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Structural health analysis and monitoring of RC jetty structure and rehabilitation methodology

Aniket Pradeep Bhandari
aniketbhandari1995@gmail.com
Datta Meghe College of Engineering, Navi Mumbai, Maharashtra

P. A. Dode
padode@redifmail.com
Datta Meghe College of Engineering, Navi Mumbai, Maharashtra

ABSTRACT

Jetty is the interface between the land mode of transportation and waterways mode of transportation. The structural deterioration of jetty structure depends upon various parameters such as their exposure conditions, oceanographic conditions, salinity, ballast water contamination, wind velocity and its direction. Jetty structure are subjected to dead load, live load, earthquake load and additional marine loads like current load, wave load, berthing load and mooring load. The present study is carried out to suggest the most appropriate rehabilitation measures or repair methodology by inspecting, analyzing and monitoring of RC jetty structure. The inspection reports and NDT test results helps to find the extent of spread of damages and level of deterioration of jetty structure.

Keywords: *Berthing Load, Mooring Load, NDTS, Rehabilitation*

1. INTRODUCTION

The sea mode is very cheap mode as compared to land mode for transporting huge quantity of material, raw material and passengers. There are various kind of jetties depending upon its location, material used for construction, purpose of it etc. The Jetties along with other infrastructure like breakwater, channel, ship anchorages, navigation aids, landside facilities including material handling equipment together form the Port. The jetties are constructed using Reinforced Concrete structures now a days. Jetty structures are generally located in deep sea. Generally berthing jetties are constructed away from the shoreline inside the sea to get sufficient depth for anchorage of ships. These are connected to the shore by approach jetties supported by piles, which generally are embedded in the sloping ground. Non destructive testing (NDT) of concrete structures has a key role in detecting various defects in reinforced jetty structures including crack, voids, determining the depth of surface opening cracks, reinforcement condition, delaminations, etc. The defination of terminology of some jetty structures are dissucssed below.

JETTY : It is a structure on open sea coast which extends into body of the water

Fig.1.1: Jetty

Zones of Deterioration

While studying the jetty structure it is very much necessary to understand that the same structure has various degree of deterioration and the deterioration patterns also changes within the same structure. This happens because various parts of the structure has different exposure conditions. Hence depending upon exposure conditions the jetty structure can be bifurcated in different zones as under.

