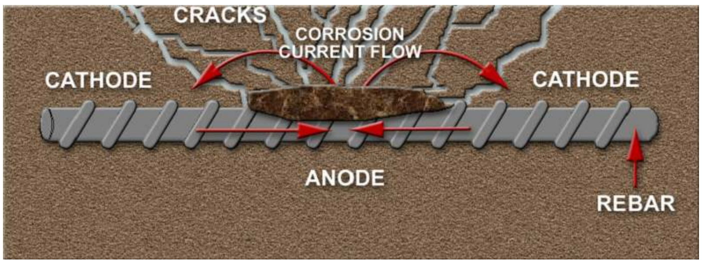
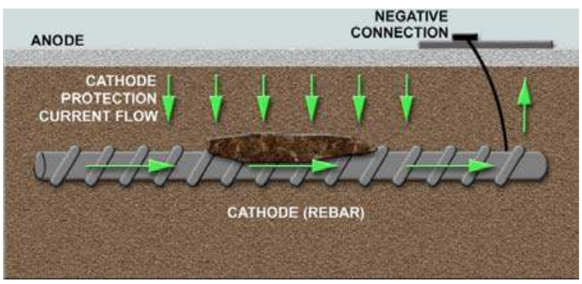
Cathodic Protection of Steel in Concrete

For many years industrial companies have fought to protect steel reinforced concrete from corrosion. The prime causes of corrosion in concrete include salt, chloride and de-icing treatments. The salt seeps into the concrete and erodes the steel reinforcing bar (rebar) causing cracks and spalling in the concrete and eventually the potential for failure of the structure. One very effective, long-term solution is metal or thermal spraying the concrete with zinc or a variety of zinc alloys. This is a technology that protects or extends the life of a wide variety of products in the most hostile environments.



A rebar in a dry alkaline concrete surrounding is usually protected by a passive ferric oxide film. However, when the rebar is exposed to 250 ppm chloride solution from surface salt, the protective ferric oxide film is converted to red rust and corrosion begins. Concrete thickness >4 cm will prevent chloride penetration. For exposed rebars and chloride concentration in excess of 250 ppm, rebar corrosion will start with the red rust spalling adjacent concrete. The environmental conditions described that cause rebar corrosion are most commonly found in coastal regions and cold areas where heavy road salting occurs during the winter months.

The majority of metallised zinc cathodic protection systems are operated in galvanic or sacrificial mode. However, metallised zinc cathodic protection systems can be, and are in many instances, operated in impressed current mode. In impressed current cathodic protection systems, the anode is made of material with an



unpolarised potential that may be equal, higher or greater than that present initially in the steel to be protected. An external power supply is then connected between the anode and the steel with the appropriate polarity voltage to deliver the required amount of electronic current to the steel. The anode is usually embedded near the concrete surface and an external power supply installed nearby. The sprayed coating, a high purity zinc or a zinc alloy, is then connected to one pole of a DC power supply and the steel rebars are connected to the other pole. The electrical circuit is completed between the rebar and the zinc by the presence of moisture in the concrete. The action of the corrosion cell causes the zinc to corrode in preference to the steel rebars, therefore protecting the rebars from corrosion. It is important with impressed current that the anode and the reinforcing bars must not short out. As mentioned, many systems are used in galvanic mode where contact between the anode and the rebar is not a problem.

The use of sprayed zinc anodes is an advantage as the zinc follows the surface to which it is applied and does not obscure architectural features of the concrete being sprayed. This is important in the spraying of bridges or aesthetic, architectural structures for example. The bond between the sprayed zinc is key to the success of the system. Typical specifications require a minimum bond strength of around 1MPa. However, with coatings performed during the 1990's in the USA, initial zinc-concrete bond strengths averaged over 2MPa. 10 years later, the bond strength still averaged 0.8Mpa. Bond strength is measured by attaching metal dollies with a strong adhesive to the spray coating and pulling the dolly perpendicular to the surface. The zinc-concrete bond is essential to the longevity of the life of the anode. To achieve the ideal bond strength, the concrete surface must be clean and dry and the climate of the work area carefully controlled. An ideal temperature of 10°C - 32°C is required with humidity in the range of 20% to 60%.

