Corrosion in Reinforced Concrete

Chris Atkins

CED Working Day
What is concrete?

1. Cement
   Clay and limestone heated in a furnace to drive off water, some can be replaced with slag / pfa

2. Crushed Rock
   Filler, cheaper than cement, doesn’t generate heat

3. Water
   Chemically reacts, cement goes hard
Why’s it reinforced?

1. Good compressive strength
2. Poor tensile strength
3. Add steel to cope
   Reinforced
   Prestressed
   Post Tensioned
Where does the tension come from?

1. When casting concrete heats up then cools
   Early Thermal Shrinkage
2. Over time moisture levels equilibriate
   Long Term Drying Shrinkage
3. Structural Requirements
   Bending
   Shear
Shrinkage
Settlement
Chemical Attack

- **Sulphates**
  - Typically in the ground or sewage

- **Acids**
  - Concrete is Alkaline (pH 13.5)

- **Soft Water, Aggressive Carbon Dioxide**
  - Concrete has lots of calcium in it

- **Alkali Aggregate Reaction**
  - Alkali in concrete reacts with the aggregate
Salt Recrystalisation / Frost
Fire Damage
Abrasion

- Concrete is considered hard wearing
- Everything can be worn away given enough time
Mechanical Damage
Mostly

- Steel Rusts
Corrosion – Eg Steel
How Do Metals Corrode?

- Different voltages form on the metal
- Anode = lower voltage
- Cathode = higher voltage
- Electrons flow from anode to cathode in the metal
- Electrons released by turning into ions in solution at the anode
- Electrons consumed at cathode by generating alkalinity
Potentials

Voltmeters subtract the value in the negative terminal from the value in the positive terminal. For European corrosion measurements, the reading is termed as positive vs negative, or positive against negative.

<table>
<thead>
<tr>
<th></th>
<th>Zinc as +ve</th>
<th>Stainless as –ve</th>
<th>Col 2 + 756 + Col 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc</td>
<td>0</td>
<td>-756</td>
<td>0</td>
</tr>
<tr>
<td>Anode</td>
<td>-843</td>
<td>121</td>
<td>34</td>
</tr>
<tr>
<td>Iron</td>
<td>-619</td>
<td>-93</td>
<td>44</td>
</tr>
<tr>
<td>Stainless</td>
<td>-756</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Potential Measurements

- Use a reference electrode
- Provides a stable value to measure against
- Steel connected to positive
- Reference connected to negative (com)
IR Error

Current flows from anode to rebar.

Anode - 750 - 1000 - 1250
Corrosion
Corrosion of steel in concrete

- Concrete is a high pH – Steel passive.
- Chlorides cause local depassivation
- Punch holes in the passive film
- Internal or External
- Carbonation reduces pH
- Rust is bigger than steel
- Concrete spalls off
- Coatings can prevent carbonation and chloride ingress
Corrosion of steel in concrete

Anodes
Fe → Fe\(^{2+}\) + 2e\(^-\)
Iron dissolves into solution, electrons release into the metal

Cathodes
4e\(^-\) + O\(_2\) + 2H\(_2\)O → 4 OH\(^-\)
Electrons from the anode react with water and oxygen and generate alkalinity
Repairing Chloride Induced Corrosion
Cathodic Protection, Impressed vs Galvanic
Decision To Repair

- BS EN 1504 covers process, cross referenced to BS EN ISO 12696 for additional investigations to confirm suitability for CP
- Review available records
- Visual / Delam survey
- Chlorides / Carbonation can be undertaken if required
- Cover survey mandated
- Continuity testing mandated
- Half-cell survey mandated
Cathodic Protection

\[
\frac{1}{2}O_2 + H_2O + 2e^- \text{(metal)} \rightarrow 2OH^- \text{(aq.)}
\]
Criteria

- BS EN ISO 12696 provides 4 criteria:
  - No value more negative than -1100mV (-900mV for prestressed concrete) due to hydrogen embrittlement
  - Instant off more negative than -720mV OR
  - 100mV decay over 24 hours OR
  - 150mV over longer periods
  - All measured against a silver/silver chloride 0.5M reference electrode
  - Decay probes can also be used
Competence of People

- BS EN 15257 (soon to be ISO 15257)
- Level 1 – follows method statements, takes readings (ISO level 2)
- Level 2 produces method statements, interprets readings (ISO level 3)
- Level 3 does design, commissioning and fault finding (ISO level 4)
- Supported by contractors, suppliers and designers
Summary

- Steel Rusts
- Chlorides and carbonation
- CP fixes it
- Saves breakouts, propping, access and materials
- Codes available
- For design, materials, installation and competence of people
- Training available
- From lunch time seminars to full week training