Corrosion of Steel in Concrete

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Why?
How?

- Anodes and Cathodes
- Anode loses Metal
- Cathode reacts with oxygen and water
- Electrons in the metal
- Ions in the Electrolyte
How?

Salt Solution

ZINC

COPPER
Are you sure?
Steel in Concrete

• Passive Film Protects
• But....
  – Chlorides
  – Carbonation
• Steel Rusts
  – Lose reinforcement
• Rust is bigger than steel
• Bits fall off
Steel in Concrete Carbonation
Steel in Concrete - Chlorides
Steel in Concrete - Chlorides

Repaired CATHODE

CATHODES

SALTY and ANODIC
Steel in Concrete

• Similar problem if steel frames are embedded in concrete

1900-1950 Steel framed buildings

Facade

Structural Frame

Mortar
So Is it Rusting?

- Can you see any rust?

- **Visual Inspection**
  - Testing
    - Carbonation, Chlorides, Cover
    - Half-cell potentials
  - Measure voltages,
  - Need to think about results

- **Delamination**
  - On the surface or at depth
Carbonation

• Expose fresh concrete
• Spray on phenolphthalein
• Measure depth of pink
Chlorides

- Find steel
- Miss steel
- Drill hole
  - Ignore first 5mm
- Collect dust at depth increments
- Send off for analysis
- Dust can be used for
  - Cement content
  - Sulphates
• Sweep meter around, record lowest reading
• Hilti Ferroscan
  – Logs as it goes
  – Large amounts of data can be used to indicate bar sizes, spacing and variability
  – Has its limits
Half-cell

- Measures voltages and currents
- Guidance available on meanings, but take care
  - Upside down half-cells
  - Galvanised metal
  - 600mV not necessarily worse than 500mV
- Looking for higher or lower
  - Don't always need to connect to steel

Half-cell
Hammer survey

- Hit with small hammer
- Record where it thunks
- Sometimes it thunks when it's solid
- Sometimes it doesn't thump when it's loose
Cathodic Protection

- Using CP stops rust in any environment
- Chloride contaminated concrete can remain
- Saves
  - Propping
  - Access
  - Materials
  - Carbon
- Impressed Current or Galvanic
Cathodic Protection

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

- BS EN ISO 12696 2012 - CP of concrete
  - Includes criteria, first published in 2000
- BS EN 15257 2006 – Certification of CP people
- BA 83 – Highways Agency Advice Note
- TR 73 – Concrete Society Guidance
Hydrogen Embrittlement

- BS EN 12696:
  - -720mV vs Silver / Silver Chloride / 0.5M Potassium Chloride
- OR
  - 100mV Decay in 24 hours
- OR
  - 150mV decay over longer periods
- AND
- No potentials more negative than -900mV for prestressed concrete
Prestressed Beams

- Prestressed concrete now getting around the age
- “Improved QA”
- Risk of Hydrogen Embrittlement
Prestressed Beams
Hydrogen Embrittlement

• If steel is >600MPa UTS
• AND
  – Is under high stress
• AND
  – Is susceptible to it
• AND
  – Hydrogen is being generated
• Risk of hydrogen embrittlement
Hydrogen Embrittlement

• Most cases are self corrosion in very high strength steels
• Simple to avoid in most reinforced concrete
  – Don’t turn the system up that high
• Use Galvanics if you’re not sure
Summary

- Steel rusts
- Inspection needs care
- For chloride induced corrosion CP saves
  - Carbon Dioxide
  - Repairs
  - Access
  - Propping

- Codes are available
  - Competence of personnel
  - Safe Operation of Systems