Corrosion Protection for Reinforced Concrete Highway Structures

Sam Beamish – EM Highway Services

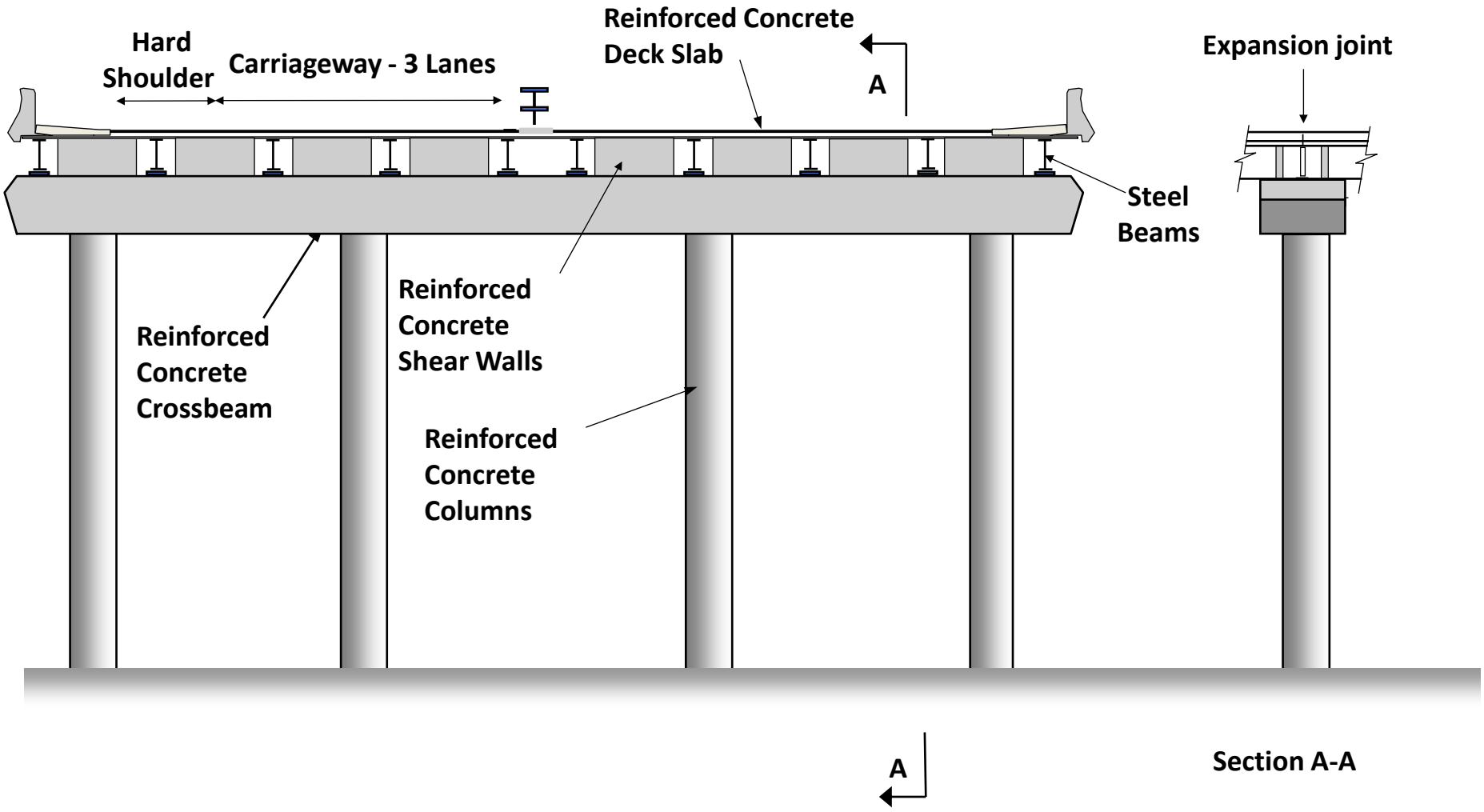
Track Record of Electrochemical Corrosion Protection Systems

