Fact File No 2

CATHODIC PROTECTION OF REINFORCED CONCRETE STRUCTURES

AN OVERVIEW

Cathodic Protection Co Ltd
INTRODUCTION

Cathodic protection is applied to reinforced concrete structures to either prevent or halt the problem of corrosion of the reinforcement.

Concrete is a porous material, which readily absorbs contaminants from the surrounding environment. The contaminants, which lead to corrosion of the reinforcement are water, Oxygen and Chlorides in the form of salts.

The water and oxygen in the presence of the chlorides, react with the iron to create corrosion products on the surface of the reinforcing steel. The growth in volume of these corrosion products exerts tensile stresses on the concrete, which eventually cause the concrete cover to crack, delaminate and become detached from the structure (spall).

The corrosion reaction of reinforcement is catalysed by the chloride ions although these take no part in the reaction itself. The potential differences between different parts of the reinforcement cage cause electrons to be released from the most negative areas. This in turn creates positive areas, i.e. ferrous ions, which dissolve into the pore solution. The electrons that were released are consumed by electrolysing water and oxygen to make hydroxide ions.

The areas where ferrous ions are created are known as anodes or corrosion sites. The areas where electrons are released to form hydroxyl ions are called cathodes, i.e. non-corroding sites. This is shown pictorially as below:
Cathodic Protection

Cathodic protection is a technique dating back to the nineteenth century where it was used on copper clad sailing ships. Later it spread to be applied to pipelines, tanks, jetties and all manner of steel structures either buried in soils or immersed in waters.

The technique was first applied to airborne concrete structures in 1973 in California. Since then it has been applied to over a million square metres of concrete around the world.

The typical range of structures to which it has been applied is shown pictorially below.

In cathodic protection a new anode material is introduced into the concrete, which is artificially made more negative than any part of the reinforcement. This highly negative material releases its excess electrons. These released electrons are spread to all areas of reinforcement where they electrolyse water and oxygen to make hydroxide ions. The anodic reaction on the new anode reverses this process to convert hydroxide ions back into water and oxygen. This is shown below.
Practical Applications

Cathodic protection is applied under two distinctly different situations, i.e. where corrosion has actually already occurred and in new structures to prevent it from starting.

The case of existing deteriorated conditions is typically addressed as shown below.

Protection for existing corroding structures can either be by applying anode mesh and encapsulating it in an exterior overlay or by cutting saw slots into the concrete and grouting in a ribbon mesh.

The case where CP is applied to stop corrosion from even starting is more properly known as cathodic prevention and this has a common approach as shown below.

Cathodic prevention is best achieved by use of Ti/MMO ribbon mesh mounted on the reinforcement using non-metallic spacers and secured by cable ties.

This technology is endorsed by a wide range of International bodies as under.

International Bodies Endorsing Cathodic Protection

European Committee for Standardization (CEN) British Standards Institute (BS)
Concrete Society, UK
National Association of Corrosion Engineers (NACE) American Concrete Institute (ACI)
Federal Highway Authority (FHWA)
American Association of State Highway & Transportation Officials (AASHTO)
A typical endorsement from such bodies as the National Association of Corrosion Engineers (NACE) who state:

“Cathodic protection is the only means to control corrosion on steel reinforced concrete structures that have chloride contaminated concrete.”

The Technology

The key component of any cathodic protection system is the anode material as this determines the lifetime of the applied system.

Concrete structures are designed with typical lifetimes ranging from 25 to 120 years. Thus it is essential for the installed anodes to match this lifetime requirement without any need for replacement, which would be extremely expensive and in many cases impossible.

For this reason we promote the use of the Elgard range of anode materials manufactured by Eltech/DeNora as these have proven their capabilities even in the harshest environment for over 30 years.

Elgard™ Anodes – The Facts

Using patented technology, Elgard™ anodes have been proven to prevent rebar corrosion. Indeed, they are the market leader in this field. Manufactured from an expanded titanium substrate, on to which is applied a mixed metal oxide coating, the anode material is lightweight and easy to install.

Key Features

- Design life in excess of the concrete structure.
- Proven track record.
- Mesh and mesh ribbon formats to suit all applications.
- Suitable for both new build and repair applications.

