (bored/driven) : bored

Pile Diameter (m) **1.9**

**Ref Code : IRC:78 - 2014**

As per Appendix 5 , load bearing capacity of a pile can be found out with the following relationship :

$$Q_u = A_p(\frac{1}{2}D.\gamma.N_\gamma + P_d.N_q) + A_pN_cc_p + \sum_{i=1}^{n} KP_{Di}\tan\delta A_{si} + \alpha.CA_s$$

where, $Q_u$ = Ultimate load capacity in a in kN

$A_p$ = sectional area of pile base, in $m^2$

$\alpha$ = Reduction factor

C = Average cohesion of soil in $kN/m^2$

$A_s$ = Surface area of pile shaft in $m^2$

K = Co-efficient of earth pressure

$N_c$ = bearing capacity factor, may be taken as 9

$C_p$ = average cohesion at pile tip in $kN/m^2$

$P_{Di}$ = Effective overburden pressure in $kN/m^2$

D = Pile Diameter (m)

$\gamma$ = Effective unit weight of soil at pile tip in $kN/m^2$

$N_q$ , $N_\gamma$ = Bearing Capacity factors based on angle of internal friction at pile tip

$\delta$ = angle of wall friction between pile & soil , in degree ,(may be taken equal to $\phi$)

$A_{si}$ = Surface area of pile shaft in $m^2$ in the $i^{th}$ layer where i varies from 1 to n

Max$^m$ overburden taken upto 20 times the dia. of pile = 38 m

### *Calculation of ultimate shaft resistance*

***LAYER V***

| Bottom R.L of layer concerned | Depth below scour level (m) | Pile shaft length in this layer (m) | Overburden thk. at top of pile (m) | Overburden thk. at bottom of layer (m) | $\gamma_{sat}$, ($kN/m^3$) | C($kN/m^2$) | $\phi$(degree) | K |
|---|---|---|---|---|---|---|---|---|
| -2.519 | 9.619 | 9.619 | 0.000 | 9.619 | 19 | 121 | 0.00 | 1.50 |

Average N value = 62 Now, corresponding to this N value, $\alpha$ = 0.3

$A_s$ = 3.14159 x 1.9 x 9.619 sq m, or 57.42 $m^2$

$P_{Di}$ at top of pile = (19 - 10) x 0, or 0 $kN/m^2$

$P_{Di}$ at bottom of this Layer = (19 - 10) x 9.619, or 86.571 $kN/m^2$

Average $P_{Di}$ = 43.286 $kN/m^2$

So, shaft resistance = 1.5 x 43.286 x TAN(0) x 57.42 + 0.3 x 121 x 57.42 = 2084 kN

***LAYER VI***

| Bottom R.L of layer concern | Depth below scour level (m) | Pile shaft length in this layer (m) | Overburden thk. at top of layer (m) | Overburden thk. at bottom of layer (m) | $\gamma_{sat}$, ($kN/m^3$) | C($kN/m^2$) | $\phi$(degree) | K |
|---|---|---|---|---|---|---|---|---|
| -16.450 | 23.550 | 13.931 | 9.619 | 23.550 | 19.7 | 0 | 34 | 1.50 |

Average N value = 100 Now, corresponding to this N value, $\alpha$ = 0.3

$A_s$ = 3.14159 x 1.9 x 13.931 sq m, or 83.15 $m^2$

$P_{Di}$ at top of this Layer = 86.571 $kN/m^2$

$P_{Di}$ at bottom of this Layer = 221.702 $kN/m^2$

Average $P_{Di}$ = 154.137 $kN/m^2$

So, shaft resistance =1.5 x 154.137 x TAN(34) x 83.15 + 0.3 x 0 x 83.15 = 12959 kN

Total ultimate shaft resistance = 15043.00 kN

***Calculation of ultimate base resistance***

$C_p$= 0 kN/m$^2$ $\phi$(degree)= 35 Nq = 48.5 N$\gamma$ = 48.03

Ultimate base resistance = 3.1415/4 x 1.9 x 1.9 x { 0.5 x 1.9 x ( 19.7 - 10) x 48.03 + 221.702 x 48.5 } = 31741 kN

***Calculation of safe load carrying capacity***

Ultimate Capacity = Ultimate Base resistance + Ultimate shaft resistance = 46784.00 kN

Considering factor of safety = 2.5

Hence safe pile capacity : 18713.60 kN say 1871 ton

***Calculation of safe uplift capacity***

Weight of pile = 2550.5 kN (Bouyant weight considered)

Ultimate Shaft Resistance = 15043.00 kN

Considering factor of safety on Shaft Resistance = 2.5 / 0.7 = 3.5

Hence safe uplift capacity = 15043 / 3.5 + Weight of pile = 6848 kN

say 685 ton

## Determination of Pile Capacity (P165 new) for 60 m pile length

GL = 48.755 m
Pile tip level = -16.450 m
Max Scour Level = 7.100 m
Cut off level = 43.55 m
Effective shaft length 23.55 m

