Performance Assessment of An Existing Jetty Slab Under Modified Service Condition

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***Abstract*—A Jetty structure is a type of coastal engineering construction designed to extend into bodies of water, such as oceans, seas, rivers, or lakes. It typically consists of a series of connected elements, such as piles, beams, and decking, that are built perpendicular to the shore or coastline. As we venture into the distant future, the need to adapt and innovate becomes increasingly paramount. Nowhere is this more evident than in the realm of coastal engineering, where the design of structures that can withstand the challenges of rising sea levels, changing climate patterns, and evolving technologies is of utmost importance. Therefore, we must update our port infrastructure in order to preserve the country's economic expansion and keep up with the constantly shifting demands of the global logistics industry. This paper presents an attempt to evaluate such an existing jetty slab structure in Mumbai's Jawaharlal Nehru Port. Using structural drawings that were on hand and analysis of the jetty model in STAAD-PRO, the present load bearing capability of the jetty was determined. Ideas for future development as well as steps to repair the harm the jetty accrued through time were also suggested based on the studies' conclusions.**

***Index Terms*—Jetty Structure, Slab design, Mooring, STAAD-PRO, Coastal Engineering**

I. Introduction

Offshore constructions known as jetties are built with the intention of giving huge cargo ships a secure platform on which to birth and anchor. Crane loads and lateral loads induced by vessel hit are two significant factors that affect jetties. . A multitude of variables, including as wind direction and speed, salt, ballast water pollution, exposure conditions, and oceanographic conditions, can affect jetty structural deterioration. The main sign of the structural health of the jetty is corrosion of the reinforcing steel in the concrete. India now has 504 jetties with a length of about 100 kilometres. To ensure the security, effectiveness, and durability of these coastal engineering structures, jetty structures must be designed and analysed for varied service circumstances. Jetty structures are subjected to a variety of environmental forces and operational demands, necessitating careful consideration and adaptation to meet specific service requirements. Modified service conditions encompass scenarios where jetties may experience unique or altered operational situations beyond the typical design parameters. These conditions may arise due to changes in environmental factors, such as extreme weather events, sea-level rise, or evolving navigational requirements. Additionally, modifications can arise from the need to accommodate larger vessels, increased traffic, or changing utilization patterns.

The major subjects of this work are the modelling and analysis of an existing jetty structure in STAAD-PRO. Based on the results of the study, it may be easy to compute the slab and beam element's load bearing capacity. If necessary, additional actions might be suggested to strengthen the structure and improve its ability to support loads.

II. METHODOLOGY

The JNPT jetty case study was used to determine if the jetty structure could handle new service circumstances. JNPT has been serving for around 27 years and is being used for this investigation.

A. *JNPT Port, Mumbai - A Case study*

The current Container berth is of 830m long, which includes a 150-meter wharf expansion. JNPT, on the other hand, only uses 680m, while other operators utilise the north 150m.

A consultant named M/S Howe (India) Pvt. Ltd. created the container berth (680m length) in 1983. The same expert verified a 6000 TEU (Twenty Foot Equivalent) vessel in 2003 and a 9000 TEU vessel in 2004. The cargo berth was extended by 150 metres in 1997.The former container berth is made up of 150 metres of wharf expansion to the south and 530 metres of the original berth (blocks 1, 2, and 3). A different operator were given the container berth 150 metres from block 3, hence it was excluded from the present analysis. The deck is currently 40 inches wide. The structure consists of many huge cranes spaced around 20 meters apart.

B. *Berthing Structure Elements*

The container berth was initially designed to accommodate a ship carrying 6000 TEU, however JNPT later certified the capacity to accommodate ships carrying 9000 TEU. To accommodate the larger vessel, which has a capacity of 12200 TEU, JNPT plans to expand the dock. All three types of vessels' dimensions are displayed in the table below.

TABLE I
VESSEL CHARACTERISTICS

[illegible]	Displacement tonnage	LOA (m)	Beam (m)	Loaded draft (m)	Berthing [illegible] (m/s)
6000 TEU	110,000	300	41.0	13.5	0.1
9000 TEU	150,000	340	51.0	14.5	0.1
12200 TEU	215,000	398	56.4	15.0	0.1

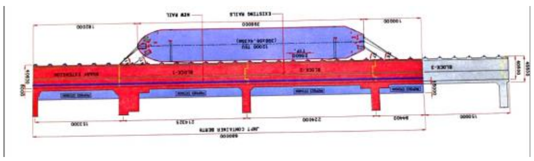

Fig. 1. Mooring Layout for 12200 TEU

Based on ship size, dock cranes' container handling capacities are divided into three primary types.Panamaxboats with an outreach of 30–40m and the ability to transship 11–13 containers wide (rows) or more. The Panama Canal may be crossed by these cargo ships. Post-Panamax vessels having an outreach of 40–50 m and the ability to transship containers that are at least 17–19 containers wide.Super Post-Panamax vessels having a transshipment capacity, 21–23 container width, and 50–70 metre outreach.

