ANALYSIS AND DESIGN OF A HEAVY CARGO BERTHING STRUCTURE

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Abstract*— The structures which are constructed for the intention of berthing and mooring of vessels to facilitate loading and unloading of cargo and also for embarking and disembarking of passengers or vehicles etc. is called berthing structure. Various factors influence the analysis and design of the berthing structures. The berthing structures are designed for dead load, live load, berthing force, mooring force, earthquake load and other environmental loading due to winds, waves, currents etc. In the present study, a proposed berthing structure EQ-10 is taken for analysis and design .All suitable data is collected from Visakhapatnam port trust and their website like geotechnical data, environmental data, and traffic forecasting data. By using all these data, we planned and modeled a structure. After that we calculated various loads induced on structure and we analyzed the modeled structure in STAAD-PRO due to the typical load distribution on structure. Actually we have trailed with different dimensions for most acceptable structure, in that trailing we concluded that larger diameter pile gets less deflection when compare with smaller diameter piles. Finally the structure was analyzed and designed with resisting of marine conditions and satisfying in the aspect of economical and safety

***Key words*—Berthing structure, STAAD-PRO, Marine Conditions.**

I. INTRODUCTION

In the present study, we described a suitable way to design a new berthing structure with example of one of the proposed berthing structure in Visakhapatnam port. So before analyzing 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 basic Data was adopted from Visakhapatnam port which were supposed to be used in the project such as geotechnical data, environmental data, and traffic forecasting data. The entire Berth length of 100m was divided into 3 units of each 33.33 in length with an expansion joint of 40mm between successive units and proposed in the inner harbor, meant for handling liquid cargo like Sulphuric acid, Phosphoric acid, phosphoric acid, edible oils etc. The details of the structural element are discussed under the conceptual design. The design dredge level is taken as -16.10m. Factors to be considered before going to design a berthing structure like fixing of a location, selection of type of berth, deciding of Number of berths, selecting Length of berth and Area of berth, required Draft alongside berth ,Apron width, Deck elevation, turning circle, and Stacking area requirements Area requirements for other facilities. The entire EQ (Eastern Quay)-10 berth length of 100.07 m is divided into 3 units of each 33.33 in length with an expansion joint of 40mm between successive units. The proposed EQ-10 berth at Visakhapatnam Port in the inner harbor is meant for handling liquid cargo like Sulphuric acid, Phosphoric acid, phosphoric acid, edible oils etc. the details of the structural element are discussed under the conceptual design .although the concession agreement provides for dredging has to be carried up to -16.10m .hence the design dredge level is taken as -16.10m

II. GEOMETRY OF STRUCTURE

Thickness of apron layer	: 200mm
Thickness of slab	: 300mm
Size of transverse beam	: 1800mmX1100mm
Size of longitudinal beam	: 1100mmX600mm
Size of pile	: 1.70 diameters, height 21.65 meters
Total height of the structure	: 23.30meters
Design dredged level	: 16.60 meters
Pile submerged level	: 19.60 meters
Deck elevation	: 3.70mt
Kerb wall height	: 1mt
Area of berth	: 100m X12m
Number of divided units	: 3
Area of each unit	: 33m X 12m
Slab panel size	: 2.62m X 2.62m

III. LOADS ON STRUCTURE

Wearing coat (Apron)	= 5 kN/m^2(density of the concrete is taken 25 kN/m^3)
Slab weight	= 7.55 kN/m^2
Beams	
Transverse beams	= 50kN/m
Longitudinal beam	= 16.5 kN/m
Pile	= 920.12 kN/m

Live load is based functioning of berth and truck loading on berth as per IS: 4851 (Part III) – 1974. The function of berth related to Truck loading A or AA or 70R (Heavy cargo berth) so we are adopted 50 kN/m^2.