Pile type (bored/driven) : bored
Pile Diameter (m) **1.9**

**Ref Code : IRC:78 - 2014**

As per Appendix 5 , load bearing capacity of a pile can be found out with the following relationship :

$$Q_u = A_p(\frac{1}{2}D.\gamma.N_\gamma + P_d.N_q) + A_pN_cc_p + \sum_{i=1}^{n} KP_{Di}\tan\delta A_{si} + \alpha.CA_s$$

where, $Q_u$ = Ultimate load capacity in a in kN
$A_p$ = sectional area of pile base, in $m^2$
$\alpha$ = Reduction factor
C = Average cohesion of soil in $kN/m^2$
$A_s$ = Surface area of pile shaft in $m^2$
K = Co-efficient of earth pressure
$N_c$ = bearing capacity factor, may be taken as 9
$C_p$ = average cohesion at pile tip in $kN/m^2$
$P_{Di}$ = Effective overburden pressure in $kN/m^2$
D = Pile Diameter (m)
$\gamma$ = Effective unit weight of soil at pile tip in $kN/m^2$
$N_q$ , $N_\gamma$ = Bearing Capacity factors based on angle of internal friction at pile tip
$\delta$ = angle of wall friction between pile & soil, in degree ,(may be taken equal to $\phi$)
$A_{si}$ = Surface area of pile shaft in $m^2$ in the $i^{th}$ layer where i varies from 1 to n
Max$^m$ overburden taken upto 20 times the dia. of pile = 38 m

### *Calculation of ultimate shaft resistance*

***LAYER V***

| Bottom R.L of layer concerned | Depth below scour level (m) | Pile shaft length in this layer (m) | Overburden thk. at top of pile (m) | Overburden thk. at bottom of layer (m) | $\gamma_{sat}$, ($kN/m^3$) | C($kN/m^2$) | $\phi$(degree) | K |
|---|---|---|---|---|---|---|---|---|
| 0.155 | 6.945 | 6.945 | 0.000 | 6.945 | 19 | 121 | 0.00 | 1.50 |

Average N value = 52 Now, corresponding to this N value, $\alpha$ = 0.3

$A_s$ = 3.14159 x 1.9 x 6.945 sq m, or 41.45 $m^2$

$P_{Di}$ at top of pile = (19 - 10) x 0, or 0 $kN/m^2$

$P_{Di}$ at bottom of this Layer = (19 - 10) x 6.945, or 62.505 $kN/m^2$

Average $P_{Di}$ = 31.253 $kN/m^2$

So, shaft resistance = 1.5 x 31.253 x TAN(0) x 41.45 + 0.3 x 121 x 41.45 = 1505 kN

***LAYER VI***

| Bottom R.L of layer concern | Depth below scour level (m) | Pile shaft length in this layer (m) | Overburden thk. at top of layer (m) | Overburden thk. at bottom of layer (m) | $\gamma_{sat}$, ($kN/m^3$) | C($kN/m^2$) | $\phi$(degree) | K |
|---|---|---|---|---|---|---|---|---|
| -16.450 | 23.550 | 16.605 | 6.945 | 23.550 | 19.4 | 0 | 34 | 1.50 |

Average N value = 100 Now, corresponding to this N value, $\alpha$ = 0.3

$A_s$ = 3.14159 x 1.9 x 16.605 sq m, or 99.12 $m^2$

$P_{Di}$ at top of this Layer = 62.505 $kN/m^2$

$P_{Di}$ at bottom of this Layer = 218.592 $kN/m^2$

Average $P_{Di}$ = 140.549 $kN/m^2$

So, shaft resistance = 1.5 x 140.549 x TAN(34) x 99.12 + 0.3 x 0 x 99.12 = 14086 kN

**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

Total ultimate shaft resistance = 15591.00 kN

## *Calculation of ultimate base resistance*

$C_p$= 0 kN/m$^2$ $\phi$(degree)= 35 Nq = 48.5 Nγ = 48.03

Ultimate base resistance = 3.1415/4 x 1.9 x 1.9 x { 0.5 x 1.9 x ( 19.4 - 10) x 48.03 + 218.592 x 48.5 } = 31274 kN

## *Calculation of safe load carrying capacity*

Ultimate Capacity = Ultimate Base resistance + Ultimate shaft resistance = 46865.00 kN

Considering factor of safety = 2.5

Hence safe pile capacity : 18746.00 kN say 1875 ton

## *Calculation of safe uplift capacity*

Weight of pile = 2550.5 kN (Bouyant weight considered)