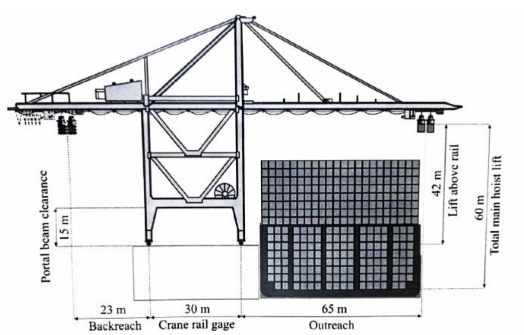

Fig. 2. Cross Section of Typical Crane

III. DESIGN CONSIDERATIONS

A. Structural Arrangement

1) For the purposes of the analysis in this research, we are taking into account the 150 m Wharf expansion and creating a STAAD model of the jetty structure.

2) Every 30 metres along the length, a 50 mm Expansion Joint is offered. The berth comprises a portion with 7 Nos. of piles, both fender- and non-fender- placed (Grids A to G), with a 1200 mm diameter for grid at E. Other grids have a 900 mm diameter. The piles are placed 6.4 metres apart in the longitudinal direction and 7 and 6 metres apart in the transverse direction. The crane rail is located on grid A and E.

3)A slab with a screed width of 50 to 75 mm connects the beams. The slab is 500 mm thick (225 precast + 275 insitu). The five fender panels that make up the 150 m wharf addition are positioned 25.6 m apart.

4)The 150 m wharf extension's deck level is EL (+) 7.06m. At the end of block 1, the 150 m wharf expansion and the current container berth are situated.

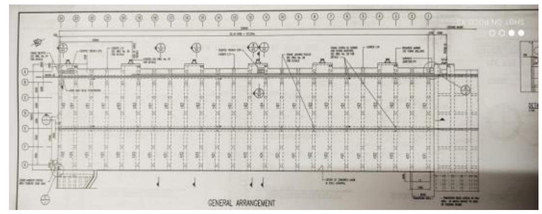

Fig. 3. Layout of 150 m Wharf STructure

B. Structural Sizes

According to the data provided by JNPT, the sizes of the structural elements taken into consideration for the analysis are as follows: Grid B's crane beam measurements are 1300 x 1200, whereas grid E's are 1600 x 1200. The diameter of the piles in grid E is assumed to be 1200 mm, whereas that of the piles in grids A, B, C, D, F, and G is 900 mm. Cross beams are 1300 x 1200 in size, whereas fender beams are 2250 x 600 in size. The slab is 500 mm thick all around.

C. Materials

All structural components must be made of concrete of M40 grade.On the reference designs for the wharf construction, the reinforcement steel specification is listed as HYSD - Fe 500.

IV. MODELLING OF THE STRUCTURE

Commercially accessible computer software (STAAD Pro - v8i) will be used to model and analyse the structure. Following completion of the aforementioned investigation, it was determined that the RCC jetty construction at Mumbai's JNPT Port should be taken up for detailed analysis as a case study. Taking into account the 150 m x 40 m Wharf addition for the analysis. Every 30 m, an expansion gap is offered. The portion of the typical section up to the expansion joint, or 30 m x 40 m, is taken into consideration for a more straightforward analysis. This structure is supported by piles spaced at 6.4 m c/c in the longitudinal direction and 7 m / 6 m c/c in the transverse direction. Founding level of the proposed piles is at -22.00m.

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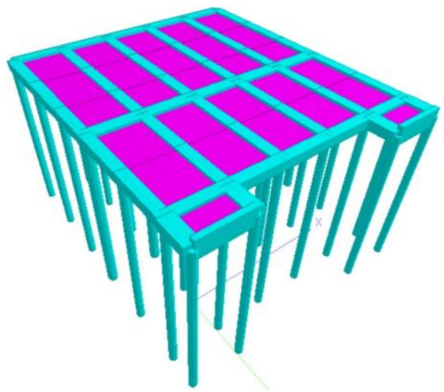

Fig. 4. Layout 150 m Wharf extension

V. Load Calculations

In order to provide appropriate water depth for ship mooring, berthing jetties are often built offshore. Approach jetties that are supported by piles, which are often buried in the sloping terrain, link them to the beach. The navigation channel, which is often perpendicular to the beach, is paralleled by jetties. Normally, the jetty head should be positioned such that the boat is berthed against the strongest currents. For information on the various types of loads affecting the maritime structure, see fig. 5.

