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# ANALYSIS AND DESIGN OF BERTHING STRUCTURE FOR HANDLING BULKCARGO

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**ABSTRACT:**

*This paper presents basic ideas and terminology of structural optimization of a berthing structure which was analysed and designed using different load conditions and the best possible way to construct a new berthing structure. All the suitable and useful data was adopted from the proposed site location at Belekeri port in Karnataka state and studied carefully before designing the structure. The berth is to be designed for a vessel having capacity of 120000DWT. The structure is subjected to various forces and combinations such as, High tide, Earthquake, High winds, heavy live loads as per IS: 4651-1983.The proposed berthing structure Model was generated with suitable geometry using STAAD-Pro software, after which all considerable loads on the structure were induced and analysed carefully. Different sectional dimensions were trialed during the analysis and the most acceptable structure was designed with providing all structural members with suitable reinforcement and satisfying all marine safety conditions. This research is an attempt to understand the concept of design and analysis of berthing structures under different conditions of loading.*

## I. INTRODUCTION

The berthing structures are constructed for the berthing and mooring of vessels to enable loading and unloading of cargo and for embarking and disembarking of passengers, conveyances etc. Thedesigns of berthing structures depend on various factors. In the present study of the project, we described a felicitous way to design an incipient berthing structure with example of one of the proposed berthing structure in Belekeri port in Karnataka state under Sagarmala Scheme, which is initiated by Government of India. So afore analysing and designing, the influence factors which effected on the structure were taken into consideration such as soil characteristics of the proposed location, environmental conditions and range of traffic.

All the necessary Data was adopted from Belekeri port which were supposed to be utilized in the project such as geotechnical data, environmental data, and traffic forecasting data. The entire Berth length of 300m was divided into 3 units of each 100m in length with an expansion joint of 50mm between successive units and proposed in the inner harbour, designated for handling Bulk cargo like Thermal coal, coking coal, Iron ore, etc. The details of the structural element are discussed under the conceptual design. The design dredge level is taken as -16.10m.

A berthing structure is a capital demanding project, thereby; optimum use of both space and capital becomes essential. This means that proper planning of the various units of the berthing structure, for the present and an optimistic future demands, is compulsory. Berthing structures world over undergo from congestion or inflexibility due to short comings in planning or due to wrong estimate of the traffic and or land requirement. Berthing structures vary generally from port to port. The number of berths will depend upon the number of ships to use the port and the time it will take to ejection and take on cargo or passengers. Berthing structures should be located in the most protected part of the harbor or along the lee side of the breakwaters. Where possible the berth should beso oriented as to have the ship alongside headed as nearly into the wind and waves aspossible.

Berthing facilities contain mooring bollards, bitts, and rings for protect mooring cables. Fenders, which are customarily composed of resilient materials in sund ry shapes and are hanging in front of the berthing facilities, are provided to diminish the impact when the ship is brought alongside or is driven in opposition to the dock by the wind.

**Keywords***:*Structural Loads, Dead Load, Live Load, Berthing Load, Mooring Load, Current Load, Wind Load, Hydrostatic Pressure, Earth Pressure, Basic Load Combinations, Staad- Pro, Load Analysis.

## NOMENCLATURE:

| | |
|---|---|
| F [KN] | Force |
| Cw | Shape Factor |
| Aw [$m^2$] | Wind age area |

P [KN/$m^2$] Pressure

V [m/s] Velocity of current

H [m] Wave Height

D [m] Water Depth

G [m/sec2] acceleration due to gravity

E [N/mm2] elastic modulus of the material

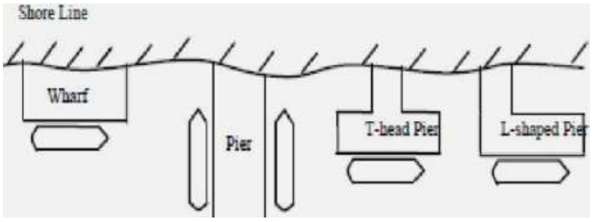
## 1. BELEKERI PORT – CASE STUDY

The proposed site for development of Belekeri port is located in Ankola taluka of Uttara Kannada District of the state of Karnataka. The co-ordinates of the site are 14° 42’ N and 74° 15’ E.