Berthing load: this load is happened when a ship hits the berthing structure

$$E = \frac{W_D V^2}{2g}(C_m)(C_e)(C_s)$$

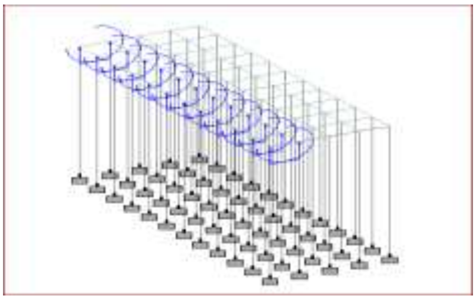

Fig1: berthing load representation on structure

E =80kN.m
27 kNm/33m for 1unit of berth (33 meters)

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 wind or current.

$$F = C_w A_w P$$

Actually this is the actual procedure but port engineers suggested that bollard pull =900kN is adopted (Design load)

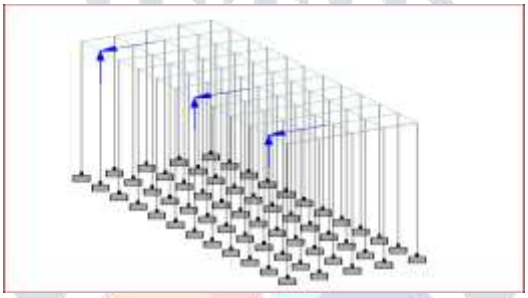

Fig2: mooring load representation on structure

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

$$F = w\, v^2/2\, g$$

For 1 unit of berth F = 25kN
25kN for 12 piles for each pile F = 2.02 kN
Load distribution is converted as uniform on pile F =0.096KN/m

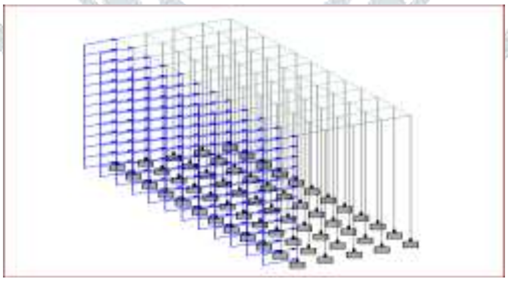

Fig3: current load representation on structure

Wind load: Wind contributes primarily to the lateral loading on a pier. It blows from many directions and can change without notice.
Design wind speed (V_z) = $V_b k_1 k_2 k_3$
Design wind pressure = $0.6(v_z)^2$
p =1.4kN/ m^2
Now the design wind pressure is resolved as nodal loads on structure =3.85 kN

Seismic load

Design seismic base shear V_B= $A_h W$

$$A_h = \left(\frac{Z}{2}\right)\left(\frac{S_a}{g}\right)\left(\frac{I}{R}\right)$$

Z= zone factor =0.16
I= importance factor =1.5
R= response reduction factor =5

$\left(\frac{S_a}{g}\right)$ =2.50(hard rock)

A_h =0.06

W= seismic weight of the structure =55318.5kN

V_B = 4500.5kN

The approximate fundamental natural frequency period of vibration ($T_s$in sec) = $\frac{0.09h}{\sqrt{d}}$

T_s = 0.35 sec

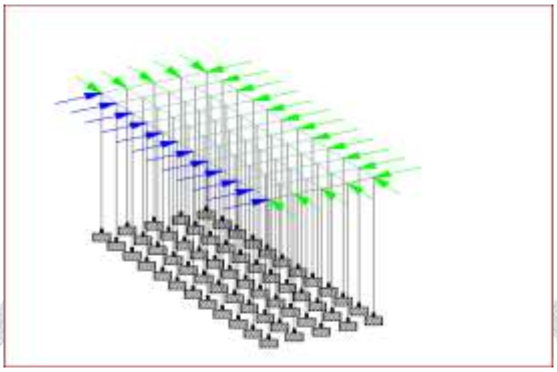

Fig4: lateral load representation on the structure

Earth pressure:

$P_a = K\gamma h$

P_a = 17.4 kN/m^2

Converted as uniform load =47.85kN/m

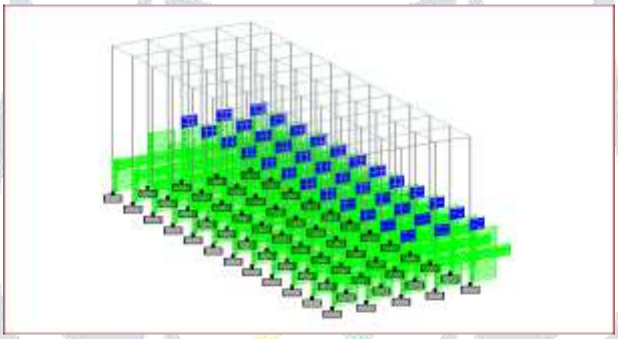

Fig5: Earth pressure representation on the structure

Table1: Level wise earth pressure on piles

Level (m)	Pressure kN/m	On each pile kN/m
0-3	17.4	47.85
3-4.5	28.7	78.92
4.5-7.5	19.14	52.6
7.5-9	9.57	26.31