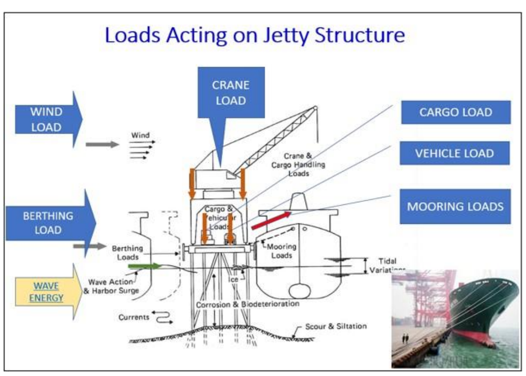

Fig. 5. Loads Acting on a Jetty Structure

A. Dead Load [IS 875-1987 Part I]

The majority of the dead load is applied to the berthing structure's components, including the slab, beams, piles, pile cap, fender block, retaining wall, etc. In order to determine this type of which the total load is estimated and the sufficiency of the member sizes is assessed. While member load is directly defined as self weight as shown in fig. 6, screed load is calculated independently in STAAD Pro Modelling as 1.875 KN/ m2.

B. Live Load [IS 4651(Part III)-1974]

For material that is stacked and stored, such as general cargo, bulk cargo, containers, and loads from all sorts of

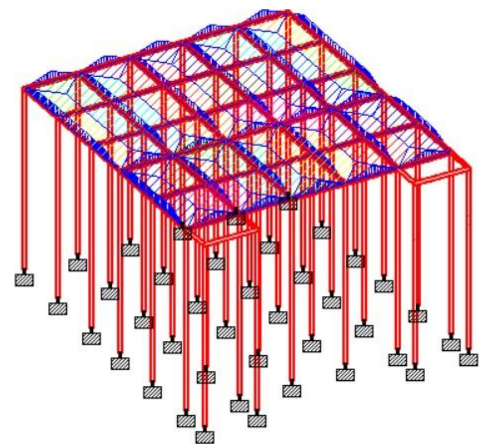

Fig. 6. Application of Dead Load

vehicle traffic, such as trucks, trailers, trains, cranes, container handling equipment, and construction gear, there are surcharges called vertical live loads. Truck Loading and Uniform Loading: As specified in table II, the berths must be generally designed for truck loading and uniform loading.

TABLE II
Table for Uniform Loading

Function of Berth	Truck Loading (IRC Class)	Uniform Vertical Live loading (T/m2)
Passenger Berth	B	1
Bulk unloading and Loading Berth	A	1 to 1.5
Container Berth	A or AA or 70R	3 to 5
Cargo Berth	A or AA or 70R	2.5 to 3.5
Heavy Cargo Berth	A or AA or 70R	5 or more
Small boat Berth	B	0.5
Fishing Berth	B	1

As illustrated in Fig. 7, the requirement is that a live load of 3 t/m2 be directly applied equally across the whole deck slab for the jetty.

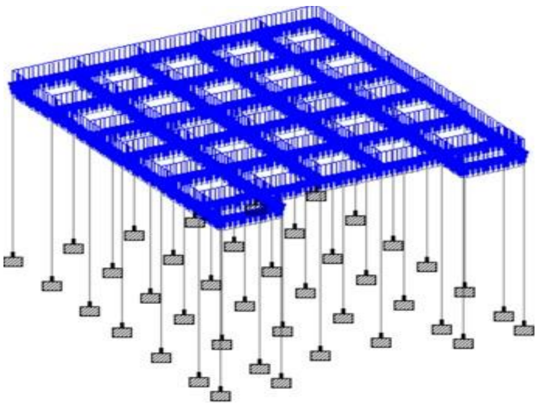

Fig. 7. Application of Live Load

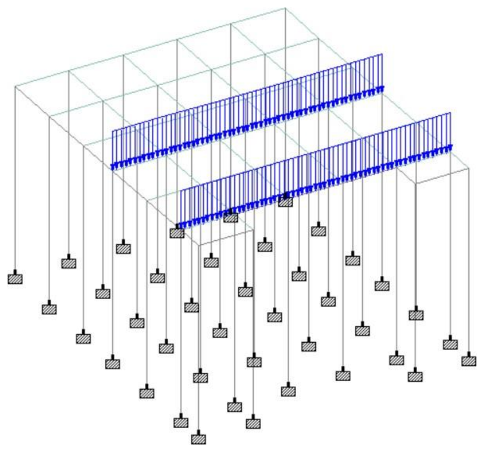

Fig. 8. Application of Crane Load

C. Additional Live Load

1. CRANE LOAD (JNPT feasibility report No. IITM-JNPT-CT-RPT-002)

Total of 9 Nos of Rail Mounted Quay Crane (RMQC) has been used in the container terminal at JNPT. The existing cranes at JNPT container terminal are supplied by Doosan Anupam. The details of the crane at the wharf extension berth is summarized in the table III.

TABLE III
DETAILS OF RMQC AT CONTAINER BERTH

Description	RMQC 7
Make	Doosan
Lift Capacity	50 MT
Clearance between Legs	18.27
No. of wheels	12 Wheels/ Corner Total 48 Wheels
Rail Gauge (m)	20
Wheel loads	33 T/m
Outreach (m)	50
Total Weight	1200 MT

The Quay crane wheel reaction loads are applied at berth corner and middle location, two number of cranes is assumed as working condition and the distance between two cranes are assumed as 20 m. Each wheel load is taken adding 25 percentage of impact to it. Hence calculating each wheel load adding impact of 25 percentage, load of about 40 T/m is applied as UDL to the crane beam and berth corner location as shown in the fig no 8.