Ultimate Shaft Resistance = 15591.00 kN

Considering factor of safety on Shaft Resistance = 2.5 / 0.7 = 3.5

Hence safe uplift capacity = 15591 / 3.5 + Weight of pile = 7005 kN

say 701 ton

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Total ultimate shaft resistance = 15228.00 kN

## *Calculation of ultimate base resistance*

$C_p$= 0 kN/m$^2$ ϕ(degree)= 35 Nq = 48.5 Nɣ = 48.03

Ultimate base resistance = 3.1415/4 x 1.9 x 1.9 x { 0.5 x 1.9 x ( 19.4 - 10) x 48.03 + 217.989 x 48.5 } = 31191 kN

## *Calculation of safe load carrying capacity*

Ultimate Capacity = Ultimate Base resistance + Ultimate shaft resistance = 46419.00 kN

Considering factor of safety = 2.5

Hence safe pile capacity : 18567.60 kN say 1857 ton

## *Calculation of safe uplift capacity*

Weight of pile = 2550.5 kN (Bouyant weight considered)

Ultimate Shaft Resistance = 15228.00 kN

Considering factor of safety on Shaft Resistance = 2.5 / 0.7 = 3.5

Hence safe uplift capacity = 15228 / 3.5 + Weight of pile = 6901 kN

say 690 ton

**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## Determination of Pile Capacity (P167 new) for pile length 60 m

GL = 48.737 m

Pile tip level = -16.450 m

Max. Scour Level = 7.100 m

Cut off level = 43.55 m

Effective shaft length 23.55 m

Pile type (bored/driven) : bored

Pile Diameter (m) **1.9**

**Ref Code : IRC:78 - 2014**

As per Appendix 5 , load bearing capacity of a pile can be found out with the following relationship :

$$Q_u = A_p(\frac{1}{2}D.\gamma.N_\gamma + P_d.N_q) + A_p N_c c_p + \sum_{i=1}^{n} KP_{Di}\tan\delta A_{si} + \alpha.CA_s$$

where, $Q_u$ = Ultimate load capacity in a in kN

$A_p$ = sectional area of pile base, in $m^2$

$\alpha$ = Reduction factor

C = Average cohesion of soil in $kN/m^2$

$A_s$ = Surface area of pile shaft in $m^2$

K = Co-efficient of earth pressure

$N_c$ = bearing capacity factor, may be taken as 9

$C_p$ = average cohesion at pile tip in $kN/m^2$

$P_{Di}$ = Effective overburden pressure in $kN/m^2$

D = Pile Diameter (m)

$\gamma$ = Effective unit weight of soil at pile tip in $kN/m^2$

$N_q$ , $N_\gamma$ = Bearing Capacity factors based on angle of internal friction at pile tip

$\delta$ = angle of wall friction between pile & soil , in degree ,(may be taken equal to $\phi$)

$A_{si}$ = Surface area of pile shaft in $m^2$ in the $i^{th}$ layer where i varies from 1 to n

Max$^m$ overburden taken upto 20 times the dia. of pile = 38 m

### *Calculation of ultimate shaft resistance*

***LAYER V***

| Bottom R.L of layer concerned | Depth below scour level (m) | Pile shaft length in this layer (m) | Overburden thk. at top of pile (m) | Overburden thk. at bottom of layer (m) | $\gamma_{sat}$, ($kN/m^3$) | C($kN/m^2$) | $\phi$(degree) | K |
|---|---|---|---|---|---|---|---|---|
| -1.613 | 8.713 | 8.713 | 0.000 | 8.713 | 19 | 121 | 0.00 | 1.50 |

Average N value = 37 Now, corresponding to this N value, $\alpha$ = 0.3

$A_s$ = 3.14159 x 1.9 x 8.713 sq m, or 52.01 $m^2$

$P_{Di}$ at top of pile = (19 - 10) x 0, or 0 $kN/m^2$

$P_{Di}$ at bottom of this Layer = (19 - 10) x 8.713, or 78.417 $kN/m^2$

Average $P_{Di}$ = 39.209 $kN/m^2$

So, shaft resistance = 1.5 x 39.209 x TAN(0) x 52.01 + 0.3 x 121 x 52.01 = 1888 kN

***LAYER VI***

| Bottom R.L of layer concern | Depth below scour level (m) | Pile shaft length in this layer (m) | Overburden thk. at top of layer (m) | Overburden thk. at bottom of layer (m) | $\gamma_{sat}$, ($kN/m^3$) | C($kN/m^2$) | $\phi$(degree) | K |
|---|---|---|---|---|---|---|---|---|
| -16.450 | 23.550 | 14.837 | 8.713 | 23.550 | 19.5 | 0 | 34 | 1.50 |

