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The design and study of structural behaviour of figer jetty in royapuram fishing harbor at Ennore port

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INTRODUCTION

1.1 GENERAL

Chennai is one of the metropolitan cities of India, situated in the eastern coast. Chennai port trust is located at 13°18' east on the eastern seaboard of India. The port is well connected to the Chennai city through a well-developed network of roads in all directions and to other important cities. The airport is located at a distance of about 25km from port of Chennai are interlinked by both road and rail networks in the city. Chennai port, formally known as madras port, is the second largest port of India behind the Mumbai port, and largest port in the Bay of Bengal. This is the third oldest port among the 12 major ports of India situated in the Coromandel Coast in South-East-India. Strategically located and well connected with major parts of the world, it is today the hub port on the Indian subcontinent. Committed to efficiently through innovation the four corner stone's of the port will see much growth in the years to come. The main aims are continuous modernization, efficient services at minimum cost, simple and integrated procedures and user-friendly approach. The port with 3 docks, 24 berths and draft ranging from 12 to 16.5m (39 to 54.1ft) has become a hub port for containers, cars and project cargos in the east coast of India. Chennai fishing harbour handles maximum fishing activities compared to other major fishing harbour for the past 5 yrs. In 2009-10, the port handled 61.06 million tonnes of cargo against 57.49 million tonnes in 2008-09 marking an increase of 6.20 per cent and has set a target to handle75 million tonnes in 2011-2012 and 100 million tonnes in 2015-16.this increasing traffic lead to the construction of finger jetties at royapuram fishing harbour to meet the increasing demand.

Jetties are structures generally built singly or in pair perpendicular to a shore at harbour entrances or river mouths to prevent the accretion of littoral sand drift. Finger jetty is a structure projecting into water in a harbour basin. They are also located in open water outside actual harbours. Finger jetty have berths on two sides and abut land over their fill width. Thus such a structure serves as a platform for loading and unloading cargo. Jetties may also be built into rivers to narrow a wide channel and making it navigable. They can also be built in appropriate places on a river to allow ships to navigate the channel without running around on the sand banks. Here finger jetty is constructed to meet the increasing demand of royapuram fishing harbour by serving as a berthing platform.

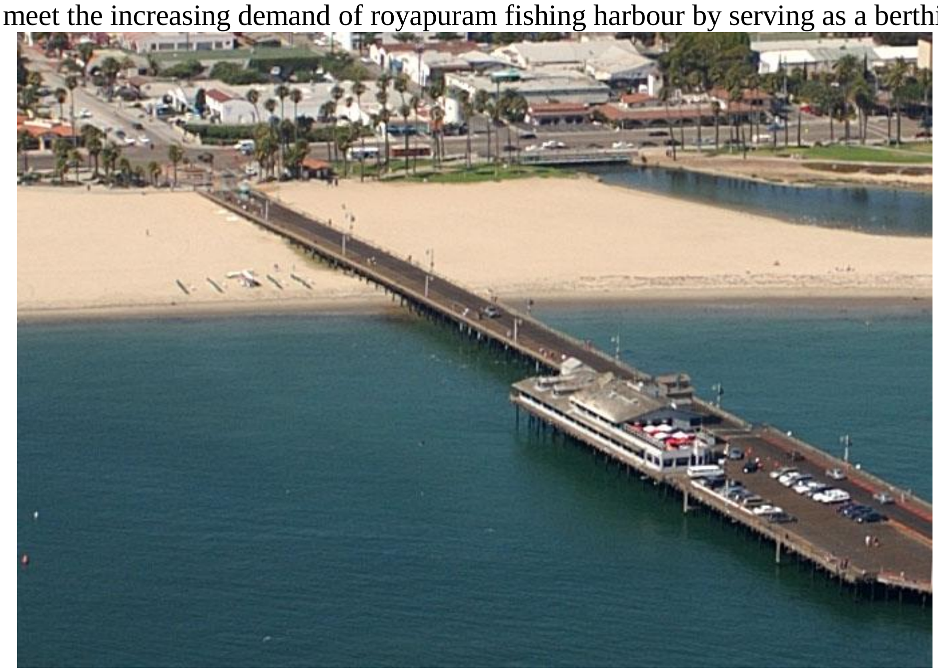

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Figure.1 Finger Jetty

1.2 SITE LOCATION

The finger jetty is proposed to be constructed in royapuram fishing harbour Chennai, Tamilnadu. The Chennai fishing harbour is constructed in Kasimedu at royapuram area facing the Ennore expressway and Suryanarayana Chetty road. This is the place where the first railway station of south India was constructed. Royapuram has a deep history in calculated within itself and has been part of the Chennai city for centuries. The Royapuram fishing harbour plays a major role in the development of the area. This development leads to the construction of finger jetty to meet the demands of fishing as a berthing structure. The various surveys undergone in Royapuram fishing harbour are taken into account for the design and analysis of the finger jetty.

Figure.2 Existing Finger Jetty at Royapuram Fishing Harbour

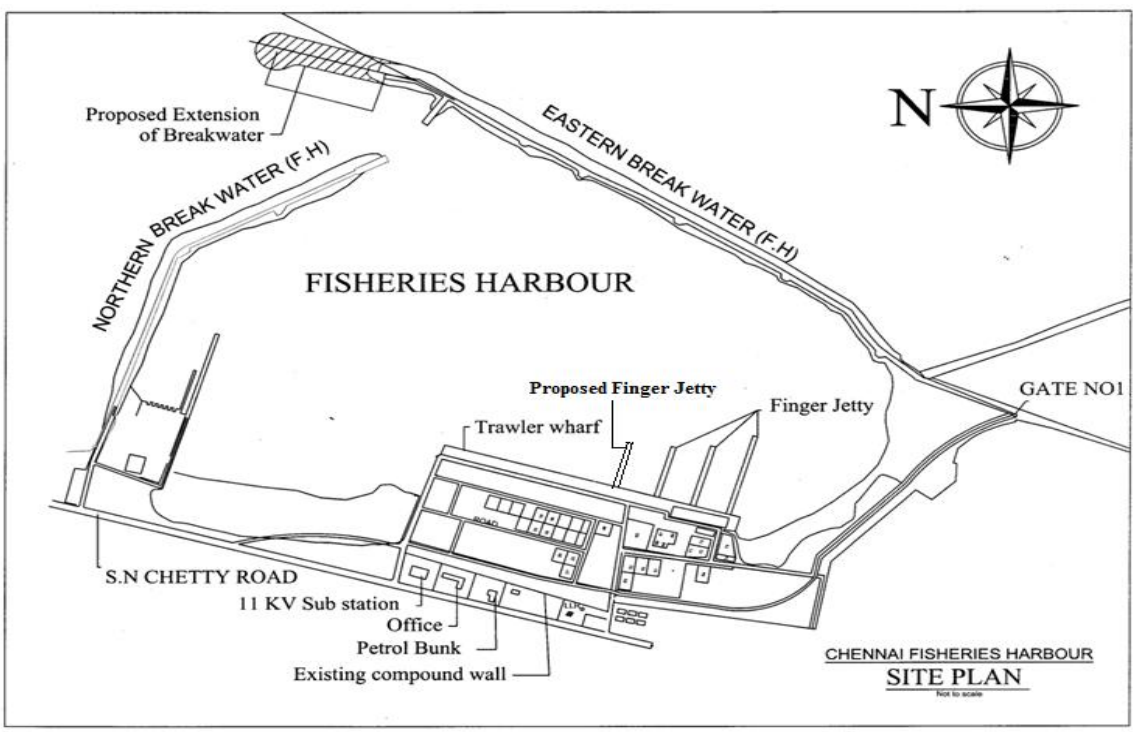

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Figure.3 Royapuram Fishing Harbour

1.3 OBJECTIVES:

- To design the finger jetty at Royapuram fishing harbour to serve as a berthing platform for handling fishing boats.
- To analyse the forces acting on the finger jetty and design efficiency to meet the requirements.

1.4 METHODOLOGY

The following methodology has been adopted for the completion of this project:

- Site investigation.
- Collecting the available information from Chennai Port Trust.
- Preparation of literature review.
- Conducting topographical and Hydrographical survey.
- Collection of IS codes and bore hole data.
- To analyse the various force acting on the structure.
- Analysis of proposed structure using STAAD por.
- Design of different structural components.
- Preparation of design drawings using AUTO CAD, STAAD pro software.
- Preparation of report.

LITERTURE REVIEW

2.1 GENERAL

The data's collected from various books for analysing and designing finger jetty. Various studies carried out have been reviewed to understand the forces acting on it and design economically and safely to meet the requirements. This review of literature study is useful for designing and analysing the finger jetty

2.2 EXTRACTS

S.Narashimhan, & S.Kathiroli, Harbour and Coastal Engineering (Indian Scenario), Volume-I

This book clearly explains the principles and concepts of design of various harbour components especially jetties. It describes the loads and forces acting on a berthing structure along with the calculation of loads from seaside, loads from the deck and loads from landside.

Standards specifications were given for the design of deck slab, beam and piles.

S.Narashimhan, & S.Kathiroli, Harbour and Coastal Engineering (Indian Scenario), Volume-II

This book states that requisite for constructing the berthing platforms at fishing harbour, the various surveys that have to be carried out at the site, soil investigation, and impact on environment. The effect of tides, waves, currents, quality of water, suspended load, salinity and depth of water is also studied for efficient designing and implementation of the project.

IS 456-2000

Indian standard code for plain and reinforced concrete structures

The standard specifications for design of deck slab and beams are considered for the calculation of reinforcements. The following are those specifications.

- Spacing of bars in columns-cl.26.5.3.1, pg48
- Lateral ties in columns-ci.26.5.3.1,pg49
- Check for shear, T_c max value-Table 20,pg 73
- Check for shear, T_c value- table 19,pg73
- Spacing of bars in slab-ci.263.3(b),pg46

IS 2911 (PART I SEC 2)-1979

Indian standard code for design and construction of pile foundation .The pile has been designed by considering the following standard specifications.

- Spacing of piles-cl.5.6,pg 11
- Pile reinforcement-cl.5.11,pg14
- Material-cl.6.3,pg16

IS 4651(PART I TO V)

Indian standard code for planning and design of ports and harbours

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
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The following standard specifications are considered to analyse and design the finger jetty

- Meteorological data-cl.4(part I),pg5
- Oceanographic data –cl.5(part I),pg6
- Geological data-cl.6(part I),pg13
- Soil investigation –cl.7 (part I),pg14
- Vertical live loads–cl.5.1 (part III),pg5
- Berthing load–cl.5.2.1 (part III),pg6
- Mooring loads–cl.5.3.2 (part III),pg10
- Load combinations–cl.5.1,Table1 (part IV),pg14
- Bollard loads–cl.76.4.1(part V),pg23

SITE INVESTIGATION DETAIL

3.1 GENERAL

A brief description of the site including s latitude, longitude, geographical location, accessibility etc, should be given, the area, purpose of the project, historical background should also be described.

3.1.1 Information Availability

Wherever possible, advantage should be taken of existing local data on tides, storms, wave heights, littoral drifts, mud banks, etc, and records of previous investigations in the vanity and information compiled. The behaviour of existing structures which may be of similar nature to the ones proposed, and the influence of the soil and the water on the materials of construction should be studied and recorded. At such places, site exploration, soil investigation and the examination of the materials of construction may be limited to confirm the site data that may be expected in the neighbourhood of proposed work.

3.2 TOPOGRAPHICAL SURVEY

The adequate area covered by the project is the first requirement and should be obtained at the earliest. Survey maps of scale 1:50000 and contour interval of 20m are required for general planning. The recommended scale for survey maps detailed planning are 1:50000 1:2500 and 1:1250 with contour interval of 1m.in no case shall the survey maps for detailed planning be scale less than 1:5000 with contour interval of 1m,depending however on topography of the area. In our project the lay out will prepare 1:5000 scale.

3.3 HYDROGRAPHIC SURVEY

As will be seen, survey planning is a complex process requiring considerable attention to detail, a flexible approach, good management and effective decision making. If the planning is through, the chances are that the survey will good too. Hydro-graphic survey charts for the coastal region extending to continental shelf (up to the line at which depth of water is 200m) and scale 1:50000 or 1:25000 (whichever is available) are required for general planning shall be drawn PO a scale as large as possible but in no case shall be less than 1:5000. Recommended scales are 1:2500 and 1:12502 in our project depth will be from 14m to 25m is in port.

3.4 METEROLOGICAL DATA

Meteorological data can be collected from meteorological department they cover the following:

- Winds
- Cyclones
- Rainfall
- Relative humidity
- Temperature
- Barometric pressure

3.4.1 Winds

For preliminary studies, information may be obtained from in the available meteorological records of the area. Recording of velocity and direction of winds at the proposed site shall be obtained by installing continuous and self recording anemometers. The data shall be obtained by collected for at least a period of one year and shall also be correlated with the data available at places nearest to the site. From the data collected wind roses should be prepared for each month in the form presented as shown in cyclones-information should be compiled regarding track of cyclones. The velocity of maximum winds, radius of maximum wind velocity duration, pressure drop at cyclones centre and speed of movement of cyclone centre is required. From this the design cyclone is adopted and waves that could be incident at a place computed. Determine the most severe wind condition that might occur at the site room historical meteorological records. Wind direction and its effect on low speed manoeuvrings should also be evaluated

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
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Vol. 36 Issue 1, Jan-June 2026, Pages: 357-394

3.4.2 Rainfall

Data on rainfall as available should be collected from Indian meteorological department for a minimum period of 3years as follows:

- Annual average rainfall
- Months in which the maximum rainfall occurs
- Maximum intensity of rainfall duration
- Average number of wet days in a year

Adequate surface drainage shall be provided which is capable of draining the water resulting from a maximum probable rainfall without eroding the perimeter land and diverting any possible inflows from then the surroundings land or safely through the craft harbour complex.

