Using Galvanic Anodes in Shotcrete Repairs

By David W. Whitmore and J. Chris Ball

In recent years, the use of embedded galvanic anodes in concrete repair has continued to increase. Corrosion of reinforced concrete structures such as bridges and marine piers is typically caused by penetration of chlorides into the concrete. When sufficient chloride reaches the reinforcing steel, typically 0.03% by weight of concrete in noncarbonated concrete, the natural protection afforded to the steel in alkaline concrete breaks down and corrosion is initiated. Because the corrosion by-product, iron oxide, occupies a greater volume than the steel, internal concrete tensile forces from expansion of the reinforcing steel cause concrete cracking, delaminations, and spalling.

Fig. 1: Corrosion damage on concrete bridge pier

Patch-Accelerated Corrosion

When these structures are repaired, chloride-contaminated but sound concrete remains in place. An electrochemical incompatibility can occur between the new chloride-free repair and the remaining chloride-contaminated concrete. These new corrosion sites can eventually cause new concrete damage adjacent to the previous repairs.

Embedded Galvanic Anodes

The purpose of using embedded galvanic anodes is to mitigate this patch-accelerated corrosion activity. Embedded anodes can be used around the perimeter of the repair or on a grid pattern throughout the repair area. When the anode is connected to the reinforcing steel, a protective current is provided to the steel, which will prevent or control corrosion in the area around the anode.

A good reference for those specifying and applying embedded galvanic anodes is "Repair

Fig. 2: Patch-accelerated corrosion in parent concrete around previous repair

Fig. 3: Galvanic anode for concrete repair

Application Bulletin (RAP) 8—Installation of Embedded Galvanic Anodes," which is a free download from the American Concrete Institute (ACI) (**http://www.concrete.org/Store/ProductDetail.aspx?ItemID=ERAP8**). This guideline details anode nomenclature and installation guidelines. For example, Type 1 anodes are attached inside the patch repair and Type 2 anodes are placed into drilled holes in sound concrete.

Resistivity of Repair Materials

As detailed in the ACI RAP 8 document, concrete repair material selection is an important consideration for repairs that include Type 1 galvanic anodes installed inside repairs.

> *"Resistivity of repair materials or concrete for use with embedded galvanic anodes should be less than 15,000 ohm-cm. High-resistivity materials such as epoxies or highly polymer-modified repair mortars greatly reduce the available galvanic current or prevent the anodes from functioning properly. If a low-resistivity material is not suitable for the full repair, anodes can be embedded in individual pockets of low-resistivity material. These pockets should completely encapsulate the anode and completely fill the space between the anode and the concrete substrate."*

The recommendation for repair materials to have a resistivity of less than 15,000 ohm-cm allows sufficient protective current to flow from the anode to the steel. Based on our experience, a maximum of 15,000 ohm-cm resistivity approximates to roughly a minimum rating of 1500 coulombs using the Rapid Chloride Permeability Test (ASTM C1202). Figure 4 shows a graph based upon data compiled from various sources and could be used as a general guide; however, actual resistivity testing of the repair material is recommended. As a service to the industry, our company will test submitted repair material samples at no charge.

Anode Installation Methods

On the surface, the resistivity requirement may cause a problem for many shotcrete mixture designs, especially if it contains significant levels of silica fume to densify the mortar and to improve shotcrete build. But as the ACI RAP 8 guide suggests, it is acceptable to place lower-resistivity mortar between the anode and the concrete substrate to create a conductive bridge between the anode and the concrete substrate. When anodes are used with shotcrete, using a conductive bridge of embedding mortar will also eliminate the possibility of shadowing and overspray pockets behind the anode (more on that later).

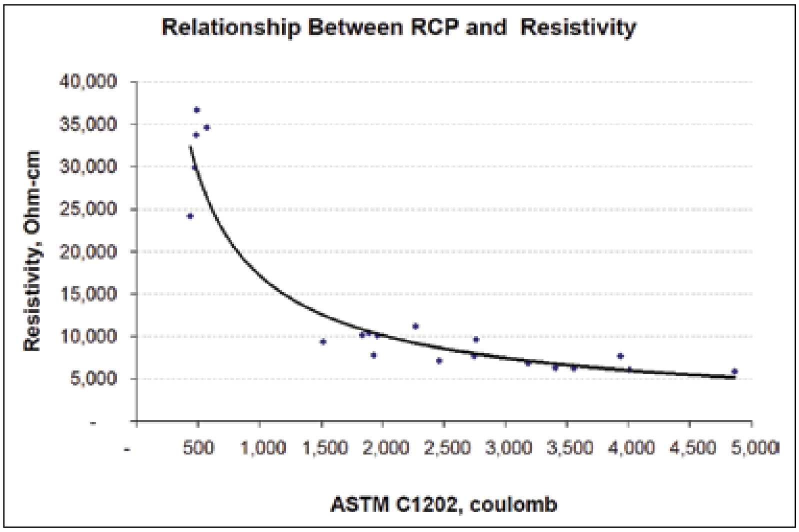


Fig. 4: Approximate relationship between resistivity and rapid chloride permeability

Fig. 5: Embedding mortar used to create a conductive path between the anode and the concrete substrate

Fig. 6: Type 2 anodes placed into holes drilled into the parent concrete and connected to the steel in the repair

Another option is the use of Type 2 anodes. In this case, holes for the anodes are drilled around or adjacent to the repair. In some instances, using Type 2 anodes may be preferred for repairs where concrete removal behind the reinforcing steel is limited for structural reasons or where low cover is present. If the use of Type 1 anodes with embedding mortar is acceptable to the designer, this process would be preferred, as it is considerably less labor-intensive.

