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RESEARCH ARTICLE

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ANALYSIS OF COAL HANDLING JETTY WITH DIAPHRAGM WALL

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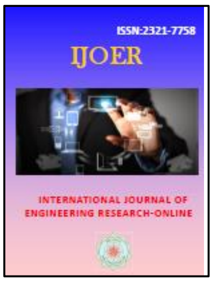

ABSTRACT

The proposed project involves construction of an offshore captive coal jetty with two berths for unloading and transporting coal through pipe conveyors for a thermal plant. The jetty consists of two berths protected by breakwater and is connected to the landside by an approach trestle. Coal brought by ships shall be unloaded on the exclusive berth designed to handle bulk carriers up to Capsize. A diaphragm wall is also added to the open pile system to enhance the efficiency of the berthing structure. Diaphragm walls are generally constructed using stiff concrete of same stiffness throughout. In this project the main emphasis will be on the performance of the coal handling jetty with and without the diaphragm wall. Modeling and analysis is done on STAAD pro V8.

Introduction

Jetties are open structures, usually of steel tubular or hexagonal piling with a heavy concrete deck .They extends out into the sea, usually at right angles to the shoreline. Jetties may be used for offloading heavy cargos. The jetty structure must be designed to withstand impact loads and 'bollard pulls' from berthing ships. Coal handling is to a vast extent related to steel manufacturing and power generation. The increased power supply and steel demands in the world pushes shipping of coal to higher volumes. To facilitate this, operators are changing to use larger vessels and hence requiring higher handling rates. Today's demands force many terminals to be able to accommodate capsize vessels up to 200,000 dwt and to ensure quick turnaround times that push loading/unloading - handling rates to higher levels.

Structural system of berthing structure

The Main berth shall be designed for berthing of two Panmax size vessels having total length and width of 555m and 25m respectively. Berthing structure proposed to be on piles, which provide least resistance to natural equilibrium and ease of extension/addition of port facilities at a later date. The present water depth requirement shall be (-) 17.0 m CD and dredged to (-) 21.0 m CD for future vessel size. The berth structure shall be designed to cater present and future requirements. Dredging for handling future cape size vessels is in the scope and since dredging shall be necessary, to achieve required water depth, the foundation of berth structure shall be taken well below the dredging level considering stability at later stage.

Piles and portions of the diaphragm wall are to be constructed in marine conditions where tidal variations are expected. The piles proposed in marine environment will have to be driven under marine conditions.

General Design Considerations and Workmanship

The main title (on the first page) should begin 1-3/8 inches (3.49 cm) from the top edge of the page, centered, and in Times 14-point, boldface type. Capitalize the first letter of nouns, pronouns, verbs, adjectives, and adverbs; do not capitalize articles, coordinate conjunctions, or prepositions (unless the title begins with such a word). Leave two blank lines after the title.

The detailed engineering comprises design of Berth and Diaphragm Wall .The major design considerations for the structures are as follows:

Table 1. Materials

Structure	Material	
	Concrete	Steel
Sub-Structure	M40	Fe500
Super Structure	M40	Fe500

The cover to the main reinforcement used for the design of Berthing Structure as well as approach jetty and diaphragm wall are in the range of 75 mm to 50 mm depending upon the exposure to the environment.

Design basis

The loads acting on the structures are calculated in accordance with IS 4651 (PART-3), & IS 875 (wind load)

All RCC piles shall be designed using Limit State method in accordance with IS 456-2000 & IS 2911 (5 parts)

All other structural steel members shall be designed using working stress method in Accordance with IS 800.

Reinforced concrete members shall be designed using limit state design method as per IS 456: 2000.

Three-dimensional structural analysis of structure shall be conducted under all specified Load combinations using STAAD Pro.

Structural modelling shall consider pile fixed at fixity depth below global scour level for all piles.

Local scour shall be considered below global scour additionally for 10% of piles out of all piles of respective structural elements in modelling.

Live loads and special loads: Live loads selected in general as per IS: 875. However, the following minimum loads is considered in the design of structures.