3.4.3 Relative Humidity

Data on the maximum, mean and minimum relative humidity for every month shall be obtained for minimum period of 5years.

3.4.4 Temperature

The normal ambient air temperatures with emphasis on daily and seasonal variation may be noted.

3.4.5 Barometric Pressures

Data on monthly average barometric pressures should be collected for the nearest site from the Indian meteorological department.

3.5 OCEANOGRAPHIC DATA

Oceanographic data to be obtained as following:

- Tides
- Waves
- Strom surges
- Currents
- Salinity
- Sea water temperature
- Suspended load
- Sea bed

3.5.1 Tides

Record of the tidal information, over as long a period as possible from port authorities or geodetic and research branch, survey of India or hydro graphic department of Indian navy, including any local information specific to the site of the works should be obtained. Based on this the data as given in fig.3 should be compiled and presented.

- Data over a full metric cycle of 19years will be useful
- Information on tidal bores, if any, in the area should also be collected and included in the above data.
- Ocean tides may attend considerable length upstream from the mouth of large rivers and are semi-predictable for most harbour sites.
- For any coastal site, it is possible to interpolate predictions for the site from values given in the national oceanic and atmospheric administration tide prediction tables for two nearest stations.
- Extremes of predicted spring tides provide criteria for small craft harbour design accommodating any water level fluctuations that may occur

3.5.2 Waves

For planning and preliminary design purposes, wave data collected by ships plying in the area can be obtained from the India metrological department. Wave heights can also be computed by hind casting studies using the storm data and synoptic charts from India meteorological department .For important project wave records may be installed and information collected on wave height and period of at least two years. Separate wave recorders should be installed foe long period and short period waves. From the Indian tide table published yearly by the survey of India, Dehra Dun.

3.5.3 Currents

The direction, strength and duration of current during complete tidal cycles at maximum spring and neap tide over a year should be recorded. In riverine ports where there is a fresh water discharge, current pattern at highest expected flood should be assessed and recorded, current pattern at the specific location of structures, should be assessed for a period of at least one year for purposes of alignment of berth, dock entrances, moorings, etc. Current readings should be taken at a maximum of three points preferably at depths of 0'1d, 0'5d and 0'9d where d is the depth of water, and recorded.

3.5.4 Sea Bed

Classification of sea bed material in the vicinity of structured and approaches and up to an area in the sea where depth of water is 6m more than the maximum depth for which the harbour is being designed, should be ascertained from hydro graphic survey charts.

3.5.5 Suspended Load, Salinity and Temperature

These observations shall be carried out both during the dry and wet seasons at different locations in the harbour and channels over the full tidal cycle during neap and spring tides. The suspended load and salinity and suspended load shall be measured depths of 0'1d, 0'5d and 0'9d below the water level (water d is the depth of water) at every our" during the tide cycle. Salinity may also be measured during these observations. The quantum of littoral drifts may be estimated from observations at nearby harbour sites over a period of at least one year. The direction of drifts at the site may be ascertained from radio florescent tracer studies and other observations of the coast line in the vicinity of the structure, such as dredging records, shore line changes, accretion erosion, wave data and the orientation of river mouths. These studies may be conducted up to a location where the depth of water is 12m more than the design depth.

3.5.6 Strom Surges

- Surge oscillations in the basin cause stress in mooring lines and anchorage systems, and can make boat manoeuvrings in to slip difficult
- Vertical basin walls are usually more desirable than poorly reflective basin perimeters, and rectangular basins are more efficient than irregular shaped basins for berthing arrangements.
- Most re-creational boats in a small craft harbour are insensitive to long period surging. Larger craft may experience fender and mooring line difficulties under long period surging.

3.6 GEOLOGICAL DATA

3.6.1 Geophysical Survey

The geo physical survey method of locating base rock aims at giving a continuous record of strata .geophysical survey by seismic refraction method may also be resorted to find out more reliable information about the strata. This may be suitably used to determine the thickness of various sediment layers and deposition of underlying bed rock. It may also be used to map the top of the first compacted layer and to check the water depths. A first interpretation can be made on the spot from the onboard cross sections. Consequently, the survey programmed can be modified, while operating. Finally, a geophysical interpretation is made by preparing a location map and a cross section showing the stratification of various layers and pointing out the main geological features. During or after the survey it is common practice to select some locations for shallow deep coring.

3.6.2 Complication of Geological Data

The following data about the geology of the area should be complied:

- Type of bedrock including information on its origin and method of formation
- Any faults, fissures, folds and other unconformities in the area of the project
- Crushing strength and other properties of the rock in the project area its suitability for use in marine works

3.7 SOIL INVESTIGATION

3.7.1 Earlier Uses of the Site

In a site which has been partially developed enquiries be made regarding the past structures layout of pipes and obstructions likely to be met in the area for new works. Enquires should also be made regarding old creek lets, excavated pits etc, which might have either silted up or reclaimed. This information will be particularly useful in deciding the number and location of trial pits and borings; and assessing in general, the likely soil strata that may be met with.

3.7.2 Subsurface Exploration

- It is not practicable to standardize the disposition and spacing of borings required for subsurface investigations as these depend upon the type of structure and nature of the site.

- Broadly speaking the number of bore holes should be sufficient to give a picture of probable variation in the subsurface strata over the site and their depth should be such as to include all strata likely to; illicit the stability of the structure.
- A few subsurface soundings like the standard penetration test and the cone penetration test may be conducted in conjunction with at least one bore hole with sampling for correlation of soil type with the penetration resistance obtained from soundings.
- The subsoil investigation should be carried out generally according to IS1892-1962
- Initially the main borings may be along the top edge of the shore
- These borings may be spaced 50m apart and taken to a depth of 3m in to hard strata of depth equal to twice the difference in the elevation ground surface either side of the structure
- In a few cases, the borings may be taken deeper to investigate the nature of the underlying strata
- It is desirable to use large diameter bores in reclaimed areas and where embedded boulder layers are encountered, depending on the size of the project.
- The intermediate borings of the second order may be drilled only when there is a considerable change in the upper layers.
- Normally, they are also located at 50m spacing but off areas .the spacing could be reduced if the subsoil conditions so require it.
- The boring depth depends upon the result of preceding borings and should extend at least to twice the design depth.
- Depth of exploration for channels and dredging-for this purpose the bore holes should be extended to a known geological formation below dredged depth whichever is less.
- Bore hole data should be presented in the form of bore hole logs along with important longitudinal and cross sectional soil profiles and bore holes location plan

3.8 MEAN GROUND WATER LEVEL IN TIDAL AREAS

This should be ascertained over a yearly cycle on the entire site under reference or may be assumed to lift at about 0’3m above the mean tides water level. With a stronger ground water influx from the short, the mean water level may be higher as in rainy season in area with poor characteristics. The results of field test and those obtained from laboratory investigations should be compiled and properties of identified strata tabulated for use in design work

3.9 IMPACT ON ENVIRONMENT

Consider the following environmental issues and concerns:

- Disposal of dredged material.
- Water quality
- Preservation of ecology
- Aesthetics

3.10 FINANCIAL AND ECONOMICAL OF PORT AND HARBOUR

- Total worth of project
- Private investment anticipated
- Past year project cost
- Present year cost of project
- Future project identified
- Development of common infrastructure
- Job opportunity to neighbourhood people directly indirectly.

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LAYOUT AND FORCES

4.1 GENERAL

The conceptual layout of berthing structure depends on various factors such as type of berthing structures, type of vessel and its dimensions, tidal and wave characteristics and type of vessel handling equipment. The layout includes length, width, dredge level, spacing of bollards and fenders and configuration of the structure. The configuration of the structure includes arrangement of piles, deck system and dimension of various structural members.

The size of pier and wharf should be decided on the basis of dimension of the largest vessel it is required to handle, the quay area required for transit shed, width if apron required to accommodate mooring facilities and utility services.

4.1.1 Length of Berthing Structure

The minimum length of berthing structure should be sufficient for mooring the largest ship expected to arrive the length of pier or wharf meant for a single vessel should be 45m to 60m more than the overall length of the design ship. For long continuous wharf for large ocean giving vessels, the recommended length of the berth should not be less than the length of the design vessel plus 10 percent subject to minimum of 15m. It may be increased to 20%, if the berth is exposed to strong winds and tidal conditions (IS 4651-part V, 1980).

4.1.2 Width of Berthing Area

The minimum width of the pier should be calculated on the basis of the area required for transit shed. The width of berthing area should not be less than 1.15 times the beam of the design vessel (IS 4651-part V, 1980).

4.1.3 Depth of Water

The minimum depth of water within the harbour should not be less than the loaded draught of the largest vessel plus an allowance of 0.6 to 0.75m for under keel clearance. Where harbour basin is hard, the allowance can be increased to 1m (IS 4651-part V, 1980).

4.1.4 Deck Elevation

The deck elevation should normally be at or above highest high water spring plus half height of an incident wave at the berth location plus a clearance of 1m (IS 4651-part V, 1980).

4.1.5 Fenders and Bollards

The important function of a fender is to absorb the kinetic energy from the impact of berthing vessel and also the chatter of moored vessel to avoid damage to the vessel as well as the structure. Functionally, fenders shall accomplish the following purpose:

- Absorb the berthing energy to impact of vessel and transmit a designed or calculated thrust to the structure.
- Hold the vessel off the face of the structure and avoid rubbing against the structure and consequent damages to the vessel and the structure.
- Impact the thrust from the berthing loads to the structure at predetermined or designed points.

The fenders with low reaction per absorbed unit of energy can be preferred. The berthing force depends on the load deflection characteristics of a fender system. A factor of safety 1.4 should be over the ultimate energy absorption capacity of fenders (IS 4651-part V, 1980).

4.2 FORCES ON BERTHING STRUCTURE

The berthing structures are subjected to:

- Berthing force
- Mooring force
- Dead load
- Live load
- Active earth pressure if the earth retains the earth
- Environmental forces
- Seismic force

4.3 CLASSIFICATION OF LOADS

The various loads acting on the berthing structure are classified as:

- Loads from seaside
- Loads from deck
- Loads from landside

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Vol. 36 Issue 1, Jan-June 2026, Pages: 357-394

4.3.1 Loads from the Seaside

The horizontal forces from the seaside includes wave forces, forces caused by berthing and vessel's pull from bollard, the forces caused by berthing of vessel and forces caused by vessels lying at the berth (due to wind, waves and current on the vessels). The vertical forces from sea side are due to the vessels hanging upon the fendering system, vertical component of the forces from bollards etc.

4.3.2 Loads from the Deck

The important loads from the deck are the vertical loads caused by self weight of the deck, superimposed loads from building and handling equipment. Horizontal loads are mostly due to wind forces on buildings and the structure and also due to the breaking force of cranes.

4.3.3 Loads from Landside

The horizontal loads are caused from the landslide due to the earth pressures and differential water pressure. The vertical loads are caused by the weight of filling and superimposed load on filling.

4.4 LIVE LOAD

4.4.1 Vertical Live Load

Surcharges due to stored and stacked material such as general cargo, bulk cargo, containers and loads from vehicular traffic of all kinds including trucks, trailers railway cranes, containers handling equipment and construction plants, constitute vertical live loads.

4.5 BERTHING LOAD

When an approaching vessel strikes a berth horizontal forces acts on the berth. The magnitude of this force depends on the kinetic energy that can be absorbed by the fendering system. The reaction force for which the berth is to be designed can be obtained and deflection-reaction diagrams of the fendering system chosen. These diagrams are obtainable from fender manufacturers. The kinetic energy (E) imparted to a fendering system, by a vessel moving with a velocity V is given by,

$$E = (W_D \times V^2 \times C_m \times C_s \times C_e)/2g$$

Where,

E = berthing energy in T-m.
W_D = displacement tonnage in T.
V = berthing velocity in m/sec.
C_m = mass coefficient.
C_s = eccentricity coefficient.
C_e = softness coefficient.
g = acceleration due to gravity m/sec.

4.6 MOORING LOAD

The mooring loads are the lateral loads caused by the mooring lines when they pull the ship into or along the dock or hold it against the forces of winds or current.

4.6.1 Forces due to Current

Pressure due to current will be applied to the area of the vessel below the water line when fully loaded. It is approximately equal to ($wv^2/2g$) per square meter of area, where v is the velocity in m/s and w is the unit weight of water in T/m^3. The ship is generally berthed parallel to the current. With strong current and where berth alignment materially deviates from the direction from the direction of the current, the likely force should be calculated by recognized method and into account.

LOAD CALCULATIONS AND STADD ANALYSIS

5.1 ASSUMPTIONS

1. Concrete used for piles and super structure is M_{35} grade conforming to IS 456-2000.
2. Reinforcement used consists of HYSD bars conforming to IS 1786.
3. The live load on the deck is 1t/m^2.
4. The displacement tonnage (DT) of the fishing vessel considered for calculation is 400T and the bollard pull is 3T.
5. The design is based on limit state design.
6. The analysis is carried out using STAAD pro.
7. The fixity length below design dredge level is assumed as spring supports.
8. The design dredged bed level is -6.00RL.

