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DEPICTION OF DAMAGE MECHANISM AND DETERIORATING PATTERN OF CONCRETE JETTY STRUCTURE IN MARINE ENVIRONMENT : A LITERATURE REVIEW

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Abstract: Marine jetty structures are essential for enabling marine activities and providing critical infrastructure for coastal towns. These constructions, however, are constantly subjected to harsh environmental conditions such as seawater exposure, wave action, tidal variations, and chemical agents, all of which contribute to their deterioration over time. Understanding how marine jetty constructions deteriorate is critical for guaranteeing their long-term integrity, safety, and sustainability. The evaluation of research begins with an examination of the principal deterioration factors impacting concrete jetty structures, which include both natural and anthropogenic impacts. Environmental exposure (e.g., sea conditions, temperature changes), chemical attacks (e.g., chloride intrusion, sulfate attack), mechanical loads (e.g., waves, berthing forces), and structural inadequacies (e.g., design flaws, poor construction practices) are examples of these issues. This review paper intends to examine the fundamental causes of concrete jetty structure deterioration, identify important degradation mechanisms, and estimate the corresponding structural performance decline.

***Index Terms* - Visual Inspection, Corrosion, Non-Destructive test, Rebound Hammer test, Carbonation Depth, Electrical Resistivity, Chemical attack.**

INTRODUCTION

The jetty structures are built to provide access ways for ships and vessels to coastal locations. These structures aid in the resistance to waves, tides, and currents. Loading and unloading of cargo ships, fueling facilities, and jetty exercises vary depending on the type of facility, such as commercial, fishing, or passenger port. Because of the high salt concentration in seawater, corrosion is a major concern for coastal jetty structures. Constant seawater exposure, combined with the presence of oxygen and other corrosive chemicals, can initiate and accelerate corrosion of metallic components, jeopardizing their strength and structural integrity. Similarly, erosion produced by wave action can cause soil or sediment loss surrounding the jetty construction, weakening its base and potentially triggering structural failure. Wave loads, current loads, structure overloading, fatigue, corrosion, environmental exposure, biological and chemical activity are all factors that influence jetty structure. This research investigates some of the parameters that influence jetty structure. A preliminary survey, or visual assessment, can help determine the behavior of structural components that are failing. Structural health assessment tests such as non-destructive examinations and lab tests are performed to identify the level of deterioration in order to maintain structural stability.

VISUAL INSPECTION

When conducting a structural health assessment of a coastal jetty structure, the findings of a visual inspection might offer useful insight into forecasting the trend of deterioration. The following are some particular visual inspection findings and their implications for determining structural health and anticipating deterioration. Corrosion, including rust, pitting, or material loss, can foreshadow probable future degradation. In order to prioritize maintenance or repair actions and determine the structure's remaining service life, the amount and severity of corrosion can be evaluated. Areas of stress concentration or structural instability may be indicated by cracks in the jetty structure. It is possible to identify potential failure causes and decide whether reinforcement or repair is required by measuring the length, width, and depth of cracks as well as their locations and orientations. Concrete degradation and weakened structural integrity are indicated by the spalling and delamination of concrete components. Determining the severity of the degradation and assisting in the selection of the best restoration techniques can be aided by the extent and depth of spalling or delamination.

Marine organisms and bio-fouling can hasten degradation by encouraging corrosion and jeopardising the jetty's structural integrity. To stop future damage and protect the structure's health, monitoring and managing marine growth is crucial. Assessing the exposure and susceptibility of the jetty structure involves taking into account environmental conditions such tidal movement, wave effect, salinity levels, and temperature changes. Accurate deterioration pattern prediction and efficient design and maintenance decisions are made possible by an understanding of the environmental conditions.

A visual evaluation of the water quality, vegetation cover, reinforcement, and spalling carried out by B.H.J. Pushpakumara and M.S.G.M. Fernandon [1] shows The corrosion process accelerates when reinforcement is present in the splash zone exposed to the atmosphere due to causes such as chloride ion assaults and interaction with oxygen, and this is the most vulnerable thing that can happen to a structure. Concrete projects, like spalling, can decay more quickly. The rating algorithm prioritizes reinforcement exposure above spalling. Variation in water level and vegetation cover are assigned low priority weights.