Berth: The berth is designed for the following Live/Equipment Loads:

Stacking Loads: Uniform Stack 1.5 T/sq. m

Vehicular Loads: IRC Class-AA / A/ 70-R Loading

Equipment Load: Conveyer load

Marine growth: Marine growth of 50 mm thick is taken into consideration while assessing wave and current forces.

Wave loads: Wave load on single pile is calculated using stokes V^{th} order wave theory. The wave loading generated on a single pile for the considered wave height and period is trapezoidal in nature.

Current force: The currents at the project site are wind induced surface currents from North and South directions varying with the seasonal wind, with a current magnitude of 0.50 m/s predominantly towards North of project site. Maximum current speed shall be 0.75m/s.

Pressure due to currents will be applied to the area of the vessel below the water line when fully loaded; as per IS: 4651 - Part III. Clause 5.6.

Wind force: The wind load on structure is considered as per IS: 875-Part 3. The basic wind speed (Vb) for operational and extreme condition shall be 20 m/s and 50 m/s respectively.

Design wind speed to be obtained using the formulae given by

Design Wind speed = Vz = k1 x k2 x k3 x Vb

Where,

K1 - risk co-efficient as per Table-1 of IS 875:Part3

K2 - terrain (category 1), height and structure size factor as per Table-2 of IS 875: Part 3

K3 - Topography factor = 1.0

Design wind pressure $P_z = 0.6 \, xVz^2$

Berthing Force: Berthing loads shall be calculated in accordance with IS: 4651 (Part III) – 1974 for the design vessels mentioned above. Berthing velocity for moderate wind and swells and moderate berthing conditions is given below.

Table 2.Berthing velocity

Vessel range	Berthing Velocity
Up to 1,00,000 DT	0.20 m/s
More than 1,00,000 DT	0.15 m/s

Berthing energy $E = \frac{W_D x V^2}{2g} x C_m x C_e x C_s$, Where,

mass coefficient, $C_m = 1 + \frac{2D}{B}$

Eccentricity coefficient, $C_e = \frac{1+\left(\frac{l}{r}\right)^2 (\sin\theta)^2}{1+\left(\frac{l}{r}\right)^2}$

Softness coefficient, C_s = 0.9 to 0.95

Fendring system: It is required to provide a suitable fender system, not only to absorb the design berthing energy of the vessel but also to keep the

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vessel's hull pressure low. Based on these criteria, the fender of Super corn (SCN) of Trellborg make has chosen at the different berthing points

Mooring Force: 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.

Mooring Force due to wind, F = $C_w A_W$P

Where, Shape factor C_w is between 1.3 to 1.6

A_W is the wind age area in m²,

$A_W = 1.175\ \mathrm{Lp(Dm\ - DL)}$

Temperature Load: The following maximum and minimum temperatures are considered for the design.

Maximum temperature : (+) 40^{0}C

Minimum temperature : (+) 15^{0}C

Seismic force: Earthquake forces shall be adopted as applicable for the site as per IS 1893 – 2002 Design horizontal seismic coefficient shall be evaluated as per procedure detailed in IS 1893-2002.

Various parameters are as follows:

Table 3.Seismic parameters

Seismic zone :	Two
Design horizontal seismic coefficient, Ah	ZI(Sa/g)/(2R)
Zone Factor Z :	0.10
Importance Factor I:	1.5
Response Reduction Factor R :	5 (for steel piles)
	3 (for concrete piles)
Type of Soil	Hard soil
Damping	5% for Reinforced concrete

Time period of specified structures shall be evaluated by STAAD analysis considering Dead load + Super imposed dead load + 50% Live load.

Load combinations: Both serviceability and ultimate limit state load combinations are considered based on IS-4651:2014. The structure is designed for limit state of collapse and checked for limit state of serviceability.