9. The codes referred are:
- IS 456-2000
- IS 2911-(part I sec2) 1979
- IS 4651-part I to V

Live load taken = 1 T/m^2 (for fishing berths) as per IS 4651 (part-3)-1974, pg-5 (table1)

5.2 LOAD CALCULATION

5.2.1 Load on Facia Beam

Dead Load

1. Wearing coat = 0.95x1x0.05x25 = 1.19 kN/m
2. Deck slab = 0.95x1x0.15x25 = 3.56 kN/m
3. Precast plank = 0.45x1x0.06x25 = 0.675 kN/m
4. Self-weight of facia beam = 0.5x1x25 = 12.5 kN/m

Therefore Total dead load = 17.98 kN/m

Live Load

1x0.95x10 = 9.5 kN/m

5.2.2 Load on Secondary Beam 1

Dead Load

1. Wearing coat = 1x1.334x0.05x25 = 1.667 kN/m
2. Deck slab = 1x1.334x0.15x25 = 5.0025 kN/m
3. Self-weight of the beam =0.1575x25 = 3.94 kN/m
4. Precast plank = 1x1.484x25x0.06 = 1.9245 kN/m

Total dead load = 12.8 kN/m

Live Load

1x1.334x10 = 13.34 kN/m

5.2.3 Load on Secondary Beam 2

Dead Load

1. Wearing coat = 1x1.468x0.05x25 = 1.835 kN/m
2. Deck slab = 1x1.468x0.15x25 = 5.505 kN/m
3. Self-weight =25x.1575 = 3.94 kN/m
4. Precast plank = 1x0.06x1.168x25 = 1.752 kN/m

Total dead load = 13.03 kN/m

Live Load

1x1.468x10 = 14.68 kN/m

5.2.4 Area of Secondary Beam

i.0.3x0.5 = 0.15m^2

ii.2x(1/2)x0.05x0.05 = 0.0075m^2

Total area = 0.1575m^2

5.2.5 Total Dead Load of the Structure

1. Pile = (1/3) (30x((π/4)x0.6^2x22.40x25)) = 1583.33 kN
2. Pile cap = 30x1x1x0.2x25 = 150 kN
3. Transverse beam = 10x7.5x0.5x1.15x25 = 1078.125 kN
4. Secondary beam = 9x4x4.5x0.158x25 = 640 kN
5. Deck = 45.5x7.5x0.15x25 = 1279.7 kN
6. Wearing coat = 45.5x7.5x0.05x25 = 426.56 kN
7. Precast plank

i.9x3x4.5x1.167x0.06x25 = 212.7 kN

ii.9x2x4.5x0.9x0.06x25 = 109.35 kN

Total load = 5479.77 kN

5.2.6 Total Live Load

45.5x7.5x10 = 3412.5 kN
50% of live load = 1706.25 kN

5.2.7 Seismic Force Calculation

Formula

Seismic force = A_h x (total dead load + 50% of live load)

Where,

A_h = $(ZIS_a)/2Rg$ (from IS1893)
Z = 0.10 (Chennai zone III)
I = 1.0
R = 5 (from table-5, IS 1893)
T = 0.35 sec
S_a/g = 2.5 (from graph, IS 1893)

Calculation

A_h = (0.16x1x2.5)/ (2x5) = 0.04
Total seismic force = 0.04x (5479.77 + 1706.25)
= 287.44 kN

Seismic force at individual joint = 287.44/ no. of joints
= 287.44/30
= 9.6 kN

5.2.8 Berthing Load

(From IS 4651 (part III)-1974, cl.5.2.1)

$E = (W_D x V^2 x C_m x C_e x C_s)/2g$

Where,

W_D = displacement tonnage (DT) of the vessel in tonnes.
V = velocity of vessel in m/s, normal to the berth (from table-2 of IS 4651, part III) where V = 0.2 m/s
g = acceleration due to gravity in m/s^2 = 9.81 m/s^2
C_m = mass coefficient (from cl.5.2.1.2)
C_m = 1 + (2b/B)
= 1 + ((2x3.5)/7

Vessel Data

L =40m
DT =400T
GRT =200T
WIDTH =7m
DEPTH =3.5m
WD =400t
C_e =Eccentricity co-efficient (from cl.5.2.1.3.a)
C_e = $1 + (l/r)^2 \sin^2\theta/1+ (l/r)^2$ from(cl.5.2.1.3.b)
θ =10 from (cl.5.2.1.3(c))
l =L/4=40/4=10m
Radius of vessel (R) =L/4=10m=l/r =10/10=1
Therefore from table 3 of IS 4651(PART 3)
C_e =0.51
C_s =softness co-efficient .From cl5.2.1.4 of IS4651 (part 3)
Therefore C_s =0.95(higher safety margin)
E =$400*(0.2)^2/2*9.81 *2*0.51*0.95$
=0.79Tonns-m
Say 0.8t-m =8KNm

5.2.9 Mooring Force

Line pull is taken as 9T, since three numbers of bollards is used mooring load is taken as 3T=30k.

5.2.10 Wind Force

The effect of wind might not be predominant since most of the structure is constructed under water.

5.2.11 Hydrostatic Force

The effect of differential water pressure on the pile is very less or nil.

5.3 STADD ANALYSIS OF FINGER JETTY

5.3.1 Loads

1. D.L = Dead load
2. L.L = Live load
3. B.L =Berthing load
4. M.L= Mooring load
5. S.L = Seismic load

5.3.2 Load Combinations

1. 1.0 D.L + 1.0 L.L
2. 1.0 D.L + 1.0 L.L + 1.0 M.L
3. 1.0 D.L + 1.0 L.L + 1.0 B.L
4. 1.5 [D.L + L.L + B.L]
5. 1.5 [D.L + L.L + M.L]
6. 1.2 [D.L + L.L]
7. 1.2 [D.L + L.L] + 1.5 EQx
8. 1.2 [D.L + L.L] + 1.5(-EQx)
9. 1.2 [D.L + L.L] + 1.5EQz
10. 1.2 [D.L + L.L] + 1.5(-EQz)
11. 0.9 [D.L + L.L] + 1.5 EQx
12. 0.9 [D.L + L.L] + 1.5 (-EQx)
13. 0.9 [D.L + L.L] + 1.5 EQz
14. 0.9 [D.L + L.L] + 1.5(-EQz)

5.3.3 Analysis Results

5.3.3.1STAAD Editor

```
STAAD SPACE
START JOB INFORMATION
ENGINEER DATE 11-Sep-12
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES
1 0 0 0; 2 0 0 3.25; 3 0 0 6.5; 4 5 0 0; 5 5 0 3.25; 6 5 0 6.5; 7 10 0 0;
8 10 0 3.25; 9 10 0 6.5; 10 15 0 0; 11 15 0 3.25; 12 15 0 6.5; 13 20 0 0;
14 20 0 3.25; 15 20 0 6.5; 16 25 0 0; 17 25 0 3.25; 18 25 0 6.5; 19 30 0 0;
20 30 0 3.25; 21 30 0 6.5; 22 35 0 0; 23 35 0 3.25; 24 35 0 6.5; 25 40 0 0;
26 40 0 3.25; 27 40 0 6.5; 28 45 0 0; 29 45 0 3.25; 30 45 0 6.5;
31 0 -16.175 0; 32 0 -16.175 3.25; 33 0 -16.175 6.5; 34 5 -16.175 0;
35 5 -16.175 3.25; 36 5 -16.175 6.5; 37 10 -16.175 0; 38 10 -16.175 3.25;
39 10 -16.175 6.5; 40 15 -16.175 0; 41 15 -16.175 3.25; 42 15 -16.175 6.5;
43 20 -16.175 0; 44 20 -16.175 3.25; 45 20 -16.175 6.5; 46 25 -16.175 0;
47 25 -16.175 3.25; 48 25 -16.175 6.5; 49 30 -16.175 0; 50 30 -16.175 3.25;
51 30 -16.175 6.5; 52 35 -16.175 0; 53 35 -16.175 3.25; 54 35 -16.175 6.5;
55 40 -16.175 0; 56 40 -16.175 3.25; 57 40 -16.175 6.5; 58 45 -16.175 0;
59 45 -16.175 3.25; 60 45 -16.175 6.5; 61 0 0 -0.5; 62 5 0 -0.5; 63 10 0 -0.5;
64 15 0 -0.5; 65 20 0 -0.5; 66 25 0 -0.5; 67 30 0 -0.5; 68 35 0 -0.5;
69 40 0 -0.5; 70 45 0 -0.5; 71 0 0 7; 72 5 0 7; 73 10 0 7; 74 15 0 7;
75 20 0 7; 76 25 0 7; 77 30 0 7; 78 35 0 7; 79 40 0 7; 80 45 0 7;
81 0 0 3.9835; 82 5 0 3.9835; 83 10 0 3.9835; 84 15 0 3.9835; 85 20 0 3.9835;
86 25 0 3.9835; 87 30 0 3.9835; 88 35 0 3.9835; 89 40 0 3.9835; 90 45 0 3.9835;
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MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 357-394

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MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 357-394

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E 2.17185e+007
POISSON 0.17
DENSITY 23.5616
ALPHA 1e-005
DAMP 0.05
END DEFINE MATERIAL
MEMBER PROPERTY AMERICAN
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79 80 160 TO 195 PRIS YD 1.15 ZD 0.5
86 88 90 92 94 96 98 100 102 105 107 109 111 113 115 117 119 121 124 126 128 -
130 132 134 136 138 140 143 145 147 149 151 153 155 157 -
159 PRIS YD 0.65 ZD 0.3
CONSTANTS
MATERIAL CONCRETE ALL
SUPPORTS
121 TO 150 FIXED BUT FY MX MY MZ KFX 42080 KFZ 42080
151 TO 180 FIXED BUT FY MX MY MZ KFX 36820 KFZ 36820
181 TO 210 FIXED BUT FY MX MY MZ KFX 26300 KFZ 26300
211 TO 240 FIXED BUT FY MX MY MZ KFX 21039 KFZ 21039
241 TO 270 FIXED BUT FY MX MY MZ KFX 15780 KFZ 15780
271 TO 300 FIXED BUT FY MX MY MZ KFX 2920 KFZ 2920
301 TO 360 FIXED BUT FY MX MY MZ KFX 1460 KFZ 1460
31 TO 60 FIXED
LOAD 1 LOADTYPE None TITLE LOAD CASE 1
SELFWEIGHT Y -1 LIST 1 TO 30 79 80 86 88 90 92 94 96 98 100 102 105 107 109 -
111 113 115 117 119 121 124 126 128 130 132 134 136 138 140 143 145 147 149 -
151 153 155 157 159 TO 435
LOAD 2 LOADTYPE Dead TITLE LOAD CASE2
MEMBER LOAD
79 80 160 TO 175 UNI GY -17.93

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 357-394

124 126 128 130 132 134 136 138 140 143 145 147 149 151 153 155 157 -
159 UNI GY -13.54
86 88 90 92 94 96 98 100 102 105 107 109 111 113 115 117 119 121 UNI GY -13.03
LOAD 3 LOADTYPE Live TITLE LOAD CASE3
MEMBER LOAD
124 126 128 130 132 134 136 138 140 143 145 147 149 151 153 155 157 -
159 UNI GY -13.34
86 88 90 92 94 96 98 100 102 105 107 109 111 113 115 117 119 121 UNI GY -14.6
79 80 160 TO 175 UNI GY -9.5
LOAD 4 LOADTYPE Live TITLE LOAD CASE4
JOINT LOAD
76 FZ -70
LOAD 5 LOADTYPE Live TITLE LOAD CASE5
JOINT LOAD
73 76 79 FZ 30
LOAD 6 LOADTYPE Live TITLE LOAD CASE6
JOINT LOAD
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1 3 TO 30 FZ -9.6
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LOAD COMB 101 COMBINATION LOAD CASE101
1 1.0 2 1.0 4 1.0
LOAD COMB 102 COMBINATION LOAD CASE102
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LOAD COMB 202 COMBINATION LOAD CASE202
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1 1.2 2 1.2 6 1.5
LOAD COMB 204 COMBINATION LOAD CASE204
1 1.2 2 1.2 6 1.5
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1 1.2 2 1.2 6 1.5
LOAD COMB 206 COMBINATION LOAD CASE206
1 1.2 2 1.2 6 1.5
PERFORM ANALYSIS
FINISH

5.3.3.2 STAAD Output

Facia Beam

```
=========================================================
            BEAM NO      241   DESIGN   RESULTS
       M40                Fe415 (Main)            Fe415 (Sec)
     LENGTH:  5000.0 mm      SIZE:   500 mm X 1000 mm   COVER: 25 mm
```

Table-1 Design Load Summary of Facia Beam (KN MET)

