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ACI RAP Bulletin 8

FIELD GUIDE TO CONCRETE REPAIR APPLICATION PROCEDURES

Installation of Embedded Galvanic Anodes

Field Guide to Concrete Repair Application Procedures

Installation of Embedded Galvanic Anodes

Reported by ACI Committee E706

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This document is intended as a voluntary field guide for the Owner, design professional, and concrete repair contractor. It is not intended to relieve the user of this guide of responsibility for a proper condition assessment and structural evaluation of existing conditions, and for the specification of concrete repair methods, materials, or practices by an experienced engineer/designer.

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Introduction

In the last 20 years, there has been an increase in the need for concrete rehabilitation. In many structures, exposure to deicing chemicals and marine-sourced chloride is a significant cause of corrosion, playing a more detrimental role than originally anticipated. Corrosion of reinforcing steel within concrete is recognized as a significant problem facing present-day 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 a few 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. 1), is a phenomenon that is frequently overlooked but is a common cause of premature patch failure or increased repair volume. Generally stated, 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.

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, one can slow down corrosion of the steel. 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.

Embedded galvanic anodes—Embedded galvanic anodes are installed by burying them within the concrete. Type 1 embeddable galvanic anodes are available to be included in standard concrete repair (Fig. 2) or along a joint between new and existing concrete. Type 2 embeddable galvanic anodes are designed to be installed in sound concrete (Fig. 3). Anodes are activated such that they continue to provide current over time. Anodes are available that use one of two methods of activation: alkali-activated anodes (A), and halide-activated anodes (H). Each method of activation has its own benefits and limitations. When Type 1 anodes are included in a concrete repair, 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.

What is the purpose of this repair?

Embedded galvanic anodes reduce the corrosion activity of the reinforcing steel in the vicinity of the installed anode. Anodes are installed in areas of the concrete where there is a high likelihood of corrosion occurring or recurring. Type 1 anodes are installed to provide improved protection of rein-
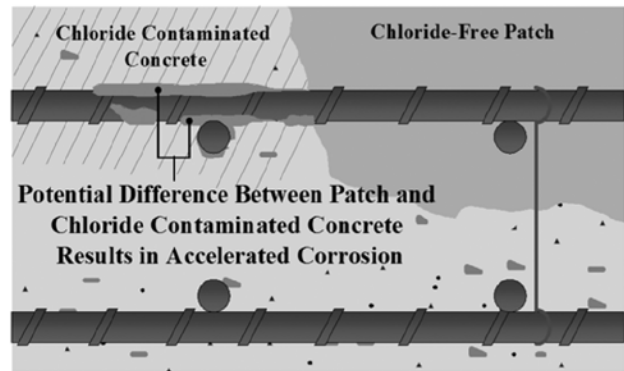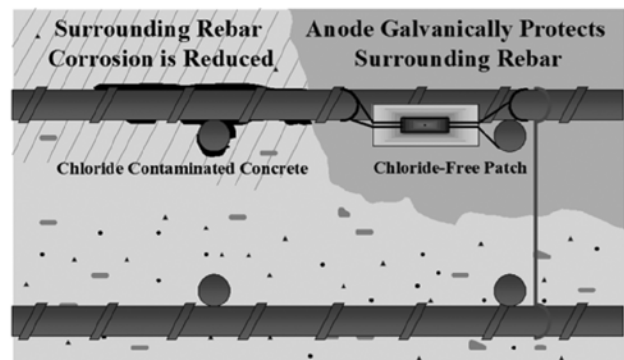

Fig. 1—"Ring-anode" corrosion.

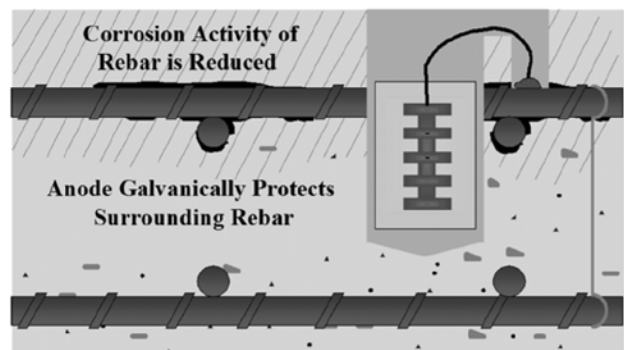Fig. 2—Chloride-accelerated corrosion.