STAAD Model

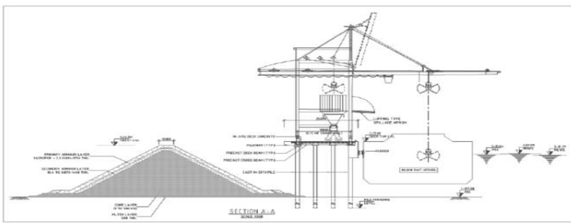

Fig.1 Section of Berth

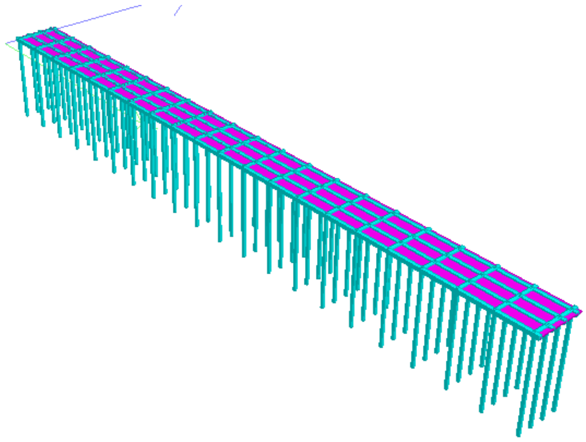

Fig.2 STAAD model of berth

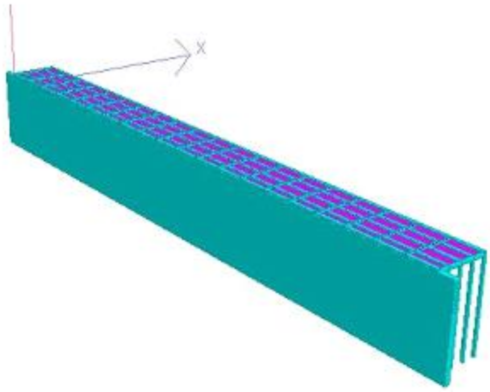

Fig.3 STAAD model of berth with D wall

4.1. Live load

For main berth consider a live load of 5 kN/m (UDL) over the deck. Along with this

- Stacking Loads: Uniform Stack 15 kN/m (UDL)
- Conveyor: The approach bridge is designed for the lateral loads from conveyor

The horizontal conveyer loads are as follows

- Vertical live load (i.e., along conveyor) is 10 kN/m for one pipe conveyor (Incl. belt, idlers & stringer supports)
- Longitudinal live load (i.e., along conveyor) is 50 kg/m for one pipe conveyor
- 50T capacity Rubber tyre crane used for Pipe conveyor lifting /placing during erection stage

4.2. Wave loads

From the calculations wave loads obtained as follows,

a) For operating condition:

- Time period = 12 sec
- Wave height = 1.0 m

- Bed level = -21.0 m
- MHWS = 0.99 m
- Diameter of pile = 1.2 m
- Cd = 0.7 , Cm = 2.00

Maximum force due to wave = 8.267 kN

Trapezoidal force ((a+b)xh)/2 = 8.267 kN

Let a be 70% of (a+b) = 0.526 kN

Let b be 30% of (a+b) = 0.225 kN

b) For extreme condition

- Time period = 18 sec
- Wave height = 3.6 m
- Bed level = -21.0 m
- MHWS = 0.99 m
- Diameter of pile = 1.2 m
- Cd = 0.7 , Cm = 2.00