- 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

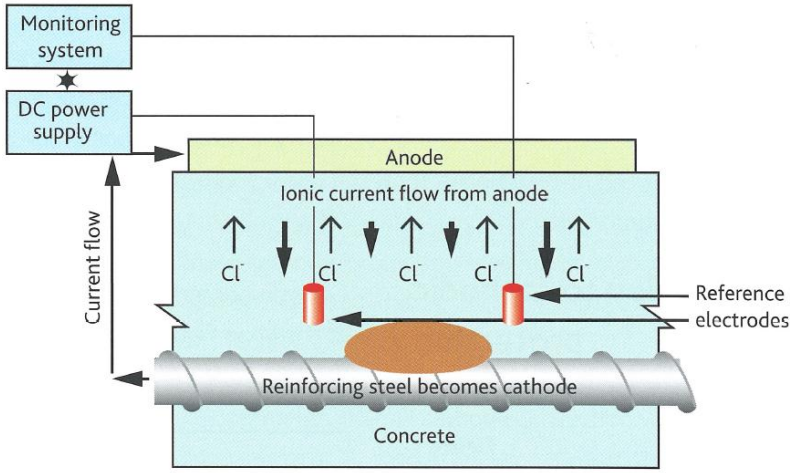
Midland Links Viaducts

Typical Sub-structure Arrangement

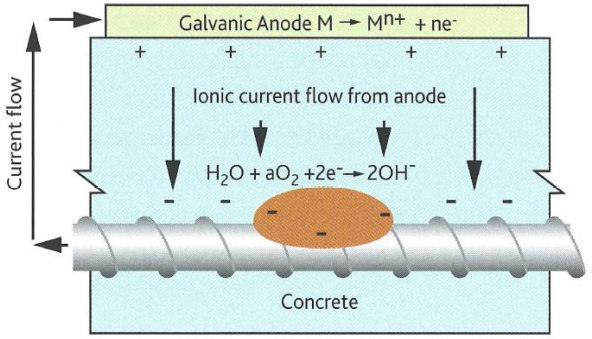


Deterioration Due to Chloride Contamination

Cathodic Protection



Impressed Current



Galvanic/Sacrificial Anode

Cathodic Protection

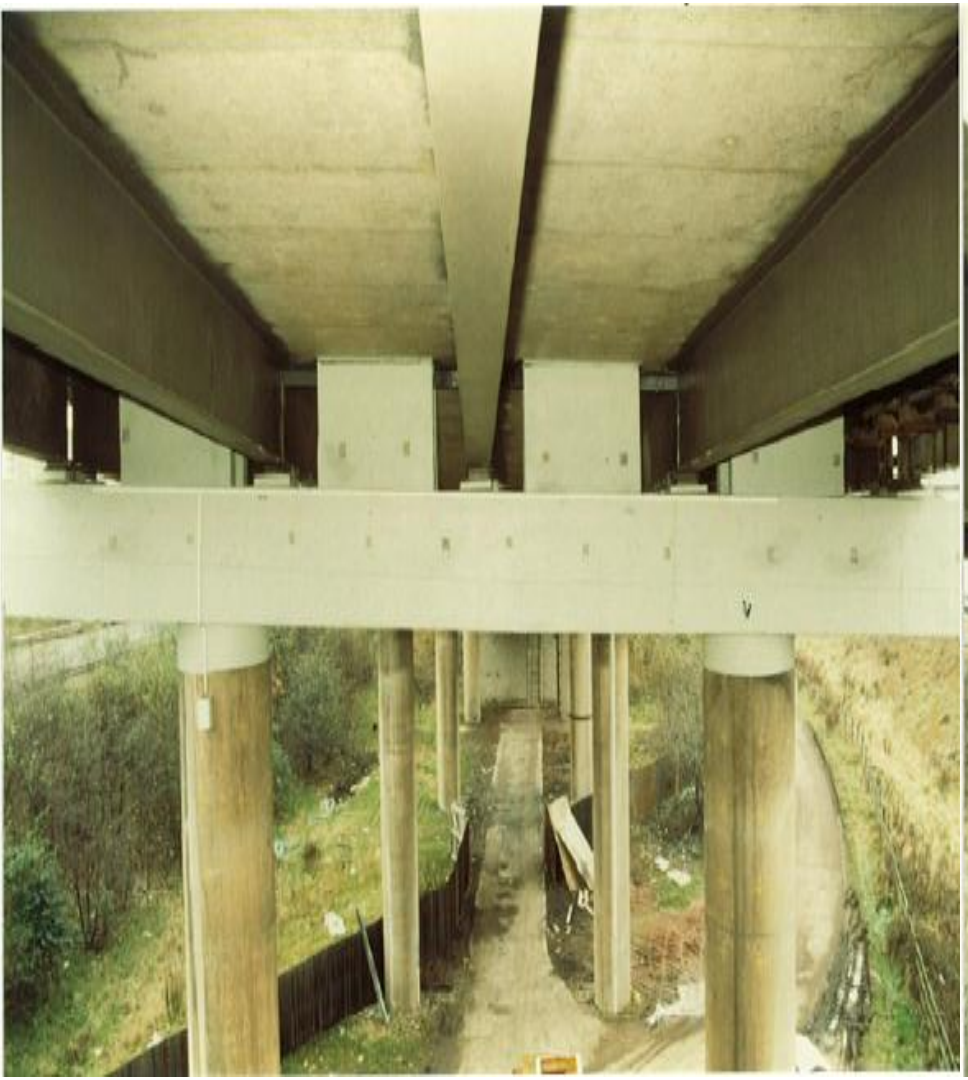
- Repair of physical defects only (e.g. spalling, delamination, etc)
- Contaminated concrete can remain.
- Structural impact is reduced.
- Minimal disruption to travelling public.