2. VEHICLE LOAD (IRC Code) In Jetty structures, trucks and tractors of higher load carrying capacity are used to transfer all the huge goods and raw materials from shore to some other locations i.e. vehicles importing higher axle loading are being used. The vehicular load is applied as moving load in STAAD throughout the lane with the datas available in IRC 6 – IRC CLASS A Vehicle loads are applied on the structure. The loading data is given in the image given below.

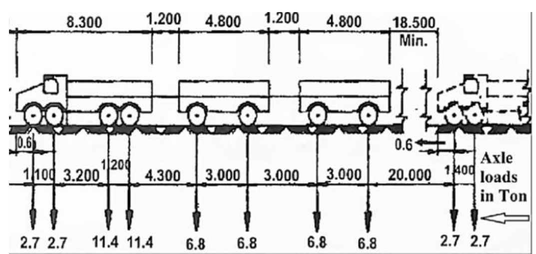

Fig. 9. IRC Class A Vehicle Loading

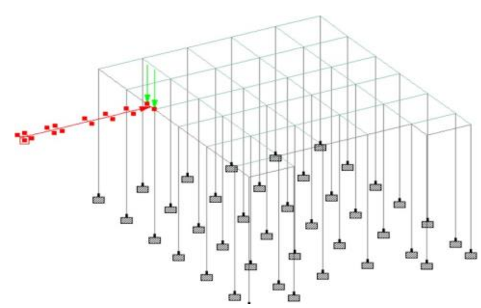

Fig. 10. Application of Vehicular traffic load (Moving load)

D. Wind Force (IS 875 (Part 3) : 2015)

When necessary, IS: 875-1987 should be used to calculate the wind force on a building. The wind pressure technique may be used to compute the wind force on any portion of the structure.

Where, Pz = Design wind pressure in kN/m2 at height z.

Vz = Design wind speed at any height in m/s

Vb = Basic wind speed at any height in m/s = 44 m/s for Mumbai

K1 = Probability factor (risk coefficient) = 1.0 (50 years design life)

K2 = Terrain height and structure size factor = 1.05 for 10 m for Category 1 (Open areas)

K3 = Topographic factor = 1.0 for unobstructed terrain

K4 = Importance factor = 1.0 (No cyclone in west coast)

Vz = 44 * 1 * 1.05 * 1 * 1 = 46.2 m/s

Pz = 0.6 * 46.22 = 1.280 KN/m2

E. Seismic Force (IS 1893 (Part 1) : 2016)

A horizontal force with a centre of gravity equal to a multiple of the acceleration of gravity times the applied weight should be utilised in areas where earthquakes are likely to occur. The percentage will be estimated in accordance with IS: 1893-2002 and will depend on the likelihood of seismic activity in the area. The weight that must be used is made up of the full dead load plus 50 percent of the live load. The seismic force is specifically calculated using base shear (VB).

According to IS 1893 (Part 1) : 2016,

VB= Ah×W

Where Ah is given by

$$Ah = ZISa/2Rg \quad (1)$$

Where, Z= Zone factor

I= Importance factor

R= Response reduction factor

Sa/g= Spectral Acceleration coefficient

Therefore, Total Dead Load = 21662 kN

(Computing the self weight of all the main beams,cross beams, slab, piles of 1200 and 900 diameter and wearing coat)

Total Live Load = 32640 kN

Siesmic Weight = (D.L + 50 percent of L.L)

$$Ah = 0.16x1.5x2.5/2x3 = 0.10 \quad (2)$$

Seismic Force Vb = Ah x (D.L + 50percent of L.L)= 3798 kN

Seismic force on each pile = 3798 / 40 = 95 kN ..(Say 100 kN)

Seismic force of 100 kN is applied on all the joints in all the 4 horizontal direction of the berth (+X, -X, +Z, -Z)).

According to the seismic map of India published in IS 1893 - 2002, Mumbai is located in Zone III. For this structure, importance factor 1.5 has been taken into account. The response reduction factor R is taken as 3.0 as per IS – 1893 for special RC moment resisting frame. The value of spectral acceleration (Sa/g) is calculated from the graph given in IS 1893.Soil will be considered as hard soil profile (Type 1). The approximate fundamental natural period of vibration (Ta) in seconds is calculated for the corresponding natural frequency.