```
  ---------------------------------------------------------------------------------------
  SECTION | FLEXURE (Maximum Sagging/Hogging moments)| SHEAR
  (in mm) |    P        MZ        MX     Load Case  |    VY        MX    Load Case
  ---------------------------------------------------------------------------------------
```

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 357-394

0.0	0.00	0.37	6.64	6	68.79	15.02	200
	0.00	-15.77	15.02	200			
416.7	0.00	10.06	15.02	6	55.18	15.02	200
	0.00	0.00	0.00	200			
833.3	0.00	30.21	15.02	6	41.57	15.02	200
	0.00	0.00	0.00	200			
1250.0	0.00	44.70	15.02	6	27.95	15.02	200
	0.00	0.00	0.00	200			
1666.7	0.00	53.51	15.02	6	14.34	15.02	200
	0.00	0.00	0.00	200			
2083.3	0.00	56.65	15.02	6	0.73	15.02	200
	0.00	0.00	0.00	200			
2500.0	0.00	54.11	15.02	6	-12.89	15.02	200
	0.00	-0.01	6.64	200			
2916.7	0.00	45.91	15.02	6	-26.50	15.02	200
	0.00	-0.07	6.64	200			
3333.3	0.00	32.03	15.02	6	-40.11	15.02	200
	0.00	-0.13	6.64	200			
3750.0	0.00	1.48	15.02	6	-53.73	15.02	200
	0.00	-0.20	6.64	200			
4166.7	0.00	0.00	0.00	6	-67.34	15.02	200
	0.00	-12.74	15.02	200			
4583.3	0.00	0.00	0.00	6	-80.95	15.02	200
	0.00	-43.63	15.02	200			
5000.0	0.00	0.00	0.00	6	-94.56	0.00	200
	0.00	-80.20	15.02	200			

Table-2 Summary of Reinf Area of Facia Beam (Sq.mm)

SECTION (in mm)	TOP reinf/ provided reinf	BOTTOM reinf/ provided reinf	STIRRUPS (2 legged)
0.0	901.20/1206.37 (6- 16i)	901.20/1884.96 (6- 20i)	8i @ 100mm
416.7	901.20/1206.37 (6- 16i)	901.20/1884.96 (6- 20i)	8i @ 100mm
833.3	901.20/1206.37 (6- 16i)	901.20/1884.96 (6- 20i)	8i @ 100mm
1250.0	0.00/402.12 (2- 16i)	901.20/1884.96 (6- 20i)	8i @ 100mm
1666.7	0.00/402.12 (2- 16i)	901.20/1884.96 (6- 20i)	8i @ 100mm
2083.3	0.00/402.12 (2- 16i)	901.20/1884.96 (6- 20i)	8i @ 100mm
2916.7	901.20/1206.37 (6- 16i)	901.20/1884.96 (6- 20i)	8i @ 100mm
3333.3	901.20/1206.37 (6- 16i)	901.20/1884.96 (6- 20i)	8i @ 100mm
3750.0	901.20/1206.37 (6- 16i)	901.20/1884.96 (6- 20i)	8i @ 100mm
4166.7	901.20/1206.37 (6- 16i)	901.20/1884.96 (6- 20i)	8i @ 100mm
4583.3	1024.10/1206.37 (6- 16i)	0.00/628.32 (2- 20i)	8i @ 100mm
5000.0	1024.10/1206.37 (6- 16i)	0.00/628.32 (2- 20i)	8i @ 100mm

SHEAR DESIGN RESULTS AT DISTANCE d (EFFECTIVE DEPTH) FROM FACE OF THE SUPPORT
SHEAR DESIGN RESULTS AT 740.0 mm AWAY FROM END SUPPORT
VY = 44.61 MX = 15.02 LD= 200
Provide 2 Legged 8í @ 100 mm c/c

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 357-394

Transverse Beam

BEAM NO 272 DESIGN RESULTS
M40 Fe415 (Main) Fe415 (Sec)
LENGTH: 5000.0 mm SIZE: 500 mm X 500 mm COVER: 25 mm

Table-3 Design Load Summary of Transverse Beam (KN m)

SECTION (in mm)	FLEXURE (Maximum Sagging/Hogging moments) P	MZ	MX	Load Case	SHEAR VY	MX	Load Case
0.0	0.00	0.00	0.00	6	81.19	1.15	200
	0.00	-38.46	1.15	200			
135.4	0.00	0.00	0.00	6	77.97	1.15	200
	0.00	-27.68	1.15	200			
270.8	0.00	0.00	0.00	6	74.74	1.15	200
	0.00	-17.34	1.15	200			
406.2	0.00	2.41	1.12	6	71.51	1.15	200
	0.00	-7.44	1.15	200			
541.7	0.00	11.22	1.12	6	68.28	1.15	200
	0.00	-6.13	0.02	200			
677.1	0.00	19.60	1.12	6	65.06	1.15	200
	0.00	-5.69	0.02	200			
812.5	0.00	27.53	1.12	6	61.83	1.15	200
	0.00	-5.26	0.02	200			
947.9	0.00	35.03	1.12	6	58.60	1.15	200
	0.00	-4.82	0.02	200			
1083.3	0.00	42.10	1.12	6	55.37	1.15	200
	0.00	-4.39	0.02	200			
1218.8	0.00	48.72	1.12	6	52.14	1.15	200
	0.00	-3.95	0.02	200			
1354.2	0.00	54.91	1.12	6	48.92	1.15	200
	0.00	-3.52	0.02	200			
1489.6	0.00	60.66	0.00	6	-80.95	15.02	200
	0.00	-3.63	1.12	200			
1625.0	0.00	65.98	0.02	6	42.54	0.00	200
	0.00	-2.64	0.02	200			

Table-4 Summary of Reinf Area of Transverse Beam (Sq.mm)

SECTION (in mm)	TOP reinf/ provided reinf	BOTTOM reinf/ provided reinf	STIRRUPS (2 legged)
0.0	452.65/603.19 (3- 16i)	0.00/402.12 (2- 16i)	8i @ 180mm
135.4	452.65/603.19 (3- 16i)	0.00/402.12 (2- 16i)	8i @ 180mm
270.8	452.65/603.19 (3- 16i)	0.00/402.12 (2- 16i)	8i @ 180mm
406.2	452.65/603.19 (3- 16i)	452.65/603.19 (3- 16i)	8i @ 180mm
541.7	452.65/603.19 (3- 16i)	452.65/603.19 (3- 16i)	8i @ 180mm
677.1	452.65/603.19 (3- 16i)	452.65/603.19 (3- 16i)	8i @ 180mm
812.5	452.65/603.19 (3- 16i)	452.65/603.19 (3- 16i)	8i @ 180mm
947.9	452.65/603.19 (3- 16i)	452.65/603.19 (3- 16i)	8i @ 180mm
1083.3	452.65/603.19 (3- 16i)	452.65/603.19 (3- 16i)	8i @ 180mm
1218.8	452.65/603.19 (3- 16i)	452.65/603.19 (3- 16i)	8i @ 180mm
1354.2	452.65/603.19 (3- 16i)	452.65/603.19 (3- 16i)	8i @ 180mm
1652.0	452.65/603.19 (3- 16i)	452.65/603.19 (3- 16i)	8i @ 180mm

SHEAR DESIGN RESULTS AT DISTANCE d (EFFECTIVE DEPTH) FROM FACE OF THE SUPPORT
SHEAR DESIGN RESULTS AT 440.0 mm AWAY FROM END SUPPORT
VY = 70.71 MX = 1.15 LD= 200
Provide 2 Legged 8í @ 180 mm c/c

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 357-394

Longitudinal Beam

BEAM NO 292 DESIGN RESULTS

M40 Fe415 (Main) Fe415 (Sec)

LENGTH: 5000.0 mm SIZE: 300.0 mm X 500.0 mm COVER: 25.0 mm

Table-5 Design Load Summary of Longitudinal Beam (KN m)

SECTION (in mm)	FLEXURE (Maximum Sagging/Hogging moments) P	MZ	MX	Load Case	SHEAR VY	MX	Load Case
0.0	0.00	0.07	-0.06	6	51.63	-0.04	200
	0.00	-45.75	-0.04	200			
416.7	0.00	0.58	-0.06	6	43.17	-0.04	200
	0.00	-27.68	-0.04	200			
833.3	0.00	0.46	-0.06	6	34.74	-0.04	200
	0.00	-9.78	-0.04	200			
1250.0	0.00	3.45	-0.11	6	26.51	-0.04	200
	0.00	-0.01	-0.04	200			
1666.7	0.00	12.34	-0.11	6	17.28	-0.04	200
	0.00	0.00	0.00	200			
2083.3	0.00	17.60	-0.11	6	9.06	-0.04	200
	0.00	0.00	0.00	200			
2500.0	0.00	19.53	-0.11	6	0.88	-0.44	200
	0.00	-0.01	-0.04	200			
2916.7	0.00	18.48	-0.04	6	-8.04	-0.04	200
	0.00	-0.13	-0.06	200			
3333.3	0.00	13.56	-0.04	6	-16.50	-0.11	200
	0.00	-0.24	-0.06	200			
3750.0	0.00	5.11	-0.04	6	-24.95	-0.11	200
	0.00	-0.36	-0.06	200			
4166.7	0.00	0.05	-0.02	6	-33.41	-0.11	200
	0.00	-7.66	-0.11	200			
4583.3	0.00	0.06	-0.02	6	-41.95	-0.11	200
	0.00	-23.63	-0.11	200			
5000.0	0.00	0.07	-0.02	6	-52.54	-0.11	200
	0.00	-42.64	-0.11	200			

Table-6 Summary of Reinf Area of Longitudinal Beam (Sq.mm)

SECTION (in mm)	TOP reinf/ provided reinf	BOTTOM reinf/ provided reinf	STIRRUPS (2 legged)
0.0	295.02/402.12 (2- 16i)	271.59/402.12 (2- 16i)	8i @ 140mm
416.7	271.59/402.12 (2- 16i)	271.59/402.12 (2- 16i)	8i @ 140mm