Average N value = 100 Now, corresponding to this N value, $\alpha$ = 0.3

$A_s$ = 3.14159 x 1.9 x 14.837 sq m, or 88.56 $m^2$

$P_{Di}$ at top of this Layer = 78.417 $kN/m^2$

$P_{Di}$ at bottom of this Layer = 219.369 $kN/m^2$

Average $P_{Di}$ = 148.893 $kN/m^2$

So, shaft resistance =1.5 x 148.893 x TAN(34) x 88.56 + 0.3 x 0 x 88.56 = 13332 kN

Total ultimate shaft resistance = 15220.00 kN

***Calculation of ultimate base resistance***

$C_p$= 0 kN/m$^2$ $\phi$(degree)= 35 Nq = 48.5 N$\gamma$ = 48.03

Ultimate base resistance = 3.1415/4 x 1.9 x 1.9 x { 0.5 x 1.9 x ( 19.5 - 10) x 48.03 + 219.369 x 48.5 } = 31394 kN

***Calculation of safe load carrying capacity***

Ultimate Capacity = Ultimate Base resistance + Ultimate shaft resistance = 46614.00 kN

Considering factor of safety = 2.5

Hence safe pile capacity : 18645.60 kN say 1865 ton

***Calculation of safe uplift capacity***

Weight of pile = 2550.5 kN (Bouyant weight considered)

Ultimate Shaft Resistance = 15220.00 kN

Considering factor of safety on Shaft Resistance = 2.5 / 0.7 = 3.5

Hence safe uplift capacity = 15220 / 3.5 + Weight of pile = 6899 kN

say 690 ton

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## Determination of Pile Capacity (P168) for pile length 60 m

GL = 48.940 m

Pile tip level = -16.450 m

Max. Scour Level = 7.100 m

Cut off level = 43.55 m

Effective shaft length 23.55 m

Pile type (bored/driven) : bored

Pile Diameter (m) **1.9**

**Ref Code : IRC:78 - 2014**

As per Appendix 5 , load bearing capacity of a pile can be found out with the following relationship :

$$Q_u = A_p(\frac{1}{2}D.\gamma.N_\gamma + P_d.N_q) + A_p N_c c_p + \sum_{i=1}^{n} K P_{Di} \tan\delta A_{si} + \alpha.CA_s$$

where, $Q_u$ = Ultimate load capacity in a in kN

$A_p$ = sectional area of pile base, in $m^2$

$\alpha$ = Reduction factor

C = Average cohesion of soil in $kN/m^2$

$A_s$ = Surface area of pile shaft in $m^2$

K = Co-efficient of earth pressure

$N_c$ = bearing capacity factor, may be taken as 9

$C_p$ = average cohesion at pile tip in $kN/m^2$

$P_{Di}$ = Effective overburden pressure in $kN/m^2$

D = Pile Diameter (m)

$\gamma$ = Effective unit weight of soil at pile tip in $kN/m^2$

$N_q$ , $N_\gamma$ = Bearing Capacity factors based on angle of internal friction at pile tip

$\delta$ = angle of wall friction between pile & soil, in degree ,(may be taken equal to $\phi$)

$A_{si}$ = Surface area of pile shaft in $m^2$ in the $i^{th}$ layer where i varies from 1 to n

Max$^m$ overburden taken upto 20 times the dia. of pile = 38 m

### *Calculation of ultimate shaft resistance*

***LAYER V***

| Bottom R.L of layer concerned | Depth below scour level (m) | Pile shaft length in this layer (m) | Overburden thk. at top of pile (m) | Overburden thk. at bottom of layer (m) | $\gamma_{sat}$, $(kN/m^3)$ | $C(kN/m^2)$ | $\phi$(degree) | K |
|---|---|---|---|---|---|---|---|---|
| -1.910 | 9.010 | 9.010 | 0.000 | 9.010 | 19 | 115 | 0.00 | 1.50 |

Average N value = 37

Now, corresponding to this N value, $\alpha$ = 0.3

$A_s$ = 3.14159 x 1.9 x 9.01 sq m, or 53.78 $m^2$

$P_{Di}$ at top of pile = (19 - 10) x 0, or 0 $kN/m^2$

$P_{Di}$ at bottom of this Layer = (19 - 10) x 9.01, or 81.09 $kN/m^2$

Average $P_{Di}$ = 40.545 $kN/m^2$

So, shaft resistance = 1.5 x 40.545 x TAN(0) x 53.78 + 0.3 x 115 x 53.78 = 1855 kN

***LAYER VI***

| Bottom R.L of layer concern | Depth below scour level (m) | Pile shaft length in this layer (m) | Overburden thk. at top of layer (m) | Overburden thk. at bottom of layer (m) | $\gamma_{sat}$, $(kN/m^3)$ | $C(kN/m^2)$ | $\phi$(degree) | K |
|---|---|---|---|---|---|---|---|---|
| -16.450 | 23.550 | 14.540 | 9.010 | 23.550 | 19.5 | 0 | 34 | 1.50 |