NON-DESTRUCTIVE TEST

NDT methods provide a means to evaluate the integrity and quality of structures without causing damage or significantly disrupting operations. It offers a non-invasive approach that can detect defects, anomalies, or deterioration without compromising the structure's integrity. Rebound hammer test performed using Schmidt hammer identifies the compressive strength using calibration graph. Difference in strength values shows non-uniformity of concrete quality. Rebound hammer test result helps to detect cracks and hardness of concrete surface. Carbonation depth results helps to identify the durability and corrosion resistivity of r/f concrete structure. The main factors affecting carbonation depth is exposure of chloride, chloride reduces PH of concrete and it accelerates the CO_2 penetration and it leads to greater carbonation depth. As CO_2 is carried by moisture, it forms carbonic acid and its reaction with calcium hydroxide forms calcium carbonate and as carbonation is increasing depth of CO_2 penetration increases. Increasing temperature speed up the carbonation rate and vice versa.

The pH level of concrete is above 10 and is alkaline. Due to this, concrete act as a protective passivating layer for steel embedded in it. The detection of these de-passivating layers is identified by performing half-cell potentiometer test. As potential value is negative it represents the highly active corrosion and presence of de-passivating layer. The data obtained from electrical resistivity test helps to interpret the condition of concrete structure. As higher resistivity values indicate denser concrete volume and less permeability which resist corrosion activity. Whereas lower resistivity values indicate porosity and moisture content and hence corrosion risk increases. An electrical resistivity test conducted by Sylvester Obinna Osuji *et* al [2], which revealed that the splash and tidal zones have lower resistivity values, while the atmospheric zone and submerged zone have higher resistivity values, as shown in the figure below. Waves and splashing in the splash and tidal zones can cause salt particles to accumulate on the jetty structure's surface. These salt deposits can form conductive pathways, allowing electrical current to flow more freely and resulting in reduced resistivity values.

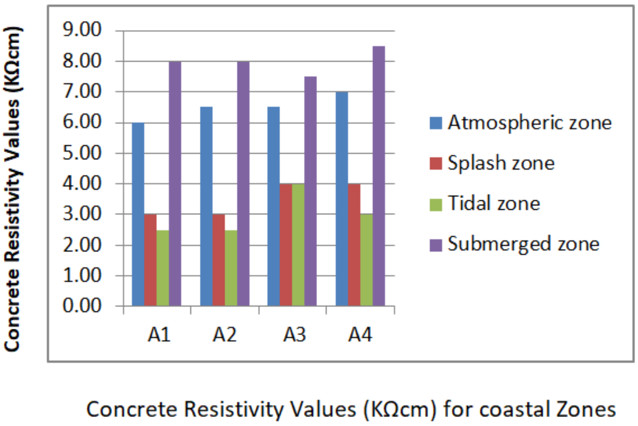

Figure 2: Concrete resistivity values Vs Section of Coastal structure

The Concrete Quality Assessment of Structural Elements Using Ultrasonic Pulse Velocity Test presented by Tarun Gehlot *et* al. [3]. The objective of this investigation is to study the applicability, performance, availability, complexity and restrictions of NDT. The poor quality concrete allows the ingress of moisture and oxygen to the reinforcing bars, the pulse velocity method is an ideal tool for establishing whether concrete is uniform. It can be used on both existing structures and those under construction, if large differences in pulse velocity are found within a structure for no apparent reason, there is strong reason to presume that defective or deteriorated concrete is present. The Durability studies of Concrete structure presented by V L Satish [4] using Half Cell Potential Studies on Concrete Structures in Coastal Environment. The goal of this study was to examine the state of buildings by visual observations and non-destructive (ND) testing such as Profometer surveys, Rebound Hammer tests, and Ultrasonic pulse velocity tests. The following sections describe the details of the Half-cell potential studies, analysis, and findings. Half-cell potential levels suggest a 50% chance of corrosion. This can be due to insufficient cover to reinforcement or a lack of cover concrete compaction, resulting in a porous microstructure visible on the site. Use of Non-Destructive Methods: Case Studies of Marine Port and Bridge Structures in Surabaya was investigated by Y. Oktavianus *et* al. [5].This study makes use of two reinforced concrete bridges at Tanjung Park's first port, which demonstrate an increase in the rate of cl-induced corrosion in the maritime environment. Surabaya's second toll-way exhibits a rise in carbonation rate due to traffic environment.

Various NDT tests were performed on the Longitudinal RC Beam at TPS Bridge, the Longitudinal RC Beam at TL Bridge, and the RC Columns at the tollway Bridge. According to the Schmidt Hammer results, Average Compressive strength is greater than Design Compressive strength. Here the mean value and 5% likelihood of exceeding are significantly higher than the criterion for low corrosion rate, indicating that the quality of concrete to prevent Chloride ingestion to reinforcement is extremely good. The average coefficient of air permeability demonstrates that the painted surface has a higher quality concrete cover than the unpainted surface. The concrete mix at the bottom of the girder is more compacted than the web, resulting in a higher coefficient of air permeability for the flange at the TL bridge Beam. Because of the higher moisture content due to the water surface, the electrical resistivity at the bottom flange is lower than at the web. The results of the RC Column at the tollway Bridge reveal that the lower the concrete compressive strength, the higher the value of the coefficient of air permeability. A higher KT value indicates that there is more water in the concrete mix, which leads to increased porosity when the concrete is set.