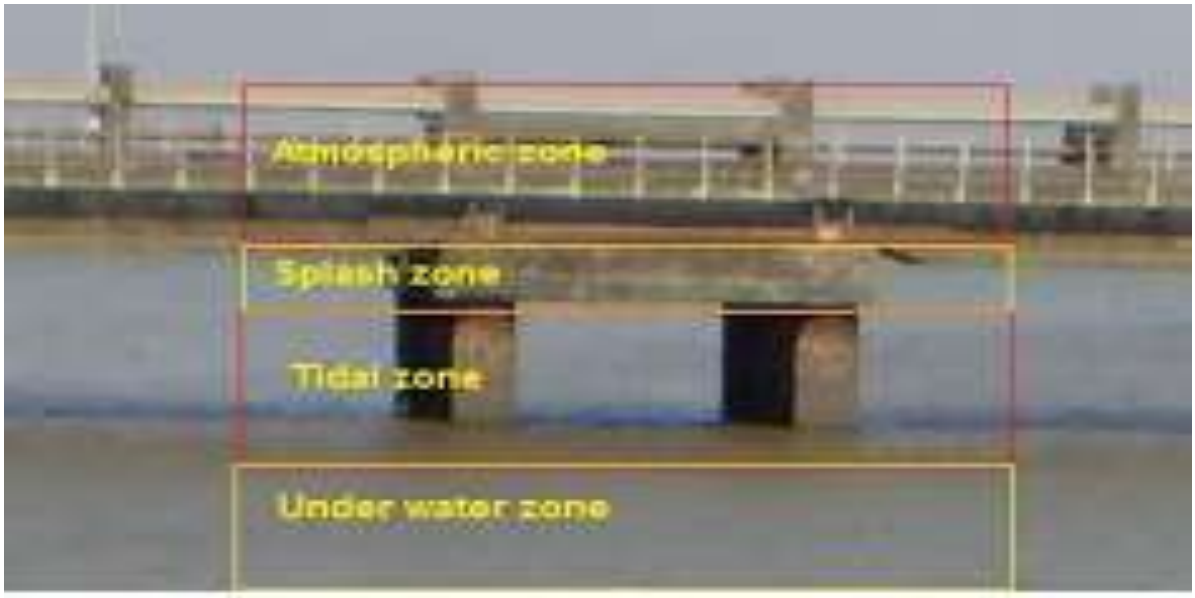

Fig. 1.2: Various Zones of Exposure of Jetty Structure

Under water zone: In this zone structure is directly in contact with sea water which contains lots of corrosive agents & salinity.
Tidal zone: In this zone there is intermittent wetting and drying of the concxrete surface which leads to deterioration at very fast rate.
Splash zone: In this zone, the waves coming from sea splashes on the concrete surface which contains corrosive agents.
Atmospheric zone: As surrounding air is saline, this causes the salt fumes getting sprayed on the structure, thus impregnated in concrete surface.

Loads Acting on Jetty Structure:

A. Loads from Seaside: The loads from the sea side include the horizontal forces caused by waves, the forces caused by berthing and vessel's pull from bollard. The forces caused by berthing of vessels are determined from the velocity and angle of approach of the vessels.

B. Loads from Deck: The important loads from the deck are the vertical loads by self weight of the deck, superimposed loads from handling equipments. Horizontal loads are mostly due to wind forces on structures and also due to the breaking force of cranes if applicable.

C. Loads from Landside: Horizontal loads are caused from landside due to the earth pressures and differential water pressure.

2. LITERATURE REVIEW AND FINDINGS

Odd E. Gjrorv (1969)presented the study of comparative field inspection carried out for 219 reinforced concrete wharves constructed in Norwegian harbours during half century prior to this study. The structures comprising of 1,90,000 Sqm of deck slab area and more than 5,000 slender R.C. pillars poured under water. The study observed that the below low water the structures are sound and in good condition. Deterioration is slowly occurring in the tidal zone but above high water the deck beams showed vulnerable to steel corrosion whereas neither deck slab nor sea walls strengths were seriously impaired. The deck beams should be avoided and if cannot be avoided (from economy point of view) then should be made as shallow as possible in all reinforced concrete structures exposed to marine environments.

Mazurkiewicz Boleslaw (1995)presented the way to strengthen the existing harbour structure to meet the requirement of modern day ships which are increased in size and draught. This project has three aspects viz. analysis using recalculations, deepening of harbour bottom, rehabilitation and strengthening of existing structure. The fleet of ships now in existence and beingdeveloped, built to meet the requirements of certain seaways(e.g. Panamax,Suezmax, Chinamax) impose changed demands on harbour facilities, like different types ofberthing structures. It requires readjustment of harbour facilities to assure adequate depths, handlingand mooring facilities, as well as adequate strength and stability of the jetty structure for the significantly increasedloadings.The option of constructing entirely new structure was ruled out and use of existing pier or jetty as a structural element of a new deeper berthing structure which will meet all structural and functional requirements was considered. Accordingly the jetty strengthening was done by utilizing the existing structure in various ways like part of main structure as main structural element, support for new berthing structure and as an anchor to new berthing structure.

Antonio Costa and Julio Appleton (2002) presented study of deterioration of Reinforced concrete through various case studies of Dock, Wharves and bridges wherein the concrete is exposed to Marine conditions. They have stated that the marine is one of the most corrosive atmospheres in which chloride penetration and chloride induced reinforcement corrosion lead to reduction in service

life of structures. Repair strategies to extend service life of structure are also discussed. Various zones of the corrosion were identified depending upon marine water exposure also the accessibility of atmospheric oxygen to reinforcement. This is causing rusting of steel resulting into spalling of cover concrete and deterioration of the concrete further. Various tests were conducted to assess the condition of concrete and corrosion rate was also measured.

N. Dawood, H. Marzouk, A. Hussein and N. Gillis (2013) presented an Nondestructive Assessment of a Jetty Bridge Structure Using Impact-Echo and Shear-wave Techniques. Two AASHTO girders of the jetty were chosen to carry out the various NDTs. In this case study, a jetty bridge structure was inspected using the impact-echo and shear wave techniques. The main objective was to assess the efficiency of these techniques to detect the extent and location of cracks and local damage. The combination of these two non destructive strategies enabled engineers to detect various defects in the structural members of the jetty bridge. Based on the results obtained from the use of these methods, rehabilitation procedures were performed to maintain safe and economic operation for the jetty structure.