As part of the OD study carried out under Sagarmala assignment, it has been assessed that there is a good potential for coastal movement of thermal coal from the mines located in the eastern region (i.e. Mahanadi Coal fields, Talcher, IB Valley etc.) to the power plants located in the western region.
At Central Karnataka power and steel plants have been set up at Kudgi, Bellary etc. which can be best served by a port located along the coastline of north Karnataka. This is however subject to the timely completion of Hubli - Ankola rail line, which will act as a catalyst for the proposed port and the development of the region.

The existing New Mangalore port has draft limitations and also not suitably located to serve the north Karnataka hinterland. It is therefore proposed to develop a Port at Belekeri as a satellite port for NMPT. The present report has been prepared to assess its technical suitability and cost economics.


**Figure 1**: Belekeri Port Location




## 2. DESIGNOBJECTIVE

To Analyze and design the bulk cargo handling berthing structure as per the guidelines provided by the bureau of Indian Standards and followed by the bye laws of International Maritime Organization.

- The Objective of this project is to analyze a bulk cargoberthingstructureofsize300mx30m
- To design all the components in the berthing structure as per the codalprovisions.
- ToanalyzethestructureusingtheSTAAD.Pro.

## II. DESIGN PARAMETERS OF BERTHING STRUCTURES

### 1. SITE LOCATION

The determination of location influenced by easy accessibility for ships, sufficient draft availability during the year, favorable metrological and wave hydro dynamic conditions. Amount of the forces on marine structure depends on last two factors.

### 2. TYPES OF BERTH

After determination of the location for structure, have to select the kind of structure for construction and the factors controlling the selection of the kind of structure are depending on the conditions of water flowing and Geotechnical properties of soil.
Classifications of berthing structure are basically Piers and Wharfs:

**Figure 2** -: Types of Berthing Structure

6. Wharf – A berthing structure which is parallel to shore line. It is generally adjacent to the shore, and may not be very near to shore

3. Pier - A berthing structure which is project into water that means perpendicular to shore. This structure need not be exactly perpendicular to shore; it may be with some angle to shore. These structures also are like T or L shape.

### 3. SELECTION OF TYPE OF BERTHING STRUCTURE

Type of berthing structure and utilized material for construction depend on various factors, such as:

- Material availability.
- Construction cost.
- Method of construction.
- Dimension and mass of ships handled in the

port.

### 3.1. SELECTION AND REQUIREMENTS OFBERTH

a) After having decided about the location of the berthing structure, the type of the structure to be constructed needs to beexamine.
b) The factors controlling the selection of the type of structure are the flow conditions and based on the soilproperties.
c) Berthingstructurescanbeclassifiedaswharfsand piers.
d) The number of berth required in the terminal largely depends on the traffic to be handled in terms of number of ships to be serviced and their arrivingpattern,
e) The length of berth to be provided depends upon the function of the terminal and the size and the typesofshipsthatarelikelytocallattheport.
f) Berthing area should be based on the length and breadth of the largest size of the ships using the berths.

## 4. REQUIRED NUMBER OF BERTHS

- The determination of number of berths depends on handling of traffic in port .the planning of a new terminal was influenced by initial investment.
- The approximate relations used for the determination of the required number of berths are:
  N1= W/ R* H * D
  Where,
  N1= essential amount of berths for a certain cargo.
  W = yearly amount of this cargo imported and exported (T/year) = 20,920,000 tonnes

  R = handling rate of this cargo on the berth. (T/ hour) = 850 tonnes/hour
  H = number of working hours per day (Hour/ day) = 22 hr/day
  D = amount of working days per year. (Day/ year) = 300 day/year
  N1 is calculated for each kind of cargo, and the overall number of berths in the port N for all types of cargo is:

  N = Essential amount of berths for a certain cargo
  N = 3.72

Number of berths to be taken = 4

## 5. LONGITUDINAL DIMENSION OF BERTH

- The function of the terminal and size of vessel determines the berth length and ships calling to port also influence the length

- Berth length required for main line vessels is 275+25=300m
  Berth length required for feeder vessels is 150 +50 = 200m

## 6. REQUIRED AREA OF BERTH

- Berthing territory ought to be focused around the length and broadness of the biggest size of boat utilizing for the berths. Berthing range is the zone before the berthing structure needed for berthing vessels furthermore suits the administration vessels. Length needed for berthing a vessel and its surging developments because of wave and momentums are for the most part defined as 10% of boats length, subject to at least 15m. drought not be short of what (L1+l2)/20 and d2 >= (L2+l3)/20 where there are solid obstructions, the safe separation of d0 = 25 – 30 m is permitted. The width of the berthing zone ought to be 1.15 B + b where B is the shaft width of the outline vessel and b is the width of the attending craft.

