JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

STRUCTURAL HEALTH ASSESSMENT AND REMEDIAL MEASURES FOR AN EXISTING JETTY STRUCTURE

[1]Mohit M. Patil, [2]Dr S.A. Rasal

[1]*Post Graduate Student, Dept of Civil Engineering, Datta Meghe College of Engineering Airoli, Navi Mumbai - 400 708, India.*

[2]*Assistant Professor, Dept of Civil Engineering, Datta Meghe College of Engineering Airoli, Navi Mumbai - 400 708, India.*

Abstract: This study investigates the structural health of a 27-year-old jetty structure located at Jawaharlal Nehru Port Trust in Navi Mumbai, India. The assessment aims to determine the structure's adequacy under current service loading conditions and propose remedial measures if necessary. Various factors affecting the structural deterioration of the jetty, such as exposure conditions, oceanographic conditions, salinity, ballast water contamination, and wind velocity, are considered. The assessment primarily focuses on the corrosion of reinforcing steel embedded in the concrete, as it plays a crucial role in the structural integrity of the jetty. To evaluate the extent of deterioration and distress in the concrete beams, a comprehensive condition assessment is conducted. This includes tests such as the Rebound hammer test, Ultrasonic pulse velocity test, and compressive strength analysis of core samples. Jetty beams are analyzed to obtain a statistically significant sample size. The test results are classified into different categories based on the geometry and loading pattern of the beams. Statistical analysis reveals a highly significant difference in the distress condition between the crane beam and the secondary beam/main beam. The crane beams, subjected to dynamic loads from cargo-loading cranes, exhibit greater distress compared to other beams, despite similar distress-causing factors affecting all beams. The findings indicate that the ingress of saline environment through fissures and cracks in the concrete cover contributes to the deterioration of the jetty structure. Based on the results, it is concluded that the crane beams require specific attention and remedial measures due to their higher distress levels. The study emphasizes the importance of considering various parameters in assessing the structural health of a jetty and determining its residual service life. The outcomes of this study can guide the formulation of appropriate strengthening and rehabilitation schemes for the jetty, ensuring its ability to withstand present and future loading conditions. By understanding the structural condition and implementing necessary measures, the longevity and safety of the jetty can be ensured for continued operational efficiency.

Keywords: *structural deterioration, jetty, exposure conditions, distress, Rebound hammer test, Ultrasonic pulse velocity test*

I.INTRODUCTION

Jetties play a critical role as an interface between land and water transportation modes, facilitating the efficient movement of goods, raw materials, and passengers via the sea. They provide a cost-effective means of transporting large quantities of cargo and offer safe berthing for ships and vessels. Jetties are constructed in various locations, such as rivers, river mouths, and seas, and their design and materials vary depending on their purpose and environmental conditions.In the past, jetties were constructed using materials such as wooden piles, masonry, and steel. However, modern jetties predominantly employ reinforced concrete structures due to their durability and strength. The successful operation of a jetty relies on several factors, including the availability of deeper waters to accommodate deep-draft vessels and the provision of supporting infrastructure such as channels, breakwaters, ship anchorages, navigation aids, and landside facilities. The marine environment presents a significant challenge to the serviceability of jetty structures. Exposure to corrosive agents, salinity, and salt fumes, along with the intermittent wetting and drying of concrete surfaces in intertidal zones, leads to rapid deterioration of both concrete and steel components. Failure to maintain the structural integrity of a jetty can result in substantial economic losses, highlighting the critical importance of implementing comprehensive maintenance plans for port structures.

II. LITERATURE SURVEY

Scott Bacon et al. (2010) discusses the Port of Newcastle in Australia, highlighting its status as one of the largest coal export ports globally. It provides information about the port's infrastructure, including berths, navigation aids, roads, rail, buildings, and seawalls. The paper also mentions the need for maintenance and corrosion management to ensure the structures' future service lives. Further R.B. Singh (2013) focuses on non-destructive testing (NDT) of hardened concrete. It presents various NDT tests, including Rebound Hammer, UPV (Ultrasonic Pulse Velocity), and Core tests. The author emphasizes the complexity of concrete as a material and cautions that interpretation of NDT data should be done by trained specialists rather than technicians.