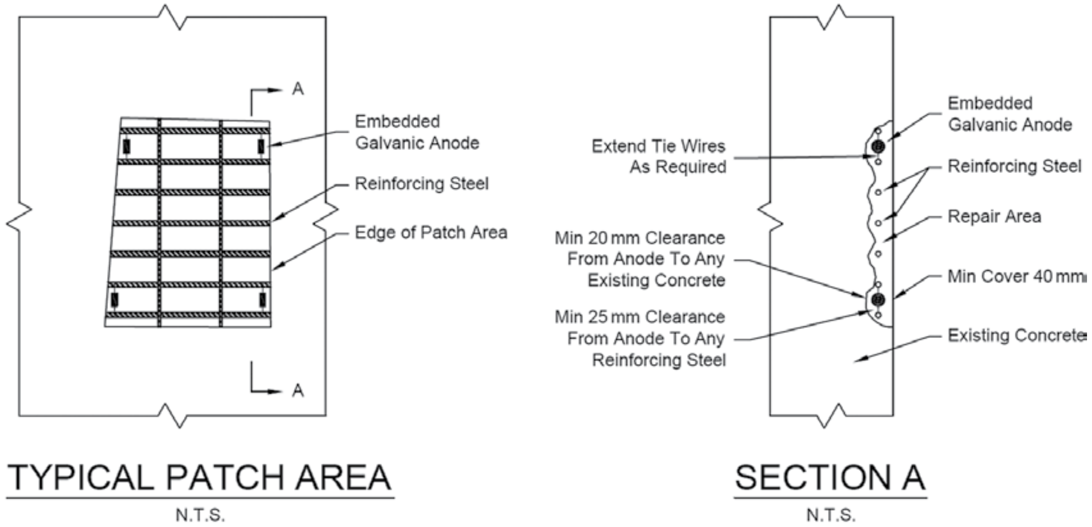

Fig. 7: Type 2 anode repairs completed with dry spray shotcrete

As mentioned previously, the use of embedding mortar to create a conductive bridge between the anode and the parent concrete allows anodes to be used with higher resistivity repair materials and to prevent the risk of shadowing behind the anode. If a shotcrete material with resistivity below 15,000 ohm-cm is used, it still may be preferred to use the embedding mortar to prevent shadowing.

If embedding mortar is not used, it is recommended to install the anode such that the flat side faces the steel. This process reduces the cross-sectional area of the anode facing the nozzleman and can be helpful in minimizing any shadowing which may occur. Another option would be to use thin, elongated anodes that fit nicely beside the reinforcing steel.

Summary

The use of embedded galvanic anodes in shotcrete repairs provides an added level of



TYPICAL PATCH AREA
N.T.S.

SECTION A
N.T.S.

Fig. 8: Installation of disc-shaped anodes with narrow side toward nozzleman to minimize area behind the anode

protection from future corrosion. If repair materials have a resistance higher than 15,000 ohm-cm then a conductive mortar bridge should be used. Alternately, anodes can be placed outside of the repair and connected to exposed steel within the repair area.

The use of embedding mortar can also be beneficial to prevent shadowing even if the repair material resistivity is less than 15,000 ohm-cm. If no embedding mortar is used, then using thin elongated anodes or installing disc- or oval-shaped anodes so that the narrow side faces the nozzleman will reduce the area behind the anode.

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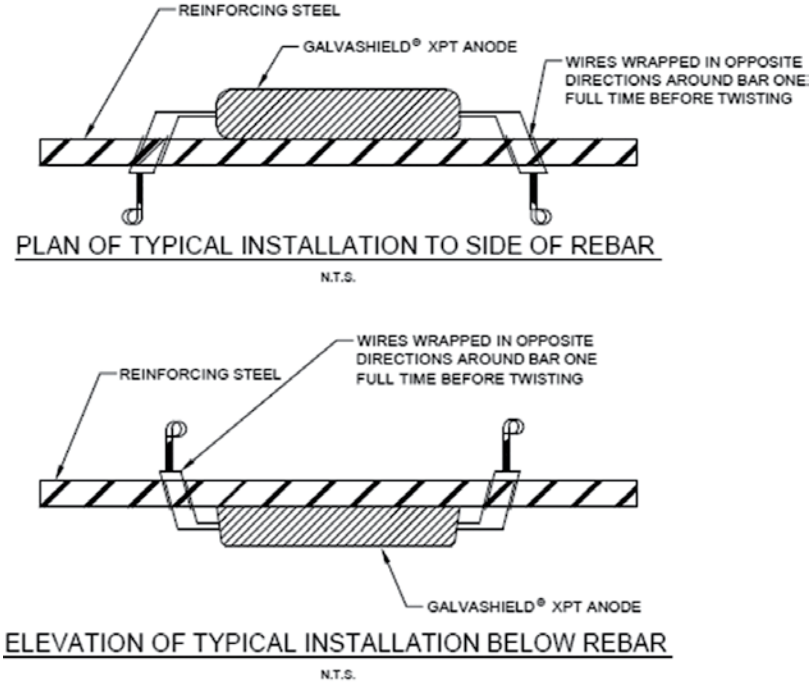

PLAN OF TYPICAL INSTALLATION TO SIDE OF REBAR
N.T.S.

ELEVATION OF TYPICAL INSTALLATION BELOW REBAR
N.T.S.

Fig. 9: Thin elongated anodes are ideal for shotcrete repairs

Fig. 10: Thin elongated anodes installed prior to shotcrete repair. Installation behind the reinforcing bar further reduces cross-sectional area