## 7. DRAFT ALONG THE BERTH

- The third era holder vessels have a draft of 12.5 m. Subsequently a depth of 13.5 m must be kept up close by the quay amid all conditions permitting sufficient depth for different remittances. Depth at the compartment ought to be 10% in abundance of most extreme stacked draft of configuration vessel to consider silting and vertical movement.

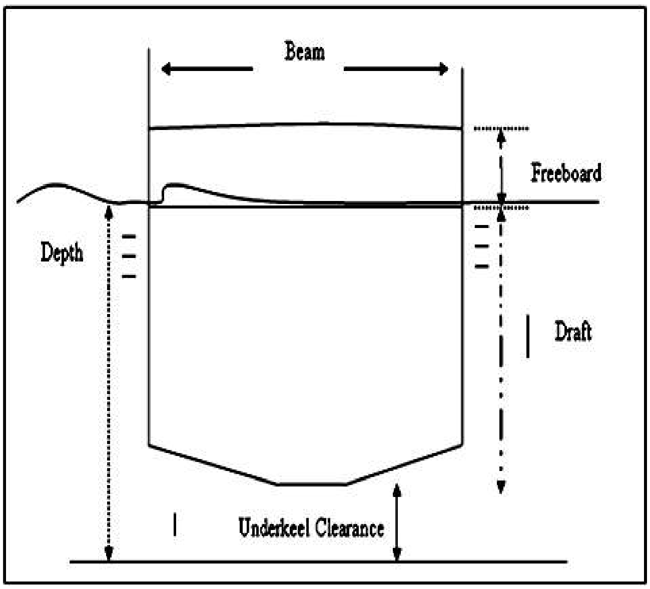



**Figure 3** -: Draft representation along the berth

### III. GENERAL METHODOLOGYADOPTED

The general methodology adopted for this project is based on the review of the existing data available and the collection of secondary resources for the project from the various government agencies with reference to special case studies of berthing structures design project. Whereas the data and resources are reviewed in order to finalize the requirements and the type of berth structure proposed to design in which all the structural elements are designed based on the bureau of Indian standards codal provisions.

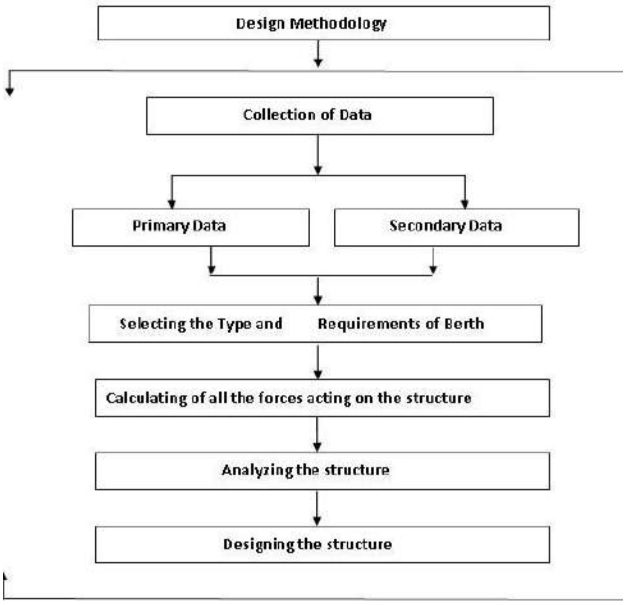



**Figure 5** -: General Methodology

### 1.DESIGNING THESTRUCTURE

The design of the slabs, beams and piles are design as per IS 456:2000, SP: 16 and IS 2911 (1). Suitable forms have been developed to design and draw the required reinforcement in the structural members.