Midland Links - Site Trials

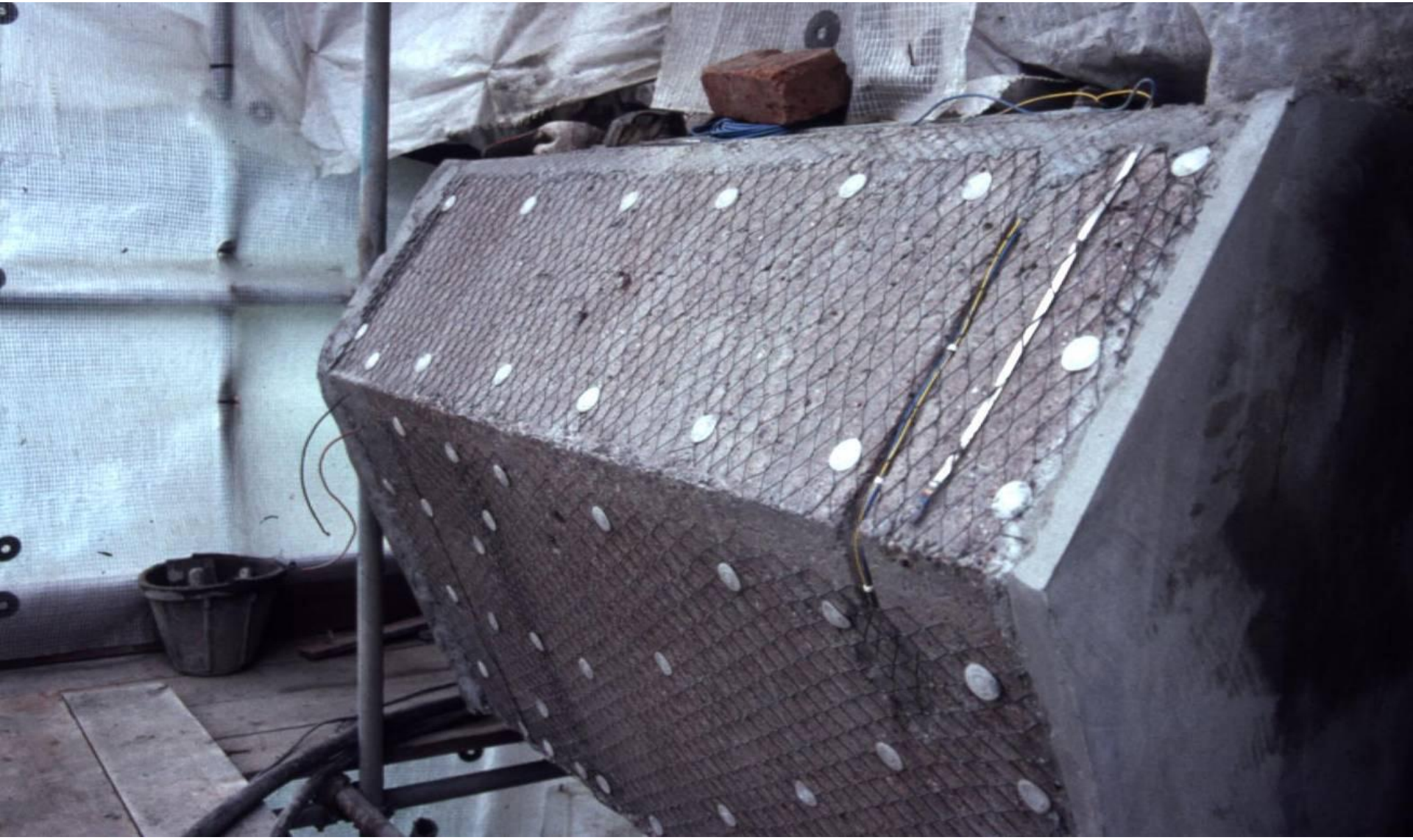
Site Trials – Two Stages

- 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



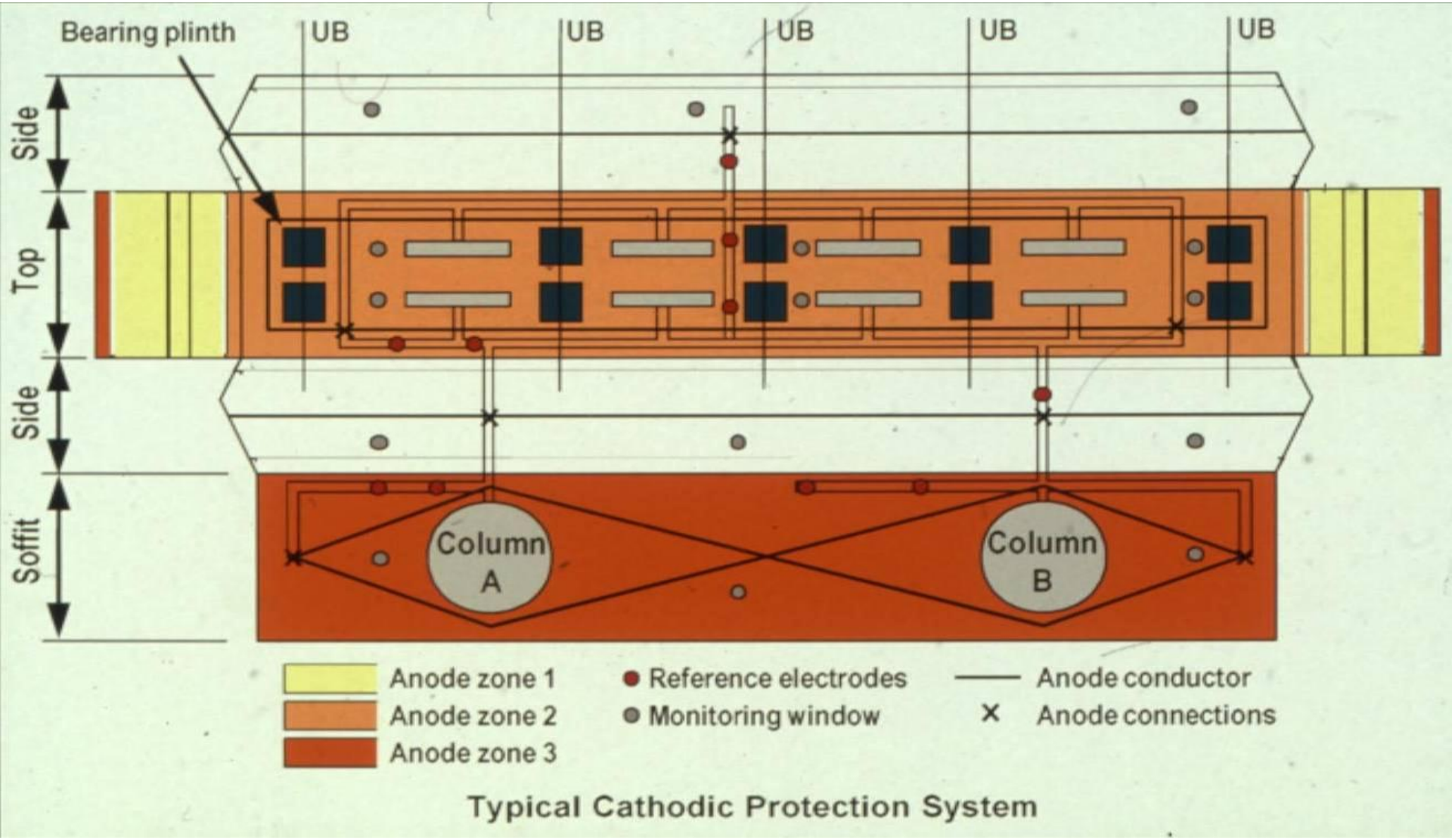
Site Trials – Evaluation

- 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

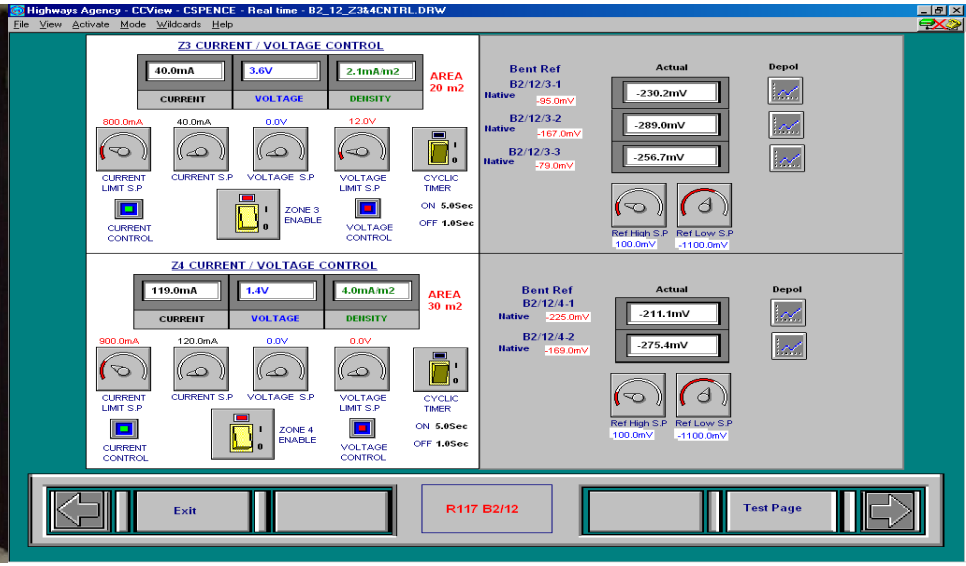
- Operational checks.
- Performance monitoring and adjustment of control parameters (where required).
- Anode inspections.
- System reviews and reports.

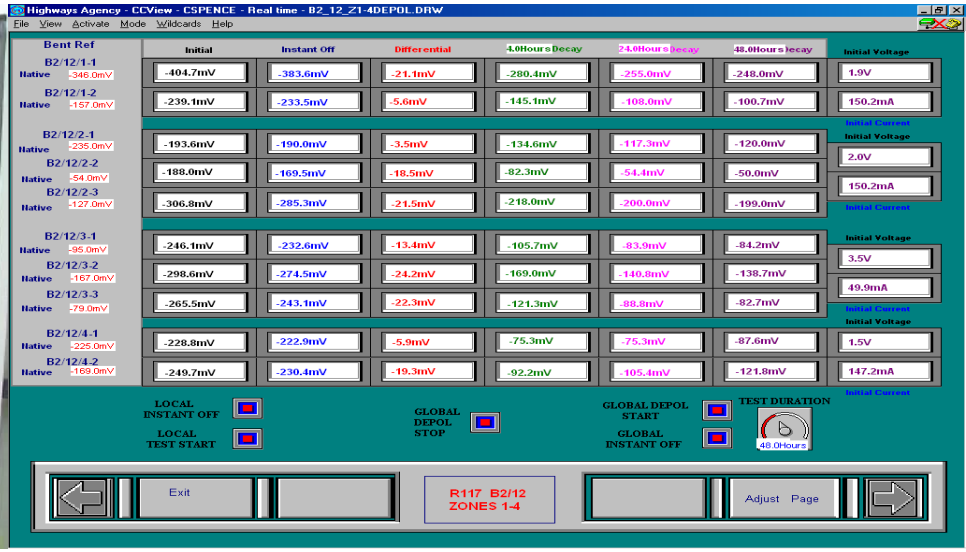
Cathodic Protection – Remote Monitoring

Benefits:

- Reduced visits to site
- Better quality data
- Potential for automated monitoring and control
- Alarms
- Less susceptible to vandalism