Average N value = 100

Now, corresponding to this N value, $\alpha$ = 0.3

$A_s$ = 3.14159 x 1.9 x 14.54 sq m, or 86.79 $m^2$

$P_{Di}$ at top of this Layer = 81.09 $kN/m^2$

$P_{Di}$ at bottom of this Layer = 219.22 $kN/m^2$

Average $P_{Di}$ = 150.155 $kN/m^2$

So, shaft resistance =1.5 x 150.155 x TAN(34) x 86.79 + 0.3 x 0 x 86.79 = 13177 kN

Total ultimate shaft resistance = 15032.00 kN

***Calculation of ultimate base resistance***

$C_p$= 0 kN/m$^2$ ϕ(degree)= 35 Nq = 48.5 Nɣ = 48.03

Ultimate base resistance = 3.1415/4 x 1.9 x 1.9 x { 0.5 x 1.9 x ( 19.5 - 10) x 48.03 + 219.22 x 48.5 } = 31373 kN

***Calculation of safe load carrying capacity***

Ultimate Capacity = Ultimate Base resistance + Ultimate shaft resistance = 46405.00 kN

Considering factor of safety = 2.5

Hence safe pile capacity : 18562.00 kN say 1856 ton

***Calculation of safe uplift capacity***

Weight of pile = 2550.5 kN (Bouyant weight considered)

Ultimate Shaft Resistance = 15032.00 kN

Considering factor of safety on Shaft Resistance = 2.5 / 0.7 = 3.5

Hence safe uplift capacity = 15032 / 3.5 + Weight of pile = 6845 kN

say 685 ton

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**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

## Determination of Pile Capacity (P169) for pile length 60 m

GL = 48.073 m

Pile tip level = -16.450 m

Max. Scour Level = 7.100 m

Cut off level = 43.55 m

Effective shaft length 23.55 m

Pile type (bored/driven) : bored

Pile Diameter (m) **1.9**

**Ref Code : IRC:78 - 2014**

As per Appendix 5 , load bearing capacity of a pile can be found out with the following relationship :

$$Q_u = A_p(\frac{1}{2}D.\gamma.N_\gamma + P_d.N_q) + A_p N_c c_p + \sum_{i=1}^{n} KP_{Di} \tan\delta A_{si} + \alpha.CA_s$$

where, $Q_u$ = Ultimate load capacity in a in kN

$\alpha$ = Reduction factor

$A_s$ = Surface area of pile shaft in $m^2$

$N_c$ = bearing capacity factor, may be taken as 9

$P_{Di}$ = Effective overburden pressure in $kN/m^2$

$\gamma$ = Effective unit weight of soil at pile tip in $kN/m^2$

$N_q$ , $N_\gamma$ = Bearing Capacity factors based on angle of internal friction at pile tip

$\delta$ = angle of wall friction between pile & soil , in degree ,(may be taken equal to $\phi$)

$A_{si}$ = Surface area of pile shaft in $m^2$ in the $i^{th}$ layer where i varies from 1 to n

$A_p$ = sectional area of pile base, in $m^2$

C= Average cohesion of soil in $kN/m^2$

K = Co-efficient of earth pressure

$C_p$ = average cohesion at pile tip in $kN/m^2$

D = Pile Diameter (m)

$Max^m$ overburden taken upto 20 times the dia. of pile = 38 m

### *Calculation of ultimate shaft resistance*

***LAYER V***

| Bottom R.L of layer concerned | Depth below scour level (m) | Pile shaft length in this layer (m) | Overburden thk. at top of pile (m) | Overburden thk. at bottom of layer (m) | $\gamma_{sat}$, ($kN/m^3$) | C($kN/m^2$) | $\phi$(degree) | K |
|---|---|---|---|---|---|---|---|---|
| -2.027 | 9.127 | 9.127 | 0.000 | 9.127 | 18.9 | 120 | 0.00 | 1.50 |

Average N value = 51 Now, corresponding to this N value, $\alpha$ = 0.3

$A_s$ = 3.14159 x 1.9 x 9.127 sq m, or 54.48 $m^2$

$P_{Di}$ at top of pile = (18.9 - 10) x 0, or 0 $kN/m^2$

$P_{Di}$ at bottom of this Layer = (18.9 - 10) x 9.127, or 81.23 $kN/m^2$

Average $P_{Di}$ = 40.615 $kN/m^2$

So, shaft resistance = 1.5 x 40.615 x TAN(0) x 54.48 + 0.3 x 120 x 54.48 = 1961 kN

***LAYER VI***

| Bottom R.L of layer concern | Depth below scour level (m) | Pile shaft length in this layer (m) | Overburden thk. at top of layer (m) | Overburden thk. at bottom of layer (m) | $\gamma_{sat}$, ($kN/m^3$) | C($kN/m^2$) | $\phi$(degree) | K |
|---|---|---|---|---|---|---|---|---|
| -16.450 | 23.550 | 14.423 | 9.127 | 23.550 | 19.4 | 0 | 34 | 1.50 |