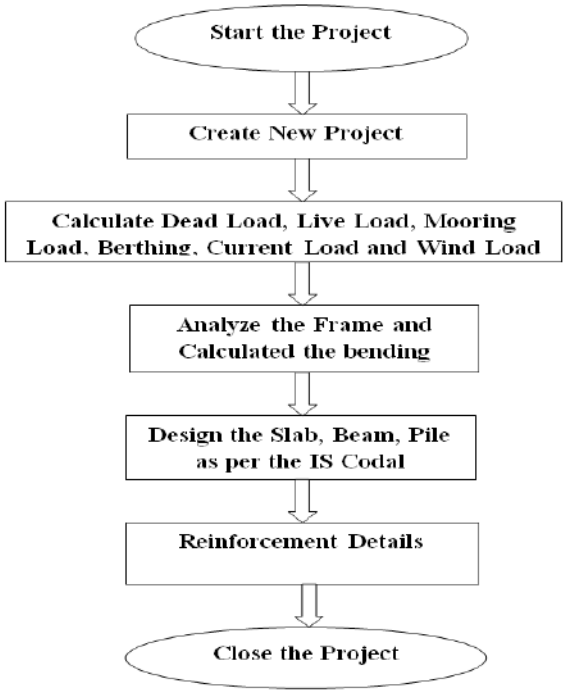



**Figure 6** -: Flow chart of project

### 2.WORKING STRESSDESIGN

There are uncertainties in load, material and theoretical models. Two different methods are available to take into account the uncertainties, namely the working stress design method and the limit state design method. The working stress method can be expressed as:

$$S^* < S/SF$$

Where,

S = Nominal stress capacity

SF =Safety Factor

S* = Design stress Stress: Nominal orShear

The disadvantages of working stress method are not consistency reliable.

### 3. LIMIT STATEMETHOD

Limit state design is a design method in which the performance of a structure is checked against various limiting conditions at appropriate load levels. The limiting conditions to be checked in structural steel design are ultimate limit state and serviceability limit state. Ultimate limit states are those states concerning safety, for example load carrying capacity, overturning, sliding, and fracture due to fatigue or other cause. Serviceability limit state are those state in which the behaviour of the structure under normal operating conditions is unsatisfactory, and these include excessive deflection, excessive vibration, and excessive permanent deformation.

**INDUCED LOADS ON BERTHING STRUCTURE**

The whole berth length of 300 m is separated into 3 units of every 100m long with an expansion joint of 50 mm between progressive units.

The proposed berth is implied for taking care of Bulk cargo like Thermal coal, coking coal, Iron ore, etc and so on the subtle elements of the structural component are talked about under the applied configuration in spite of the fact that the concession understanding accommodates dredging must be conveyed up to -16.10m. Hence for the outline dredging level is taken as -16.10m.

## IV. LOADCALCULATIONS AND ANALYSIS OF THE BERTHING STRUCTURE

### 1. DEAD LOAD [IS 875-1987 PARTI]

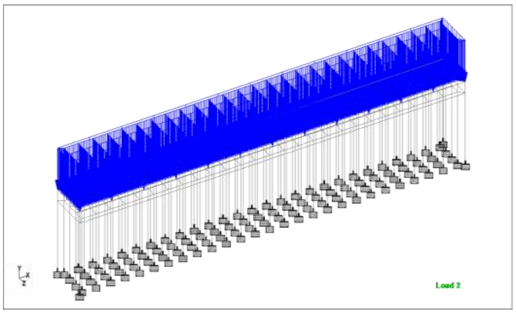



**Figure 7** -: Dead load representation on structure

All dead loads of and on structures relating to docks and harbor should be assessed and included in the design. Dead loads consist of the weight of all components of the structure as well as the weight of all permanent attachments. The DL of a port related marine structure constitutes a relative small percentage of the total load acting on the structure.