The study by B.M. Lehane *et al*. (2014) investigates the effective stresses and mechanisms controlling shaft friction in displacement piles installed in quartz sand. It discusses how stress development depends on soil depth and initial state, and how pile loading induces effective stress changes and dilation phenomena at the pile-soil interface. The study also addresses the operational angles of interface friction. Similarly, Chenna Rajaram and Ramchandra Pradeep Kumar (2014) focuses on the nonlinear dynamic analysis of a Kandla port building subjected to ground motion. It utilizes ground motion data generated by the Institute of Seismological Research and estimates the damage of the structure using fragility curves. The authors discuss the importance of considering the fundamental frequency of the structure and its relationship with the predominant frequency range of ground motions.

Further, Gopal Rai (2014) explores new generation structural strengthening materials and techniques, particularly for the rehabilitation of bridge structures. It presents case studies of bridge rehabilitation using materials like carbon laminates and discusses their advantages. The author emphasizes the need for further research on these newer materials. Also, Mohd Fauzi Mohamad *et al*. (2014) introduce a coastal vulnerability index (CVI) for the Peninsular Malaysia coastline. The CVI incorporates variables such as geomorphology, shoreline change rate, current speed, tidal range, wave height, and sea level rise to assess the vulnerability of different coastal areas. The paper presents the ranking of vulnerability and emphasizes the importance of cooperation among government departments, agencies, the private sector, and the public in implementing a management plan. Similarly, Gopal L. Rai and A.N. Bambole (2015) focuses on the repair work carried out on the Karal Rail Over Bridge at Jawaharlal Nehru Port Trust. It discusses the instrumentation system installed for monitoring the effectiveness of the repairs and the structural health of the bridge. The authors highlight the significance of structural health monitoring in India.

On perusal of the literature it is found that RCC is used all over the globe to construct the jetties. It is further observed that, assessment of structural health of jetty mainly corresponds to corrosion of reinforcing steel embedded in the concrete. To assess the extent of the corrosion and to understand the extent of deterioration caused to the structure various tests are carried out. The Rebound hammer test, Ultrasonic pulse velocity test, Half-cell potentiometer test are carried out to obtain various structural parameters which can be used to calculate the structural strength and residual life.

This study focuses on the analysis of an existing jetty structure located at Jawaharlal Nehru Port Trust in Navi Mumbai, India, which is approximately 27 years old. The primary objective is to assess the structural adequacy of the jetty under present service and loading conditions and identify any necessary remedial measures. While the study does not encompass the design of these measures, it serves as a crucial step toward ensuring the continued safe and efficient operation of the jetty. By evaluating the deterioration patterns and exposure conditions within different zones of the jetty structure, this study aims to provide valuable insights into the maintenance requirements and potential strengthening or rehabilitation schemes. The findings will contribute to the development of a comprehensive structural maintenance plan that can be implemented to preserve the functionality and longevity of the jetty, minimizing downtime and economic losses for the port and the nation as a whole.

III. SITE INSPECTION AND NON-DESTRUCTIVE TESTING

Site Inspection

The site of the Port Civil (Marine) Infrastructure of JNPT was visited to assess their current structural health and stability. The structures are RCC Deck supported on piles in sea environment. The Non-destructive tests (NDT) of the sample RCC elements of the structures were carried out on all the above days. The locations of RCC elements were identified and surface preparations were carried out, prior to NDT. Based on the inspections, the NDT selected for assessment of strength of RCC members include the Ultrasonic Pulse Velocity Test (UPVT), Rebound Hammer Test, Half Cell Potentiometer Test, and Concrete Core Compression

Test. The marking of structural members was carried out based on the structure's plan and the locations of the structural members. The details of the tests and their guiding principle are summarized below.

Rebound Hammer Test

Rebound hammer test is done to find out the likely compressive strength of concrete by using rebound hammer as per IS 13311 (Part 2): 1992. The underlying principle of the rebound hammer test is "the rebound of an elastic mass depends on the hardness of the surface against which its mass strikes". When the plunger of the rebound hammer is pressed against the surface of the concrete, the spring-controlled mass rebounds and the extent of such a rebound depends upon the surface hardness of the concrete. The surface hardness and therefore, the rebound are taken to be related to the compressive strength of the concrete. The rebound value is read from a graduated scale and is designated as the rebound number or rebound index. The compressive strength can be read directly from the graph provided on the body of the hammer.