Water pressure/hydrostatic pressure: 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

$P = \gamma h$

P =180kN/m^2

=270kN/m on each pile

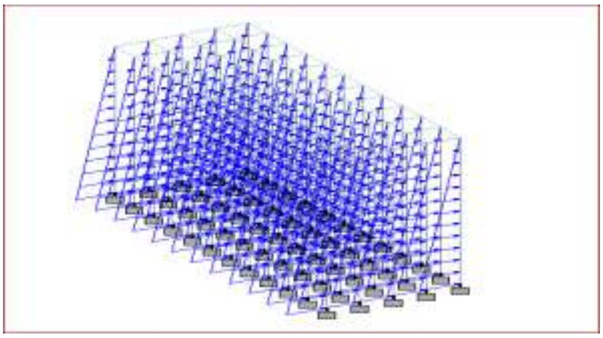

Fig6: water pressure representation on structure

Table2:Node displacements at worst load combinations

	Node	Load comb	X (mm)	Y (mm)	Z (mm)	Resultant (mm)	rX	rY	rZ
Max X	2	17	**93.83**	0.556	0.003	93.83	-0.00	0.00	-0.001
Min X	10	14	**-4.3**	0.024	0.001	4.371	0.00	0.00	0.000
Max Y	12	15	81.81	**0.86**	0.003	81.82	-0.00	0.00	-0.001
Min Y	30	17	93.82	**-1.52**	-0.004	93.83	0.00	0.00	-0.001
Max Z	120	20	77.46	-1.23	**1.971**	77.502	0.00	0.00	-0.001
Min Z	10	21	77.46	-1.23	**-1.971**	77.502	-0.00	0.00	-0.001
Max rX	120	20	77.46	-1.23	1.971	77.502	**0.00**	-0.00	-0.001
Min rX	10	21	77.46	-1.23	-1.971	77.502	**-0.00**	0.00	-0.001
Max rY	2	17	93.83	-0.556	0.003	93.83	-0.00	0.00	-0.001
Min rY	112	16	76.81	0.271	-0.010	76.81	0.00	-0.00	-0.001
MaxrZ	2	14	-4.366	-0.053	0.001	4.366	-0.00	0.00	0.00
MinrZ	22	17	93.83	0.47	0.002	93.83	-0.00	0.00	-0.001
Max Rst	10	17	93.83	-1.43	-0.006	**93.84**	-0.00	0.00	-0.001

Table3:Beam end forces

	Beam	Node	L/C	Axial	shear		Torsion	Bending	
				Fx(kN)	Fy(kN)	Fz(kN)	Mx kN/m	My kN/m	Mz kN/m
Max Fx	135	99	16	**4.29E+3**	2.34E+3	0.490	0.490	1.534	13.3E+3
Min Fx	15	11	15	**-2.04E+3**	2.79E+3	-0.199	-0.199	0.817	14.15E+3
Max Fy	15	11	17	-469.19	**3.05E+3**	-1.661	-0.247	11.642	16.15E+3
Min Fy	8	10	17	-35.70	**-2.43E+3**	-0.140	7.381	-2.772	4.58E+3
Max Fz	145	105	21	2.25E+3	2.43E+3	**20.552**	0.157	-222.263	13.9E+3
Min Fz	19	15	20	2.25E+3	2.43E+3	**-20.552**	-0.157	222.263	13.9E+3
Max Mx	2	2	16	69.05	-1.67E+3	-0.545	**29.064**	5.335	-3.46E+3
Min Mx	156	112	16	68.53	-1.68E+3	0.041	**-29.525**	-4.024	-3.46E+3
Max My	19	15	20	2.25E+3	2.43E+3	-20.55	-0.157	**222.263**	13.9E+3
Min My	145	105	21	2.25E+3	2.43E+3	20.55	0.157	**-222.263**	13.9E+3
Max Mz	19	15	17	2.25E+3	3E+3	-2.383	-0.188	16.513	**17E+3**
Min Mz	33	26	17	935.19	58.55	-0.013	-0.159	-0.225	**-6.15E+3**