F. Berthing Force[IS 4651(Part III)-1974]

An arriving vessel strikes the berth with a horizontal force. The magnitude of this force depends on how much kinetic energy the fender system can hold. The design vessel will make contact with the fenders at a 10° approach angle. As a result, as can be seen in the graphic below, the effect of the vessel berthing is frequently close to the quarter point. Deflection-reaction diagrams of the fender system may be selected, and it is possible to determine the reaction force for which the berth is to be designed. When berthing takes place, the fender converts kinetic energy into strain energy and transfers it to the structure, applying a reaction force. These schematics are provided by the fenders' manufacturers. Kinetic energy is transferred by a moving object with velocity imparts kinetic energy, E, to a fender system as shown below,

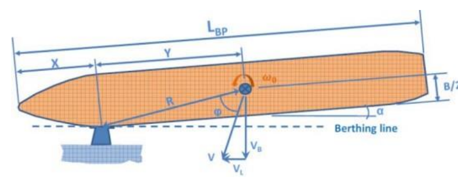

Fig. 11. Vessel Approaching Berth at an Angle

$$E = ((WDXV^2)/2g) * Cm * Ce * Cs \quad (3)$$

Where, E = Berthing Energy (Tm)

WD = Displacement Tonnage (T) = 215 000 T

V = Berthing Velocity in m/sec = 0.1 m/s (IS 4651 Part 3 – Table 2)

Cm = Mass Co-efficient

Ce = Eccentricity Co-efficient = 0.41 (IS 4651 Part 3 – Table 3)

Cs = Softness Co-efficient = 0.95 (IS 4651 Part 3 – CL.5.2.1.4)

g = Acceleration due to gravity (m/sec2)

Kinetic Energy = 58 MT = 580 KN

Using SCN 1200 Super Cone Fender of E1.0 from the Fender Catalogue Chart For a Berthing Energy of 580 KN

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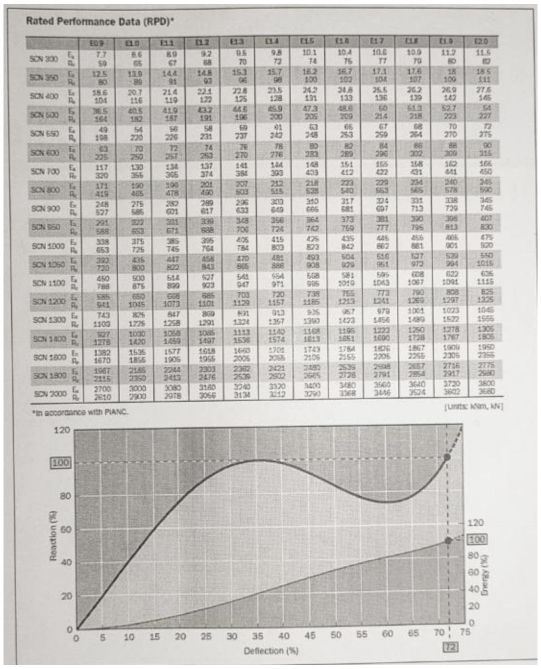

Rated Performance Data (RPD)*

		E0.9	E1.0	E1.1	E1.2	E1.3	E1.4	E1.5	E1.6	E1.7	E1.8	E1.9	E2.0
SCN 300	E_R	7.7	8.6	8.9	9.2	9.5	9.8	10.1	10.4	10.6	10.9	11.2	11.5
	R_R	59	65	67	68	70	72	74	76	77	79	80	82
SCN 350	E_R	12.5	13.9	14.4	14.8	15.3	15.7	16.2	16.7	17.1	17.6	18	18.5
	R_R	80	89	91	93	96	98	100	102	104	107	109	111
SCN 400	E_R	18.6	20.7	21.4	22.1	22.8	23.5	24.2	24.8	25.5	26.2	26.9	27.6
	R_R	104	116	119	122	125	128	131	133	136	139	142	145
SCN 500	E_R	36.5	40.5	41.9	43.2	44.6	45.9	47.3	48.6	50	51.3	52.7	54
	R_R	164	182	187	191	196	200	205	209	214	218	223	227
SCN 550	E_R	49	54	56	58	59	61	63	65	67	68	70	72
	R_R	198	220	226	231	237	242	248	253	259	264	270	275
SCN 600	E_R	63	70	72	74	76	78	80	82	84	86	88	90
	R_R	225	250	257	263	270	276	283	289	296	302	309	315
SCN 700	E_R	117	130	134	137	141	144	148	151	155	158	162	165
	R_R	320	355	365	374	384	393	403	412	422	431	441	450
SCN 800	E_R	171	190	196	201	207	212	218	223	229	234	240	245
	R_R	419	465	478	490	503	515	528	540	553	565	578	590
SCN 900	E_R	248	275	282	289	296	303	310	317	324	331	338	345
	R_R	527	585	601	617	633	649	666	681	697	713	729	745
SCN 950	E_R	291	322	331	339	348	356	364	373	381	390	398	407
	R_R	588	653	671	688	706	724	742	759	777	795	813	830
SCN 1000	E_R	338	375	385	395	405	415	425	435	445	455	465	475
	R_R	653	725	745	764	784	803	823	842	862	881	901	920
SCN 1050	E_R	392	435	447	458	470	481	493	504	516	527	539	550
	R_R	720	800	822	843	865	886	908	929	951	972	994	1015
SCN 1100	E_R	450	500	514	527	541	554	568	581	595	608	622	635
	R_R	788	875	899	923	947	971	995	1019	1043	1067	1091	1115
SCN 1200	E_R	585	650	668	685	703	720	738	755	773	790	808	825
	R_R	941	1045	1073	1101	1129	1157	1185	1213	1241	1269	1297	1325
SCN 1300	E_R	743	825	847	869	891	913	935	957	979	1001	1023	1045
	R_R	1103	1226	1258	1291	1324	1357	1390	1423	1456	1489	1522	1555
SCN 1400	E_R	927	1030	1058	1085	1113	1140	1168	1195	1223	1250	1278	1305
	R_R	1278	1420	1459	1497	1536	1574	1613	1651	1690	1728	1767	1805
SCN 1600	E_R	1382	1535	1577	1618	1660	1701	1743	1784	1826	1867	1909	1950
	R_R	1670	1855	1906	1955	2005	2055	2105	2155	2205	2255	2305	2355
SCN 1800	E_R	1967	2185	2244	2303	2362	2421	2480	2539	2598	2657	2716	2775
	R_R	2115	2350	2413	2476	2539	2602	2665	2728	2791	2854	2917	2980
SCN 2000	E_R	2700	3000	3080	3160	3240	3320	3400	3480	3560	3640	3720	3800
	R_R	2610	2900	2978	3056	3134	3212	3290	3368	3446	3524	3602	3680