Maximum force due to wave = -16.70 kN

Trapezoidal force ((a+b)xh)/2 = -16.70 kN

Let a be 70% of (a+b) = -1.063 kN

Let b be 30% of (a+b) = -0.455 kN

4.3. Wind load

a) Operational condition

Basic wind speed : Vb = 20 m/s

Co efficients : K1 =1, K2 =1.17, K3 =1

Design wind speed : Vz = K1 x K2 x K3 x Vb

Design wind pressure : Pz = 0.6 x Vz2 = 0.328 kN/m^2

Wind force : F = Cf x Pz x Ae

Where Cf = Drag coefficient

Ae is the frontal area

b) Extreme condition

Basic wind speed : Vb = 50 m/sec

Co efficients : K1 =1, K2 =1.17, K3 =1

Design wind speed : Vz = K1 x K2 x K3 x Vb

Design wind pressure: Pz = 0.6 x Vz2 = 2.053kN/m^2

Wind force : F = Cf x Pz x Ae

where Cf = Drag coefficient

Ae is the frontal area

4.4. Current load

Force due to current, F = per unit area

a) Operation condition

Current velocity = 0.5 m/sec

Diameter of pile = 1.2 m

Unit weight of sea water w = 1030 kN/m^3

Current Force worked out to be = 0.157 kN/m^2

b) Extreme condition

Current velocity = 0.75 m/sec

Diameter of pile = 1.2 m

Unit weight of sea water w = 1030 kN/m^3

Current Force worked out to be = 0.354 kN/m^2

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4.5. Temperature load

Maximum temperature : up to +40o c

Minimum temperature : + 15o c

4.6. Berthing load

The design vessels are assumed to approach the berths under difficult berthing conditions at an angular approach of Berthing load is considered as per IS 4651 part III. The Berthing energy calculated for 1,20,000 DWT vessel using IS: 4651, clause 5.2.1 as per details below:

Site condition :Moderate wind and swells

Berthing condition :Moderate

Berthing energy E = x x x

Where, mass coefficient, = 1.90

Eccentricity coefficient, = 0.41

Softness coefficient, = 0.9 to 0.95 = 0.925

The design berthing energy works out to be 1282.71kNm as per the above formula after allowing a 10% of maximum energy absorption.

For the max. Berthing energy of 1282.71 kN-m select super cone fenders (from Trelleborg fender manual)

SCN: 1600 (E0.9) is having less reaction force for corresponding berthing energy.

ER = 1282.71 kN-m corresponding reaction is RR = 1670 kNm.

4.7. Mooring load

Mooring bollard pull is taken as 137.5 t from IS 4651-part 3, Clause 5.3.4 & 6.1, table 4.

5. Results and Discussion

5.1. Comparison

One of the major objectives of the project is to compare the two analysed structural models of coal handling jetty with diaphragm wall and that without the diaphragm wall.

After the analysis of both of the model, the results are obtained for both structural model with all possible loads and load combinations. Comparisons are made mainly based on the total deflection of the structures, moments, shear and also the design details of the structural elements.

5.2. Deflection

The allowable deflection of the entire structure was found to be 149.8 mm, according to the pile length of 37.45 m.

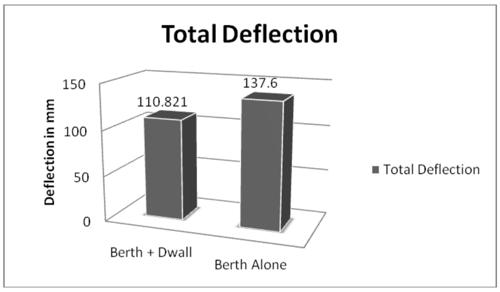

Fig.4 Total deflection

After the analysis the total deflection of the structure with berth alone was found to be 137.6 mm, and that of the structure with diaphragm wall was found to be 110.8 mm. Even though both of the structures are safe under the deflection criteria, deflection of the model with berth alone was near to the limiting value. The percentage increase in the deflection of the structure with berth alone as compared to the structure with diaphragm wall was found to be 19.47 %

Considering the life time of 50 years, there might be a chance of increasing the deflection. Hence in the deflection point of view the structure with a diaphragm wall is more preferable.

