ANALYSIS OF CORROSION IN SUBMERGED CONCRETE STRUCTURE

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ABSTRACT: Non destructive testing is applied to both old and new concrete structures, for new structures the principal application are likely to be for quality control or the resolution of doubts about the quality of materials and construction. The testing of existing structures usually related to the assessment of structural integrity and adequacy of structure service. Half-cell potentiometer data are useful to find out corrosion rate and to establish the remaining life service of the reinforced concrete structures. The reinforced Concrete structures deteriorates under water in Marine exposed environment. It is not the disintegration of concrete itself, but the electrochemical corrosion of the reinforced steel. Corrosion of steel reinforcement is one of the main causes of damage in concrete structures. The most critical and serious problems to the durability and safety of concrete structures. The corrosion of reinforcement in under water of R.C.C. structures depends on the factors of steel, cement, water cement ratio, concrete cover, salinity of water, design and construction methodology. Under water concrete structures are subject to deterioration due to their continuous exposure to marine environment. The electrochemical corrosion of the reinforcing steel results in disintegration of concrete structures. The various models available on prediction of service life of structure is reviewed in the present study and selected a model with reviewing certain parameter as applicable in this case study. Service life predicted of case study and the cases used for validation of their service life is compared and found workable. The service life model to predict the end of service function of structures, the data are used for strategic plan to rehabilitee major repairs to avoid total loss.

Keywords: Steel, Corrosion, NDT, Bridge, USPVT, etc.

I. PROBLEM STATEMENTS
Corrosion of steel in concrete is an electrochemical process. The electrochemical potentials to form the corrosion cells may be generated in two ways:
Composition cells may be formed when two dissimilar metals are embedded in concrete, such as steel rebars and aluminum conduit pipes, or when significant variations exist in surface characteristics of the steel.
Concentration cells may be formed due to differences in concentration of dissolved ions near steel, such as alkalies, chlorides, and oxygen.
The differences in electrochemical potential can arise from differences in the environment of the concrete. Electrochemical cells form also due to a variation in salt concentration in the pore water or due to a non-uniform access to oxygen. Thus, one of the two metals (or some parts of the metal when only one metal is present) becomes anodic and the other cathodic. When there exists a difference in electrical potential along the steel in concrete, an electrochemical cell is set up: there form anodic and cathodic regions, connected by the electrolyte in the form of the pore water in the hardened cement paste. It is recognized that steel embedded in a heavily alkaline medium with pH values from 9 upwards will not rust. During the setting of concrete, cement begins to hydrate, this chemical reaction between cement and water in the concrete causes calcium hydroxide to be formed from the cement clinker. This ensures the concrete’s alkalinity, producing a pH value of more than 12.6 which renders the steel surface passive.

II. OBJECTIVES OF THE RESEARCH
The specific objectives of the research are:
- To appropriately find out the root causes of concrete structures deterioration under marine environment.
- To investigate the factors influencing the corrosion of embedded steel in concrete structures through non-destructive test.
- Prediction of the service life of marine concrete structures with the help of suitable established mathematical models.
- To develop an oval method of integrating the conventional methods of NDT with the advanced and established service life models in accurately determining the service life of marine structures.

Methods for NDT of Concrete Structures
The following methods, with some typical applications, have been used for the NDT of concrete:
- Visual inspection, which is an essential precursor to any intended non-destructive test.
- An experienced civil or structural engineer may be able to establish the possible cause(s) of damage to a concrete structure and hence identify the required test among the various NDT methods.
- Half-cell electrical potential method, used to detect the corrosion potential of reinforcing bars in concrete.
- Schmidt/rebound hammer test, used to evaluate the surface hardness of concrete.
- Carbonation depth measurement test, used to determine whether moisture has reached the depth of the reinforcing bars and hence corrosion may be occurring.

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III. RESULTS AND DISCUSSION ON NDT TESTS

- The tests carried on R.C.C. concrete surface which depicts the conditions and status of concrete quality to encompass the surrounding environment further deteriorations. The aggressive chemical ingredient present in the concrete compositions. The design and material quality adopted for the durability and serviceability of the structures.
- The probability of the corrosion occurrence in the steel reinforcement embedded in Concrete attract the attention. The material and grade of steel used reflects the corrosion process in progress to deteriorate the structures. The test-report on concrete of carbonation, chloride and sulphate shows the concrete leaching out and due to the presence of inter force of the chemical ingredient which aid to timely control and rectify the concrete structures.
- As the quality of concrete and chemical ingredient present assessed through Non-Destructive Test.
- The Ultra Sonic Pulse velocity test on concrete surface and the Half Cell Potential test on R.C.C. piers in splash zone are used and aids to find out the concrete strength quality and the probability of corrosion. Initial and advance conditions with the effect of salinity and marine environment on concrete cover leading to deterioration of concrete. The NDT tests are conducted for a period of 30 months to monitor the time and environment effect in the interval of 9-10 months on bridge and results compared.