Tan jooee (2016) reported the field assessment of old jetty in Malaysia. The project report presents detailed investigation findings on 68 year oldjetty facility which is still in service in northern part of Peninsular Malaysia to assess its structural condition. The objective of the report is to develop a practical assessment programme, to determine the long term relation between the rate of structure deterioration by measurements of material properties, and to determine the remaining sevice life of the jetty. A combination of direct tests and non-destructive tests such as concrete core compression test, rebound hammer test, carbonation test, chloride ion ingression test and steel pile thickness measurements were performed. Field assessment tests proposed in this report is simple yet produces reliable results for assessments of structures.

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A case Study of Concrete Repairs on Jetty in Port Nolloth, Northern Cape, South Africa was presented by Malan Schrecker, Duan Viljoen, and Pierre van der Spuy.The jetty structure consists of a deck on piles approach bridge and main jetty. The approach bridge isapproximately 50m long, perpendicular to the coastline, while the main jetty is approximately 66m long, parallel to the coastline.A forensic investigation was conducted to determine the true extent of the corrosion and deterioration of the jetty structure.The investigation included the methodologies such as Ferro-scanning, Core Samples, Non-destructive testing on the structure, Visual Inspections, etc. Also the investigation included condition assessment of various parts of the structure.A very few piles showed significant rebar corrosion damage with signs of delamination. Most of the piles (approximately 80%) showed rebar-corrosion related cracking on one or more corners. The delamination survey revealed that many beams experienced high degrees of delamination. On the slab soffits, delamination was often occurring on more than 25% of the total area.Most beams showed horizontal cracking at the bottom reinforcement, often along the entire length of the beam. The following repair methodologiesare applied such as removal of damaged concrete and preparation of substrate, replacement of reinforcement steel, sprayed concrete method, trowel applied mortar method, application of water repellent surface coating. This paper presented the findings of a forensic investigation conducted by concrete specialists, a structural modelling analysis to verify the structural capacity of the jetty and the repair methodology proposed by the designer.

3. METHODOLOGY

In order to suggest most appropriate rehabilitation measures the following methodolgy shall be adopt.

- Detailed visual inspections to map the distress with various degree of damages/distresses of the jetty structure. Simple tests like tapping shall also be associated with visual observations.
- Extent of spread of damages and level of deterioration shall be noted.
- Carryout inspection of the Jetty to observe the performance characteristics of various structural members of the jetty.
- To obtain the strength, homogeneity and integrity by Non Destructive Evaluation.
- To assess the level of corrosion, depth of carbonation, salt ingress from the various tests carried out
- To find out the strength of concrete and available thickness of concrete cover to the reinforcing steel.
- To study the old drawings and literature related to this structure.
- To check the physical dimensions of the jetty and Structural System i.e. primary secondary beams system etc.
- With regard to original design the capacity of existing jetty structure, its strength and stability shall be assessed.
- To study the new service conditions and loadings to which the structure is being subjected to and shall be subjected to, in near future.
- To find out the suitable measures to be taken-up for rehabilitation or maintenance of the Jetty structure in order to enhance the service level of the structure.
- To assess immediate repair and strengthening measures for expansion joints, service ducts, beams under crane rails etc.
- The details of the new remedial system for structural strengthening and remedial measures required to be taken against corrosion shall be suggested as found required.

4. CONCLUSION

From above stated literature review it can be summarized that lot of study in this field is being carried out world over, but still being dynamic industry the jetty structure needs to respond to dynamically changing service conditions. Also every jetty structure is a unique entity having very much unique geographical, oceanographically and design features. From study of the literature review it can be seen that lot of studies are carried out on the RCC jetty structure elsewhere in the world. But no such comprehensive study of the jetty structure in the Indian conditions is reported. The jetties in India are very old and are seen deteriorating very fast as compared to the life for which they are designed. We as a county are having scarcity of resources hence to utilize our resources in better way is a need of an hour. In order to head towards this goal the life of jetty structures can be enhanced so that replacement of it can be successfully prolonged, maintenance expenditure can be reduced and thus funds so saved can be made available for creating newer infrastructures which is a need of our country. For this purpose the structural assessment of jetty structure is a prerequisite. In India, most of the RC jetties are constructed approximately 30-40 years back with then specifications and loading considerations, those jetties needs to be upgraded to withstand current loadings conditions. This paper deals with the structural health analysis and monitoring of the jetty structure mainly corresponds to the corrosion of reinforcing steel embedded in the concrete which are exposure to different marine conditions. Thus a most appropriate repair or rehabilitation scheme can be suggest for particular type of structure exposure to different marine conditions.

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