Slab Weight

= 0.3×25 = 7.55 5KN/m$^2$

Transverse beam

= 1.10×1.80×25 = 50KN/m

Longitudinal beam

= 1.10×0.6×25= 16.5KN/m

Pile

= ((pi×2$^2$)/4) ×25 = 2.27 × 25

= 56.75KN/m

### 2. LIVE LOAD [IS 4651(PARTIII)-1974]

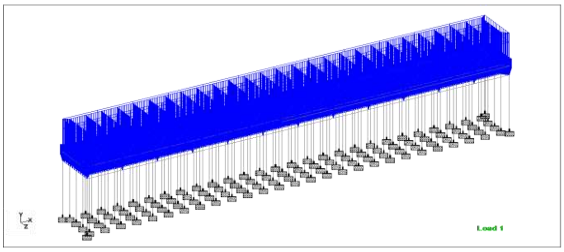



**Figure 8** -: Live load representation on structure

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 constructionplantconstitutevertical1iveloads.VerticalLL consists of the weight of all movable equipment on the structure. The function of berth related to Truck loading B (Passenger Berth) so we are adopted15KN/m$^2$

| S. No | Functioning of Berth | Truck Loading | Uniform Vertical LL(T/m$^2$) |
|---|---|---|---|
| 1 | Passenger Berth | B | 1.0 |
| 2 | Bulk unloading & loading berths | A | 1.0 to 1.5 |
| 3 | Container berths | A or AA or 70R | 3 to 5 |
| 4 | Cargo berth | A or AA or 70 R | 2.5 to 3.5 |
| 5 | Heavy Cargo berth | A or AA or 70 R | 5 or 6 |
| 6 | Small boat berth | B | 0.5 |
| 7 | Fishing berth | B | 1.0 |

## 3. BERTHING LOAD [IS 4651(PART III) –1974]

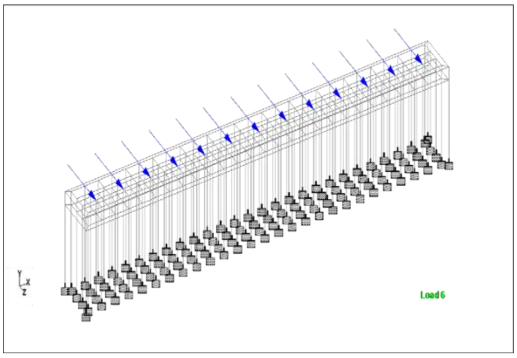


**Figure 9** -: Berthing load representation on structure

Berthing Energy, when an approaching vessel strikes a berth a horizontal force acts on the berth. The magnitude of this force Depends on the kinetic energy that can be absorbed by the rendering 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 velocity is given by:

$$E = \left(\frac{W_D V^2}{2g}\right)(Cm)\,(Ce)(Cs)$$

Where,

WD = Displacement Tonnage (DT) of the vessel (120000DWT)

V = Velocity of Vessel in m/s, Normal to the Berth (0.10m/s)

g = Acceleration due to Gravity in $m/s^2$ (9.81 $m/s^2$)

Cm = mass coefficient (Refer Table-2) =1.39 m/s

Ce = eccentricity coefficient = 0.41m/s

Cs = soft coefficient = 0.96 m/s

E = 35 kN.m

Ultimate Energy, E= 35×1.4 =49 kN-m

1 unit of berth (100 meters)

## 4. MOORING LOAD [IS 4651 (PART III)-1974]

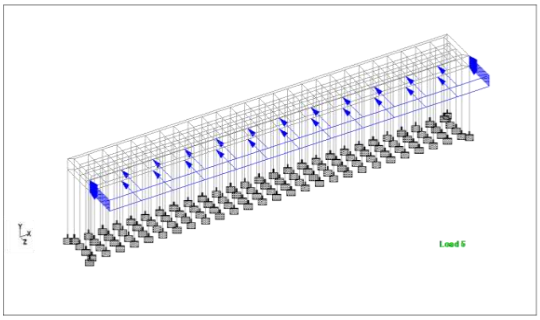


**Figure 10** -: Mooring load representation on structure

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 wind or current. The maximum mooring loads are due to the wind forces on exposed area on the broad side of the ship in light condition.