Average N value = 100 Now, corresponding to this N value, $\alpha$ = 0.3

$A_s$ = 3.14159 x 1.9 x 14.423 sq m, or 86.09 $m^2$

$P_{Di}$ at top of this Layer = 81.23 $kN/m^2$

$P_{Di}$ at bottom of this Layer = 216.806 $kN/m^2$

Average $P_{Di}$ = 149.018 $kN/m^2$

So, shaft resistance =1.5 x 149.018 x TAN(34) x 86.09 + 0.3 x 0 x 86.09 = 12971 kN

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**M/s Anand Raj Infratech Pvt. Ltd.**

*Project: Geo-Technical Investigation for various locations of Elevated portion for the project of Construction of Ganga Path from Digha to Didarganj at Patna (P164 to P169)*

Total ultimate shaft resistance = 14932.00 kN

## *Calculation of ultimate base resistance*

$C_p$= 0 kN/m$^2$ ϕ(degree)= 35 Nq = 48.5 Nɣ = 48.03

Ultimate base resistance = 3.1415/4 x 1.9 x 1.9 x { 0.5 x 1.9 x ( 19.4 - 10) x 48.03 + 216.806 x 48.5 } = 31028 kN

## *Calculation of safe load carrying capacity*

Ultimate Capacity = Ultimate Base resistance + Ultimate shaft resistance = 45960.00 kN

Considering factor of safety = 2.5

Hence safe pile capacity : 18384.00 kN say 1838 ton

## *Calculation of safe uplift capacity*

Weight of pile = 2550.5 kN (Bouyant weight considered)

Ultimate Shaft Resistance = 14932.00 kN

Considering factor of safety on Shaft Resistance = 2.5 / 0.7 = 3.5

Hence safe uplift capacity = 14932 / 3.5 + Weight of pile = 6817 kN

say 682 ton

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## CALCULATION OF LATERAL LOAD CAPACITY OF PILE (P164)

Pile Type : Bored Cast in situ RC Pile

Cutoff level = 43.55 m

Diameter of pile (B) = **1.9** m

Scour level = 7.1 m

Consider head condition of pile : **fixed**

Grade of concrete M 40

So, E = 33 Gpa = 33000 Mpa (As per Table 6.5, IRC 112-2011)

$I = (\pi / 64) B^4$ = 0.639712 $m^4$

The depth of fixity lies in Layer V

Soil Classification : Preconsolidated clay

Av. Unconfined Compressive Strength = 236 kPa

Referring to IS:2911 (Part 1, Sec 1)-2010, clause C-2.3.2, and Table 4

$k_1$ = 42.5 kN/ $m^3$

$$R = \sqrt[4]{\frac{EI}{KB}}$$ where R is Stiffness factor

$$K = (k_1 x\ 0.3) / (1.5 \text{ x B})$$

Substituting values we get, R = 7.06 m

The piles are connected to rigid pile cap, hence pile head is considered to be fixed

$L_1$ = Cutoff level - Scour level = 36.45 m

From Fig 3, $L_1 / R$ = 5.16

Correspondingly, $L_f / R$ = 1.46

So, $L_f$ = 10.31 m

$L_1+L_f$ = 46.76 m

Now , ref. Cl. C-4.2 , IS : 2911 (pt-I/sec-1) - 2010 , deflection in mm of the pile head may be given as follows :

$$Y = \frac{H(L_1+L_f)^3}{3EI} \quad for\ free\ head\ pile$$

$$= \frac{H(L_1+L_f)^3}{12EI} \quad for\ fixed\ head\ pile$$

Allowing a maximum deflection of pile as 1% of pile diameter at scour level as per Clause 709.3.5.2 of IRC 78 - 2014

Allowable deflection at scour level = 19 mm

So, Allowable deflection at pile head ( by extrapolation) = 86 mm

From the above equation we get allowable horizontal load H = 213 kN

**H =** **21.7** tons

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## CALCULATION OF LATERAL LOAD CAPACITY OF PILE (P165)

Pile Type : Bored Cast in situ RC Pile

Cutoff level = 43.55 m

Diameter of pile (B) = **1.9** m

Scour level = 7.1 m

Consider head condition of pile : **fixed**

Grade of concrete M 40

So, E = 33 Gpa = 33000 Mpa (As per Table 6.5, IRC 112-2011)