Ultrasonic Pulse Velocity Test (UPVT)

This test helps in assessing the quality of concrete. The time of travel for an ultrasonic pulse through a given pathlength of concrete is measured. For this purpose, two probes (transducers) are used one transmitting and the other receiving. Thus, Ultrasonic Pulse Velocity (UPV) = Path Length / travel time. It is best to have the two probes on opposite faces of concrete members. Thus, the signal passes through the entire thickness of the member. This is the direct (D) method of test and the same was used for the investigations of the RCC elements. On the other hand, when only one face of the structural element is available the two probes are kept on the same inspected face. This is the indirect (ID) method and the same was used when both sides of the RCC member was not accessible. As per the IS 13311 (Part 1): 1992, the measured indirect velocity can be lower than the direct velocity on the same concrete element. This difference may vary from 5 to 20 percent depending largely on the quality of the concrete under test. Thus, the measured indirect velocity obtained from equation is increased at least by 20 percent in the results reported. The UPV depends on the quality of concrete and is affected by all its ingredients.

Half-Cell Potentiometer Test

The instrument measures the potential and the electrical resistance between the reinforcement and the surface to evaluate the corrosion activity as well as the actual condition of the cover layer during testing. The electrical activity of the steel reinforcement and the concrete leads them to be considered as one half of weak battery cell with the steel acting as one electrode and the concrete as the electrolyte. The name half-cell surveying derives from the fact that the one half of the battery cell is considered to be the steel reinforcing bar and the surrounding concrete. The electrical potential of a point on the surface of steel reinforcing bar can be measured comparing its potential with that of copper – copper sulphate reference electrode on the surface. Practically, this is achieved by connecting a wire from one terminal of a voltmeter to the reinforcement and another wire to the copper sulphate reference electrode. This method may be used to indicate the corrosion activity associated with steel embedded in concrete and can be applied to members regardless of their size or the depth of concrete cover. It should be clearly noted that the test does not give actual corrosion rate or whether corrosion activity has already started, but it indicates the probability of the corrosion activity depending upon the actual surrounding conditions. The risk of corrosion is evaluated by means of the potential gradient obtained, the higher the gradient, and the higher risk of corrosion.

IV. DETAILS OF JETTY STRUCTURES

Jetty structure comprises of deck slab supported with grids of beams and piles, with fenders and bollard system including fender/breasting piles. The Jetty structure located at Jawaharlal Nehru Port Trust, Navi Mumbai has the following details**:**

Dimensions

Jetty size	:	685 m × 40.5 m
Slab Thickness	:	400 mm
Main Cross Beams	:	1600 mm × 1925 mm
Crane Beams	:	1000 mm × 1725 mm
Secondary Beams	:	750 mm × 1000 mm
Deck Slab Top	:	(+) 7.10 m RL (with respect to chart datum)
Sea bed level	:	(General – 13.0 m)

Rock encountered at : (-) 20 m

Founding Level of Piles : (-) 24 m

V. LOADS ACTING ON THE JETTY STRUCTURE:

Loads from Sea side: The loads from the sea side include the horizontal forces imparted by waves, by berthing and by vessel's pull on bollard/ mooring hooks. The velocity and angle of approach of the vessels determines the forces caused by berthing of vessels. The wind forces acting on the vessel body causes pushing/pulling of vessel which ultimately transferred to structure in form of bollard pull or fender push.

Landside Loads: Horizontal loads are caused from land side due to the earth pressures and differential water pressure which are not applicable in the present structure being the Jetty.

Loads coming from Deck: The important loads from the deck are the vertical loads caused by self-weight of the deck superimposed loads from handling equipment. Horizontal loads are mostly due to wind forces on structures & cranes, and also due to the breaking force of cranes when break is applied. Also, when cranes are parked using pins the strong wind force acting on crane imposes horizontal load on the rail thereby on jetty. But most vulnerable force act on jetty structure is when the crane is not moving but handling the containers.

Dead Load: The dead load of the Berthing structure is due to the self-weight of the structural members which includes slabs, beams, pile caps, piles, fender block, and retaining wall etc. for calculating this load physical dimension of the members are taken and then the load is calculated.

