Repair & Diagnostic Methods for RCC Structures

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## Service Life Requirements for Concrete Structures - ISO 2394 & EN1990

<table>
<thead>
<tr>
<th>Class</th>
<th>Notional Design Service Life (Years)</th>
<th>Example</th>
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<tr>
<td>1</td>
<td>1-5</td>
<td>Temporary Structures</td>
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<tr>
<td>2</td>
<td>25</td>
<td>Replaceable Structural Parts</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>Building Structures and other common structures</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>Monumental Building Structures, Bridges and other Civil Engineering Structures.</td>
</tr>
</tbody>
</table>
Durable concrete
Cause of Deterioration

Whether the cause is corroding rebar, poor resistance, high impact, abrasion, chemical attack or other reasons, addressing and correcting the cause of deterioration is the primary requirement in a durable repair.
Schematic Stages of Corrosion Induced Deterioration of a Concrete Structure

Limit States:
1. Depassivation of reinforcement
2. Cracking of cover concrete
3. Spalling of cover concrete
4. Collapse of element/structure

Visible signs of:

Initiation phase
- Condition established by monitoring

Propagation phase
- Deterioration established through survey and non-destructive testing
Corrosion process

<table>
<thead>
<tr>
<th>Compound</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe</td>
<td>Iron</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>Ferric oxide</td>
</tr>
<tr>
<td>Fe₃O₄</td>
<td>Magnetite / Götite</td>
</tr>
<tr>
<td>FeO•(OH)</td>
<td>Hard rust</td>
</tr>
<tr>
<td>Fe(OH)₂</td>
<td>Ferrous hydroxide</td>
</tr>
<tr>
<td>Fe(OH)₃</td>
<td>Ferric hydroxide</td>
</tr>
<tr>
<td>Fe₂O₃ xH₂O</td>
<td>Hydrated ferric hydroxide</td>
</tr>
</tbody>
</table>

Volume Ratio
Stages of corrosion induced

- Initiation Phase - Condition established by monitoring
- Propagation phase - Deterioration established through survey and NDT
Causes of Repair Failures

It is very difficult to identify a single cause for a particular failure, since, frequently. There are several reasons which are inter-related,

- Incorrect design of the repair
- Use of incorrect materials
- Poor workmanship
- Wrong diagnosis
- Other factors
The failure of repairs are attributable to -

- Design or Evaluation errors,
- Installation or Application errors
- Materials Performance

* Source: U.S. Army Corps of Engineers
Approach to Repair

- Investigate the causes & identify the problems and understand
- Use NDT methods to understand damages and defects
- Consider structural and operational requirements to select the repair method
- Selection of right Repair Materials with appropriate methodology
<table>
<thead>
<tr>
<th>Common</th>
<th>Advanced NDT</th>
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<tr>
<td>Schmidt Rebound Hammer</td>
<td>Corrosion Analyser</td>
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<tr>
<td>Ultrasonic Pulse Velocity</td>
<td>Infrared Thermography</td>
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<td>Cover Meter</td>
<td>Petrography</td>
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<tr>
<td>Cores</td>
<td>Pull off Test</td>
</tr>
<tr>
<td>Carbonation Depth</td>
<td></td>
</tr>
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</table>
Schmidt Hammer

• Simplest & Quickest estimation of surface hardness of concrete
• Carbonation is not the only important factor influencing rebound numbers
• The strength estimated from the manufacturer's regression curve is to be multiplied by a time factor.
Corrosion Assessment

- Chloride ion and carbonation testing help to establish whether passive film has been destroyed.
- If film not destroyed, when will it be destroyed?
- If film has been destroyed, what is state of corrosion?
- Half-cell potential
- Concrete resistivity
- Corrosion rate (polarization resistance)
Corrosion Rate!

- Chennai, 2nd most corrosion prone city - 0.5 mm/y
- Sriharikota - 1.6 milli metres per year mm/y
- Marmogoa - 0.45 milli meters per year mm/y

Source: Study conducted by CECRI, Karaikudi (1993 - 2003 ~ 33 field stns)
Corrosion Analyser

- Potential measurement (potential mapping), corrosion rate measurement, galvano static pulse technique (GPM)
- Linear polarisation resistance technique (LPR) and service life estimate.
Rate of corrosion measured on circumference of the column

At the marked point rate of corrosion was 220µm. For 20 years period@0.22 mm per year = 4.4 mm

Half cell potential measured on circumference of the column = -500 mV
How to locate voids and delamination?

- Impact-Echo
- Impulse Response Method
- Ground Penetrating Radar
- Ultrasonic Measurements
- Infrared Thermography
- Petrography
UPV

- Good for assessing uniformity and identifying areas for further investigation
- To identify the honey combs, voids & cracks inside the concrete
Infrared Thermography

Potential
seepage
Potential
deboning
plaster
Potential
spalling
concrete
Potential debonding plaster to be hacked and restored
Seepage along groove lines
Facade in good condition, do not require repair works.
Polarised Optical Microscope
Application of Petrography in Repair

- Alkali Silica Reaction (ASR)
- Chemical Attack
- Delayed Ettringite Formation
- Fire Damage
- Cause of Cracking
Microscope photo of air entrained, homogeneous concrete
The photograph shows the cracked oxidized pyrite grain at the surface region, and extension of cracking and reddish brown iron oxide and hydroxide oxidation products into the neighboring paste. Field widths of all photos are 5 mm.

Photomicrographs of thin sections of cores (in plane polarized light mode)
Pull-off Test
ASTM C1583/C1583M

- Direct tensile strength
- Evaluate condition of concrete surface before application of overlay or repair Material
- Measure bond strength of overlay or surface of repair materials
Summary

- Regular Inspections/Monitoring helps early detection of any deterioration
- Diagnosis of defects and condition assessments are essential pre requisites for a successful concrete repair
- Advance NDT method helps to locate exactly the place of seepages, leakages, defects, honeycombs, cracks in the structures so that repair becomes durable
- Repair cost increases without proper diagnosis
Thank You for Your
Kind Attention !