$I = (\pi / 64)\, B^4$ = $0.639712\ m^4$

The depth of fixity lies in Layer V

Soil Classification : Preconsolidated clay

Av. Unconfined Compressive Strength = 240 kPa

Referring to IS:2911 (Part 1, Sec 1)-2010, clause C-2.3.2, and Table 4

$k_1$ = 43.2 $kN/m^3$

$$R = \sqrt[4]{\frac{EI}{KB}}$$ where R is Stiffness factor

$$K = (k_1 \, x \, 0.3) / (1.5 \text{ x B})$$

Substituting values we get, R = 7.03 m

The piles are connected to rigid pile cap, hence pile head is considered to be fixed

$L_1$ = Cutoff level - Scour level = 36.45 m

From Fig 3, $L_1 / R$ = 5.18

Correspondingly, $L_f / R$ = 1.46

So, $L_f$ = 10.26 m

$L_1 + L_f$ = 46.71 m

Now , ref. Cl. C-4.2 , IS : 2911 (pt-I/sec-1) - 2010 , deflection in mm of the pile head may be given as follows :

$$Y = \frac{H(L_1 + L_f)^3}{3EI} \quad \text{for free head pile}$$

$$= \frac{H(L_1 + L_f)^3}{12EI} \quad \text{for fixed head pile}$$

Allowing a maximum deflection of pile as 1% of pile diameter at scour level as per Clause 709.3.5.2 of IRC 78 - 2014

Allowable deflection at scour level = 19 mm

So, Allowable deflection at pile head ( by extrapolation) = 86 mm

From the above equation we get allowable horizontal load H = 214 kN

**H = 21.8** tons

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## CALCULATION OF LATERAL LOAD CAPACITY OF PILE (P166)

Pile Type : Bored Cast in situ RC Pile

Cutoff level = 43.55 m

Scour level = 7.1 m

Diameter of pile (B) = **1.9** m

Consider head condition of pile : **fixed**

Grade of concrete M 40

So, E = 33 Gpa = 33000 Mpa (As per Table 6.5, IRC 112-2011)

I = $(\pi / 64)\,B^4$ = 0.639712 $m^4$

The depth of fixity lies in Layer V

Soil Classification : Preconsolidated clay

Av. Unconfined Compressive Strength = 248 kPa

Referring to IS:2911 (Part 1, Sec 1)-2010, clause C-2.3.2, and Table 4

$k_1$ = 44.6 kN/ $m^3$

$$R = \sqrt[4]{\frac{EI}{KB}}$$ where R is Stiffness factor

$$K = (k_1 x\ 0.3) / (1.5 \text{ x B})$$

Substituting values we get, R = 6.97 m

The piles are connected to rigid pile cap, hence pile head is considered to be fixed

$L_1$ = Cutoff level - Scour level = 36.45 m

From Fig 3, $L_1 / R$ = 5.23

Correspondingly, $L_f / R$ = 1.46

So, $L_f$ = 10.18 m

$L_1 + L_f$ = 46.63 m

Now , ref. Cl. C-4.2 , IS : 2911 (pt-I/sec-1) - 2010 , deflection in mm of the pile head may be given as follows :

$$Y = \frac{H(L_1 + L_f)^3}{3EI} \quad for\ free\ head\ pile$$

$$= \frac{H(L_1 + L_f)^3}{12EI} \quad for\ fixed\ head\ pile$$

Allowing a maximum deflection of pile as 1% of pile diameter at scour level as per Clause 709.3.5.2 of IRC 78 - 2014

Allowable deflection at scour level = 19 mm

So, Allowable deflection at pile head ( by extrapolation) = 87 mm

From the above equation we get allowable horizontal load H = 217 kN

**H =** **22.2** tons

## CALCULATION OF LATERAL LOAD CAPACITY OF PILE (P167)

Pile Type : Bored Cast in situ RC Pile

Cutoff level = 43.55 m

Diameter of pile (B) = **1.9** m

Scour level = 7.1 m

Consider head condition of pile : **fixed**

Grade of concrete M 40

So, E = 33 Gpa = 33000 Mpa (As per Table 6.5, IRC 112-2011)

$I = (\pi / 64)\, B^4$ = 0.639712 $m^4$

The depth of fixity lies in Layer V

Soil Classification : Preconsolidated clay

Av. Unconfined Compressive Strength = 242 kPa

Referring to IS:2911 (Part 1, Sec 1)-2010, clause C-2.3.2, and Table 4

$k_1$ = 43.5 kN/ $m^3$

$$R = \sqrt[4]{\frac{EI}{KB}}$$ where R is Stiffness factor

$$K = (k_1 \, x \, 0.3) / (1.5 \text{ x B})$$

Substituting values we get, R = 7.02 m

The piles are connected to rigid pile cap, hence pile head is considered to be fixed