Live Load: The load of surcharges because of the stored and stacked cargo/material, such as general cargo, bulk cargo, containers and loads from vehicular traffic of all types, which includes trucks, trailers, railway, cranes, containers handling equipment and construction plant constitute vertical live loads. This is Container Jetty; railway load is absent in this case.

Vessel Loads: The present jetty is designed for 50,000 DWT container vessel.

Mooring Forces: 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 load on any individual rope due to winds or currents acting on the ship or to checking the way of ship during berthing cannot be calculated with any accuracy. It depends on the tension in the rope and its angle to the berthing line. Mooring force will be two types; Mooring Loads due to Wind Forces and Mooring Loads due to Current Forces. Wind force on structure shall be taken in accordance with IS: 875-1987 as applicable. Wind force will act above the Sea water level. After calculating for our site condition wind force acting over deck slab and piles are calculated and the maximum values obtained are 0.54 kN/m on deck slab and 0.32 kN/m on piles for normal wind speed while 4.07 kN/m on deck slab and 2.44 kN/m on piles for extreme wind speed. It is applied in both X and Z direction.

VI. RESULTS AND OBSERVATION

The results obtained during the ultrasonic Pulse Velocity test are shown in table 1, 2, 3 and 4.

Table 1: Ultrasonic Pulse Velocity Results

ONEWAY	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
1. Main Beam	45	107.342	8.9405	1.3328	94.7	127.1
2. Secondary Beam	30	112.167	9.5688	1.7470	95.0	128.0
3. Crane Beam	15	122.680	9.8410	2.5409	110.3	135.4
Total	90	111.507	10.7025	1.1281	94.7	135.4

Table 2: Statistical Analysis of Ultrasonic Pulse Velocity Tests-Anova

		Df	Mean Square	F	Sig
UPV Time	Between Groups	2	1333.068	15.406	0.000
UPV Avg. Velocity	Between Groups	2	1.421	15.382	0.000

Table 3: Statistical Analysis of Ultrasonic Pulse Velocity Tests-Post Hoc Test

	Beam	Beam	Mean Difference	Std. Error	Sig.	Correlation
UPV Time	Main Beam	Crane Beam	15.3378	2.7734	0.000	Highly Significant
	Secondary Beam	Crane Beam	10.5133	2.9416	0.001	Highly Significant
	Main Beam	Secondary Beam	- 4.8244	2.1925	0.006	Not Significant
UPV Average Velocity	Main Beam	Crane Beam	- 0.50067	0.09061	0.000	Highly Significant
	Secondary Beam	Crane Beam	- 0.34267	0.09611	0.001	Highly Significant
	Main Beam	Secondary Beam	0.158	0.07163	0.006	Not Significant