Cathodic Protection – Remote Monitoring





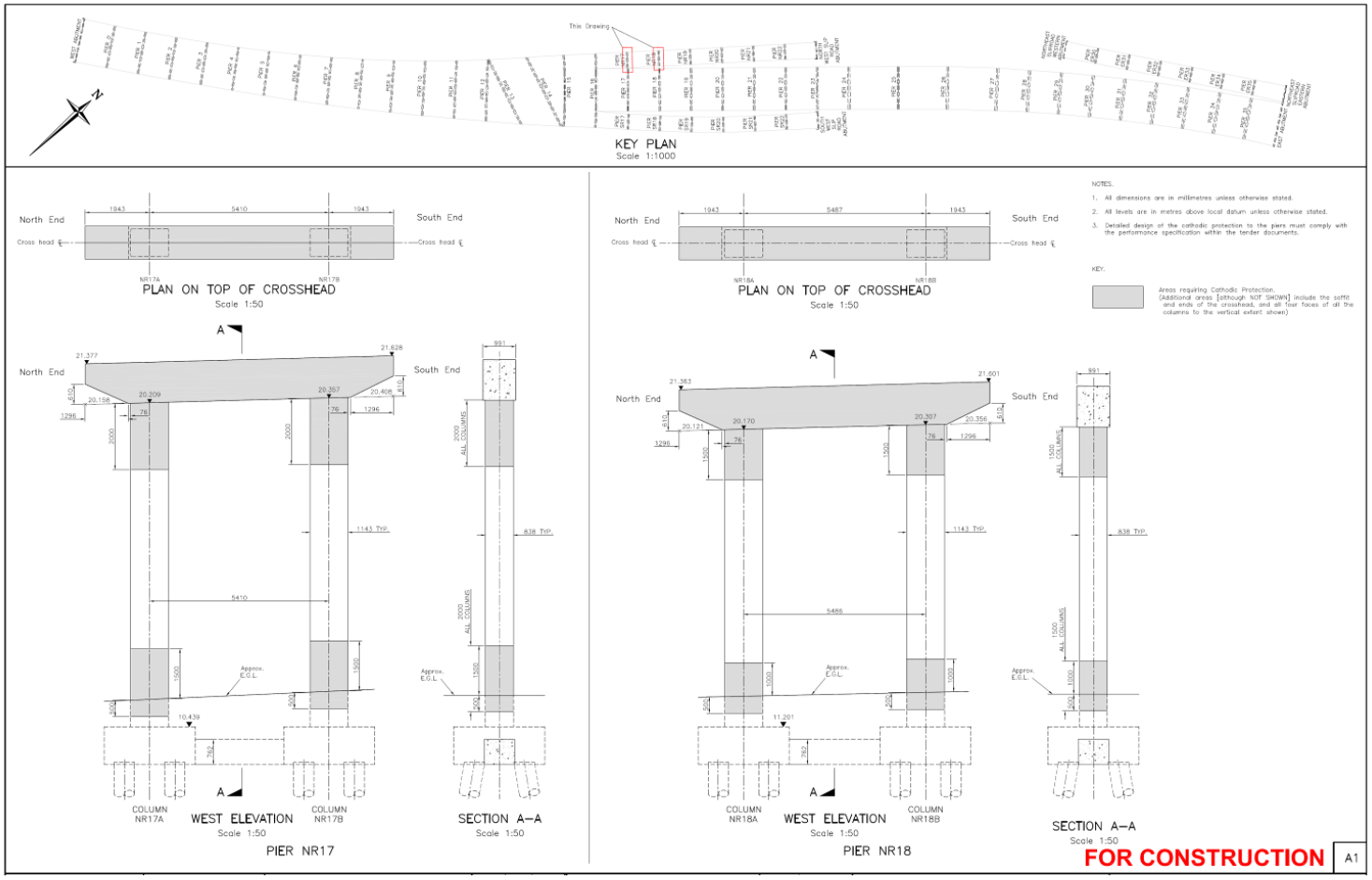
Cathodic Protection – Different Anodes

Anodes used on the Midland Links:

- Conductive paint.
- Mesh and overlay.
- Discrete anodes.
- Sacrificial anodes.

A13 Pitsea Flyover

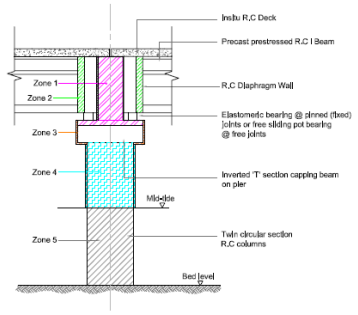
A13 Pitsea Flyover



A13 Pitsea Flyover

A9 Cromarty Bridge

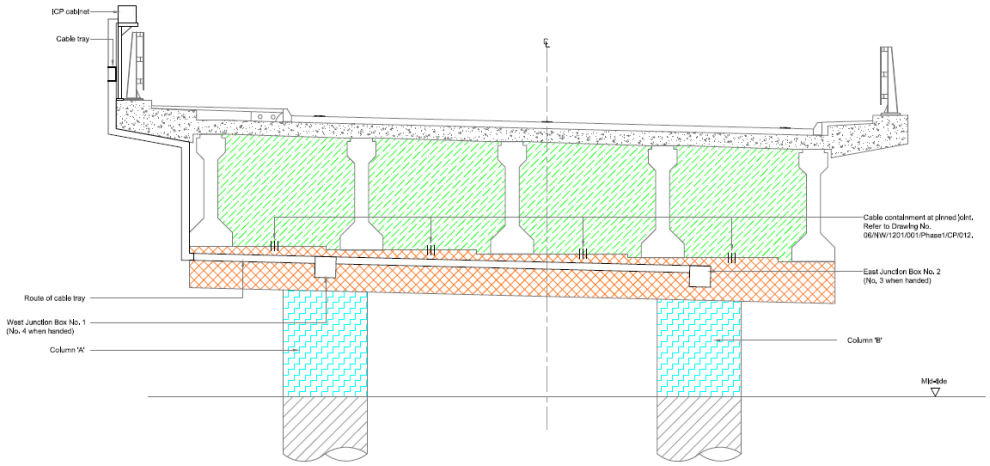
A9 Cromarty Bridge



TYPICAL SECTIONAL ELEVATION THROUGH PIER SHOWING STRUCTURAL ELEMENTS

Pier No.	Joint	Column 'A' (West Column) Extent of Zone 4	Column 'A' (West Column) Extent of Zone 5	Column 'B' (East Column) Extent of Zone 4	Column 'B' (East Column) Extent of Zone 5	Zone 4 Column 'A'		Zone 4 Column 'B'		Power Supply Unit Output (Amps)
		Atmospherically exposed column to mid-tide (m)	Submerged column from mid-tide to bed level (m)	Atmospherically exposed column to mid-tide (m)	Submerged column from mid-tide to bed level (m)	Area of Elgard 210 Anode Mesh and Overlay (m²)	Area of Elgard 150 Anode Mesh and Overlay (m²)	Area of Elgard 210 Anode Mesh and Overlay (m²)	Area of Elgard 150 Anode Mesh and Overlay (m²)	
1	Free	4.09	1.58	3.92	1.41	-	15.4	-	14.8	0.5
2	Fixed	4.18	1.80	4.02	1.80	4.9	10.9	4.9	10.3	0.5
3	Fixed	4.28	1.77	4.11	1.77	4.9	11.2	4.9	10.6	0.5
4	Free	4.38	1.89	4.22	1.78	-	16.5	-	15.9	0.5

TABLE 1: EXTENT OF ANODE ZONES 4 AND 5, ANODE DETAILS AND POWER SUPPLY UNIT (PSU) CURRENT OUTPUT REQUIREMENTS FOR ANODE ZONE 4



TYPICAL SECTIONAL ELEVATION LOOKING NORTH
(LOOKING SOUTH SIMILAR BUT HANDED)

Drawing Number
06/NW/1201/001/Phase1/CP/009

LEGEND

ZONE 1
Area of application of discrete anodes to stem wall and top of capping beam (installed vertically from above and horizontally respectively).

