Corrosion Protection of Reinforced Concrete  
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1 Introduction

Corrosion of steel reinforcement is a major cause of concrete deterioration in civil engineering, within the Gulf region, due to the aggressive environment which involves the exposures to chlorides at elevated temperatures. There are also numerous examples in the Gulf region of “spalling reinforced concrete” found on structures within marine and industrial environments. The corrosion process that takes place in concrete is electrochemical in nature. Corrosion will result in the flow of electrons between anodic and cathodic sites on the rebar. For corrosion to occur four basic elements are required: 1. anode: where iron is dissolved into solution leaving behind an excess of electrons in steel, 2. cathode: where no corrosion occurs, the excess electrons are consumed by reaction with water and oxygen, 3. electrolyte: an ionised liquid where the ionic transfer reaction occurs and the electrochemical cell is completed and 4. electron pathway: where the flow of electron takes place between the anode and the cathode. Evidently, there is a need to implement effective corrosion control methods in order to extend the long-term durability of steel reinforced concrete. This paper addresses the corrosion protection systems / methods recommend by BASF Construction Chemicals UAE LLC to extend the long-term durability of steel reinforced concrete. These systems are 1. application of zinc rich or cement-based protective primers to the reinforcement, 2. surface applied corrosion inhibitor based on organo-functional silanes, 3. cathodic protection using sacrificial zinc anodes and 4. conductive anode overlays within an impressed current cathodic protection system.

2 Surface Applied Corrosion Inhibitor  
MasterProtect® 8000 CI

2.1. What are silanes?

- Chemical compound of silicone and hydrogen  
  (Fig. 1)

- Small reactive highly mobile molecules
- Highly alkali-resistant
- Used as an adhesion promoter in adhesives and sealants, coatings and fillers & pigments
- Hydrophobic treatment for building/structure protection
- Penetrate deep into the concrete
- Chemically bond with the substrate
- Form a water vapour permeable protective barrier against harmful waterborne substances  
  (Fig. 2)

- Consider silanes as an umbrella protecting the substrate  
  (Fig. 3)
2.2 How do silanes work?

- Silanes do not only change the surface of a porous mineral substrate to hydrophobic, they also penetrate deeply into the pores and react with the surface of the pore system.
- Due to the protective function (umbrella) silanes change the surface from hydrophilic to hydrophobic (Fig. 4 & 5).

![Fig. 4. Silane / Hydrophobic effect](image)

- Hydrophobic impregnation treatments change the surface tension of the mineral substrates including concrete, render and brickwork which produces a water-repellent surface to keep water and aggressive water-soluble salts, such as chlorides and sulfates, out of the substrate.

2.3. MasterProtect 8000 CI

- Advanced corrosion inhibitor based on Organofunctional Silanes
- One component low viscosity clear liquid; sprayed at 600 g/m2 or 600 ml/m2
- The electro-chemical cell reactions at the anode and cathode are blocked
- Penetrates deeply into concrete
- Suitable for new build and refurbishment
- Re-passivates steel rebar after chloride induced corrosion
- Greatly reduces water and chloride ingress while the concrete can still breathe

- The concrete dries over time and its electrical resistance is increased
- Reduces corrosion in carbonated concrete
- Work on both chloride and carbonation induced corrosion
- Effective in high humidity environments
- Long service life; proven laboratory and field results
- Effective on concrete with micro-cracks

3 Cathodic (Galvanic) Protection MasterProtect CP Anodes

In the last 20 years, there has been an increase in the need for concrete rehabilitation. In many structures, exposure to corrosion of reinforcing steel within concrete is recognized as a significant problem facing the owners and engineers. The most common procedure for repairing deteriorated concrete involves the removal of the damaged material and replacement with new concrete or mortar. While this addresses the immediate serviceability requirements, it does not always satisfy long-term durability needs. Differences in pH, porosity, and chloride content are some of the factors that may result in corrosion activity. As a result, “chip and patch-style” repairs may fail prematurely in chloride exposed structures. Repair of corrosion-related deterioration in concrete structures offers unique challenges. In particular, the “ring anode” effect, also called the “halo” effect (Fig. 6), is a phenomenon that is frequently overlooked but is a common cause of premature patch failure or increased repair volume. The ring-anode effect describes the increase in corrosion activity adjacent to a repair area. The ring-anode effect is caused by the electrochemical incompatibility between reinforcing steel within a patch and the steel embedded within the surrounding concrete.

![Fig. 6. ‘Ring Anode’ Corrosion](image)
3.1 Galvanic Technology

Zinc anodes have been developed to provide galvanic corrosion protection to steel in concrete. These methods are used to combat the underlying corrosion rather than simply repairing the physical damage. By supplying a small electrical current to the reinforcing steel, corrosion of the steel can be slowed down. Galvanic systems are desirable because they create their protective current internally through a natural reaction wherein the anode corrodes to galvanically protect the reinforcing steel. Galvanic systems are desirable because they create their protective current internally through a natural reaction wherein the anode corrodes to galvanically protect the exposed reinforcing bar in the repair area should be reinforced steel (Fig. 7).