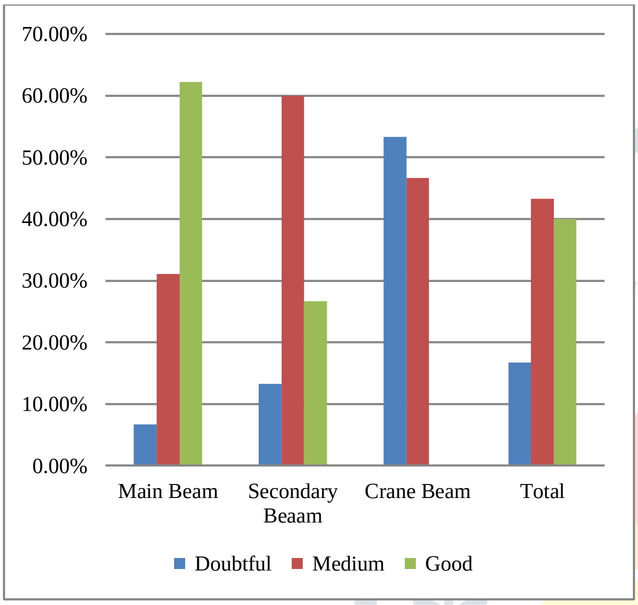

Fig 1: Beam Wise Comparison of UPV Results

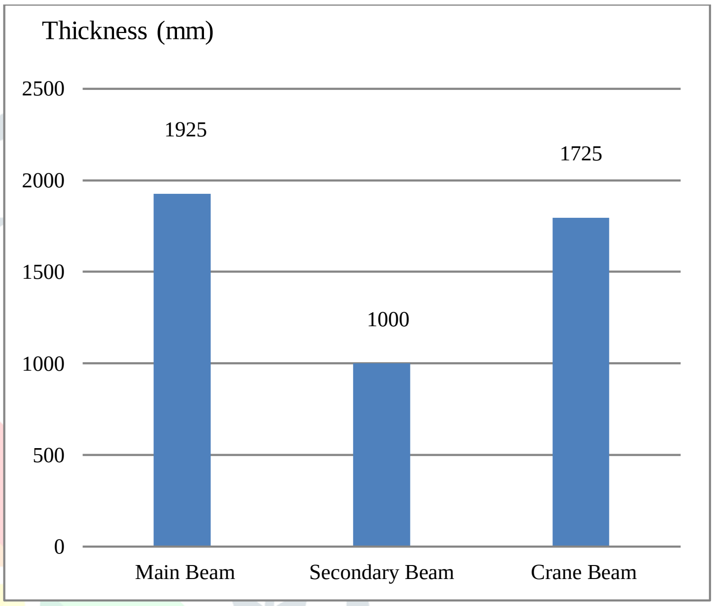

Fig 2: Comparison of Beam Thickness

Table 4: Rebound Hammer, UPV and Carbonation Test Results

NDT Test Results for Container Jetty (from Top Side of Deck Slab)												
RCC Member	Ultrasonic Pulse Velocity Test			Rebound Hammer Test								Carbon -ation
	Thickness (mm)	Time (μ)(sec)	Average Velocity (Km/sec)	R1	R2	R3	R4	R5	R6	Avg. Reading	Compr. Strength (Mpa)	Depth (mm)
Girder (Nr.B-1)	300	135.7	2.65	50	46	44	46	44	42	45	50	10
Girder (Nr.B-3)	300	135.3	2.66	44	48	46	42	48	42	45	50	10
Girder (Nr.B-6)	300	119.0	3.03	48	52	50	54	56	48	51	61	25
Girder (Nr.B-8)	300	122.7	2.93	48	52	46	44	46	50	48	55	25
Girder (Nr.B-9)	300	108.7	3.31	54	50	46	50	46	51	52	59	15
Girder (Nr.B-12)	300	100.5	3.58	46	42	40	48	46	44	44	48	10
Girder (Nr.B-13)	300	81.2	4.43	44	46	40	48	48	44	45	50	25
Girder (Nr.B-15)	300	101.8	3.54	54	50	48	48	52	50	50	59	20
Girder (Nr.B-17)	300	82.3	4.37	46	48	44	50	48	46	47	54	15
Girder (Nr.B-19)	300	101.3	3.55	52	54	54	50	52	49	52	63	15
Girder (Nr.B-21)	300	109.4	3.29	44	43	48	40	48	46	45	50	20
Girder (Nr.B-24)	300	107.5	3.35	48	50	46	46	44	48	47	54	15
Girder (Nr.B-26)	300	97.5	3.69	50	46	42	48	44	48	46	52	15
Mean			3.4							Mean	54.2	

Standard Deviation	0.6		Standard Deviation	4.9	
(*Direct Method, Indirect Method)					