ZONE 2
Area of application of MMO/Ti mesh and overlay anode to the diaphragm wall sections.

ZONE 3
Area of application of MMO/Ti mesh and overlay anode to capping beam sides and soffit.

ZONE 4
Area of application of MMO/Ti mesh and overlay anode to atmospherically exposed columns to mid-tide.

ZONE 5
Anode system for submerged columns from mid-tide to bed level to be installed at a later date.

Notes;

1. This drawing is to be read in conjunction with Drawing No. 06/NW/1201/001/Phase1/CP/010.

Do not scale this drawing

Rev	Date		Checked

TRANSPORT SCOTLAND

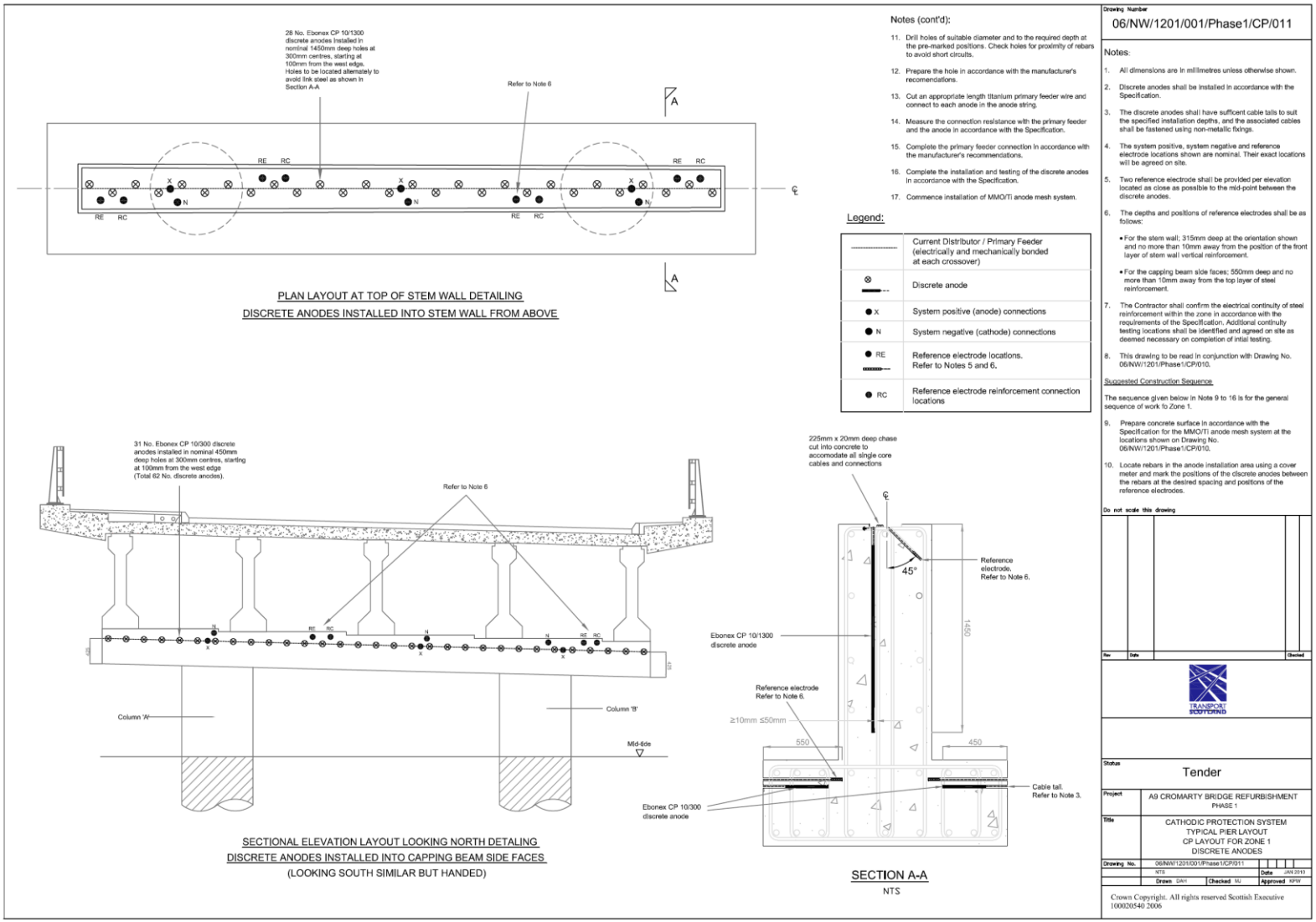
Status: Tender

Project: A9 CROMARTY BRIDGE REFURBISHMENT PHASE 1

Title: CATHODIC PROTECTION SYSTEM TYPICAL PIER LAYOUT CP LAYOUT FOR ZONES 1, 2, 3 & 4 SHEET 1 OF 2

Drawing No.	06/NW/1201/001/Phase1/CP/009		
	NTS	Date	JAN/2010
	Drawn DAH	Checked MJ	Approved KPW