*In accordance with PIANC. [Units: kNm, kN]

Fig. 12. Fender Catalogue from Telleberg

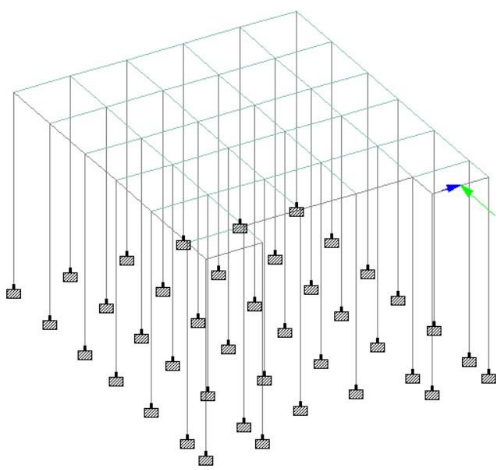

Fig. 13. Application of Berthing force

G. *Mooring Force [IS 4651(Part III)-1974]*

The mooring loads are the lateral loads that the mooring lines produce when they draw the ship into or along the dock or when they are holding it against wind or current forces. It is impossible to determine with any degree of accuracy the weight on any one rope caused by the ship's response to winds, currents, or ship-way checks during berthing. It is based on how the rope is cinched and at what angle it is to the berthing line. The mooring force will thus be of two types.

1) Wind force 2) Current force

Mooring Loads Caused By Wind Forces: In mild winds, the exposed section on the wide side of the ship has the highest mooring loads. In accordance with IS 4651 part- III clause no. 5.3.2 , the mooring load can be computed from

$$F = Cw * Aw * P \tag{4}$$

Where, F = Force due to wind in kg

Cw = Shape Factor 1.3 to 1.6

Aw = Wind age area in m2

P = Wind Pressure in kg/ m2

Wind age area can be calculated as,

Aw=1.175× Lp × (Dm - DL)

Where,

Dm = 21.2 m Mould depth in m, (from IS: 4651, appendix A)

DL = 8.4 m (Average light draught in m ,from IS: 4651, appendix A)

LP = 270 m (Length between perpendiculars = 0.9 x length of vessels)

Aw = 4061 m2

Cw = 1.5 (Refer IS 4651 (Part III) CL 5.3.2)

Max. Mooring load due to wind force (F) = P X Aw X Cw

F = 1.28 x 4061 x 1.5 = 7790 KN

No of Bollards = 6

Load on Each Bollard = 130 Tonnes

Line draw for a vessel with a maximum displacement of 200 000 DT is 200 Tonnes as per IS: 4651 (III) Cl.5.3.4. Therefore, 200 T of angular force is resolved down into its component parts and applied to the model as a point load across the deck slab, as illustrated in Fig. 16.

H. *Current Load and Hydrostatic Pressure [IS 4651(Part III)-1974]*

Pressure due to current force as said in IS 4651(Part III)-1974 will be applied to the area of the vessel below the water line when fully loaded and Hydrostatic and hydrodynamic forces are produced by water. These two forces will be applied to the pile element for the study of pile analysis, but they are not taken into account in this research because it is entirely focused on the analysis of the slab and beam elements

Examples of this include the forces of waves, currents, and differential water pressure.

VI. Basic Load Combinations

According to the reference document of the JNPT stability analysis report, the container berth and 150 m wharf expansion are intended for the following load combinations.The list below includes the load combinations for the analysis and design's limit state of serviceability and collapse.