$L_1$ = Cutoff level - Scour level = 36.45 m

From Fig 3, $L_1 / R$ = 5.19

Correspondingly, $L_f / R$ = 1.46

So, $L_f$ = 10.25 m

$L_1 + L_f$ = 46.70 m

Now , ref. Cl. C-4.2 , IS : 2911 (pt-I/sec-1) - 2010 , deflection in mm of the pile head may be given as follows :

$$Y = \frac{H(L_1 + L_f)^3}{3EI} \quad \textit{for free head pile}$$

$$= \frac{H(L_1 + L_f)^3}{12EI} \quad \textit{for fixed head pile}$$

Allowing a maximum deflection of pile as 1% of pile diameter at scour level as per Clause 709.3.5.2 of IRC 78 - 2014

Allowable deflection at scour level = 19 mm

So, Allowable deflection at pile head ( by extrapolation) = 87 mm

From the above equation we get allowable horizontal load H = 216 kN

**H = 22.1** tons

## CALCULATION OF LATERAL LOAD CAPACITY OF PILE (P168)

Pile Type : Bored Cast in situ RC Pile

Cutoff level = 43.55 m

Diameter of pile (B) = **1.9** m

Scour level = 7.1 m

Consider head condition of pile : **fixed**

Grade of concrete M 40

So, E = 33 Gpa = 33000 Mpa (As per Table 6.5, IRC 112-2011)

I = ($\pi$ / 64 ) $B^4$ = 0.639712 $m^4$

The depth of fixity lies in Layer V

Soil Classification : Preconsolidated clay

Av. Unconfined Compressive Strength = 220 kPa

Referring to IS:2911 (Part 1, Sec 1)-2010, clause C-2.3.2, and Table 4

$k_1$ = 39.6 kN/ $m^3$

$$R = \sqrt[4]{\frac{EI}{KB}}$$ where R is Stiffness factor

$$K = (k_1 x\ 0.3) / (1.5 \text{ x B})$$

Substituting values we get, R = 7.19 m

The piles are connected to rigid pile cap, hence pile head is considered to be fixed

$L_1$ = Cutoff level - Scour level = 36.45 m

From Fig 3, $L_1$ / R = 5.07

Correspondingly, $L_f$ / R = 1.48

So, $L_f$ = 10.63 m

$L_1$+$L_f$ = 47.08 m

Now , ref. Cl. C-4.2 , IS : 2911 (pt-I/sec-1) - 2010 , deflection in mm of the pile head may be given as follows :

$$Y = \frac{H(L_1+L_f)^3}{3EI} \quad for\ free\ head\ pile$$

$$= \frac{H(L_1+L_f)^3}{12EI} \quad for\ fixed\ head\ pile$$

Allowing a maximum deflection of pile as 1% of pile diameter at scour level as per Clause 709.3.5.2 of IRC 78 - 2014

Allowable deflection at scour level = 19 mm

So, Allowable deflection at pile head ( by extrapolation) = 84 mm

From the above equation we get allowable horizontal load H = 204 kN

**H = 20.8** tons

## CALCULATION OF LATERAL LOAD CAPACITY OF PILE (P169)

Pile Type : Bored Cast in situ RC Pile

Cutoff level = 43.55 m

Scour level = 7.1 m

Diameter of pile (B) = **1.9** m

Consider head condition of pile : **fixed**

Grade of concrete M 40

So, E = 33 Gpa = 33000 Mpa (As per Table 6.5, IRC 112-2011)

I = ($\pi$ / 64 ) $B^4$ = 0.639712 $m^4$

The depth of fixity lies in Layer V

Soil Classification : Preconsolidated clay

Av. Unconfined Compressive Strength = 230 kPa

Referring to IS:2911 (Part 1, Sec 1)-2010, clause C-2.3.2, and Table 4

$k_1$ = 41.4 kN/ $m^3$

$$R = \sqrt[4]{\frac{EI}{KB}}$$ where R is Stiffness factor

$$K = (k_1 \, x \, 0.3) / (1.5 \times B)$$

Substituting values we get, R = 7.11 m

The piles are connected to rigid pile cap, hence pile head is considered to be fixed

$L_1$ = Cutoff level - Scour level = 36.45 m

From Fig 3, $L_1$ / R = 5.13

Correspondingly, $L_f$ / R = 1.47

So, $L_f$ = 10.45 m

$L_1$+$L_f$ = 46.90 m

Now , ref. Cl. C-4.2 , IS : 2911 (pt-I/sec-1) - 2010 , deflection in mm of the pile head may be given as follows :

$$Y = \frac{H(L_1 + L_f)^3}{3EI} \quad for \ free \ head \ pile$$

$$= \frac{H(L_1 + L_f)^3}{12EI} \quad for \ fixed \ head \ pile$$

Allowing a maximum deflection of pile as 1% of pile diameter at scour level as per Clause 709.3.5.2 of IRC 78 - 2014

Allowable deflection at scour level = 19 mm

So, Allowable deflection at pile head ( by extrapolation) = 85 mm

From the above equation we get allowable horizontal load H = 209 kN

**H =** **21.3** tons

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