Fig. 3—Chloride-accelerated corrosion.

forcing steel in chloride-contaminated or carbonated concrete surrounding a patch repair. Type 2 anodes are used in sound chloride-contaminated or carbonated concrete to prevent the onset of delamination or spalling of the concrete.

When do I use this method?

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, embedded galvanic anodes can be incorporated in the repair to minimize corrosion of the reinforcing steel adjacent to the repair. Embedded galvanic anodes can also be attached to reinforcement at the interface of new and existing chloride-contaminated concrete. Examples of uses include bridge deck widening, replacement of deck joint nosings, or concrete pile jacketing.
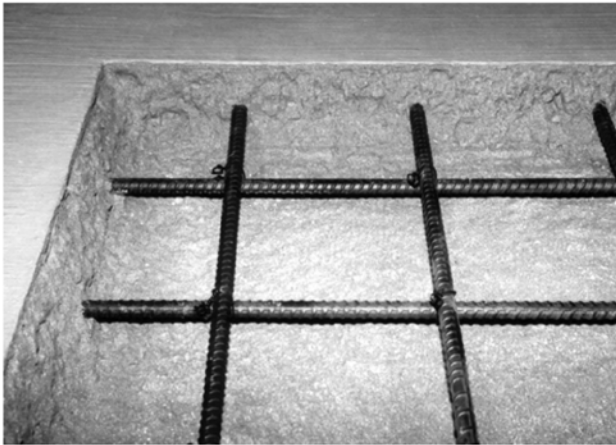
Fig. 4—Deteriorated concrete removed.

Fig. 5—Checking continuity of reinforcing steel.

During concrete condition inspections, areas of potentially active corrosion of the reinforcing steel are often discovered in mechanically sound concrete. Embedded galvanic anodes can be installed in these areas to delay corrosion damage to the concrete. These anodes can be installed on a grid pattern over a large area to provide protection for reinforcing steel in concrete that is found to be or is suspected to be contaminated.

How do I prepare the surface?

Complete surface preparation as required for the application of the repair concrete or mortar. Limit the use of bonding agents to those with low resistivity, such as slurries containing portland cement or portland cement-sand mixtures. Avoid insulating materials such as epoxy bonding agents.

How do I select the right material?

Embedded galvanic anodes should be used only in conjunction with cementitious or cementitious-polymer repair materials, which have a low resistivity. 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.

What equipment do I need?

The equipment needed to install Type 1 embedded galvanic anodes in standard repairs entails only basic hand tools and a DC ohm meter capable of reading 0 to 200 ohms. To install Type 2 embedded galvanic anodes in sound concrete, the equipment required includes a reinforcing bar locator, percussion drill or core drill, basic hand tools, and DC ohm meter.

What are the safety considerations?

It is the responsibility of the user of this document to establish health and safety practices appropriate to the specific circumstances invo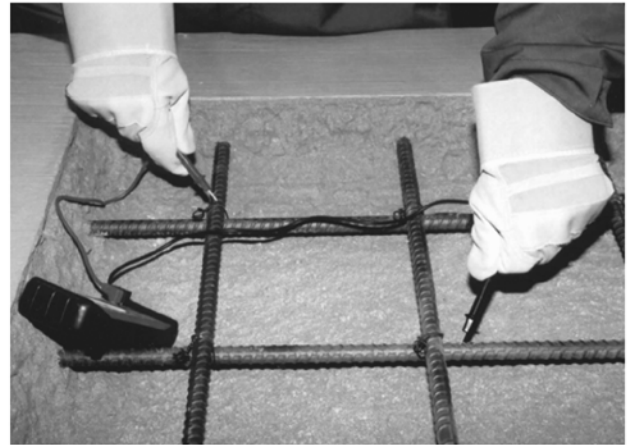lved with its use. ACI does not make any representations with regard to health and safety issues and the use of this document. The user must determine the applicability of all regulatory limitations before applying the document and must comply with all applicable laws and regulations including, but not limited to, United States Occupational Safety and Health Administration (OSHA) health and safety standards.