Table4:Bending moments at mooring pile in worst load combination in y-direction

Pile number	141	143	145	147	149
Maxi (kN.m)	23.24	30.96	33.53	29.819	20.21
Middle (kN.m)	5.80	7.84	8.50	9.61	5.20
Ends (kN.m)	11.64	15.34	16.51	14.58	9.70

Table5: Bending moments @ mooring effected beams in y-direction

Beam number	142	144	146	148
Maxi (kN.m)		-0.83		0.762

Middle (kN.m)	-0.227	-0.399	0.231	0.33
Ends (kN.m)	0.38	-0.836	0.702	0.024

Table6: Bending moments at mooring pile in worst load combination in z-direction

Pile number	**141**	**143**	**145**	**147**	**149**
Maxi (kN.m)	1684.1	1704.3	1783.2	1695.3	1632.1
Middle (kN.m)	-2393.2	-2563.7	-2513.6	-2513.2	-2216.3
Ends (kN.m)	-4428.3	-5824.3	-6158.3	-5984.2	-4789.1

Table7: Bending moments @ mooring effected beams in Z-direction

Beam number	**142**	**144**	**146**	**148**
Maxi (kN.m)	-4183.2	-3245.6	4512.3	3253.6
Middle (kN.m)	-1053.2	-237.6	125.67	1023.6

Table8: Shear force at mooring pile in worst load combination in Y-direction

Pile number	**141**	**143**	**145**	**147**	**149**
Maxi (kN)	-90.71	26.85	58.55	46.42	-39.91
Middle (kN)	760.79	877.35	909.05	896.9	810.58

Table9: Shear force @ mooring effected beams in Y-direction

Beam number	**142**	**144**	**146**	**148**	
Maxi (kN)	-2113.3	-2213.6	-2136.1	-2126.2	-2376.2
Middle (kN)		-2134.3	-2043.1	-2045.2	-2286.1

Table10: Shear force at mooring pile in worst load combination in Z-direction

Pile number	**141**	**143**	**145**	**147**	**149**
Maxi (kN)	1.661	2.205	2.383	2.114	1.425
Middle (kN)	1.661	2.205	2.383	2.114	1.425
Ends (kN)	1.661	2.205	2.383	2.114	1.425

Table11 :Shear force @ mooring effected beams in Z-direction

Pile number	**142**	**144**	**146**	**148**
Maxi (kN)	1.661	2.205	2.383	2.114

Middle (kN)	1.661	2.205	2.383	2.114
Ends (kN)	1.661	2.205	2.383	2.114

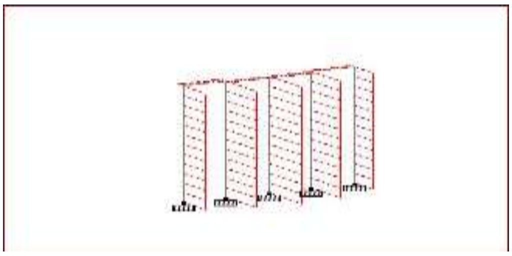

Fig7: Shear force diagram in z-direction

Table12: Axial force at mooring pile in worst load combination

Pile number	**141**	**143**	**145**	**147**	**149**
top	-1823.1	-94.64	905.76	650.67	2893.2
bottom	469.19	2347.3	2253.6	2003.1	4243.5

Beam number	**142**	**144**	**146**	**148**
Front	62.002	43.91	4.23	-27.53
back	62.002	43.91	4.23	-27.53

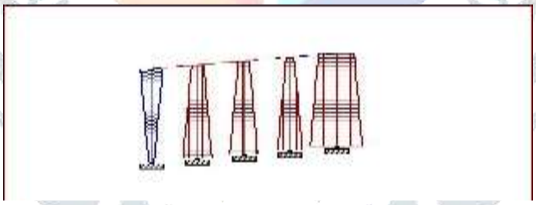

Fig8: axial force diagram

Table13: Beam stress at mooring pile in worst load combination

Pile number	**141**	**143**	**145**	**147**	**149**
Maxi- (kN/m2	35.13	34.72	34.185	34.12	31.89
Maxi+ (kN.m2	34.72	35.62	36.17	35.86	35.62