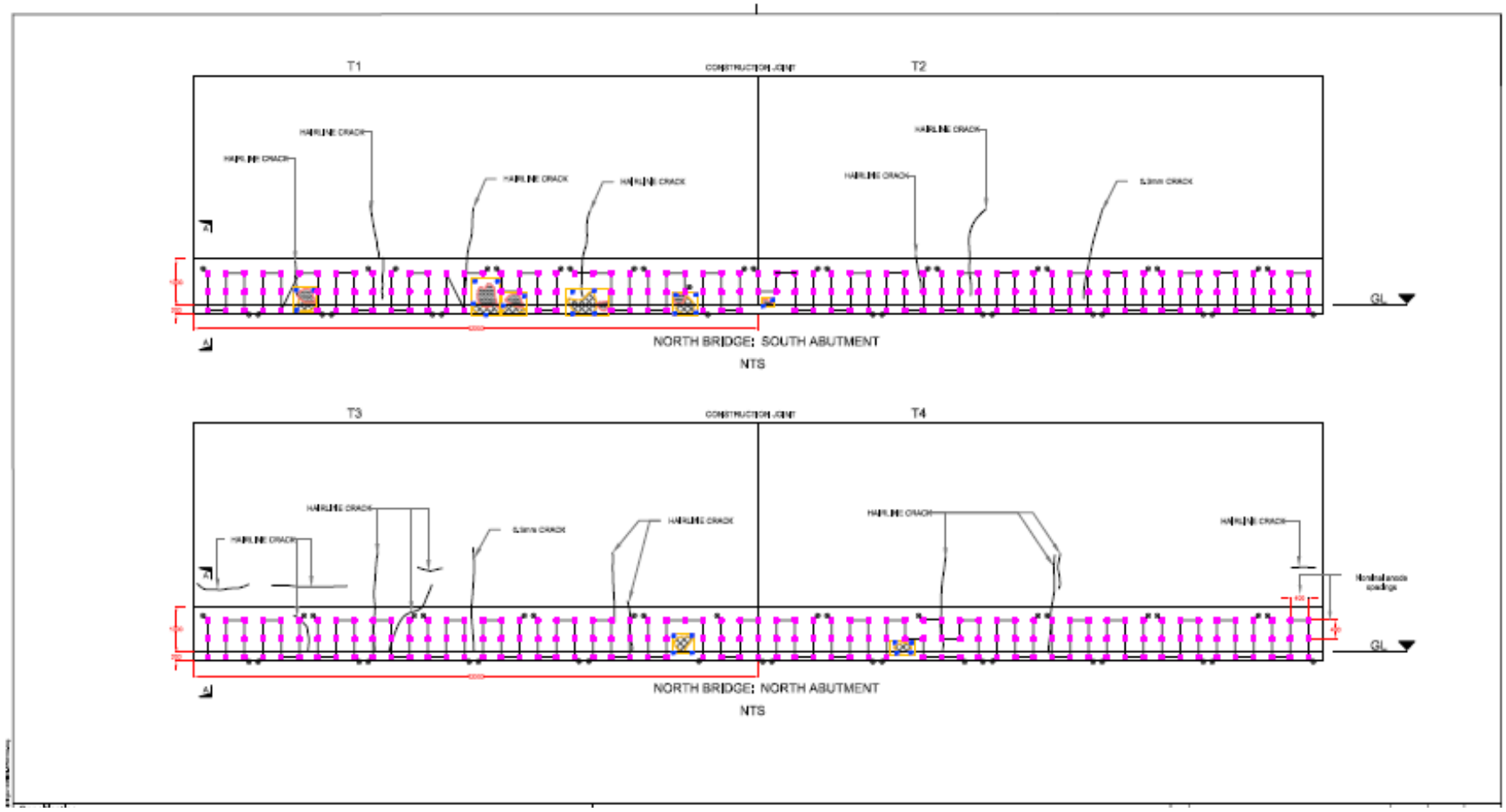
A9 Cromarty Bridge



A9 Cromarty Bridge

Sacrificial Anodes

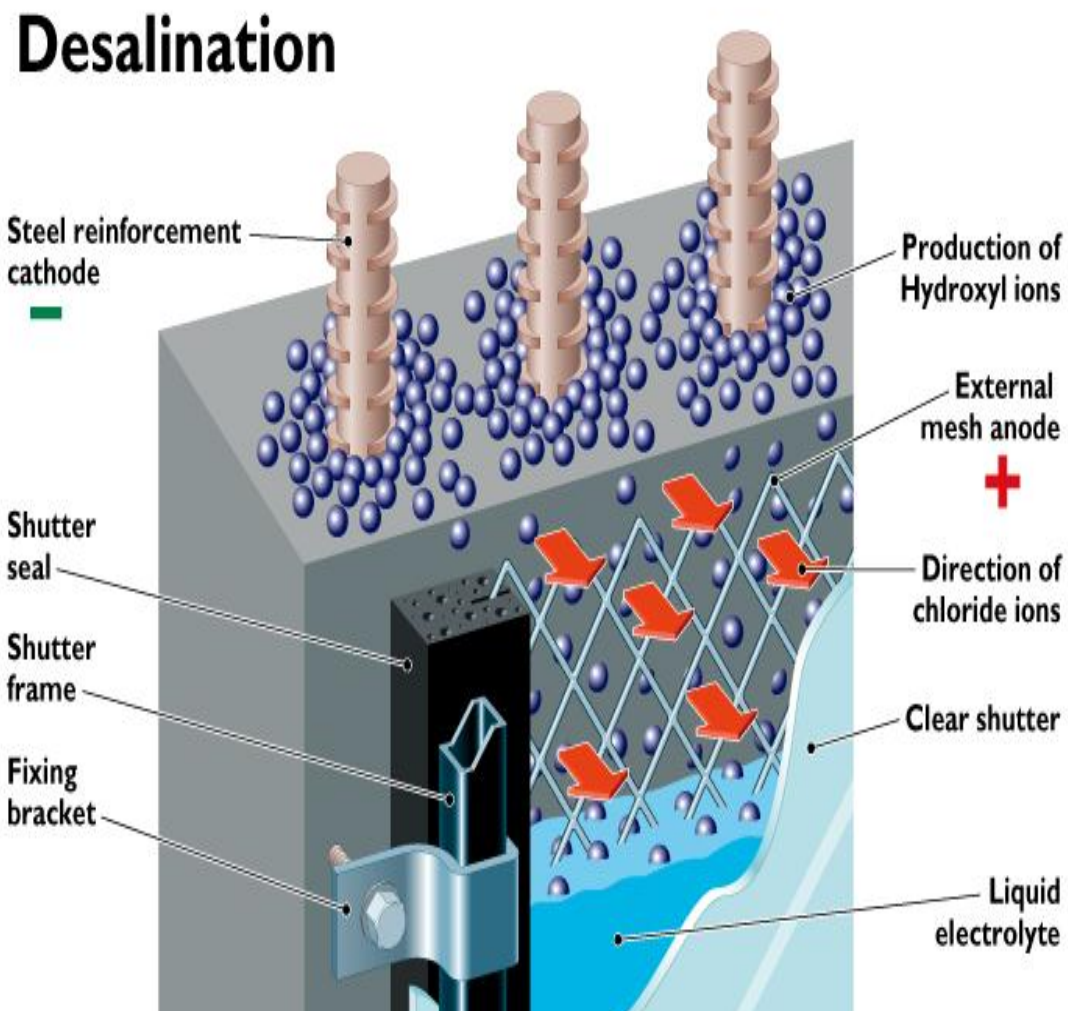
Sacrificial Anodes



Sacrificial Anodes - Galvashield

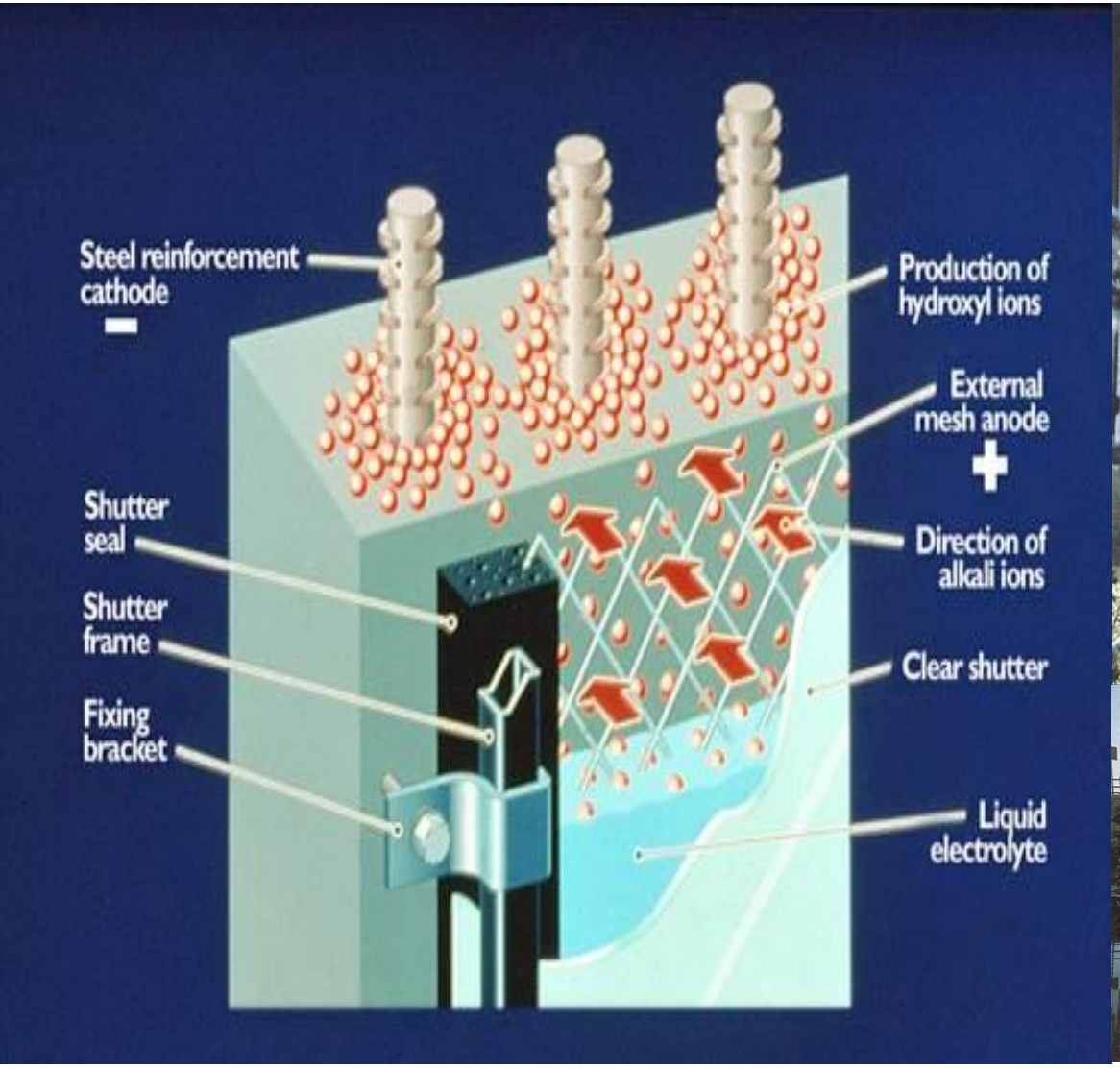
Sacrificial Anodes – Groby, Leicester

Area 13 M6 Bridges - Desalination



Area 13 M6 Bridges - Desalination

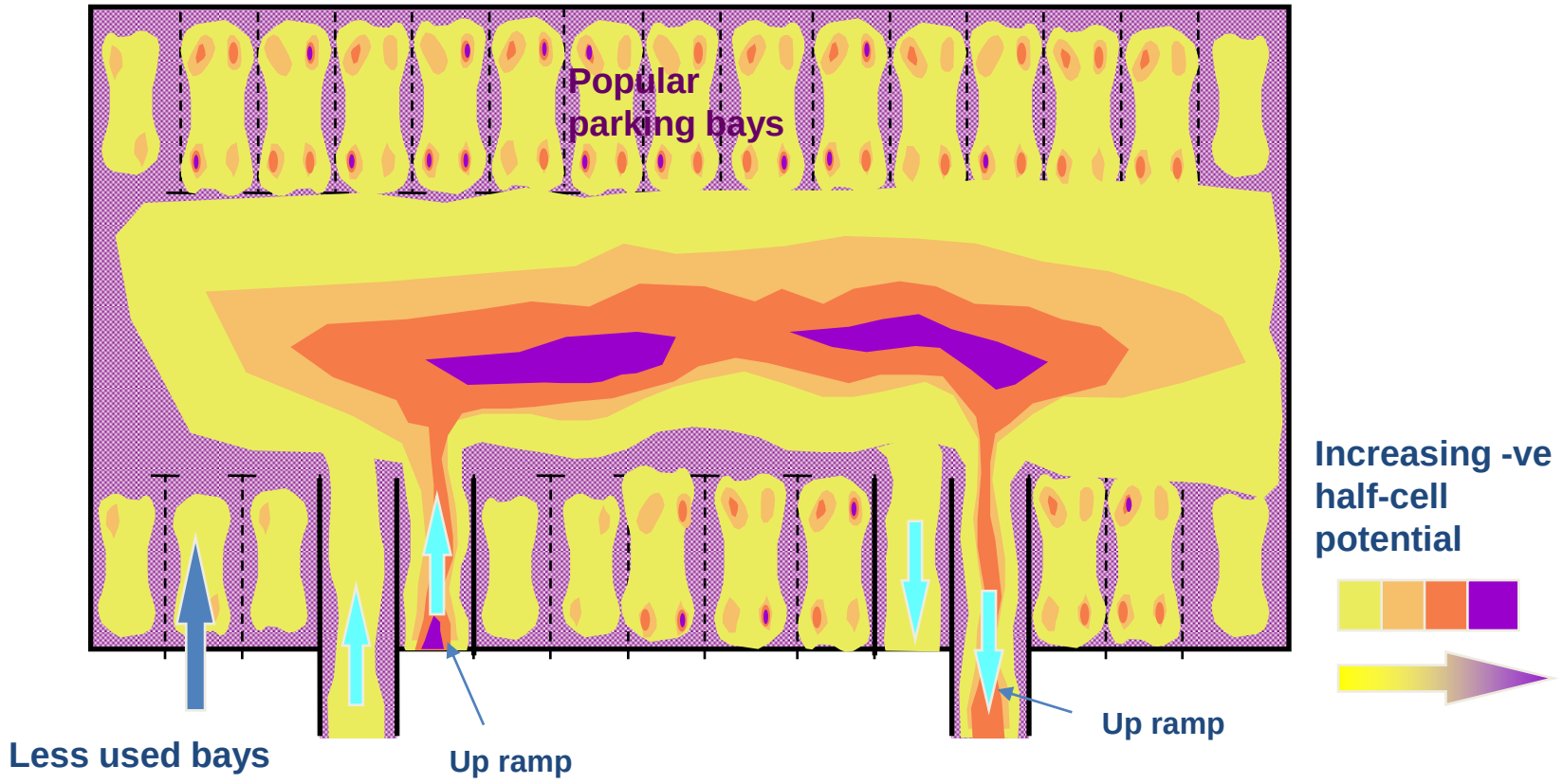
Re-akalisation



Multi-storey Car Parks

Multi-storey Car Park – Contamination Mechanism

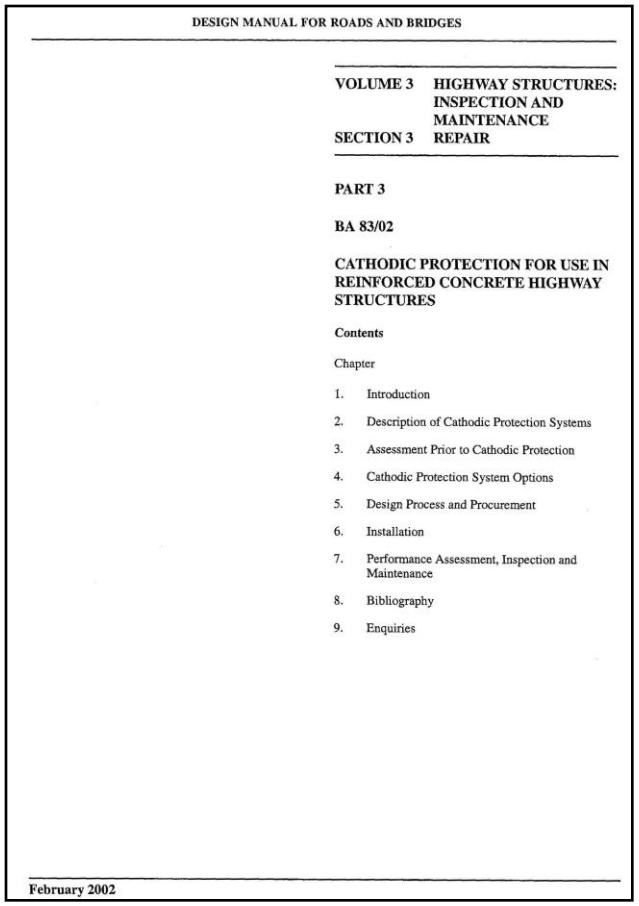
Multi-storey Car Park Deck - Half-cell Potential Mapping



Multi-storey Car Park – Cathodic Protection Installation

Standards

Highways Agency Guidance Note and Specification



DESIGN MANUAL FOR ROADS AND BRIDGES

VOLUME 3 HIGHWAY STRUCTURES: INSPECTION AND MAINTENANCE

SECTION 3 REPAIR

PART 3

BA 83/02

CATHODIC PROTECTION FOR USE IN REINFORCED CONCRETE HIGHWAY STRUCTURES

Contents

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1. Introduction
2. Description of Cathodic Protection Systems