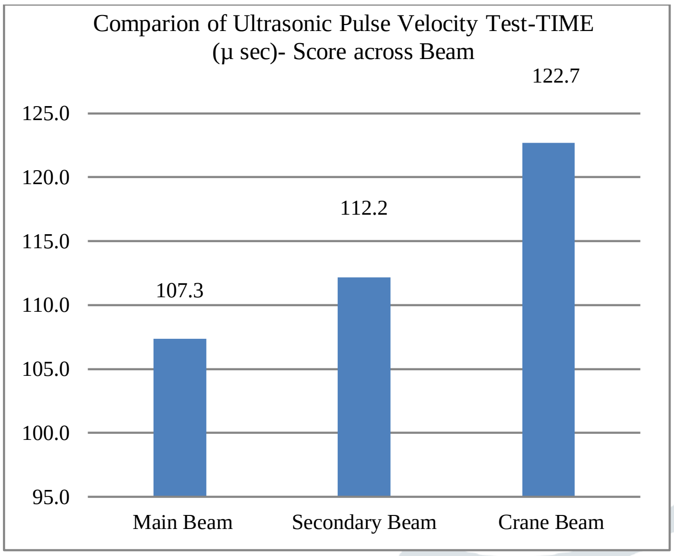

Fig 3: UPV Scores Across the Beams-Time Specific

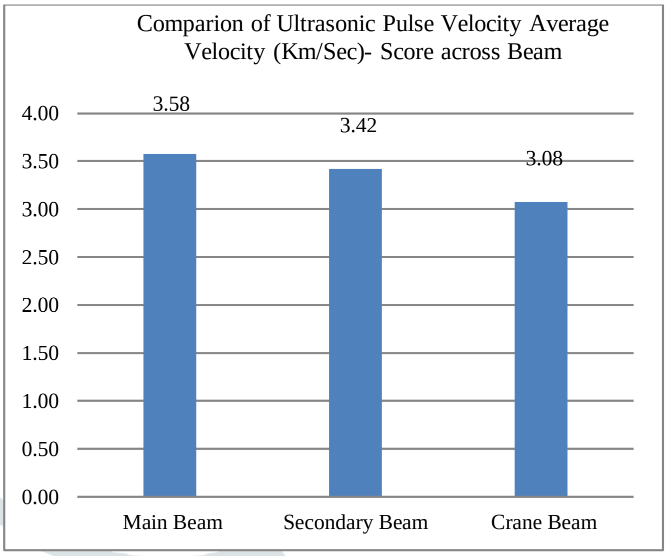

Fig 4: UPV Scores Across the Beams-Avg. Velocity Specific

From UPV tests it is found that the integrity, homogeneity and Uniformity of concrete are medium to good. Further, the Container Jetty is made with RCC deck slab resting on the piles. The detailed visual inspection and NDT of the Container Jetty lead to the following important observations:

- The wearing coat of the Jetty and Edges near Bollards were found to be damaged.
- The Bollards and Fenders of the Jetty were also observed to deteriorated and damaged.
- The Steel liners near the top location of the piles were found to deteriorated / corroded and fallen down.
- At several places, the RCC Beams of the Jetty were found to developed severe cracks along the main reinforcement direction with concrete cover fallen down. These cracks appear to be developed because of the corrosion of steel reinforcement causing cracks due to increase in the volume. The corrosion of the reinforcement in the RCC elements is expected due to severe sea environment where salinity in the atmosphere is very high.