![Fig. 7. Galvanic Protection](image)

3.2 Embedded Galvanic Anodes

EMACO® CP INTACT GALVANIC ANODES are embedded galvanic anodes for the protection of reinforcing steel and installed by burying them within the concrete (Fig. 2). They are engineered discrete zinc anodes encased in a proprietary mortar. Integral galvanized tie wires permit easy connection to concrete reinforcement. As a key component of a complete concrete repair strategy, the sacrificial zinc core generates a small electrical current as it is consumed, protecting the reinforcing steel from accelerated corrosion. They are typically installed at the perimeter of a repair area to be as close as possible to the area of concern. When a suitable concrete or mortar is placed around the anode, it begins to sacrificially protect the adjacent reinforcement.

There are 3 types of anodes (Fig. 8):

- **MasterProtect 8065 CP** / Green / 65 gm of zinc
- **MasterProtect 8105 CP** / Blue / 105 gm zinc
- **MasterProtect 8150 CP** / Yellow / 150 gm zinc

![Fig. 8. MasterProtect CP](image)

3.3 When to use this method?

The embedded galvanic anodes are attached to reinforcing steel within the patch cavity to protect the steel in concrete adjacent to the patch. For repairs in either chloride-contaminated or carbonated concrete, they can be incorporated in the repair to minimize corrosion of the reinforcing steel adjacent to the repair. They can also be installed in areas where potentially active corrosion of the reinforcing steel is noticed to delay corrosion damage to the concrete.

3.4 Repair Procedure

As in standard patch repairs, all deteriorated concrete should be removed from around and behind the reinforcing steel inside the repair area in accordance with good concrete repair practice (Fig. 9). Sufficient clearance between the anode and the substrate concrete should be provided (minimum of 3/4 in. [19 mm] or 1/4 in. [6 mm] larger than the nominal maximum size of the coarse aggregate used in the repair material, whichever is greater). The exposed reinforcing bar in the repair area should be thoroughly cleaned and at least the visible surfaces should be cleaned to a bright metal surface to facilitate good electrical connections where the anodes are attached. Prior to installation, electrical continuity of the reinforcing bar within the repair area should be confirmed with the use of a DC ohm meter.

![Fig. 9. Checking continuity of reinforcing steel](image)
Anode spacing in either repair type is often determined by the engineer, and differs for each situation, with the anodes placed along the perimeter of the repair area. Spacing of the anodes is mainly a function of steel density and the corrosiveness of the environment. Structures with heavy reinforcement or structures in highly corrosive environments often require closer spacing for the anodes to function effectively. Each anode should then be securely connected to the reinforcing steel. If less than 1 in. (25 mm) of cover exists, the anode should be placed beneath the bar (away from the surface of the concrete). Once installed, the electrical connection between the anode and the reinforcing steel should be confirmed. The resistance of the electrical connection should be less than 1 ohm. Finally, the patch cavity is filled with a compatible repair material, using normal patching procedures and taking care to completely encase the anode. The anodes are designed to function properly with low resistance mortars \(^2\) 20,000 \(\frac{1}{2}\)-cm. Mortars should not be selected that exceed 50,000 \(\frac{1}{2}\)-cm.

### 3.5 Features & Benefits

**Superior Zinc Alloy**
- ASTM B418 Type II zinc - low iron content means less intergranular corrosion
- Safer - no Cadmium; reduced toxicity; non-carcinogenic.

**Superior Design**
- Increased Zinc Surface Area - better performance under peak corrosion load; less susceptible to passivation.
- Pre-twisted tie wires - faster and easier to install; ensures proper “stand-off” from steel for optimal current throw; enhances the “throwing capacity” of the anode.
- Rounded Corners - eliminates sharp corners which lead to localized stresses and potential cracks.

**Superior Encasement Mortar**
- Uses chelation to activate – not pH driven - faster removal of oxidation products; prevents passivation of anode; reliable performance after repeated wet and dry cycles
- Safer - contains no lithium nitrate / bromide; less susceptible to job site damage; reduced potential for dusting; non-caustic, safe to handle.

### 4 Impressed Current Cathodic Protection (ICCP) - Conductive Anode Overlays

The main advantage of impressed current cathodic protection (ICCP) lies in its much greater output capacity as compared to galvanic anode systems. Therefore, whenever corrosion protection is required for large poorly coated or bare structures, ICCP would be the system of choice. ICCP system requires the use of an external DC power supply and metal anode in direct contact with concrete often embedded in a durable conductive anodic overlay for reinforced concrete cathodic protection (CP) (Fig. 10).

The conductive anodic overlays are:

**EMACO CP 30 ANODE** is a water based, one component anode coating specifically designed for steel reinforced concrete structures which are suffering ongoing corrosion damage, or require protection against future corrosion initiation. The material contains highly conductive coated fibres which provide superior current distribution and mechanical properties resulting in an enhanced anode life.

**EMACO CP 60 ANODE** is a two component highly durable anode designed specifically for impressed current cathodic protection of steel reinforced concrete structures which have active corrosion. The electro catalytic coating on the highly conductive fibres has a very low consumption rate and anode interfacial reactions are uniformly distributed throughout the body of the material resulting in a long and maintenance free life.

**EMACO CP ANODE OVERLAY** is a highly durable, wet spray applied encapsulating overlay for use with mesh anodes in impressed current cathodic protection of steel reinforced concrete structures. There are two systems available: **EMACO OVERLAY V** for vertical, inclined and overhead situations and **EMACO OVERLAY H** for horizontal applications.

![Fig. 10 – ICCP / Conductive Anode Overlay](image-url)