- 1.0 (D.L.+ L.L.)
- 1.0 (D.L. + L.L. + EQ + Z)
- 1.0 (D.L. + L.L. + EQ Z)
- 1.0 (D.L. + L.L. + EQ + X)
- 1.0 (D.L. + L.L. + EQ X)
- 1.0 (D.L. + L.L. + B.F.)
- 1.0 (D.L.+ L.L.+ M.F.)
- 1.0 (D.L.+ L.L.+ C.L.)
- 1.5 (D.L.+ L.L.)

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- 1.5 (D.L.+ L.L.+ EQ+Z)
- 1.5 (D.L.+ L.L.+ EQ-Z)
- 1.5 (D.L.+ L.L.+ EQ+X)
- 1.5 (D.L.+ L.L.+ EQ-X)
- 1.5 (D.L.+ L.L.+ B.F.)
- 1.5 (D.L.+ L.L.+ M.F.)
- 1.5 (D.L.+ L.L.+ C.L.)

Where,
DL = Dead Load
LL = Live Load
CL = Crane Load
BL = Berthing Load
ML = Mooring Load
EQ = Seismic Load

VII. ANALYSIS

A. RC Beams

Static structural Analysis is carried out to determine the structural responses such as member forces and deflections. The member forces and deflections. The member loads will be used for structural verification of the RC elements for the existing reinforcement. For open type structure for seismic zone less than III Berthing will govern, if it is a vertical face structure with active earth pressure and differential water pressure Mooring will govern, for seismic zone IV and V seismic force will govern the design. The Bending Moment and Shear force diagrams for the critical load combinations are displayed below.

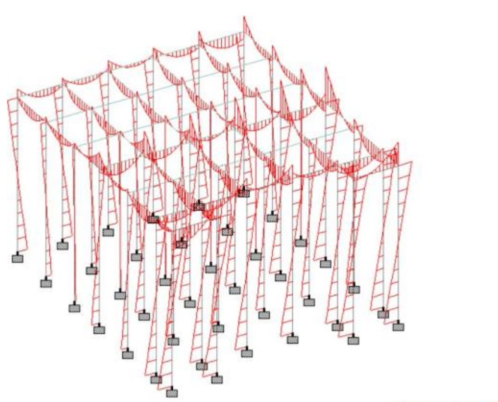

Fig. 14. Bending Moment for Load Combination (1.5*DL+LL+BL)

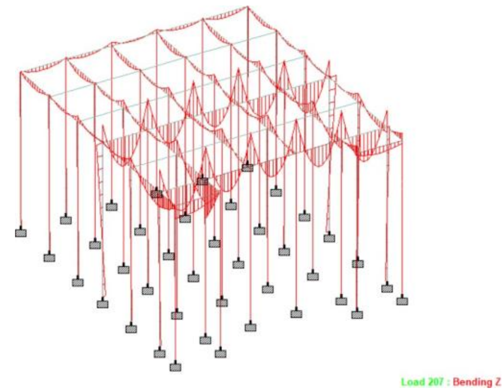

Fig. 15. Bending Moment for Load Combination (1.5*DL+LL+CL)

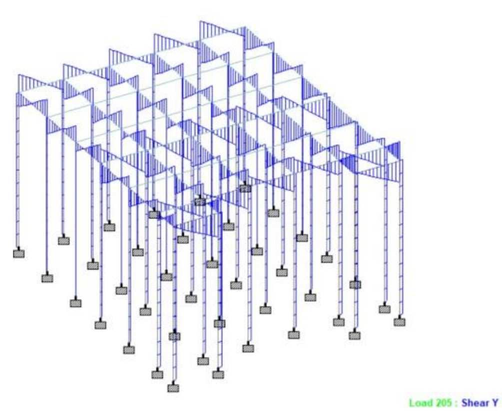

Fig. 16. Shear Force for Load Combination (1.5*DL+LL+BL)

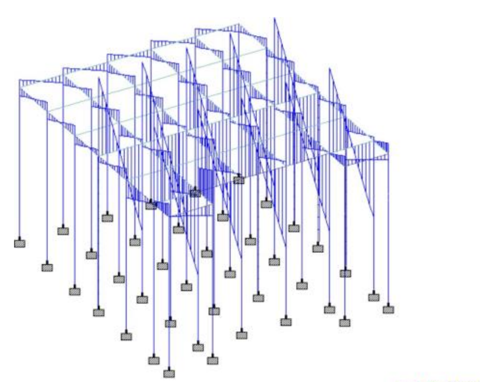

Fig. 17. Shear Force for Load Combination (1.5*DL+LL+CL)

The obtained Maximum shear forces and beams forces (Bending moment) from analysis in STAAD-PRO and manual calculations are tabulated in the table IV.