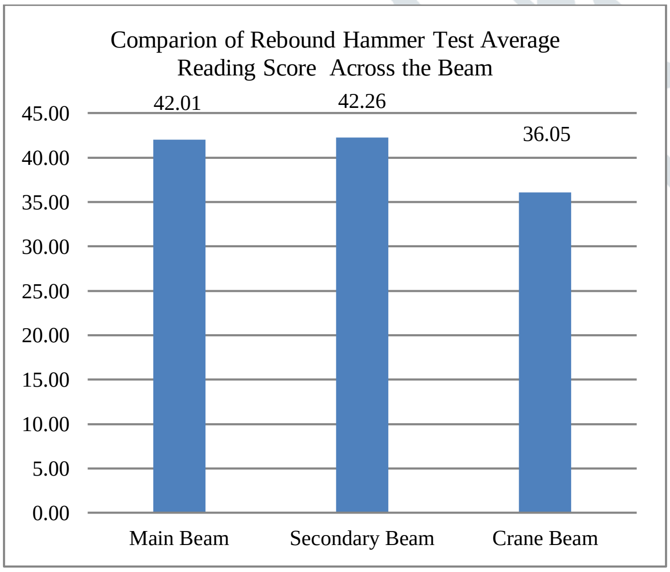

Fig 5: Rebound Hammer Test Readings Across the Beams

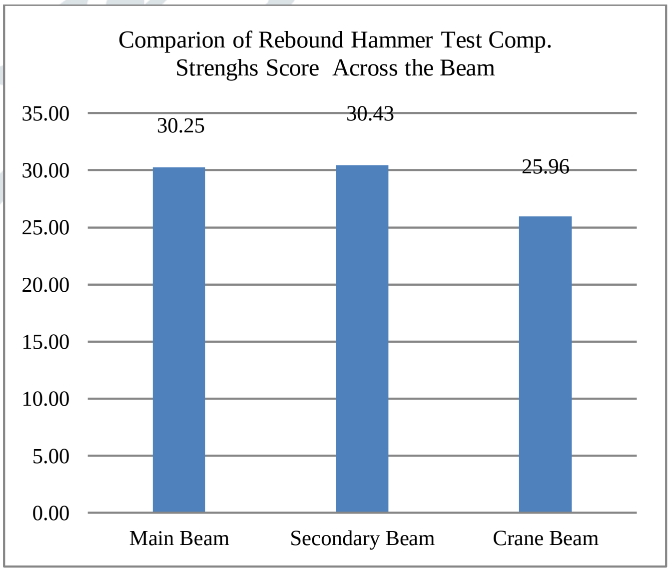

Fig 6: Rebound Hammer Test Compressive Strength Across the Beams

- Some of the repaired beams of the Jetty were also observed to have developed the similar cracks and damaged.
- Apart from the RCC Beams, the Deck Slab at various locations and Pile Caps were also found to have developed severe cracks along the main reinforcement direction with concrete cover fallen apart due to corrosion of steel reinforcement.

- Based on rebound hammer readings, the estimated average residual strength of RCC elements of the Container Jetty is observed to be 54.2 MPa and 55 MPa at the top and bottom side of the Deck Slab, respectively. The average recorded velocity in the top and bottom side of the Deck Slab is measured as 3.4 km/s and 3.4 km/s, respectively. These test results are indicative of medium grading of concrete and adequate strength in the RCC members.
- The Carbonation Test results of the concrete of the Jetty indicate that the carbonation level is 10 □ 25mm and 5mm at the top and bottom side of the Deck Slab, respectively. As per IS13111: Part-2, carbonation can increase the Rebound Hammer test results up to 50% in extreme cases.
- The Half-Cell Potentiometer Test results of the various RCC elements of the Container Jetty long indicated that there are more than 50 percent chances of corrosion activity, in general.

VII. CONCLUSION AND RECOMMENDATION:

- The Exhaustive study of the existing reinforced concrete jetty structure located at Jawaharlal Nehru Port Trust, Navi Mumbai, has revealed that the Marine Structures constructed in India of age more than 25 years, needs to be studied and analyzed for their structural health and integrity. The necessity of structural upgradation also needs to be explored to sustain heavier loads and service conditions.
- In case of the present jetty structure it was found that the severe spalling of cover concrete lead to drive the structure in vulnerable state. The Half Cell Potential test indicated possibility of further rusting of steel. UPV reviled that the concrete strengthening is must. On analysis it is found that as the deterioration of both steel and concrete has taken place, however there was no reduction in the structure’s ability to withstand against Bending moment and shear force.
- In order to avoid further deterioration, it is recommended to take up structural repairs. Even though the port structures are designed and meant to serve for longer period, periodically inspections are must and analyzing the same in the ever-changing service conditions is needed so that timely interventions can be made to delay the process of deterioration by maintaining or strengthening as required. For this the software such as “STAAD Pro v8i”, “ETABS” etc. can be effectively used.
- Absence of diagonal cracks near support and vertical cracks at the middle of the beams indicates that the members are not structurally in distressed condition due to the subjected loads. This indicates that the structures is safely transmitting the loads and appear to be stable. The jetty structure is currently not in a critically distressed condition even due to occasional and sparse corrosion of steel reinforcement observed. The reason of corrosion is severe sea environment where salinity in the atmosphere is very high. The structure requires structural and non-structural repairs as a preventive maintenance on urgent basis for safety and longevity of life of the structure.
- The distressed RCC structural elements of the Jetty such as Piles, Pile Cap, Beams and Deck slab shall be repaired with either by micro concrete or by polymer based treatment using spray technique as suggested in the Appendix-I of the dissertation. The micro concrete shall be used for making the loss of concrete more than 25 mm & Polymer based structural repairs for loss of concrete less than 25 mm. The flow chart of the methodology is given in the Appendix-II.
- The scheme for other non-structural repairs (i.e. replacement of flooring, railing, wearing coats, Bollards, Fenders etc.) should be developed by engineer-in-charge of the JNPT. The comprehensive condition analysis of Fenders and Bollards is required to be carried out and both the schemes may be implemented depending upon the site condition.
- It is recommended to monitor the Port’s Civil (Marine) Infrastructures of the JNPT at regular intervals and routine repairs and maintenance should be carried out. The concrete of the Jetty Structure located in the sea deteriorated due to the ingress of corrosion causing elements present in marine environment and varied loading conditions.
- Through services and fissures in the cover concrete of the beams salt and salt fumes ingresses in the structure deteriorating concrete. The travel of ‘element causing corrosion’ till reinforcing steel induced potential difference thus the vulnerability of corrosion increased. The cover of the crane beam needs to be enhanced while designing the new jetty structures.
- All beams / structural members those are corroded to be repaired/ treated with micro concrete and epoxy mortar. The beams bottoms to be coated with anticorrosion coating.