Preconstruction meeting

Prior to proceeding with the repair, a preconstruction meeting is recommended. The meeting should include representatives from all participating parties (owner, engineer, contractor, materials manufacturer, etc.), and specifically address the parameters, means, methods, and materials necessary to achieve the repair objectives.

Repair procedure

Anode spacing in either repair type is often determined by the engineer, and differs for each situation. 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.

Type 1 embedded anodes installed in standard repairs— 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. 4). 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. 5).

Anode spacing is as specified by the engineer, with the anodes placed along the perimeter of the repair area. Each anode should then be securely connected to the reinforcing
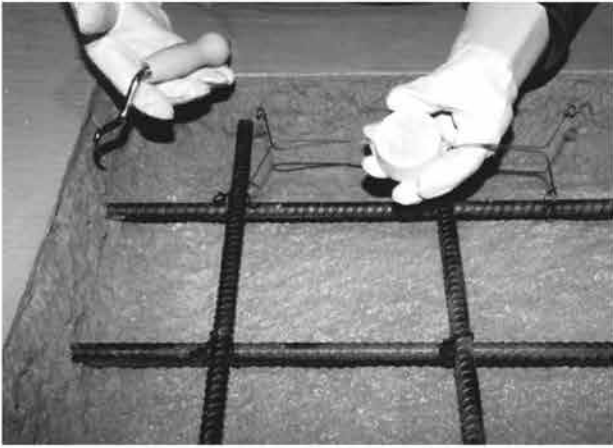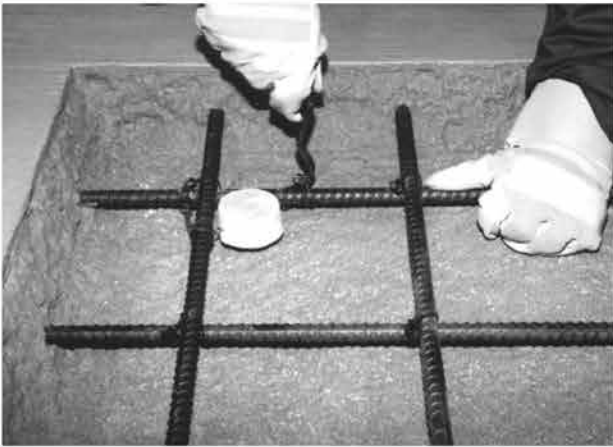
Fig. 6—Tying tool and Type 1A anode.
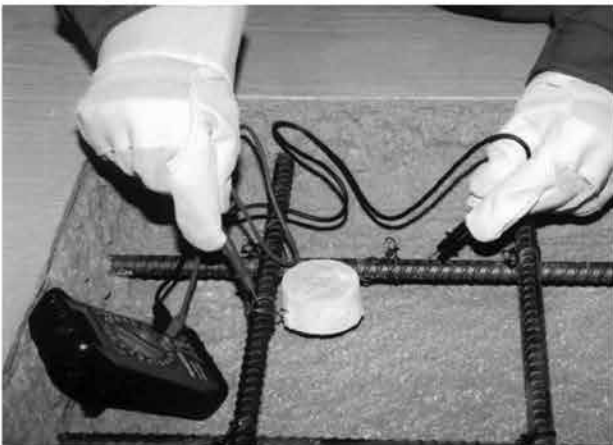

Fig. 7—Tying a Type 1A anode.

Fig. 8—Confirming connection to reinforcing steel.

Fig. 9—Locating reinforcing steel.

Fig. 10—Coring hole for anode.