833.3	271.59/402.12 (2- 16i)	271.59/402.12 (2- 16i)	8i @ 140mm
1250.0	271.59/402.12 (2- 16i)	271.59/402.12 (2- 16i)	8i @ 140mm
1666.7	0.00/402.12 (2- 16i)	271.59/402.12 (2- 16i)	8i @ 140mm
2083.3	0.00/402.12 (2- 16i)	271.59/402.12 (2- 16i)	8i @ 140mm
2916.7	271.59/402.12 (2- 16i)	271.59/402.12 (2- 16i)	8i @ 140mm
3333.3	271.59/402.12 (2- 16i)	271.59/402.12 (2- 16i)	8i @ 140mm
3750.0	271.59/402.12 (2- 16i)	271.59/402.12 (2- 16i)	8i @ 140mm
4166.7	271.59/402.12 (2- 16i)	271.59/402.12 (2- 16i)	8i @ 140mm
4583.3	271.59/402.12 (2- 16i)	271.59/402.12 (2- 16i)	8i @ 140mm
5000.0	271.59/402.12 (2- 16i)	271.59/402.12 (2- 16i)	8i @ 140mm

Design Summary of Pile

C O L U M N NO 1 D E S I G N R E S U L T S

M40 Fe415 (Main) Fe415 (Sec)

LENGTH: 1000.0 mm CROSS SECTION: 600.0 mm dia. COVER: 75.0 mm

** GUIDING LOAD CASE: 6 END JOINT: 31 SHORT COLUMN

REQD. STEEL AREA : 333.18Sq.mm.

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 357-394

REQD. CONCRETE AREA: 41648.11Sq.mm.
MAIN REINFORCEMENT: Provide 6 - 12 dia. (0.24%, 678.58 Sq.mm.)
(Equally distributed)
TIE REINFORCEMENT: Provide 8 mm dia. circular ties @ 190 mm c/c
SECTION CAPACITY BASED ON REINFORCEMENT REQUIRED (KNS-MET)

Puz: 3280.82 Muz1: 32.40 Muy1: 32.40
INTERACTION RATIO: 0.95 (as per Cl. 39.6, IS456:2000)
SECTION CAPACITY BASED ON REINFORCEMENT PROVIDED (KNS-MET)

WORST LOAD CASE: 203
END JOINT: 31 Puz: 3384.44 Muz: 91.64 Muy: 89.94 IR: 0.51
==

Concrete Take off

(FOR BEAMS AND COLUMNS DESIGNED)
TOTAL VOLUME OF CONCRETE = 269.57 CU.METER

BAR DIA (in mm)	WEIGHT (in New)
8	28914.29
10	22870.08
12	35577.24
16	69845.05
*** TOTAL=	157206.66

5.3.4 Beam End Force Summary

Table-7 Beam End Force Summary of Pile

				Axial	Shear		Torsion	Bending	
	Beam	Node	L/C	Fx(kN)	Fy(kN)	Fz(kN)	Mx(kNm)	My(kNm)	Mz(kNm)
MaxFx	8	38	200:combination	**949.966**	0.038	-0.000	0.000	0.000	0.032
Min Fx	29	59	6:load case	**-12.105**	5.979	-12.441	-1.451	16.011	6.619
MaxFy	256	181	203:combination	105.324	**31.615**	-31.615	0.000	-42.493	-42.493
Min Fy	407	332	203:combination	392.957	**-14.420**	8.944	-1.969	-90.347	-34.373
Max Fz	284	209	5:load case	-0.001	0.001	**22.608**	1.655	30.833	-0.002
Min Fz	284	209	203:combination	396.771	12.428	**-32.755**	-2.177	-44.730	-19.742
MaxMx	20	50	5:load case	-0.000	0.001	11.704	**1.655**	-15.213	0.001
MinMx	20	50	201:combination	794.138	0.031	-14.980	**-2.812**	19.222	0.026
MaxMy	374	329	5:load case	-0.001	-0.000	2.898	1.655	**84.818**	-0.005
MinMy	374	329	203:combination	364.794	-2.548	-4.113	-2.177	**-122.755**	-40.228
MaxMz	407	2	203:combination	327.603	-14.420	8.944	-1.969	-17.231	**83.507**
MinMz	346	301	203:combination	73.347	4.979	-4.979	0.000	-120.041	**-120.041**

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 357-394

Table-8 Beam End Force Summary of Secondary Beam

				Axial	Shear		Torsion		Bending
	Beam	Node	L/C	Fx(kN)	Fy(kN)	Fz(kN)	Mx(kNm)	My(kNm)	Mz(kNm)
MaxFx	119	129	200:combination	**409.556**	-0.771	20.422	-2.263	-86.359	-1.955
MinFx	245	85	200:combination	**-39.140**	80.291	3.544	3.500	-26.664	64.562
MaxFy	273	172	200:combination	103.119	**111.041**	7.138	1.004	-5.122	82.301
MinFy	322	179	200:combination	16.880	**-2.2E+3**	-9.637	0.97	-4.082	48.9E+3
MaxFz	263	266	200:combination	48.670	-80.496	**100.466**	3.335	-28.867	65.077
MinFz	241	82	200:combination	-0.002	-96.227	**-105.22**	6.545	4.778	83.351
MaxMx	241	81	201:combination	4.739	68.792	-0.862	**15.021**	0.929	15.767
MinMx	259	261	201:combination	4.739	68.792	0.862	**-15.022**	-0.928	15.767
MaxMy	160	180	200:combination	190.111	68.791	25.707	-2.126	**103.265**	-32.964
MinMy	120	130	200:combination	272.552	5.986	25.707	-2.126	**-108.817**	16.424
MaxMz	322	179	200:combination	16.880	-141.26	-9.637	0.987	-4.082	**48.9E+3**
MinMz	322	289	200:combination	16.880	-102.6	-9.637	0.987	11.578	**-76.668**

Table-9 Beam End Force Summary of Transverse Beam

				Axial	Shear		Torsion		Bending
	Beam	Node	L/C	Fx(kN)	Fy(kN)	Fz(kN)	Mx(kNm)	My(kNm	Mz(kNm)
Max Fx	187	17	201:combination	**59.204**	314.615	1.035	-6.371	-0.769	1.04E+3
Min Fx	193	26	5:load case	**-20.286**	-0.671	-1.271	3.614	0.767	-3.539
Max Fy	181	8	200:combination	-0.024	**394.166**	-0.042	0.342	0.091	1.32E+3
Min Fy	180	8	200:combjnation	-0.024	**-394.17**	0.042	-0.342	0.091	1.32E+3
Max Fz	188	67	201:combination	-6.234	-239.08	**21.244**	-3.652	-78.040	-3.513
Min Fz	184	65	201:combination	-5.856	-235.54	**-19.37**	-9.206	72.641	-1.173
Max Mx	177	2	203:combination	6.964	163.05	-10.12	**36.283**	16.317	510.749
Min Mx	176	61	203:combination	-1.980	-103.59	4.295	**-47.224**	2.178	25.213
Max My	189	77	201:combination	6.909	241.01	21.175	-3.089	**78.222**	1.830
Min My	188	67	201:combination	-6.234	-239.09	21.244	-3.652	**-78.040**	-3.513
Max Mz	180	8	200:combination	-0.024	-394.17	0.042	-0.342	-0.091	**1.32E+3**
Min Mz	194	29	6:load case	-0.327	6.366	0.153	-26.188	-0.516	**-25.363**

Table-10 Beam End Force Summary of Facia Beam

				Axial	Shear		Torsion		Bending
	Beam	Node	L/C	Fx(kN)	Fy(kN)	Fz(kN)	Mx(kNm)	My(kNm)	Mz(kNm)
MaxFx	163	75	201:combination	**58.495**	155.574	22.229	8.083	-36.014	104.705
MinFx	171	65	201:combination	**-55.375**	120.512	21.728	8.082	-34.982	98.997
MaxFy	166	78	200:combination	2.053	**169.896**	-0.021	10.934	0.055	102.509
MinFy	160	73	200:combination	2.053	**-169.89**	0.021	-10.934	0.055	102.705
MaxFz	163	75	201:combination	58.495	155.574	**22.229**	8.083	-36.014	104.705

MinFz	164	76	201:combination	57.460	117.897	**-23.57**	4.233	78.246	110.678
MaxMx	79	61	200:combination	1.479	152.696	-0.617	**35.469**	2.067	11.902
MinMx	175	69	200:combination	1.479	154.639	0.617	**-35.469**	-1.018	16.760
MaxMy	164	76	201:combination	57.460-	117.897	-23.57	4.233	**78.246**	110.678
MinMy	173	68	201:combination	-33.067	-114.21	-16.85	2.500	**-44.852**	73.575
MaxMz	162	75	200:combination	2.048	-154.12	-0.015	1.158	-0.028	**132.731**
MinMz	175	70	203:combination	0.680	-84.287	-0.111	-19.562	-0.362	**-31.968**

5.3.5 Diagrams from STAAD Pro

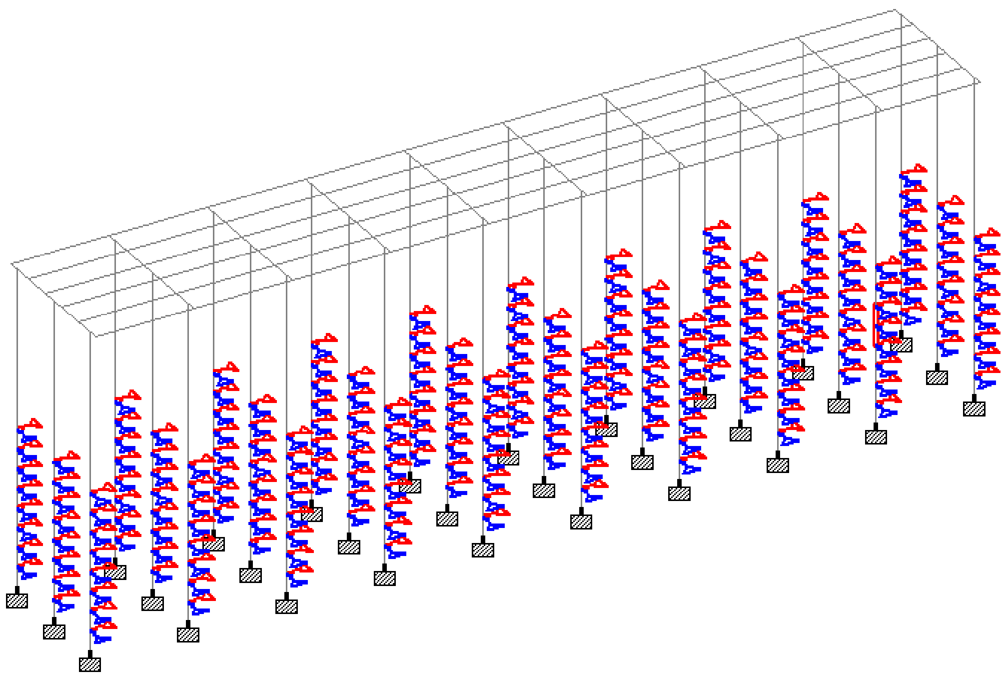

Figure.4 Skeleton Model

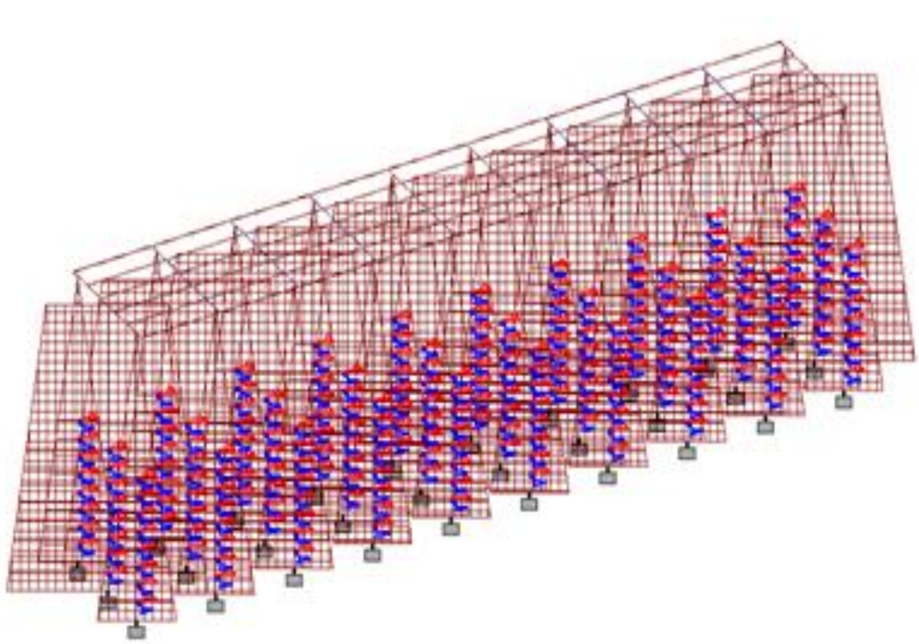

Figure.5 Shear Force Diagram Along- x direction

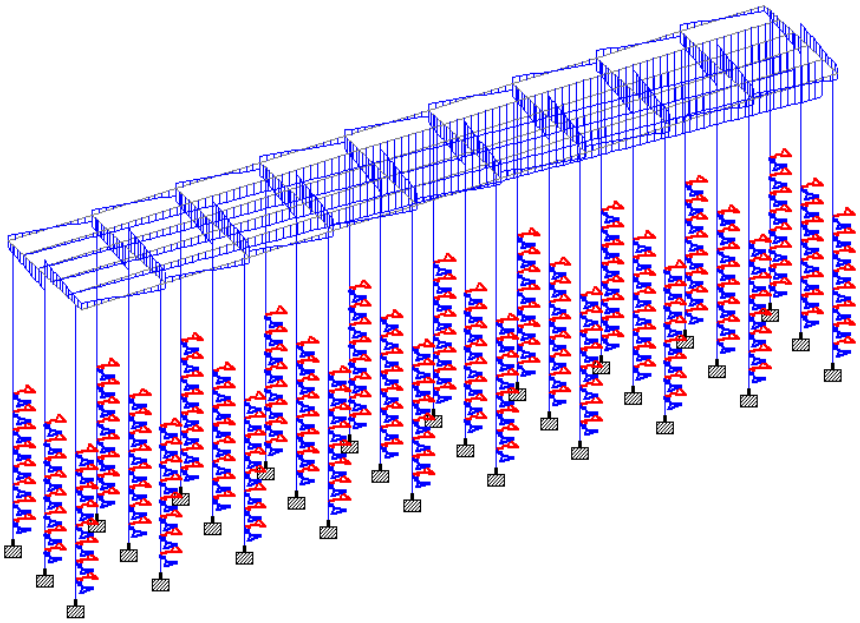