Beam number	**142**	**144**	**146**	**148**
Maxi+ kN/m2	11.539	8.942	8.954	12.4
Maxi- kN.m2	11.47	-8.898	8.949	12.7

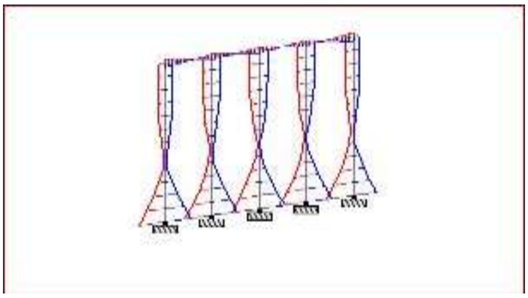

Fig9: Beam stress diagram

Table14: Reactions

Pile number	141	143	145	147	149
Support reaction	469.193kN	2342.2kN	2253.46kN	1998.39kN	4238.92kN

IV. DESIGN OF SLAB

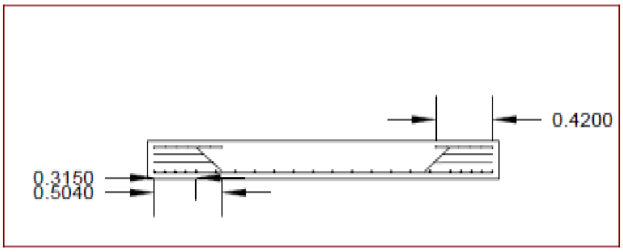

Fig10: Side view

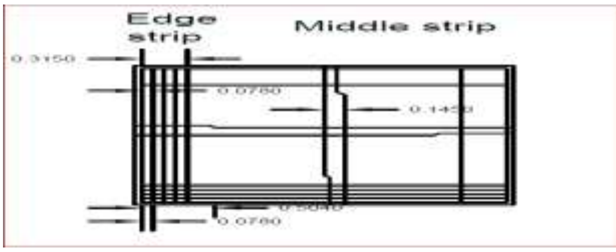

Fig11: top view

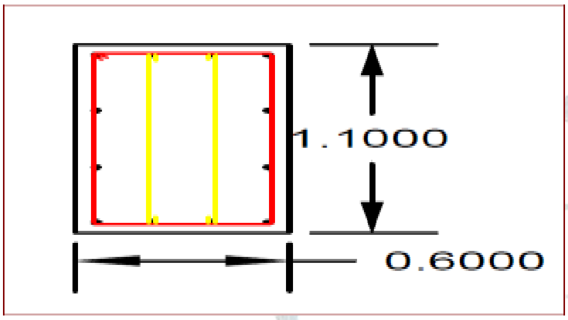

Fig11: longitudinal beam cross section view

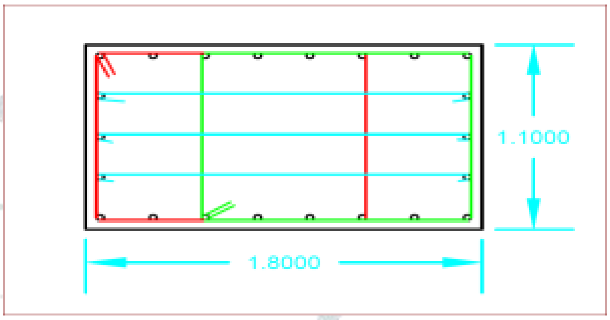

Fig12: Transverse Beam cross section view

V. CONCLUSION

Different factors are to be considered while analyzing and designing the berthing structure. Lateral loads on the berthing structures are more noteworthy than those on land–based structures. Suitable 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 use STAAD Pro software for the analysis and design. The structure was analyzed and designed satisfying various loading conditions and dimension analysis for economical aspect was also taken care of without exceeding the structural safety. Before going for designing or planning 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 also play a major role in shaping the project inception at the first place

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