3. Assessment Prior to Cathodic Protection
4. Cathodic Protection System Options
5. Design Process and Procurement
6. Installation
7. Performance Assessment, Inspection and Maintenance
8. Bibliography
9. Enquiries

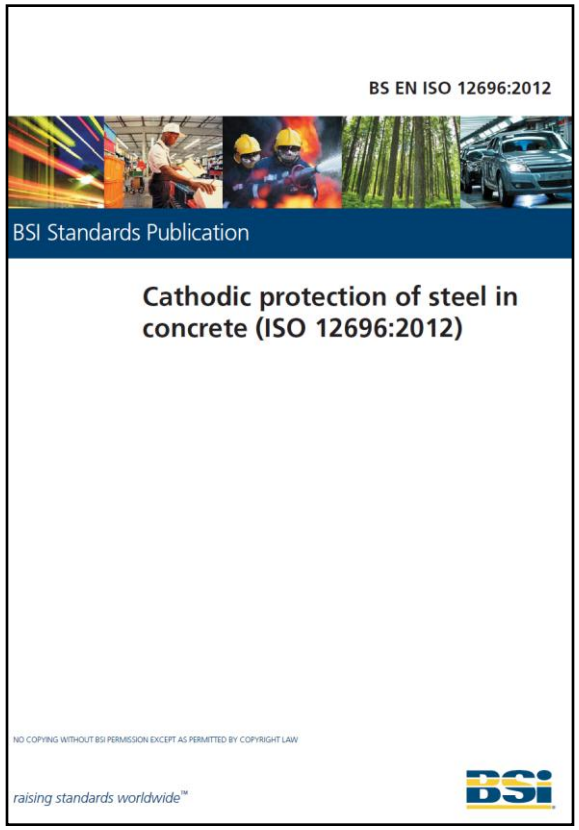
February 2002

Table 1 – Anode Types and Characteristics

Anode Type See Note 1	Long Term Anode Current Density per m² of anode	Long Term Current Density per m² concrete	Supplier's Typical Anode Life Estimate See Note 2	Suitable for Wet Structures	Suitable for Running Surfaces	Dimensional & Weight Impact/ Installation	Other Performance Queries (Seek Specialist Advice)	Typical Installed Anode Cost Incl. Surface Preparation (2000 Costs) See Notes 3-8
Conductive Organic Coatings	20mA/m²	20 mA/m² Max	Up to 15 years	No	No	No Painted	Some unproven products	£20-£40/m²
Sprayed zinc	20mA/m²	20mA/m² max	Up to 25 years	Possibly	No	No Thermal Spray	Limited UK experience Health & Safety during application	£60-£100/m²