Figure.6 Shear Force Diagram Along -y direction

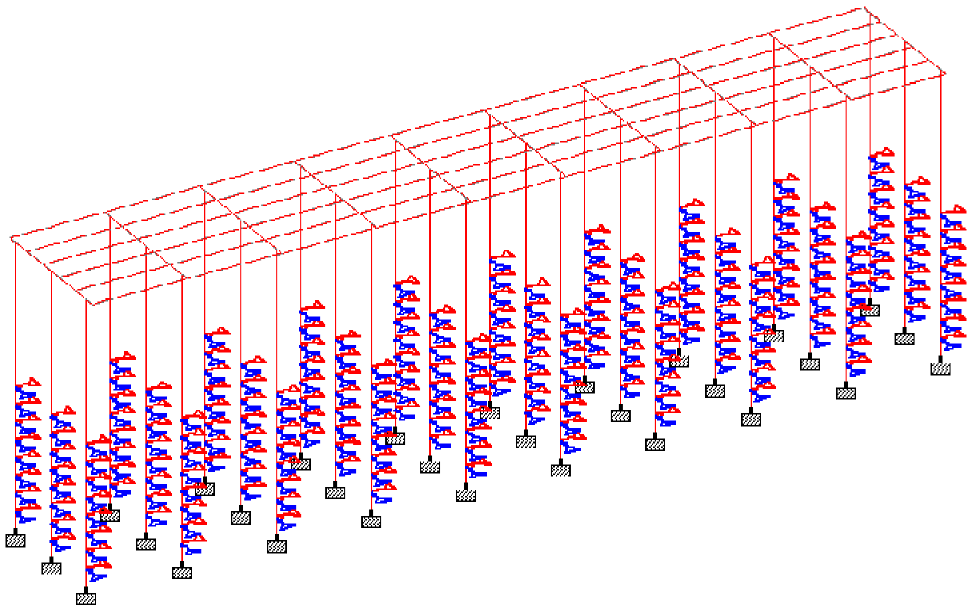

Figure.7 Shear Force Diagram Along-z direction

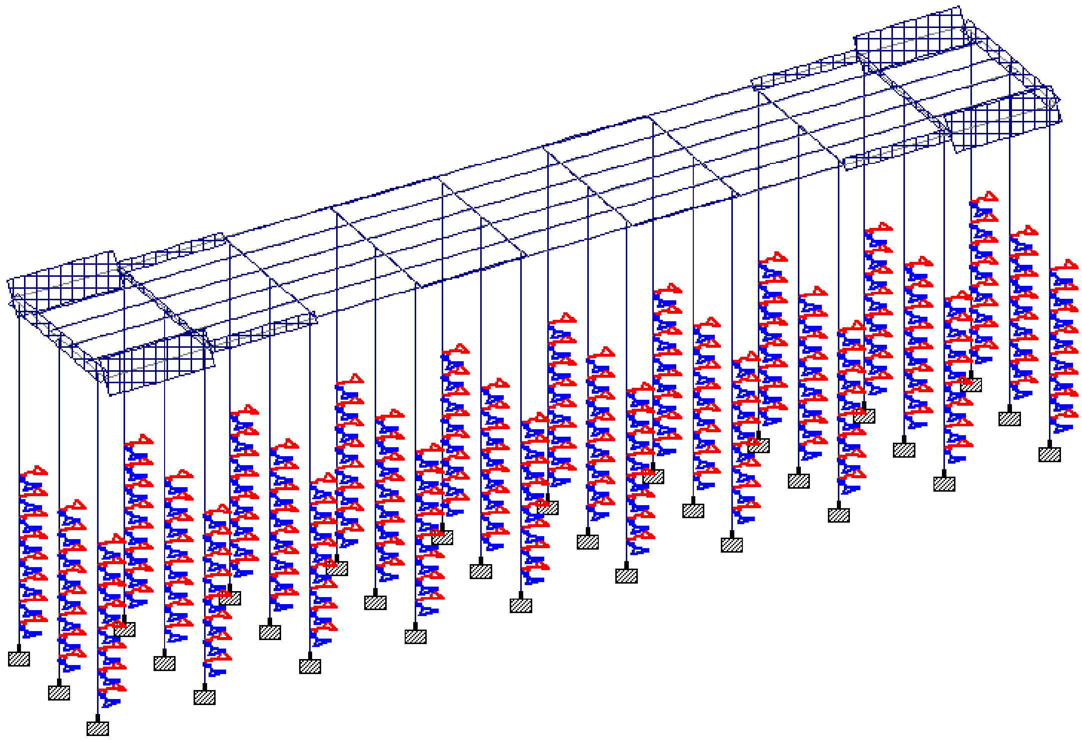

Figure.8 Bending Moment Diagram Along- x direction

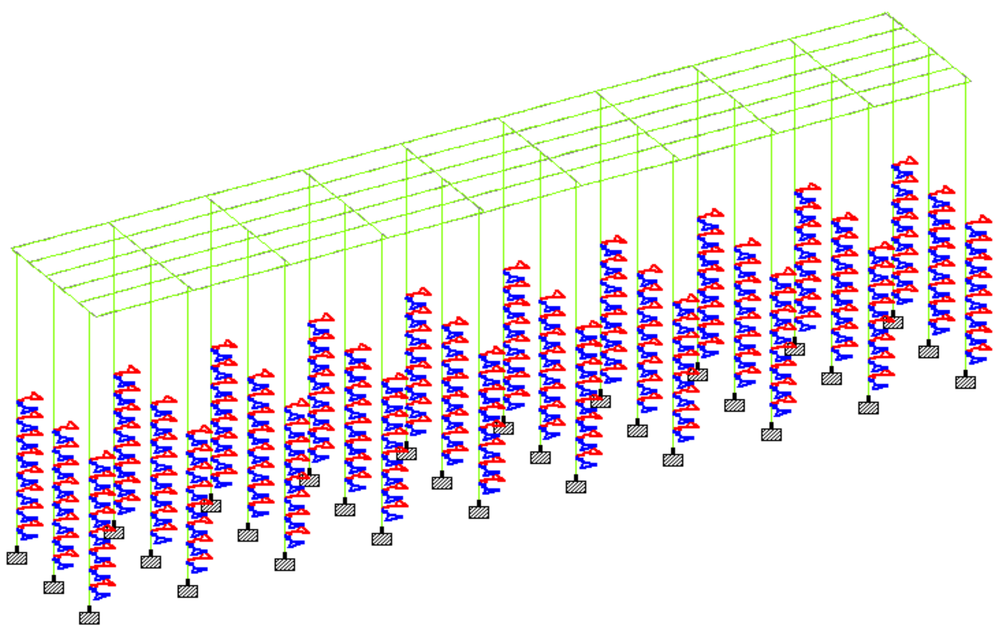

Figure.9 Bending Moment Diagram Along- y direction

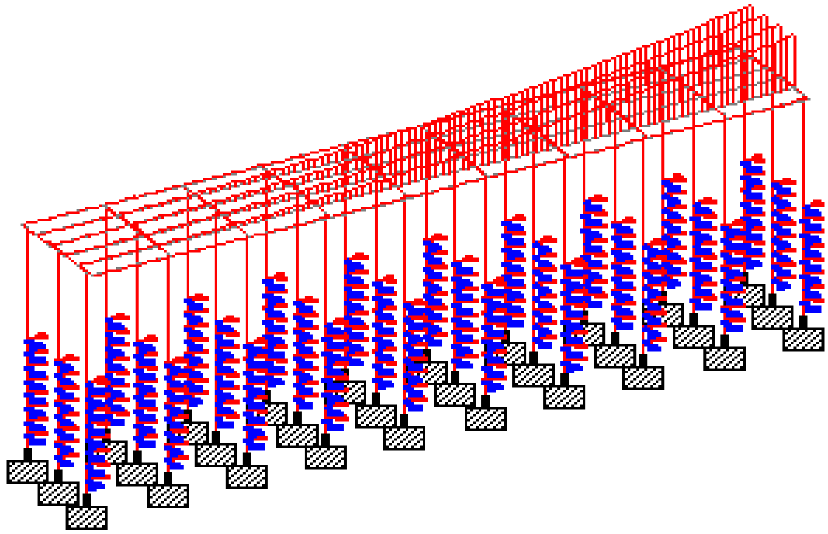

Figure.10 Bending Moment Diagram Along- z direction

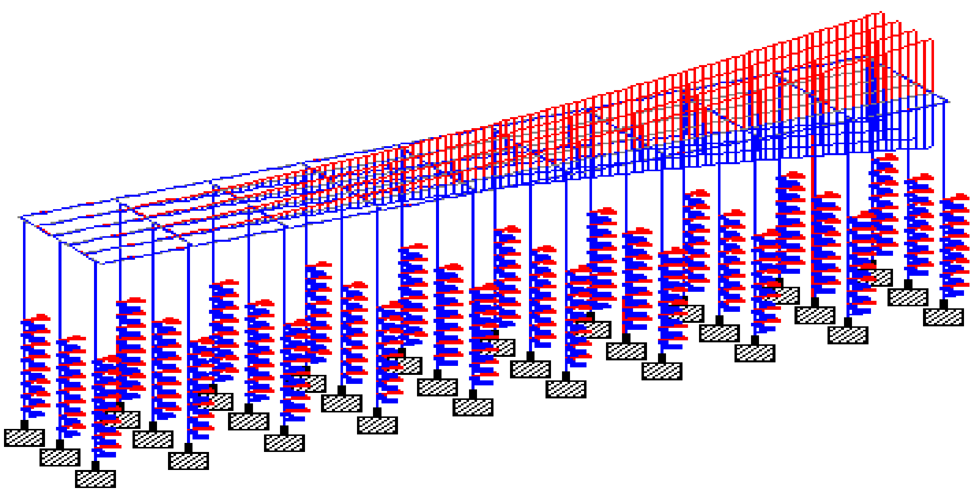

Figure.11 Beam Stress Diagram

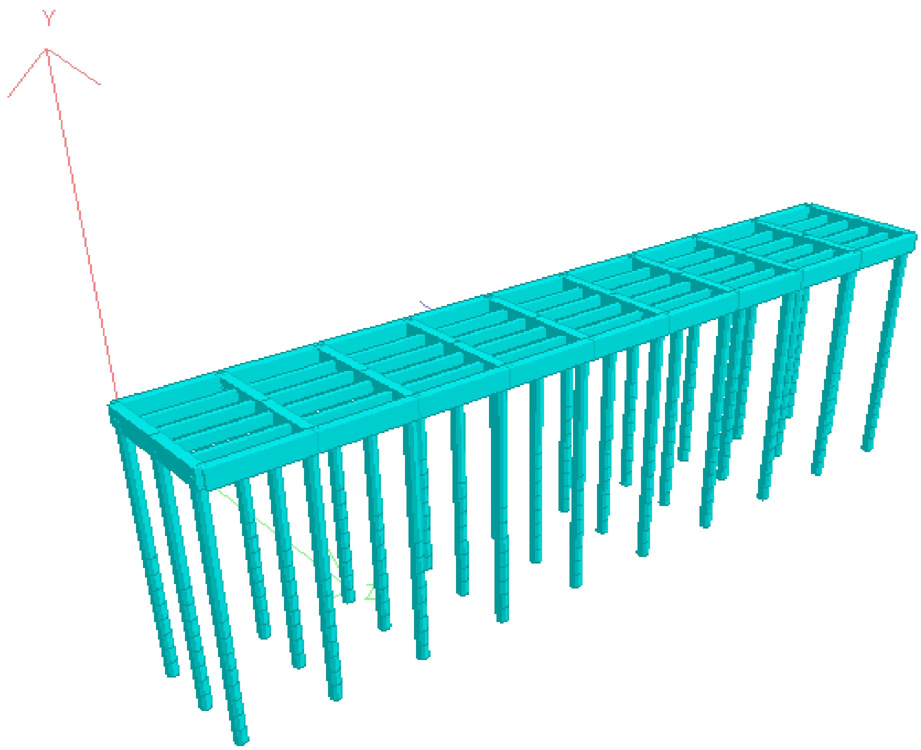

Figure.12 3D Rendered View

CHAPTER VI
DESIGN OF FINGER JETTY

6.1 DESIGN OF FINGER JETTY

Once the analysis of any structural system is completed, the next step would be the design of various elements in the structural system. Generally, the design process is iterative as the design variables chosen may not satisfy the allowable stress/strain parameters. This process should be repeated until a satisfactory solution is obtained. The design shall be carried out as per the guidelines specified in IS 456- 1978. As per IS 4651(Part IV) – 1989 the maximum grade of concrete to be used in berthing structures is specified as $M_{30.}$ The minimum cement content of $0.4T/m^3$ and maximum water cement ratio of 0.45 shall be maintained for all grades of concrete. The minimum thickness of cover for structures immersed in sea water , in splash zone or exposed to marine atmosphere should be 25mm more than the specified in 4.1 IS 456 – 1978. Hence the cover shall be as follows

Slab = 15+25 = 40mm
Beam = 25+25 = 50mm
Pile = 40+25 = 65mm

In the limit state method the design is based on limit state concept. The structures shall be designed to withstand safely all the loads liable to act on it throughout its line. It shall also satisfy the serviceability requirements such as limitation on deflection and cracking. The acceptable for safety and serviceability requirements before failure occurs called "Limit State".

6.2 SELECTION OF TYPE OF FINGER JETTY

A berthing structure is usually constructed to serve a definite use the purpose of it is to handle passengers or general cargo or a combination of both or it may be required to handle a specific type of cargo particularly bulk cargo such as oil ore, cement, and grains or to handle containers. The type of berthing structure depends upon the purpose of the berth, size of ships that use the berthing structure, the direction of the wave, wind and subsurface soil conditions, in particular the depth of the bed rock or firm bearing material and the water depth.

The selection of type of berthing structure also depends on the magnitude and nature of loading, hydraulic

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Vol. 36 Issue 1, Jan-June 2026, Pages: 357-394

conditions such as wave action and currents. Fire hazard and safety requirements, damage susceptibility and ease of repairs environmental and regularity concerns over water circulation and habitat loss always favour open type construction.

Closed type construction generally offers greater horizontal and vertical load capacity and impact resistance than the open piled construction. The vertical face of a closed type of construction reflects wave energy, if the structure face is exposed to significant wave action. The possible scouring at the face of the closed type structure due to current action influences the choice of the type. If all factors considered for selecting of the type of berthing structure remain the same the long-term maintenance govern the type of berthing structure.

When a berthing structure has to be constructed in shallow water or on existing land in connection with the dredging of a harbour basin a vertical face type structure such as the diaphragm wall is very competitive. The presence of bedrock or hard strata below the design depth of water favours the vertical type.

The vertical face type structures will be preferred when tension piles fail to penetrate to sufficient depth due to hard layers. When the existing water depth is close to the desired dredge depth then this type of structure is suitable. When dredging is expensive and when weak and soft sediments endanger the overall stability, then open type structures are adopted.

As a general rule vertical face construction such as diaphragm wall is favoured where water depths are shallow to moderate. Anchored bulkheads require some minimum embedment depths are these bulkheads are practical and economical to wall heights up to about 10 m. at deep water locations with soft soils extending relatively deep below the mud line then pile foundations are provided. Even though open pile supported construction is used at shallow rock location, the cost to anchor the piles to the bed rock and to provide adequate horizontal stability usually exceeds that of a suitable vertical face type structure.

Relieving platforms, which are a combination of open type and fill type constructing, may be used to provide uplift resistance thereby improving the lateral load resistance of the pile s. A relieving platforms, also reduces the required bulk head wall height thus extending the water depth capability of the system.

When the slope of the bottom is so steep that a jetty or a pier cannot be projected out from the shore without having the out shore end in water so deep, then foundations are either impractical or very expensive. In such conditions a wharf or quay is suitable and economical.

For bulk cargo berth, an open type construction with approach trestle is preferable. Oil docks and some forms of bulk-handling cargo docks are of lighter constructions then general cargo-handling docks, as they do not require warehouses, not do they have to support rail, road tracks or extensive cargo-handling equipment. Since the main products handled over oil docks are usually unloaded at fixed points and transported by pipelines, the required area of solid deck is very much reduced, as are width and length of the dock, if supplemented by dolphins to take the bow and stern mooring lines. For this reason, a full-length pier or wharf is not economical or essential, and the use of larger and deeper draft tankers has resulted in the adoption of the fixed mooring berth. This type of construction is economical because the large mooring forces imposed on the dock by the large ships shall be concentrated at single points. The pull of the mooring lines can be taken by dolphins off the bow and stern of the vessel and by breasting dolphins also keep the ship away from the platform and take the impact of the ship while docking.