Case Study on Distress Analysis of Jetty Structure Subjected to Dynamic Load was conducted by R. R. Gaikawad *et* al. [6].Site inspection and NDT testing. Rebound Hammer Test, Ultrasonic Pulse Velocity Test, and Half-Cell Potentiometer Test were performed on main beams, subsidiary beams, and crane beams. It was discovered that the cover of crane beams should be improved for future design purposes.

COASTAL ZONES

Examining the atmospheric zone, which exposes concrete jetty constructions to air, humidity, and contaminants. It looks at how temperature changes, airborne contaminants, and ultraviolet (UV) radiation affect the concrete matrix. The research looks into the mechanisms of chloride ingress, spalling, and reinforcement corrosion, all of which occur in the splash zone due to the aggressive nature of seawater and the presence of chlorides. The tidal zone, defined by constant immersion in seawater, poses particular challenges for concrete jetty structures. Study on Assessment of the Condition of an Existing Marine presented in the Niger Delta Region of Nigeria by Sylvester Obinna Osuji *et* al. [2]. HCP test indicates 90% chance of active corrosion from atmospheric to tidal zone, 50% from atmospheric to splash and tidal zone and 10% chance of active corrosion in completely submerged zone. The average loss in steel c/s ranged from 30% to 66%, which indicate higher corrosion rate, Tidal zone shows highest loss in c/s followed by splash zone and atmospheric zone.

The review study on Structural Health Monitoring of Existing Reinforced Concrete Jetty Structure conducted by Mohit M Patil and Dr. S. A Rasal [7]. The review found that concrete mixed with blast furnace slag and volcanic ash deteriorated less after sixty years of exposure to the marine environment. The durability of the RC member in the splash zone and atmosphere zone was discovered to be low. The RC member's durability in the tidal zone and undersea water zone is excellent. One of the most corrosive atmospheres in which chloride penetration and chloride induced reinforcement corrosion lead to a reduction in structure service life, structures below low water were in good condition but deterioration was slowly occurring in the tidal zone and above high water deck beams were severely affected by corrosion in steel and proper attention was not given to the maintenance of beams and deck slabs. In zones of alternate soaking and drying, the deterioration rate is higher.

CASE STUDY

The deterioration of coastal structure using carbonation depth test data monitored by P. Castroa *et* al.[8] The Samples of 10 buildings exposed to similar condition for 5 years of time were studied to obtain the results as per impact of elevation, geographic condition and distance to the coast. The average values of porosity, Effective porosity, Compressive strength, carbonation depth(mm),carbonation co-efficient, Resistivity test were carried out which shows decrease in compressive strength from bottom to top as porosity increases, also carbonation depth increases from bottom to top of structure. The Temperature is constant along height but humidity decreases from bottom to top of columns due to reduced access of carbon-dioxide at bottom which results in less carbonation depth at bottom of column, Chloride penetration in concrete shows increase in carbonation rate at early stage as compared to the chloride concentration in older building structure. According to the geographical orientation i.e factors influencing carbonation is marine breeze and its blocking ,sun movement also Time of wetness which is directed by atmospheric conditions flow of air, surface properties and moisture content .Therefore low TOW shows less humidity.

The impact of compaction pores on Sorptivity and Carbonation studied by Tahir Gonen and Salih Yazicioglu [9] interconnected voids allows flow of water in concrete which leads to capillary action and increasing absorption of water. Density of concrete decreases due compaction pores which results in increasing permeability of concrete. Ensuring adequate compaction technique during ongoing construction results in possibility of lower sorptivity after several years. Experimental sorptivity test were carried out to calculate the sorptivity coefficient by using numerical equation which shows minimum sorptivity coefficient on compacted concrete vice versa. The carbonation rate of concrete depends on moisture content and relative humidity, this study identifies higher carbonation rate at 55% relative humidity. Due to the exposure of CO_2, Calcium hydroxide in concrete reacts with CO_2 to form calcium carbonate which leads to the carbonation. Here calcium hydroxide has higher molar mass and conversion of calcium hydroxide to calcium carbonate leads to decrease in weight. However this indicates that initial compaction of concrete plays vital role in sorptivity and Carbonation rate of concrete.