Comparison of Cathodic Protection with Other Techniques

<table>
<thead>
<tr>
<th>Technology</th>
<th>Effective Life</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cathodic Protection</td>
<td>&gt;100 Years</td>
<td>Permanent protection. Proven track record. Longest effective life.</td>
</tr>
<tr>
<td>Stainless Steel Bars</td>
<td>Not known</td>
<td>Expensive option. Lifetime unproven. Possible issues with galvanic couples. Not suitable for hot marine environments.</td>
</tr>
<tr>
<td>Coated Reinforcement</td>
<td>High variable</td>
<td>Very sensitive to contractor handling. There is inevitably coating damage during the fabrication and concrete pouring.</td>
</tr>
<tr>
<td>Chemical Inhibitors</td>
<td>High variable</td>
<td>Limited “active” life. Conflicting data as to effectiveness.</td>
</tr>
<tr>
<td>Patch Repair</td>
<td>&lt;5 to 10 Years</td>
<td>Incipient anode effect renders corrosion inevitable in adjacent parts of the structure.</td>
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</table>
CASE HISTORY OF APPLYING CATHODIC PROTECTION TO NEW REINFORCED CONCRETE COOLING WATER STRUCTURES IN THE MIDDLE EAST
Cathodic Protection Co Limited has a license agreement with Eltech Systems Corporation for the distribution of their ELGARD range of Mixed Metal Oxide anodes.

The range includes anodes for the protection of steel reinforced concrete structures including

- **Mesh and Ribbon Mesh Anodes** for concrete structures (NACE standard test TM0294-2001 exceeds 75 years of operation at 110mA/m²)
- **Tubular Mesh discrete anodes** for protection of piers, wharfs and other difficult to protect steel reinforced concrete structures.

Ribbon mesh anodes are supplied in 5 sizes / ratings as follows, specific data sheets are available at [www.cathodic.co.uk](http://www.cathodic.co.uk)

<table>
<thead>
<tr>
<th>Product</th>
<th>Diamond Dimensions</th>
<th>Current rating @ 110mA/m.(10mA/ft.)</th>
<th>Coil Width</th>
<th>Coil Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>85 Ribbon Mesh</td>
<td>2.5 x 4.6 x 0.6mm (0.10&quot;x0.18&quot;x0.025&quot;)</td>
<td>2.8mA/m(0.85mA/ft)</td>
<td>10mm (0.4&quot;)</td>
<td>76m (250 ft)</td>
</tr>
<tr>
<td>100 Ribbon Mesh</td>
<td>2.5 x 4.6 x 0.6mm (0.10&quot;x0.18&quot;x0.025&quot;)</td>
<td>3.5mA/m (1.05mA/ft)</td>
<td>13mm (0.5&quot;)</td>
<td>76m (250 ft)</td>
</tr>
<tr>
<td>150 Ribbon Mesh</td>
<td>2.5 x 4.6 x 0.6mm (0.10&quot;x0.18&quot;x0.025&quot;)</td>
<td>5.28mA/m (1.61mA/ft)</td>
<td>19mm (0.75&quot;)</td>
<td>76m (250 ft)</td>
</tr>
<tr>
<td>170 Ribbon Mesh</td>
<td>2.5 x 4.6 x 0.6mm (0.10&quot;x0.18&quot;x0.025&quot;)</td>
<td>5.3mA/m (1.62mA/ft)</td>
<td>20mm (0.8&quot;)</td>
<td>76m (250 ft)</td>
</tr>
<tr>
<td>200 Ribbon Mesh</td>
<td>2.5 x 4.6 x 0.6mm (0.10&quot;x0.18&quot;x0.025&quot;)</td>
<td>7.0mA/m (2.13mA/ft)</td>
<td>25mm (0.8&quot;)</td>
<td>76m (250 ft)</td>
</tr>
</tbody>
</table>

Expanded mesh anodes are supplied in 3 sizes / ratings as follows, specific data sheets are available for download on the data sheets page.

<table>
<thead>
<tr>
<th>Product</th>
<th>Diamond Dimensions</th>
<th>Current rating @ 110mA/m.(10mA/ft.)</th>
<th>Roll Width</th>
<th>Roll Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 Anode Mesh</td>
<td>34 x 76 x 0.64mm (1.33&quot;x3.0&quot;x0.025&quot;)</td>
<td>18.8mA/m. (1.71mA/ft.)</td>
<td>1.22m (4ft)</td>
<td>76m (250 ft)</td>
</tr>
<tr>
<td>210 Anode Mesh</td>
<td>34 x 76 x 0.89mm (1.33&quot;x3.0&quot;x0.035&quot;)</td>
<td>24.4mA/m. (2.22mA/ft)</td>
<td>1.22m (4ft)</td>
<td>76m (250 ft)</td>
</tr>
<tr>
<td>300 Anode Mesh</td>
<td>25 x 51 x 0.89mm (0.923&quot;x2.0&quot;x0.035&quot;)</td>
<td>37.8mA/m. (3.44mA/ft)</td>
<td>1.22m (4ft)</td>
<td>76m (250 ft)</td>
</tr>
</tbody>
</table>

Cathodic Protection Co Ltd has supplied and installed these anode systems on projects in Australia, UK, USA, Europe, Hong Kong and throughout the Middle East. We can offer in house design expertise to enable the most cost effective and technically suitable package for your project.