F = Cw Aw P

Where,

F = force due to wind in Kg

$C_W$ = shape factor = 1.3 to 1.6

$A_W$ = wind age area in $m^2$

P = wind age pressure in $m^2$ to be taken in accordance with IS: 875-1964

The wind age area ($A_W$) can be estimated as follows: $A_W$= 1.175$L_P$ ($D_M$-$D_L$)

Where,

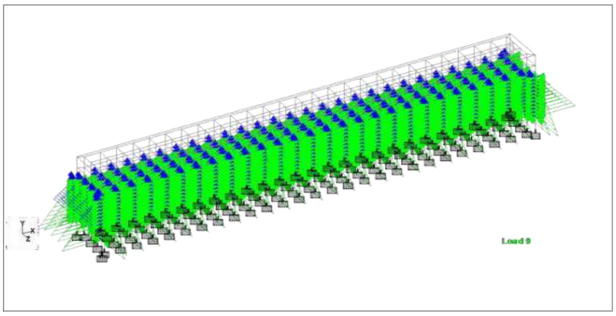
$L_P$= length between perpendicular in meter

$D_M$ = mould depth in m, and

$D_L$ =average light draft in m.

Actual this is the actual procedure but port engineers suggested that bollard pull = 900kN is adopted (Design load). Generally mooring load act in various angle of forces so we have to resolve on the mooring point while designing the berth. And spacing taken as bollard to bollard is 15m c/c, if suppose we fixed 7 bollards then the load on each bollard is

900/7 = F = 128kN




Resolving of forces on mooring points are as follows, Horizontal component = F Cos = 90kN

Vertical component = F Sin =90kN

Generally angle is taken as $45^0$ here if necessary need to calculate at different angles as per maximum ship moment observations.

γ

5. CURRENT LOAD [IS 4651(PARTIII)-1974]

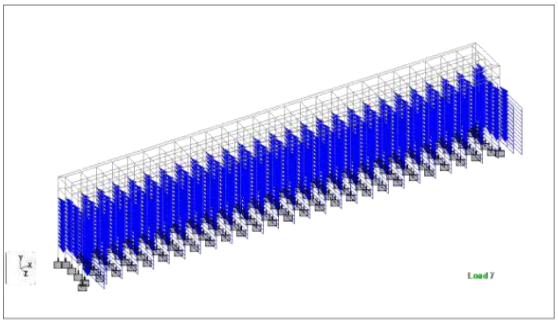



**Figure 11** -: Current load representation on structure

Forces due to Current - Pressure due to current will be applied to the area of the vessel below the water line when fully load

$$F=\frac{WV^2}{2g}$$

Where, Unit weight of water (w) = 1.025 tones/

Velocity of current (v) = 0.26m/s

Acceleration due to gravity (g) = $9.81m/s^2$

F= $0.035kN/m^2$

For 1 unit of berth F = 0.035 × 100 ×21.65 =75kN

75kN

for 20 piles for each pile F = 3.8kN

Load distribution is converted as uniform on pile F=3.8/21.6=0.18kN/m

6. EARTH PRESSURE [IS 4651(PARTIII)-1974]

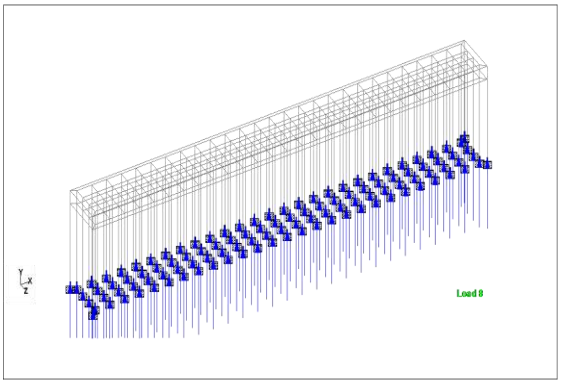



**Figure 12** -: Earth Pressure load representation on structure

$P_a$= Kγ

Where, ,K = coefficient of earth pressure

h = height of the structure = 30m

γ = unit weight of soil=$18kN/m^3$

$\phi$ = angle of internal friction of the soil = $K = \left(\frac{1-\sin\phi}{1+\sin\phi}\right)$

$$P_a=\left(\frac{1-\sin 30°}{1+\sin 30°}\right)\times 15 \text{ x } 4 = 17.4KN/m^2$$

=17.4 × 4 × 100(for 1 unit of berth)

= 6960/20 (on each pile)

= 348/4 (level)

Converted as uniform load =87kN/m

**7. HYDROSTATIC PRESSURE [IS 4651(PARTIII)-1974]**

**Figure 13** -: Hydrostatic Pressure load representation on structure

In the case of waterfront structures with backfill, the pressure caused by difference in water level at the fill side and waterside has to be taken into account in design