The Half-cell potentiometer test located at SHAR island performed by V L Satish [4] ,Case studies of housing units were conducted which shows 50% probability of corrosion for first and second unit due to inadequate compaction r/f cover to concrete and the leakage spots can lead to ingress of chloride in concrete which leads to deterioration. Housing unit 3 shows 10% probability of corrosion due to adequate cover. Chloride content plays vital role in increasing corrosion rate of concrete as housing unit 1 show CL content of 0.6 to 5%, Housing unit 2 shows CL content of 0.4 to 1%, housing unit 3 shows CL content of 0.025 to 1%.

CHEMICAL ATTACK

Chemicals found in seawater, such as chloride ions, sulfates, and acids, can enter concrete and cause reinforcing steel to corrode. This corrosion can result in the creation of expanding rust, which can cause cracking, spalling, and structural failure. Salts in seawater can penetrate the concrete. When water evaporates, salt crystals develop and put pressure on the concrete's pore structure. Internal damage, such as cracking and loss of surface layers, can result from the cyclic process of salt crystallization and evaporation. Acidic substances might come into contact with concrete structures due to industrial activity or pollution in coastal locations. Acid attack can dissolve the cementitious matrix, resulting in surface erosion, material loss, and decreased load-bearing ability.

A 24 year old jetty structure in a marine environment was studied by K.C.Liam *et* al. [10].Water samples were obtained at a depth of 2m and revealed salinities ranging from 26.0 to 32%. Concrete pile samples were collected at several depths ranging from 10mm to 70mm.The experimental results revealed 30% concrete delamination0, cracks, corrosion, and spalling in the splash and higher tidal zone. As shown in the figure below, the chloride concentration in % by weight of concrete and zone sampling. Corrosion potential data demonstrate that the splash zone has 90% active corrosion, while the tidal zone has greater negative values but is less sensitive to corrosion because low oxygen availability can counteract high chloride levels.

The chemical contents were determined by Sylvester Obinna Osuji *et* al. [7] who reported that the average chloride concentration was 17000 mg/l. Magnesium ions were detected in a respectable proportion, but sulfate ions were found to be insignificant. This suggests that chloride-related corrosion will be the predominant type of rust that affects the steel reinforcement in this area.

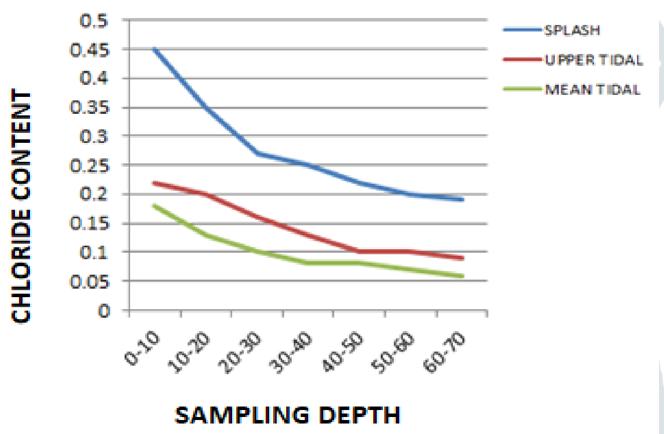

Figure 2: Chloride content (% by weight of concrete) versus sampling depth

CONCLUSIONS

The study's goal was to examine the level of carbonation within the concrete, establish its relationship with other deterioration mechanisms, and provide useful insights into the structure's overall condition. The assessment of jetty structure aids in the detection of elements impacting the structure, such as corrosion, wave impact, tidal forces, or environmental exposure.

1) The freezing of water within the concrete causes expansion, which causes cracks. Micro-cracks in concrete are generated as a result of the freezing and thawing cycle, resulting in a decrease in the compressive strength of the concrete.

2) The comprehensive study of carbonation depth results shows sections vulnerable for various deteriorating mechanism i.e reduced alkalinity, decreasing compressive strength and corrosion.

3) Electrical resistivity test result detects concrete quality and potential deterioration sections are identified. As lower resistivity values shows ingress of chloride, spalling of Concrete cover and corroded reinforcement.

4) The mix of moisture, corrosive substances, salt deposition, and porous materials in the atmospheric, splash, tidal zone and submerged zone leads to the electrical resistance values measured in the electrical resistivity test.

5) The comprehensive study of carbonation depth results shows sections vulnerable for various deteriorating mechanism i.e reduced alkalinity, decreasing compressive strength and corrosion.

6) The structural elements exposed to tidal zone and splash zone experience highest loss in mass% Splash and tidal zone is more susceptible to that of active corrosion as compared to submerged and atmospheric zone.

7) The study helps to identify the most affected sections which need special attention for repairs and retrofitting for better structural integrity.

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