5.3. Moments

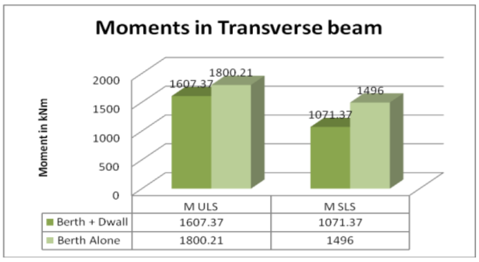

Fig.5 Moments in transverse beams

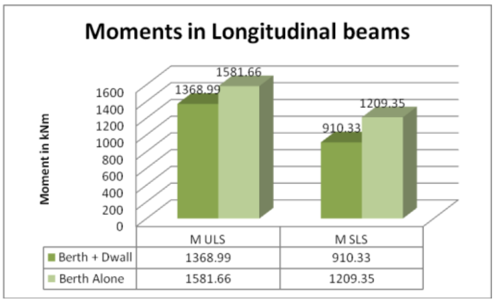

Fig.6 Moments in longitudinal beams

Results show that the ULS moments in the transverse beam of structure with berth alone are 14.83 % more than that of the structure with D-Wall. Same trend in longitudinal beam also, here there is an increase of 12.14%.The diaphragm wall improves the moment of resistance of the entire structure.

5.4. Design Shear

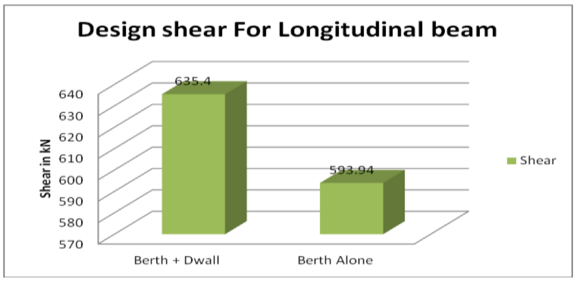

Fig.7 Shear for longitudinal beam

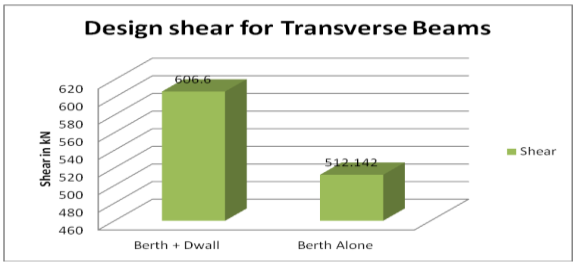

Fig.8 Shear for transverse beams

In design shear the structure with D wall is having 6.52 % increase for longitudinal beams and 15.57 % increase for transverse beams as compared to structure without D wall.

5.5. Moments of piles

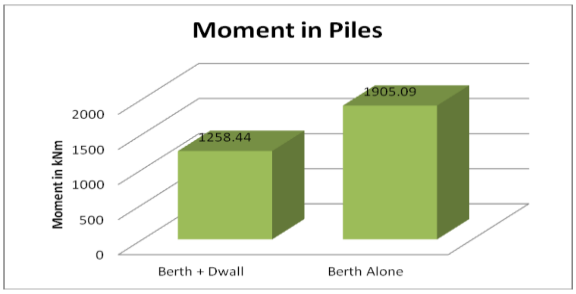

Fig.9 Moments on piles

Design moments in piles for berth structure alone are 28.94% higher than that of structure with D-wall.

6. Conclusion

After the analysis of models in STAAD pro. and comparison of the obtained results of both models under study ,The following are the major findings in this project

- The structure without diaphragm wall was found to have 19.47 % increases in deflection as compared to the structure with diaphragm wall. Hence the addition of diaphragm is favouring for more deflection control
- Crack widths of the critical elements are restricted to 0.3 mm in order to achieve serviceability throughout the design life.
- Moments in the transverse beam of structure with berth alone are 14.83 % more than that of the structure with D-Wall. Same trend in longitudinal beam also, here there is an increase of 12.14%.
- As expected the moment of resistance of the entire structure has enhanced with the introduction of diaphragm wall.
- In design shear the structure with diaphragm wall is having 6.52 % increase for longitudinal beams and 15.57 % increase for transverse beams as compared to structure without diaphragm wall.
- Addition of a diaphragm wall enhances the serviceability and ultimate strength of the entire structure and it can be adopted for the design of open pile system in marine environment and also in marine structures where there is a need of retaining the earth from one side.

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