The process of spraying the zinc onto the substrate ensures that there is a good, even connection path between the coating and the rebars through the concrete. Prior to metal spraying, damaged sections of concrete need to be repaired with damaged rebars also repaired or replaced. The surface needs to be cleaned, first removing concrete splatter, soil and other organic matter by stiff brushing. Oils and grease need to be removed with detergents and then washed clean. Directly prior to metal spraying, the surface needs to be lightly blasted at a maximum of 6 bar, to remove any final surface dirt and provide a

good key to enable the coating to bond. The coating would then be applied with either a Metallisation Arc140, Arc701 or Arc170 system, depending on the size and accessibility of the structure. Historically on installations in the USA, typical bond strength is in the region of 1 to 3MPa for zinc and coating thickness would be between 300 and 500 microns.

The costs to apply metal sprayed coatings to large concrete structures is not insignificant, particularly when many structures are difficult to access, such as bridges. In many cases, special enclosures need to be fabricated to offer containment of the blast and metal spray area. These enclosures are used to provide environmental protection but also to provide suitable environmental conditions for spraying. However, the long-term benefits can make the process extremely commercially attractive. If performed correctly and depending on the coating applied, the process can offer corrosion protection for up to 20 years before the next significant maintenance is required. The protection offered can greatly prolong the life of the structure and also prevent costly accidents from cracked sections falling from the structure. Once applied, the coating requires minimal maintenance. If required for aesthetic purposes, zinc coatings can also be painted.

A recently developed alloy of aluminium, zinc and indium has been used in a small number of applications. This material is more active than zinc and it is claimed to not require an impressed current to provide adequate levels of corrosion protection.

An example of corrosion protection using this alloy has been trialled by Aeroports de Paris at Charles de Gaulle (Roissy) airport. Aeroports de Paris, responsible for the maintenance of most of the Roissy airport infrastructure, recognised deterioration in some of the concrete panels at the airport, and sought a long-term corrosion protection solution. The precast concrete panels, which are 2.6 x 2.8m of lightly reinforced 8cm thick units, form the underside of the concrete viaducts carrying road traffic to and from a busy terminal complex. Run-off from de-icing salt has led to an important level of chloride in the panel concrete. Although the panels are not structurally significant, spalling could present a hazard to passing traffic.

Following a stringent review and testing of the panels to establish the deteriorating condition, an anode was applied to the panels in a test area. After grit blasting the panel surface, the anode of aluminium/zinc/indium alloy was applied by a Metallisation arc spray system to an application thickness of 300 microns. The anode connection plate in the centre of each panel is clearly visible by its red anode cable, which would not normally be on show in a typical commercial application. The other cables run to connections to the rebars and to embedded reference electrodes. As this is a test site it was necessary to install monitoring equipment. This was to allow the connection between the anode and cathode to be interrupted for measurement of electrochemical performance. After two years the system appears to be well adapted to treat corrosion of the viaduct panels and is deemed to be a successful test.

Another significant application of the Al-Zn-In alloy in the US is the San Luis Pass Bridge near Galveston, Texas. More than 30,000 m^2 of concrete beams and caps are protected with this alloy, installed using Metallisation ARC 700 units by Corrosion Restoration Technologies of Jupiter, Florida.

Oregon Department of Transportation (ODOT) demonstrates another success story for cathodic protection on concrete. In a bid to reduce the high costs of bridge reconstruction, ODOT has applied a system of metallised zinc anodes and impressed current cathodic protection. This process has been used to protect its Cape Creek Bridge from corrosion and subsequent reconstruction. The bridge is exposed to a coastal environment and is subject to attack by chloride from the salty air. Prior to the cathodic protection project on the bridge, it had suffered substantial concrete spalling on its columns and underdeck. By selecting to protect the bridge in this way ODOT saved over $13 million by not having to reconstruct the bridge. The cost of cathodic protection is quite expensive. This is due to the requirement of a movable work platform, which is enclosed to contain the abrasive blasting and zinc spraying residues. These measures are critical when spraying zinc to protect the environment. However, when compared to the cost of reconstructing a bridge the size of Cape Creek Bridge – the savings are phenomenal.

Dave Wixson, Metallisation distributor in the US says: “Cathodic protection is a cost effective way to stop rebar corrosion in existing structurally sound structures. Rebars in dry alkaline concrete are protected by a passive ferric oxide film, however, when the rebar is hit with 250 ppm chloride solution, generally from salt, the protection breaks down. The protective ferric oxide film is converted to red rust and corrosion begins. Concrete thickness >4cm (>1.5 in), will prevent chloride penetration. For exposed rebar and thin concrete, where there is chloride concentration in excess of about 250 ppm, rebar corrosion will be initiated with the red rust spalling adjacent concrete. Protecting the rebar with a barrier using an impressed or passive cathodic protection system, counters the corrosion.”

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For more information on thermal spraying please contact Stuart Milton on +44 (0)1384 252 464 or visit www.metallisation.com