REFERENCES

1. Scott Bacon, Warren Green and Brad Dockrili, (2010), “Engineering maintenance of port wharves structures”, Journal of Port Technology International, Mooring and Berthing, pp. 113-116.
2. R.B. Singh, (2010), “Popular non-destructive testing of concrete structure-review of std. methods”, National Seminar on Green Structures for Sustainability, pp. 1-7.
3. Dr. Gopal Rai, (2014), “Rehabilitation and strengthening of bridges by using FRP composites”, pp.1-18.
4. B. M. Lahane, R. J. Jardine, A.J. Bond and R. Frank, (2014), “Mechanisms of shaft friction in sand from instrumented pile tests”, Journal of Geotechnical Engineering, Vol. 119, No.1 pp.19-35.
5. Chenna Rajaram, Pradeep Kumar Ramancharla, (2014), “Vulnerability assessment of coastal structure: A study on port buildings”, International Journal of Education and Applied Research (IJEAR), volume.4, issue Spl-2, pp. 8-15.
6. Gopal L. Rai and A.N. Bambole, (2015), “Strengthening of bridges by pre-stressing at JNPT and testing its efficiency”.
7. R. R. Gaikawad | H. S. Chore | S. A. Rasal |Use of Non-Destructive Methods: Case Studies of Marine Port and Bridges Structures in Surabaya. (2018). Electronic Journal of Structural Engineering 18(1) 2018.
8. Odd e. Gjorv (1969), “Durability of reinforced concrete wharves in Norwegian Harbours” Proceedings of Conference Materiaux et Constructions, volume 2, no.12, pp. 467-476.
9. P Castro et. al. (2001) “Interpretation of chloride profiles from concrete exposed to tropical marine environments” Journal of Cement and Concrete Research, 31, pp. 529-537.
10. P.S. Sengupta, (2009), “Special consideration in marine pile design and construction”, Indian Geodetic Society, conference at Guntur India, pp. 709-711.
11. P.Faulkner, P.Cutter and A.Owens, (2011), “Structural health monitoring system in difficult environments- Offshore wind turbines”, 6th European Workshop on Structural Health Monitoring- Fr.2.A.3, pp.1-7.
12. Chenna Rajaram, Pradeep Kumar Ramancharla, (2014), “Vulnerability assessment of coastal structure: A study on port buildings”, International Journal of Education and Applied Research (IJEAR), volume.4, issue Spl-2, pp. 8-15.
13. R.B. Singh, (2010), “Popular non-destructive testing of concrete structure-review of std. methods”, National Seminar on Green Structures for Sustainability, pp. 1-7.
14. P.K. Satheesh Babu, A. Mathiazhagan, and C.G. Nandakumar, (2014), “Corrosion health monitoring system for steel ship structure”, Journal of Environmental Science and Development, Vol.5, pp. 491-495.
15. Dhairyashil S Mundhe and S.A. Rasal (2023) “Depiction of Damage Mechanism and Deteriorating Pattern of Concrete Jetty Structure in Marine Environment : A Literature Review” Journal of Emerging Technologies and Innovative Research (JETIR) www.jetir.org. vol.10, issue 6, pp 150-155