In some locations, it is impossible or uneconomical to provide a pier, wharf or fixed mooring depth owing to site conditions or the deep draft of some of the recently constructed super tankers and ore carrier. In such cases an offshore mooring may be provided and the cargo transferred to the shore either by lighters, long conveyors, ropeways or by submarine pipeline, if the product is a liquid such as oil, gasoline and molasses.

Soil conditions will have an important bearing on the type of dock selected. The bottom may be more favourable in the region close to the shore, thereby favouring a wharf or bulkhead installation. However, a rock may be encountered which would make it very costly to obtain the required depth of water along the dock. In such a case, a pier with an approach trestle or mole may be in the solution to eliminate the need for costly excavation.

6.3 CALCULATION OF REINFORCEMENT PERCENTAGE FOR PILE

Grade of concrete (f_{ck}) = 40 N/mm^2
Grade of steel (f_y) = 415 N/mm^2
Diameter of pile (D) = 600 mm
Clear cover (c) = 75mm
Diameter of bars (b) = 16 mm
Unsupported length of pile (L) = 7.18 + 4.5 = 11.68m

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 357-394

Effective length of pile (l_{eff}) = 1.2xL = 1.2x11.68 = 14.02m
Ratio of effective length to diameter (L_{eff}/D) = 14.02/.600 = 23.37m
(from SP-16, pg-106) (e/D) corresponding to (l_{eff}/D)

20	0.2
25	0.313

By interpolating,
= 0.2 + ((0.313-0.2)/ (25-20)) x 3.37
= 0.276
Eccentricity (e) = (e/D) x D = 0.276x0.6 = 0.165m
e_{min} = [(L/500) + (D/30)]
= (11.68/500) + (0.6/30) = 0.043m
(d/D) = (c + (b/2))/D = (75 + (16/2))/600
=0.138

Condition 1: Maximum Axial Load and Corresponding Moment

Factored axial load (P_u) = 949.97 kN
Factored moment (M_y) = 0
Factored moment (M_z) = 0.032 kN-m
Moment (M_u) = $\sqrt{My^2 + Mz^2}$ = $\sqrt{0 + 0.032^2}$
= 0.032 kN-m
Moment due to slenderness = P_u x e = 949.97x0.165
= 156.75 kN- m
Total moment (M) = 0.032 + 156.75 = 156.78 kN-m
P_u/ (f_{ck}xD^2) = 949.97x10^3/ (40x600^2) = 0.07
M_u/ (f_{ck}/D^3) = 156.78x10^6/ (40x600^3) = 0.02
(from SP-16, pg-141) p_t/fck = 0.02
p_t = 0.02x40 = 0.8%

Condition 2: Maximum Moment and Corresponding Axial Load

Factored moment (M_y) = 122.75 kN-m
Factored moment (M_z) = 40.23 kN-m
Factored axial load (P_u) = 364.79 kN
Moment (M_u) = $\sqrt{My^2 + Mz^2}$ = $\sqrt{122.75^2 + 40.23^2}$
= 129.17kN-m
Moment due to slenderness = P_u x e = 364.79 x 0.165 = 60.19 kN-m
Total moment (M) = 129.17 + 60.19 = 189.36 kN-m
P_u/ (f_{ck}xD^2) = 364.79x10^3/ (40x600^2) = 0.03
M_u/ (f_{ck}/D^3) = 189.36x10^6/ (40x600^3) = 0.02
(from SP-16, pg-141)p_t/fck = 0.02
p_t = 0.02x40 = 0.8%

6.4 DESIGN OF PILE

Diameter of pile (D) = 600mm
From STAADpro, maximum moment (M_u) = 122.75 kN-m
From STAADpro, maximum axial force (P) = 949.97 kN
Percentage of steel = 0.8%
A_{st} provided % of steel = p_t x (π/4) x D^2
= (0.8/100) x (π/4) x 600^2
= 2261.95mm^2
Provide 12 numbers of 16mm diameter bars as main reinforcement

Spacing of bars

(From IS 456-2000, cl.26.5.3.2 (g), pg-48)
Minimum centre to centre distance = 100mm
Maximum centre to centre distance = 300mm
Centre to centre distance between longitudinal bars = (600-75-75-16) x (π/12)

=120mm

Lateral ties

(As per IS 456-2000, cl.26.5.3.2 (c), pg-49)

The pitch should not be greater than

i. Diameter of the pile = 600mm

ii. 16 x 16mm diameter of main bars = 256m

Provide 12 numbers of 16mm diameter bars at 120mm centre to centre.

6.5 DESIGN OF LONGITUDINAL BEAM

Size of the beam = 300 mm x 500 mm

Grade of concrete (f_{ck}) = 40 N/mm^2

Grade of steel (f_y) = 415 N/mm^2

Moment (M_u) = 120.04 kN-m

Effective depth (d_{eff}) = 500-50-(16/2) = 442mm

Area of steel (R) = M_u/bd^2 = 48.9x10^6/ (300x442^2)

= 0.834mm^2

Percentage of steel (p_t/100) = $(f_{ck}/2f_y)\ [(1\sqrt{1-(4.14*\left(\frac{R}{fck}\right))}]$

= $(40/\ (2x415))\ [(1-\sqrt{1-(4.14*\left(\frac{.834}{40}\right))}]$

= 0.38

Area of steel = (0.38x300x442)/100

= 503.88mm^2

Area of one bar = (π/4) x d^2 = 0.785x16^2

= 201.06mm^2

No. of bars (n) = A_{st}/a_{st} = 503.88/201.06

= 2.5 nos = 4 nos

Provide 4 numbers of 16mm diameter bars.

Check for shear

Maximum shear = 4.98 kN

Shear force (τ_v) = V_u/bd

= 4.98x10^3/ (300x442)

= 0.037 N/mm^2

(from IS 456-2000, table-20, pg-73) $\tau_{c,\ max}$ = 4N/mm^2

Therefore $\tau_v < \tau_{c,\ max}$

Hence safe

Percentage of steel (p_t) = 100A_{st}/bd

= (100x503.88)/ (300x442)

= 0.38

(from IS 456-2000, table-19, pg-73)

0.25	0.38
0.50	0.51

By interpolating, = 0.38 + ((0.51-0.38)/ (0.50-0.25))x0.13

τ_c = 0.45

Therefore $\tau_v < \tau_c$

Hence safe

(from IS 456-2000, cl.26.5.1.6, pg-48)

Minimum shear reinforcement = $(A_{sv}/bxS_v) \geq (0.4/0.87f_y)$

Therefore S_v = (A_{sv} x 0.87x f_y)/ (b x 0.4)

Assuming 2 legged-Y-8 stirrups

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 357-394

= (2 x π x 8^2 x 0.87 x 415)/ (4 x 300 x 0.4)
= 302.5mm = 300mm

Provide 2L-Y-8 stirrups at 300mm center to center spacing.

6.6 DESIGN OF TRANSVERSE BEAM

Size of the beam = 500mm x 500mm
Grade of concrete (f_{ck}) = 40N/mm^2
Grade of steel (f_y) = 415 N/mm^2
Effective depth (d_{eff}) = 500-50-(16/2) = 442mm
From STAADpro, Moment (M_u) = 78.22 kN-m
Area of steel (R) = M_u/bd^2
= 78.22x10^6/ (500x442^2)
= 0.80mm^2

Percentage of steel (p_t/100) = $(f_{ck}/2f_y)[(1-\sqrt{1-(4.14*\left(\frac{R}{fck}\right))}]$

= $(40/2x415)\ [(1-\sqrt{1-(4.14*\left(\frac{0.80}{fc40}\right))}]$

= 0.202

Area of steel = (0.202 x 500 x 442)/ 100
= 446.42mm^2
Area of one bar = (π/4) x d^2 = 0.785x16^2
= 201.06mm^2
No. of bars (n) = A_{st}/a_{st} = 446.42/201.06
= 2.2 nos =4nos

Provide 4 numbers of 16 mm diameter bars.

Check for shear