TABLE IV
DESIGN FORCES FOR BEAMS

Description	Width	Depth	Design Forces for Beam (Max)	Shear KN
Transverse Beam (Grid B to G)	1300	1200	2825	2370
Crane Beam 1 (Grid E)	1600	1200	2840	2528
Transverse Beam (Grid A to B)	1300	1200	2313	1880
Crane Beam 2 (Grid A to B)	1300	1200	2301	2468
Fender Beam	2250	600	3142	1049

B. Beam Design

The design verification of the beam based on IS 456 specifications. The beams are also for allowable deflection. The design summary for the beams is tabulated in the given table V. The design beam reinforcement is taken from JNPT feasibility report No. IITM-JNPT-CT-RPT-002 and reference drawings from NSI-2-52 to NSI-2-56.

TABLE V
DESIGN SUMMARY OF BEAM

Description (Size m)	Reinforcement		% of reinforcement		Stirrups	Remarks
	Top	Bott	Top	Bott		
Transverse Beam 1 (1.3x1.2)	18 Nos 32 Ø	13 Nos 32 Ø	0.870	0.625	16 Ø 6 legged @ 70 c/c	OK
Crane Beam 1 (1.6x1.2)	18 Nos 32 Ø	15 Nos 32 Ø	0.692	0.830	12 Ø 6 legged @ 150 c/c	OK
Transverse Beam 2 (1.3x1.2)	12 Nos 32 Ø	13 Nos 25 Ø	0.680	0.448	16 Ø 6 legged @ 200 c/c	OK
Crane Beam 2 (1.3x1.2)	18 Nos 32 Ø	15 Nos 25 Ø	0.620	0.503	6 Ø 8 legged @ 125 c/c	OK
Fender Beam	26 Nos 16 Ø	52 Nos 16 Ø	0.39	0.70	20 Ø 6 legged @ 150 c/c	OK

The maximum deflection of beam is summarized in the below table VI.

TABLE VI
BEAM DEFLECTION SUMMARY

Type	Actual Deflection (mm)	Allowable Deflection (mm)	Remarks
Longitudinal Beam	4.97	25	OK
Transverse Beam	5.34	28	OK

C. RC Slab

The slab is verified as partly precast and partly in situ. The design live load for service stage is taken as 30 kPa for deck slab. The thickness of the deck slab is 500 mm. The maximum bending moment and shear force is summarized in the table VII below.

TABLE VII
DESIGN FORCES FOR SLAB

Type	Size of Planks (mm)	Thickness of Slab (mm)	Max Moment (kNm)	Max Shear (kN)
Deck Slab	6400 x 700	500	150	129

D. Slab design

The slab design is verified based on IS 456 specifications for the required bending moment. The design summary are given in the table VIII , the existing detail of slab reinforcement are taken from JNPT feasibility report No. IITM-JNPT-CT-RPT-002 and reference drawings from NSI-2-46 to NSI-2-47.

TABLE VIII
DESIGN SUMMARY OF BEAM

Type	Size of Planks (mm)	Thickness of Sla (mm)	Existing Reinforcement		% of Reinforcemen Provided	Remarks
			Main Reinf.	Dist Reinf.		
Deck Slab	6400 x 700	500	20 Ø @ 100 c/c	12 Ø @ 150 c/c	0.625	OK

VIII. CONCLUSION

- The current berth construction, including the slab and crane beams of the 150-meter wharf, has the capability to handle the extra loads brought on by the 20-meter rail gauge.
- Because the current seashore crane's beam and piles can support the heavier loads with a maximum wheel load of 70 MT, the new crane must be acquired with that restriction.
- It was discovered that the extreme spalling of the cover concrete in the instance of the current jetty construction drove the structure into a vulnerable state. The Half Cell Potential test revealed a potential for additional steel corrosion. UPV criticised the necessity of reinforcing concrete. According to studies, the structure's capacity to endure bending moment and shear force has not decreased while the degradation of the steel and concrete has occurred.

IX. RECOMMENDATIONS AND SUGGESTIONS

- The present reinforced concrete jetty structure at Jawaharlal Nehru Port Trust in Navi Mumbai required structural upgrade to support larger loads and service conditions, according to an extensive analysis of the building. It was discovered that the extreme spalling of the cover concrete in the instance of the current jetty structure led the structure into a vulnerable state. The structure's ability to resist bending moment and shear force, however, has not been reduced.It is suggested to do structural repairs in order to prevent future deterioration. Although port structures are built to survive longer, frequent inspections and analysis of the same in the continuously changing service circumstances are important so that quick modifications may be made to stop the degradation process by maintaining or reinforcing as needed. Software like "STAAD Pro v8i," "ETABS," and others can be utilised efficiently for this.
- The Jetty structure is currently not in a critically distressed condition due to corrosion of steel reinforcement. To prevent this, structural and non-structural repairs should be made

with either micro concrete or polymer-based treatment. A comprehensive condition analysis of Fenders and Bollards should be carried out and both schemes should be implemented depending on the site condition. Regular repairs and maintenance should be carried out.

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