Mixed metal oxide coated titanium (MMO Ti) mesh and grid in cementitious overlay	110-220mA/m²	15-110 mA/m² varying grades	Up to 120 years	Yes	Yes	Yes In circa 25mm overlay	Overlay Quality Control	£60-£100/m² including overlay
Discrete MMO Ti anodes, with carbonaceous surround	800mA/m² from carbonaceous surround	Circa 10-110 mA/m² subject to Distribution	Up to 50 years	Yes, not tidal	Yes	No Placed in pre-drilled holes		£40-£100/m²
Discrete anodes in cementitious surround. MMO Ti or Conductive ceramic	800mA/m²	Circa 10-110 mA/m² subject to distribution	Up to 50 years	Yes	Yes	No Placed into holes or slots		£40-£100/m²
Cementitious overlay incorporating nickel plated carbon fibre strands	20mA/m²	20mA/m² Max	Up to 25 years	Yes, not tidal	Yes, under wearing course	Yes Sprayed, circa 8mm thick	Limited experience	£30-£60/m²

Standards

European Standards

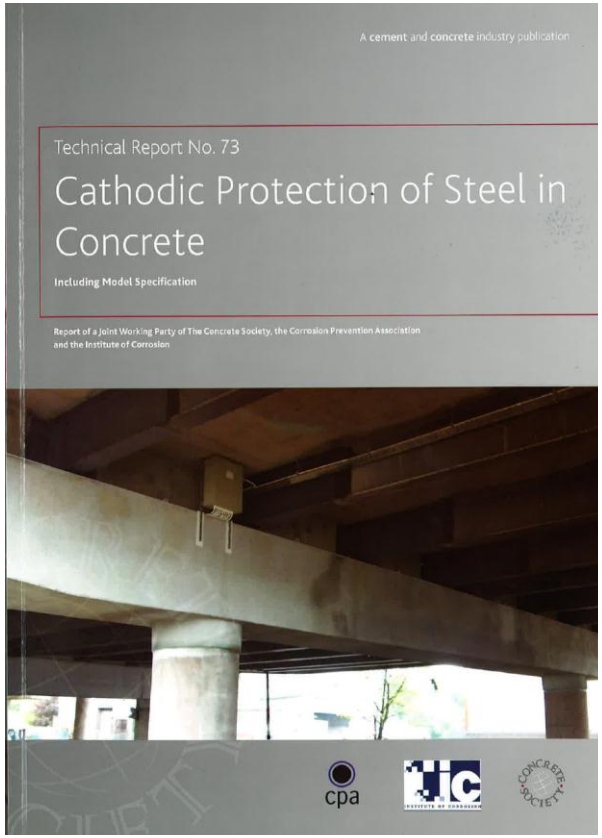


BS EN 12696 Cathodic Protection of steel in concrete.

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

Standards

Concrete Society Technical Reports TR 73



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