Schmidt Rebound Hammer Test

<table>
<thead>
<tr>
<th>Pier</th>
<th>Position</th>
<th>Apr.-2019</th>
<th>Jan.-2020</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg. Rebound No.</td>
<td>Approximate Compressive Strength (kg/sq.cm)</td>
<td>Avg. Rebound No.</td>
</tr>
<tr>
<td>P1 (Top)</td>
<td>Column - 1</td>
<td>50</td>
<td>580</td>
</tr>
<tr>
<td></td>
<td>Column - 2</td>
<td>47</td>
<td>540</td>
</tr>
<tr>
<td></td>
<td>Column - 3</td>
<td>49</td>
<td>580</td>
</tr>
<tr>
<td></td>
<td>Column - 4</td>
<td>52</td>
<td>600</td>
</tr>
</tbody>
</table>

Table 4.1: Rebound Number and corresponding Compressive Strength on P1 (Top)

<table>
<thead>
<tr>
<th>Pier (Beam Between Column No. 3-4)</th>
<th>Position</th>
<th>Apr.-2019</th>
<th>Jan.-2020</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ave. Rebound No.</td>
<td>Approximate Compressive Strength (kg/sq.cm)</td>
<td>Ave. Rebound No.</td>
</tr>
<tr>
<td>P1</td>
<td>Left</td>
<td>50</td>
<td>580</td>
</tr>
<tr>
<td></td>
<td>Centre</td>
<td>50</td>
<td>580</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>49</td>
<td>575</td>
</tr>
</tbody>
</table>

Table 4.3: Rebound Number and corresponding Compressive Strength on P1 (Beam Between Column No. 3-4)
Chloride, sulphate content and pH value of concrete

Table 4.4: Rebound No. and corresponding Compressive strength on P1 (Beam Between Column No.1-2)

<table>
<thead>
<tr>
<th>Pier</th>
<th>Position</th>
<th>April-2019 Ave. Rebound No.</th>
<th>Approximate Compressive Strength (kg/sq.cm)</th>
<th>Jan-20 Ave. Rebound No.</th>
<th>Approximate Compressive Strength (kg/sq.cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>Left</td>
<td>52</td>
<td>614</td>
<td>51</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>Centre</td>
<td>47</td>
<td>540</td>
<td>47</td>
<td>530</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>47</td>
<td>540</td>
<td>47</td>
<td>530</td>
</tr>
</tbody>
</table>

Table 4.5: Rebound No. and corresponding Compressive strength on P2 (Top)

<table>
<thead>
<tr>
<th>Pier</th>
<th>Position</th>
<th>April-2019 Ave. Rebound No.</th>
<th>Approximate Compressive Strength (kg/sq.cm)</th>
<th>Jan-20 Ave. Rebound No.</th>
<th>Approximate Compressive Strength (kg/sq.cm)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Column -1</td>
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<td>580</td>
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<td>565</td>
</tr>
<tr>
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<td>Column -2</td>
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<td>550</td>
</tr>
<tr>
<td></td>
<td>Column -3</td>
<td>51</td>
<td>600</td>
<td>50</td>
<td>590</td>
</tr>
<tr>
<td></td>
<td>Column -4</td>
<td>50</td>
<td>580</td>
<td>49</td>
<td>565</td>
</tr>
</tbody>
</table>

Table 4.6: Rebound No. and corresponding Compressive strength on P1 (Bottom)

Chloride Content in Concrete Sample

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
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<td>0.33</td>
<td>0.345</td>
<td>0.35</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>0.28</td>
<td>0.285</td>
<td>0.29</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>0.28</td>
<td>0.29</td>
<td>0.295</td>
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<tr>
<td>4</td>
<td>6</td>
<td>0.23</td>
<td>0.245</td>
<td>0.26</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>0.21</td>
<td>0.225</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Chloride Threshold Effects

Figure 4.7: Chloride content measured over a period of three years

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suitable rehabilitation
predict
The
be taken to prevent
continues over the period of time. Adequate measure need to be taken to rectify
The test
from
increment
different
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