Corrosion Protection for Reinforced Concrete Highway Structures

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Mouchel
Track Record of Electrochemical Corrosion Protection Systems

- **1824** Sir Humphry Davy reports galvanic CP of ships’ hulls.
- **circa 1910** Impressed current CP of buried steel structures.
- **late 1940s** Impressed current system to pipeline in Africa.
- **mid 1950s** CP of buried reinforced concrete structures.
- **late 1970s** CP of reinforced concrete bridge decks in US.
- **mid 1980s** First Building - conductive coatings used as anodes.  
  First UK Bridge: Midland Links - Spaghetti Junction.  
  Titanium mesh anodes with sprayed concrete overlay.
- **early 1990s** Meshless conductive overlay anodes introduced.  
  Desalination and realkalisation in the UK.
- **early 1990s** CP used to protect steel framed buildings.
- **mid 1990s** CP using discrete anodes.
- **late 1990s** Galvanic CP systems.
Midland Links Viaducts - Spaghetti Junction
Midland Links Viaducts
Typical Sub-structure Arrangement

- Hard Shoulder
- Carriageway - 3 Lanes
- Reinforced Concrete Deck Slab
- Reinforced Concrete Crossbeam
- Reinforced Concrete Shear Walls
- Reinforced Concrete Columns
- Steel Beams
- Expansion joint

Section A-A
Deterioration Due to Chloride Contamination
Cathodic Protection

Impressed Current

Galvanic/Sacrificial Anode
Cathodic Protection

- Repair of physical defects only (e.g. spalling, delamination, etc)
- Contaminated concrete can remain.
- Structural impact is reduced.
- Minimal disruption to travelling public.
Midland Links - Site Trials
Site Trials – Two Stages

- Two different conductive paint systems.
- Conductive polymer mesh anode with sprayed cementitious overlay.
- MMO coated titanium mesh in cementitious overlay.
- Sprayed zinc.
- Discrete surface mounted titanium oxide tile system.
- Instrumented controls.
Site Trials

Conductive Paint Systems
Site Trials

Mesh and Overlay System
Site Trials – Evaluation

- Physical condition.
- Review of monitoring and performance data.
- Review of secondary effects.
- Comparison of anodes.
- Choice of anode(s).
First Full Scale Cathodic Protection System
- Anode System
First Full Scale Cathodic Protection System
Cathodic Protection – Zoning Arrangements

Typical Cathodic Protection System
Cathodic Protection
Cathodic Protection – Monitoring and Control Regime

- Operational checks.
- Performance monitoring and adjustment of control parameters (where required).
- Anode inspections.
- System reviews and reports.
Cathodic Protection – Remote Monitoring

Benefits

- Reduced visits to site
- Better quality data
- Potential for automated monitoring and control
- Alarms
- Less susceptible to vandalism
Cathodic Protection – Remote Monitoring
Cathodic Protection – Different Anodes

Anodes used on the Midland Links:

- Conductive paint.
- Mesh and overlay.
- Discrete anodes.
- Sacrificial anodes.
A13 Pitsea Flyover
A13 Pitsea Flyover
A13 Pitsea Flyover
A9 Cromarty Bridge
A9 Cromarty Bridge
A9 Cromarty Bridge
A9 Cromarty Bridge
M25 DBFO/AREA 5

• M4 Elevated
• M1 Bunns Lane
• M1 Brockley Bridges
• M1 Scratchwood Railway Bridges
• M1 Deans Brook Viaduct
• A1089 Dock Road

AREA 3

• M3 Theale Railway Bridge
• M4 Chievely Interchange
• M3 Hawley Rail Bridges
• M4 Priors Court Bridge
Sacrificial Anodes
Sacrificial Anodes

1. All equipment shall be located on the north side of the bridge. The equipment and cable must shall be located a minimum distance of 10 feet from the edge of the bridge.

2. Equipment shall be installed immediately adjacent to the repair zones and shall be located at least 10 feet from the repair area.

3. The Contractor shall be responsible for all maintenance and replacement of equipment.

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5. The Contractor shall be responsible for all maintenance and replacement of equipment.

6. The Contractor shall be responsible for all maintenance and replacement of equipment.
Sacrificial Anodes - Galvashield
Sacrificial Anodes – Groby, Leicester
Area 13 M6 Bridges - Desalination

Desalination

- Steel reinforcement cathode
- Production of Hydroxyl ions
- External mesh anode
- Direction of chloride ions
- Clear shutter
- Liquid electrolyte

Shutter seal
Shutter frame
Fixing bracket
Area 16 M6 Bridges - Desalination
Re-alkalisation
Multi-storey Car Parks
Multi-storey Car Park – Contamination Mechanism
Multi-storey Car Park Deck
Half-cell Potential Mapping

- Popular parking bays
- Less used bays
- Up ramp
- Increasing -ve half-cell potential
Multi-storey Car Park – Cathodic Protection Installation
Standards

Highways Agency Guidance Note and Specification

Table 1 - Impressed Current Anode Types and Characteristics

<table>
<thead>
<tr>
<th>Anode Type</th>
<th>Typical Long Term Anode Current Density per m² of anode</th>
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<th>Supplier’s Typical Anode Life Estimate</th>
<th>Suitable for Wet Structures</th>
<th>Suitable for Running Surfaces</th>
<th>Dimensional &amp; Weight Impact/Installation</th>
<th>Other Performance/Overview/Section/Other Specialist Advice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductive Organic Coating</td>
<td>20mA/m²</td>
<td>20mA/m²</td>
<td>Max</td>
<td>Up to 5 years</td>
<td>No</td>
<td>No</td>
<td>Painted</td>
</tr>
<tr>
<td>Sprayed zinc</td>
<td>20mA/m²</td>
<td>20mA/m²</td>
<td>Max</td>
<td>Up to 25 years</td>
<td>Possibility</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Mixed metal anode coated titanium (MMO Ti) mesh and grid in cementitious overlay</td>
<td>110mA/m²</td>
<td>15-110 mA/m²</td>
<td>Varying grades</td>
<td>Up to 120 years</td>
<td>Yes</td>
<td>Yes</td>
<td>In circa 25mm overlay</td>
</tr>
<tr>
<td>MMO/Ti ribbon anode</td>
<td>110mA/m²</td>
<td>Circa 10-110 mA/m²</td>
<td>Subject to distribution</td>
<td>Up to 120 years</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Disc anodes in cementitious surround: MMO/Ti or Conductive ceramic</td>
<td>880mA/m²</td>
<td>Circa 10-110 mA/m²</td>
<td>Subject to distribution</td>
<td>Up to 50 years</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Combinations: overlay incorporating nickel plated carbon fiber strands</td>
<td>20mA/m²</td>
<td>20mA/m²</td>
<td>Max</td>
<td>Up to 25 years</td>
<td>Yes, not tidal</td>
<td>Yes, under wearing course</td>
<td>Yes</td>
</tr>
</tbody>
</table>

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BS EN 12696 Cathodic Protection of steel in concrete.

DD CEN/TS 14038-1&2
Electrochemical re-alkalisation and desalination treatments for reinforced concrete.
Standards

Concrete Society Technical Reports TR 73

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Cathodic Protection of Steel in Concrete
Including Model Specification
Report of a joint working party of the Concrete Society, the Concrete Protection Association and the Institution of Civil Engineers.