Fig. 11—Secondary hole with reinforcing steel connection.

steel (Fig. 6 and 7). 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 (Fig. 8). The resistance of the electrical connection should be less than 1 ohm. Finally, the patch cavity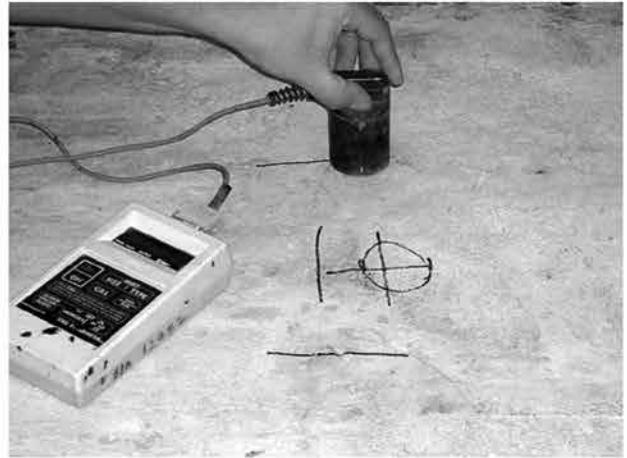 is filled with a compatible repair material, using normal patching procedures and taking care to completely encase the anode.

Type 2 embedded anodes installed in sound concrete— Reinforcing steel in the area of the desired installation should be located and marked on the concrete surface (Fig. 9). Based on the location of the reinforcing steel, the anode location should be marked, and a hole of appropriate size should be drilled to accommodate the anode (Fig. 10). A location for connection of the anode to the reinforcing steel should then
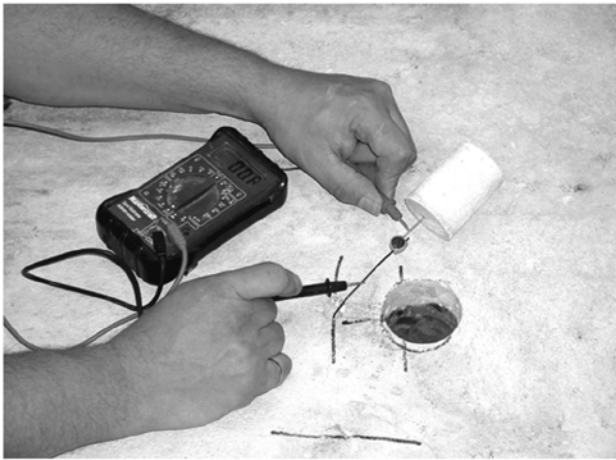
Fig. 12—Confirming connection to reinforcing steel.

Fig. 13—Type 2A anode placed in hole with patching material.

be marked, drilled if necessary, and a connection made (Fig. 11), either within the original hole or in a secondary hole. Continuity of the reinforcing steel in the location of installation should be verified with a DC ohm meter.

All holes should be cleaned of debris and dust. The anode should be securely connected to the reinforcing steel, and the contact should be confirmed using the DC ohm meter (Fig. 12). Connection resistance should be less than 1 ohm. Any connections between dissimilar metals (such as copper wires to steel) should be sealed with silicone or a two-part epoxy to prevent localized corrosion. The drilled hole(s) can then be filled using the appropriate repair material (Fig. 13).

How do I check the repair?

Embedded galvanic anodes, when normally installed, allow for very few direct measurements other than those for corrosion potentials. If more-detailed performance data are desired, anodes can be installed to allow monitoring of the current and voltage output of the anodes. With a switch installed in the circuit, corrosion potential or corrosion potential decay measurements can also be taken, if appropriate, to determine the level of polarization of the steel.

Sources for additional information

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ACI RAP Bulletins

ACI Committee E706, Concrete Repair Education, has produced 14 documents on Repair Application Procedures (RAP) that cover a wide variety concrete repair topics. These documents are available for free as downloadable PDFs. Visit **www.concrete.org/publications/educationpublications.aspx** for a complete list of the free ACI RAP documents v. Also, ACI University offers a Certificate Program that encourages concrete professionals to gain indepth knowledge about particular topics in concrete materials, design, or construction by following a defined online course of study. One of the online Certificate Programs uses many of these RAP documents as the course material. For more information on the ACI Certificate Program visit **www.concrete.org/education/aciuniversity/certificateprogram.aspx**.