P= h $\gamma$

$\gamma$ = unit weight of water =9.81 $kN/m^3$

H = water head on structure=21.65m

P =9.81 × 21.65 = 212.4 $kN/m^2$

= 212.4 × 1.7

= 361kN/m on each pile

8. WIND LOAD [IS 875-PART (III) - 1987]

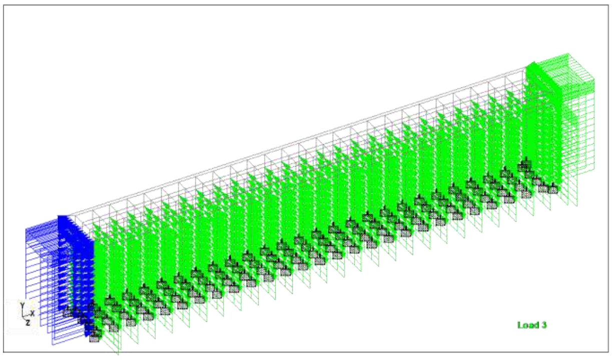



**Figure 14** -: Wind load representation on structure

Wind contributes primarily to the lateral loading on a pier. It blows from many directions and can change without notice. The wind impinging upon a surface increases the pressure on that surface and results in a force loading.

Wind speed ($V_z$) = $V_b$× $k_1$×$k_2$× $k_3$

Where,

$V_b$ = basic wind speed

$k_1$ = probability factor (Risk coefficient) =0.92

$k_2$ = terrain, height and structure size factor =1.05

$k_3$ = topography factor = 1

$V_z$ = (50) (0.92)(1.05)(1) = 48.3m/sec

Design wind pressure p = $0.6(v_z)^2P$ = 1400N/m = 1.4 kN/ $m^2$

The design wind pressure is resolved as nodal loads = 1.4× 33×1 = 46.2/12 = 3.85 kN

9. BASIC LOADCOMBINATIONS

- D.L+1.5L.L + 1(Earth Pressure) + 1 (Hydrostatic Pressure) + 1.5 (Berthing Load) + 1.5 (Mooring Load)
- 1.2D.L+1.2L.L+1E.P+1.2H.P
- 1.2D.L+1.2L.L+1E.P+1H.P+1.5 (WindLoad)
- 1.2D.L+1.2L.L+E.P+1H.P+1.5 (SeismicLoad)

## V. DESIGN OF STRUCTURAL MEMBERS

### 5.1. Transverse Beam

- Pile cap beam.
- Grade of concrete:M30.
- Grade of steel:Fe500.
- Size of the bar:25mm.
- Spacing between bars:155mm.
- Cover:50mm

### 5.2. Longitudinal Beam

- Size:600mm x 1100mm
- Grade of concrete:M30
- Grade of steel:Fe500
- Size of the bar:10mm
- Spacing between bars:125mm
- Cover:50mm
- Shear reinforcement:12mm@150mm/cc

### 5.3. Design of Slab

- Thickness of slab:300mm
- Effective depth:225mm
- Effective cover:75mm
- Grade of concrete:M30
- Grade of steel:Fe500

### 5.4. Design Of Pile

- Grade of concrete:M30
- Grade of steel:Fe500
- Dia. of the pile:1700mm
- Size of bar:40mm
- Spacing between bars:76mm
- Cover:50mm
- Tie reinforcement:10mm@300mm/cc

## VI. ACKNOWLEDEMENTS

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## VII. CONCLUSION

Different factors are to be considered while analysing and designing the berthing structure. Lateral loads on the berthing structures are more eminent than those on land– based structures. Congruous environmental data, traffic forecasting and soil data ought to be received from the proposed site location, typical load distribution is induced on the shore line structures, so need to utilize STAAD Pro software for the analysis and design.

The structure was analysed and designed satisfying various loading conditions and dimension analysis for economical aspect was additionally taken care of without exceeding the structural safety. Afore going for designing or orchestrating a berthing structure, all the present and future optimistic conditions regarding traffic data, hinterland expansion and industrialization of that particular hinterland are to be studied, which additionally play a major role in shaping the project inception at the first place.

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