Maximum shear = 394.17 kN
Shear force (τ_v) = V_u/bd
= 394.17x10^3/ (500x442)
= 1.78 N/mm^2
(from IS 456-2000, table-20, pg-73) $\tau_{c,\ max}$ = 4N/mm^2
Therefore $\tau_v<\tau_{c,\ max}$
Hence safe
Percentage of steel (p_t) = 100A_{st}/bd
= (100x3933.8)/ (500x442)
= 1.78

(From IS 456-2000, table-19, pg-73)

1.75	0.84
2.00	0.88

τ_c= 0.84 + ((0.88-0.84)/ (2-1.75)) x 0.03
= 0.84N/mm^2

Therefore $\tau_c<\tau_v$
Hence not safe
Therefore shear reinforcement is to be provided
(From IS 456-2000, cl.40.4, pg-73)
V_s = V-(τ_c x bd)
= 394.17 – (0.84 x 500 x 442)
= 208.53 kN
(from IS 456-2000, cl.40.4 (a), pg-73)
For vertical stirrups V_s = (0.87 x f_y x A_{sv} x d)/S_v
Assuming 2 legged-Y-8 stirrups
208.53x10^3 = (0.87 x 415 x 2 x π x 8^2 x 442)/ (4 x S_v)
S_v = 16043143.53/208.53x10^3

= 76.93mm

i. S_v = 76mm

ii. 0.75 x d = 0.75 x 442 = 331.5 mm

iii. The spacing should not increase = 300mm

Taking 300mm spacing since it is safe.

Therefore provide 2L-Y-8 stirrups at 300 mm center to center spacing.

6.7 DESIGN OF FACIA BEAM

Size of the beam = 500mm x 1000mm

Grade of concrete (f_{ck}) = 40N/mm^2

Grade of steel (f_y) = 415N/mm^2

Moment (M_u) = 132.73 kN-m

Effective depth (d_{eff}) = 1000-5-(16/2) = 987mm

Area of steel (R) = M_u/bd^2

= 132.72x10^6/ (500x987^2)

= 0.272

Percentage of steel (p_t/100) = $(f_{ck}/2f_y)[(1-\sqrt{1-(4.14*(\frac{R}{fck}))}]$

= $(40/2x415)[(1-\sqrt{1-(4.14*(\frac{0.272}{40}))}]$

= 0.1

Area of steel = (0.1 x 500 x 987)/ 100

= 493.5mm^2

Area of one bar = (π/4) x d^2 = 0.785x12^2

= 113.09mm^2

No. of bars = A_{st}/a_{st} = 493.5/113.09

= 4.4nos =6nos

Provide 6 numbers of 12mm diameter bars.

Check for shear

Maximum shear (V_u) = 115.12 KN

τ_v = V_u/bd

= 115.12x10^3/ (1000x442)

= 0.26N/mm^2

(from IS 456-2000, table-20, pg-73)

$\tau_{c, max}$ = 4N/mm^2

Therefore $\tau_{c, max} > \tau_v$

Hence safe

(from IS 456-2000, cl.26.5.1.6, pg-48)

Assuming 2 legged-Y-8 stirrups

Minimum shear reinforcement = $(A_{sv}/bxS_v) \geq (0.4/0.87xf_y)$

S_v = $(A_{sv}$ x 0.87 x $f_y)$/ (0.4/b)

= (2 x π x 8^2 x 415)/ (4 x 0.4 x 1000)

= 104mm = 150mm

Provide 2L-Y-8 stirrups at 150mm centre to centre spacing.

6.8 DESIGN OF SLABS FOR EACH PANEL

Centre to centre span length (L) = 5m

Grade of concrete (f_{ck}) = 40N/mm^2

Grade of steel (f_y) = 415N/mm^2

Cover to reinforcement = 50mm

Thickness of slab = 150mm

Effective depth (d_{eff}) = 150-50 = 100mm

MSW MANAGEMENT -**Multidisciplinary, Scientific Work and Management Journal**
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 357-394

Self weight of slab = 0.15 x 25 = 3.75 kN/m^2
Self weight of wearing coat = 0.05 x 25 = 1.25kN/m^2
Dead load = 5kN/m^2
Live load = 20kN/m^2
Total load = 25kN/m^2

Factored moment in critical sections

Dead load = (5+3.75)-1.25
= 7.5kN/m^2

Considering 1m width of slab,
Bending moment = $Wl^2/8 = (7.5 \times 5^2)/8$
= 23.44kN-m
Shear force = Wl/2 = (7.5 x 5)/2
= 18.75kN-m
Maximum moment is taken as = 23.44 kN-m
$M_u/bd^2 = 23.44 \times 10^6/(1000 \times 100^2)$
= 2.344kN-m

Percentage of steel ($p_t/100$) $= (f_{ck}/2f_y)\, [(1-\sqrt{1-(4.14 * \left(\frac{R}{fck}\right))}]$

$= (40/2 \times 415)\, [(1-\sqrt{1-(4.14 * \left(\frac{2.344}{40}\right))}]$
= 0.624

A_{st} required = (0.624 x 1000 x 100)/100
= 624mm^2
Area of one bar (12mm dia bars) = $(\pi/4) \times d^2$
= 0.785×12^2
= 113.09mm^2
No. of bars = A_{st}/a_{st} = 624/113.09
= 5.5 nos = 6 nos

Spacing of bars

(As per IS 456-2000, cl.26.3.3 (b), pg-46)
Required spacing = 300mm
Provide 6 numbers of 12mm diameter bars at 300mm centre to centre as main reinforcement.

Distributors

A_{st} required = 0.12% bd
= (0.12/100) x 1000 x 100
= 120mm^2

Assuming 10mm diameter of bars
Spacing S_v = $(1000 \times a_{st})/A_{st}$
= 65mm
Provide 10mm diameter of bars at 100mm centre to centre spacing.

Check for shear

Thickness of slab (D) = 150mm
Clear cover = 50mm
Effective depth = 150-50 = 100mm
Shear force (V_u) = Wl/2
= (7.5 x 5)/2
= 18.75kN
τ_v = V_u/bd
= $18.75 \times 10^3/(1000 \times 100)$
= 0.187 N/mm^2

(From IS 456-2000, table-20, pg-73)
$\tau_{c,\,max}$ = 4N/mm^2

Therefore $\tau_{c, max} > \tau_v$

Hence safe

Percentage of steel (p_t) $= (100 \times A_{st})/bd$

$= (100 \times 624)/ (1000 \times 100)$

$= 0.624$

(From IS 456-2000, table-19, pg-73)

0.50	0.51
0.75	0.60

$\tau_c = 0.51 + ((0.60-0.51)-(0.75-0.50)) \times 0.124$

$\tau_c = 0.55 N/mm^2$

Therefore $\tau_c > \tau_v$

Hence safe

6.9 REINFORCEMENT DIAGRAMS:

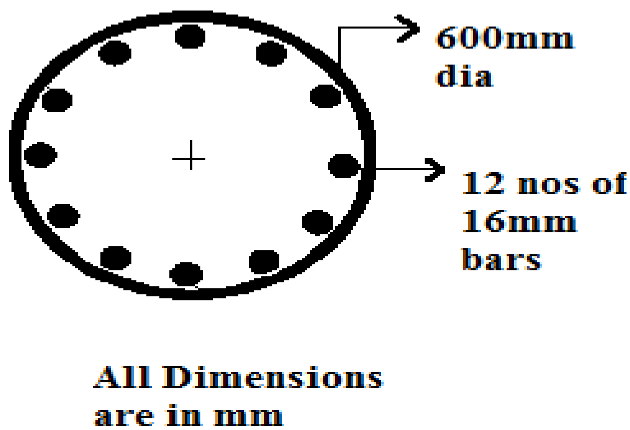
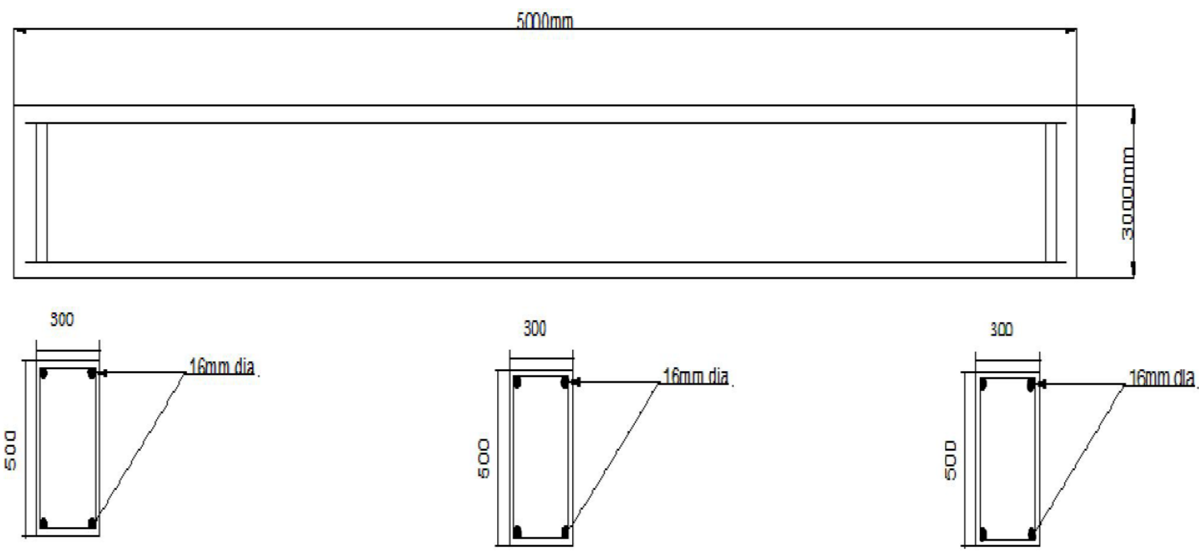


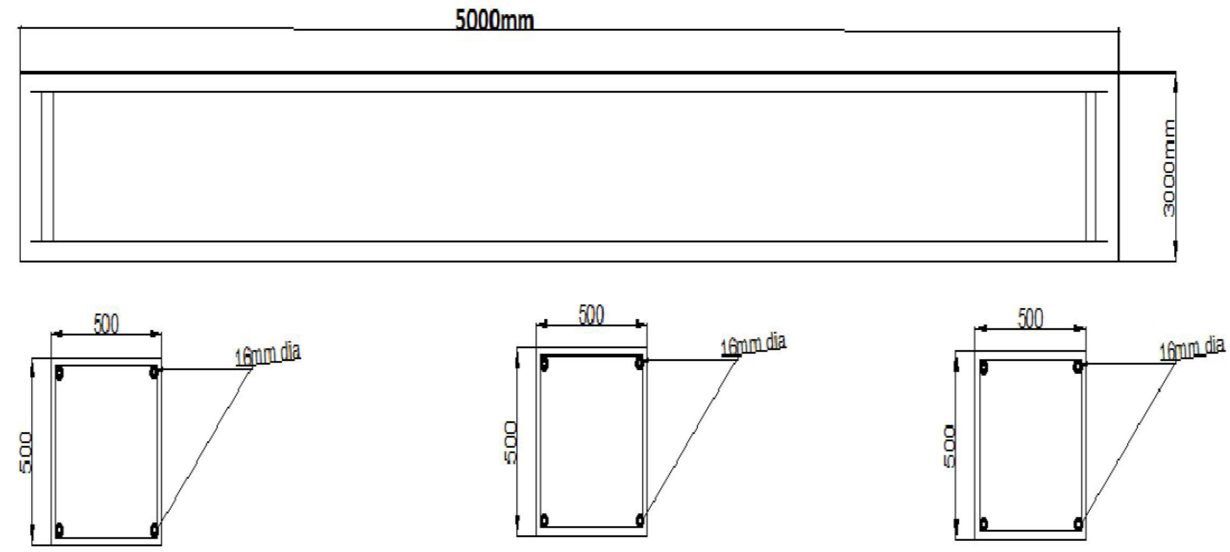
Figure.13 Reinforcement of pile



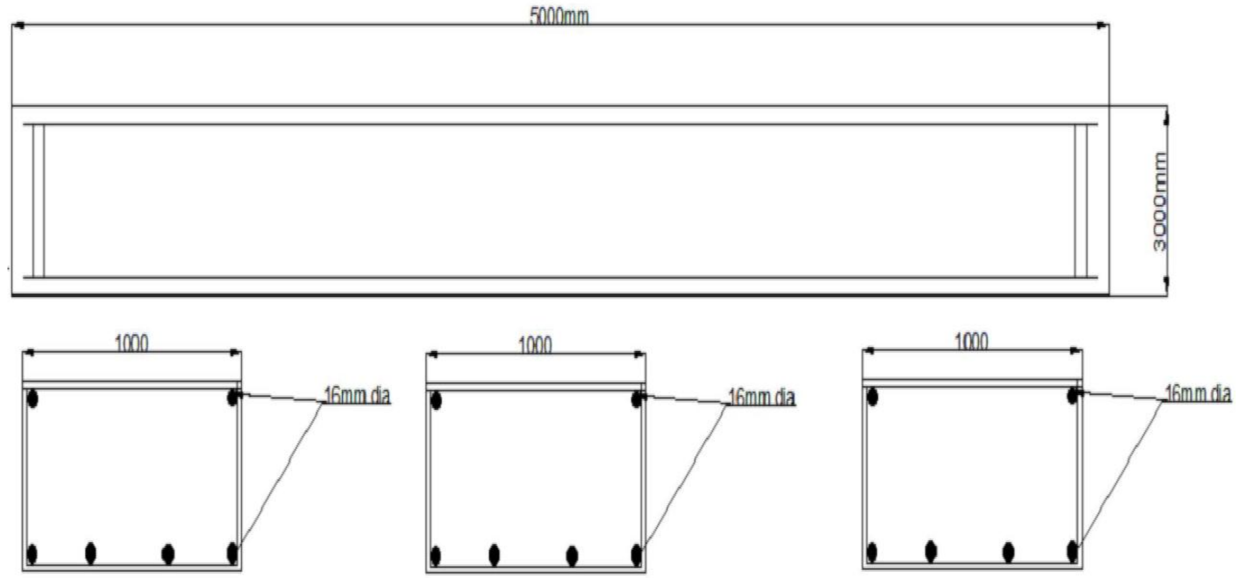
All Dimensions are in mm

Figure.14 Longitudinal Beam Reinforcement

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 357-394

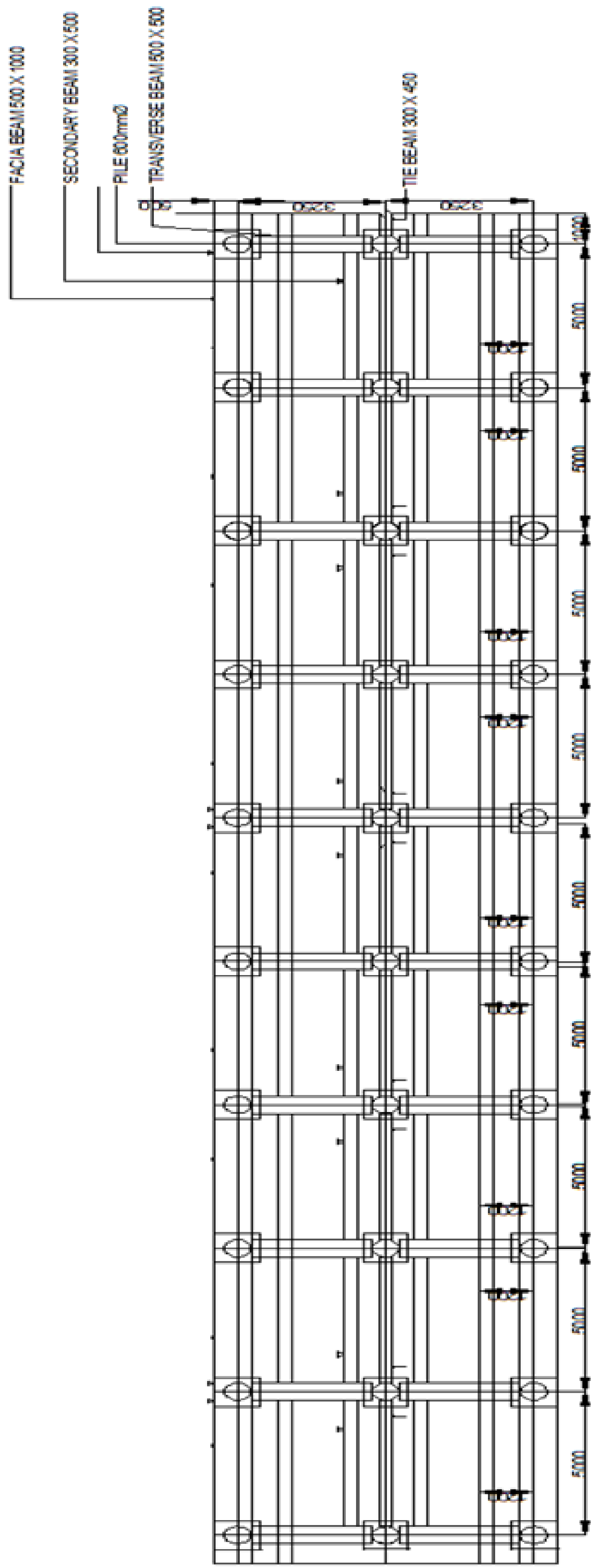


All Dimensions are in mm
Figure.15 Transverse Beam Reinforcement

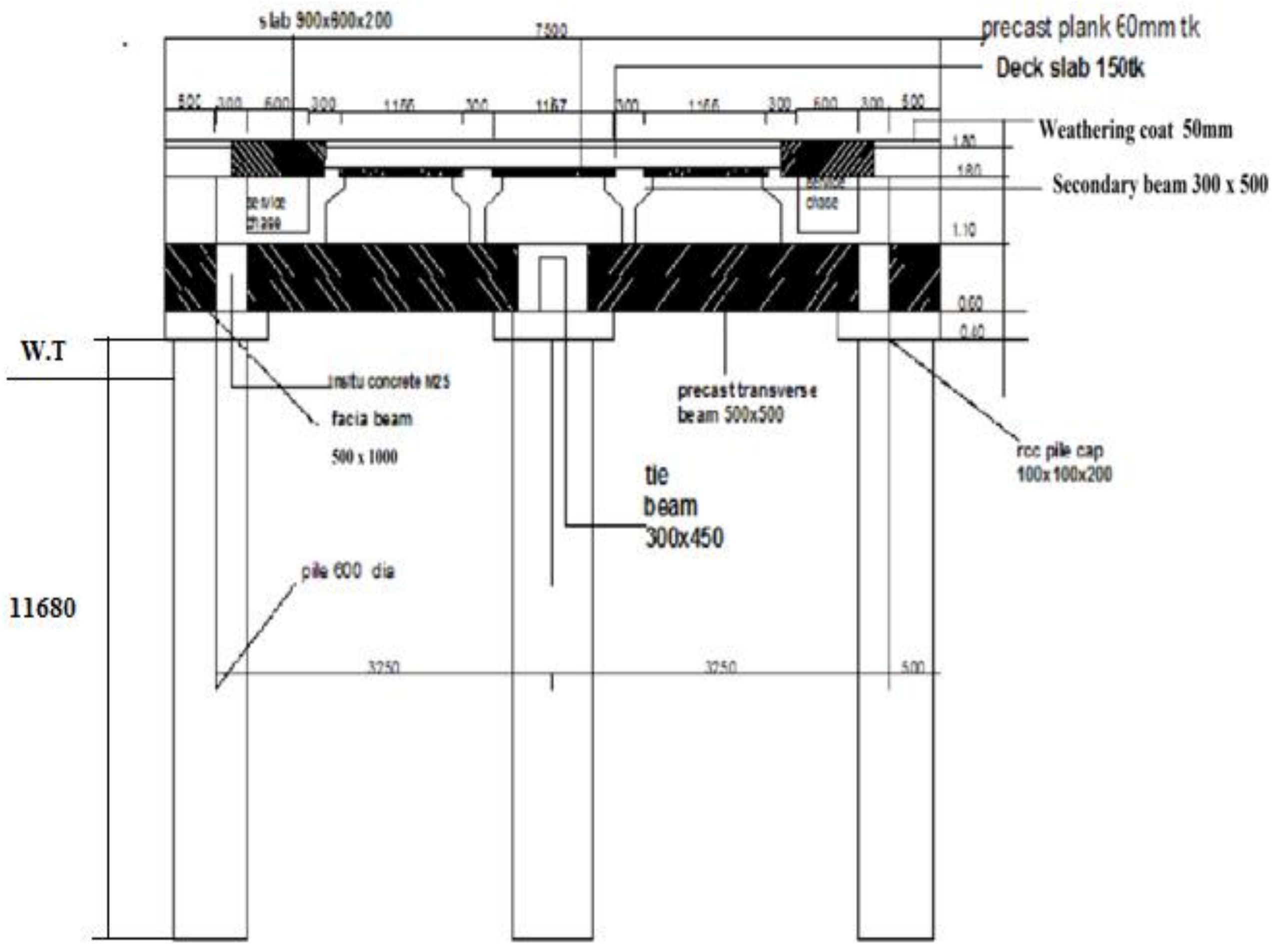


All Dimensions are in mm
Figure.16 Facia Beam Reinforcement

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 357-394



All Dimensions are in mm
Figure.17 Plan of a Finger Jetty



All Dimensions are in mm
Figure.18 Elevation of a Finger Jetty

CONCLUSIONS

Based on the data collected from Chennai fishing harbour at Royapuram the finger jetty is designed to a length of 45m and to a width of 7.5m to handle the fishing vessels in Chennai fishing harbour, for this purpose the different types of load and forces acting on the berthing platform of finger jetty are found out .The plan and elevation of the structure is done using AUTO CADD software. The 3D representation is done by using STAAD pro software .The structure is analysed and designed using STAAD Pro V8i for various load combinations. The structure is designed efficiently and safe against collapse and deflection and to meet the increasing traffic volume .Thus, the finger jetty is designed to serve as a berthing platform at Royapuram fishing harbour.

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MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
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