



MATES

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UNDERSTANDING AND PREVENTING BRIDGE DECK DETERIORATION PART II - CATHODIC PROTECTION OF STEEL REINFORCED CONCRETE BRIDGE DECKS

In the early 1960s it became clear that there is a relationship between the rock salt used to deice highways during winter months and the deterioration of concrete bridge decks. During the 1960s and 1970s many techniques such as overlays, sealers, and waterproof membranes were evaluated in both the laboratory and the field for rehabilitating salt contaminated bridge decks. At best the life expectancy of these methods has proven to be from 5 to 20 years, after which extensive further maintenance is required. Having studied all of the available techniques the Federal Highway Administration (FHWA) concluded that the only technique proven to stop corrosion in salt contaminated bridge decks, regardless of the chloride content of the concrete, is either galvanic or impressed cathodic protection (CP).

Galvanic CP

Galvanic protection is accomplished by electrically connecting the metal to be protected to another metal that is even more prone to corrosion (e.g., zinc is attached to rebar to protect the steel). The more corrosion prone or "less noble" metal will actually sacrifice itself to protect the other metal. The problem with this type of system is that the protective metal is eventually sacrificed and must be replaced or the protected metal will begin to corrode.

Impressed Current CP

The impressed current CP system is the type generally used to protect concrete bridge decks. It has long been known that the process of metallic corrosion involves the flow of electrical current. More recently it has been determined that a battery of sorts develops within the bridge deck, due to the difference in salt concentrations between the upper and lower parts of the deck which generates the corrosion current. Figure 1 shows the typical flow of current that takes place between the upper and lower mats of reinforcing steel in a salt contaminated concrete bridge

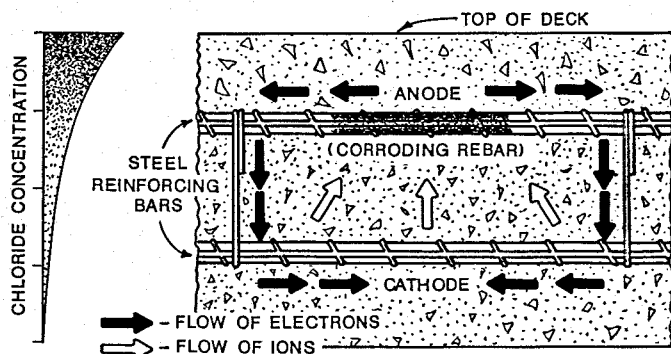


Figure 1.

deck. This reaction was discussed in last month's MATES. This normal flow of electricity is overpowered by the electrical current supplied by the CP system (Fig. 2). The current is forced to flow to both mats of reinforcing steel thus preventing the oxidation reaction (rusting) at either mat. The power needed for a small bridge is comparable to that needed to light a 100 watt bulb, and is supplied from an external direct-current power source. In other words, neither mat of reinforcing steel will corrode as long as the impressed current is present. If the system is turned off the flow of electrons will gradually revert to its original path and corrosion of the reinforcing steel will begin again.

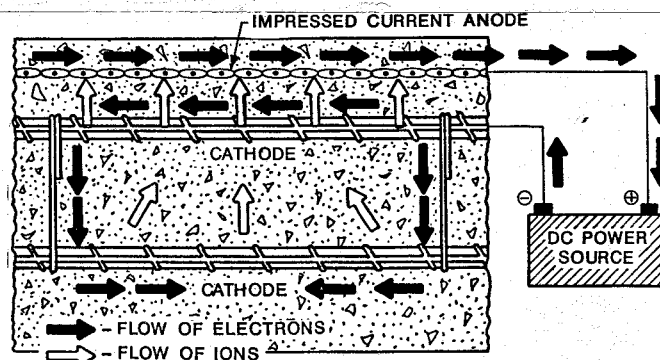


Figure 2.

Background

Although cathodic protection was first introduced for use on bridge decks in 1973, it has been in common use for over a century in other applications such as providing underground and undersea protection of metals. One of the very first bridge deck CP systems in this country was installed on the Sky Park Bridge in California in 1973. This system consisted of flat round 'pancake' anodes placed at 10-ft intervals across the deck surface. The deck surface was then covered by a layer of 'coke breeze' asphalt mixture, which is electrically conductive. Coke breeze is a soft, porous, unstable mixture and would not hold up well under traffic so it was covered with an asphalt wearing course. When the system is charged the anode transmits the protective current to the conductive overlay which in turn distributes it to the concrete deck. This type of system is used quite extensively by both the California Department of Transportation and the Ontario Ministry of Transportation, and is generally considered to be the first generation of this type of protection system. One of the main disadvantages of this system is the lack of durability of the coke breeze mixture. Other disadvantages are that the overlay is quite porous, and collects moisture on the surface of the concrete beneath the overlay, as well as adding dead load to the bridge.

The next major innovation came about when the research laboratory of the FHWA evaluated a polymer that is electrically conductive, developed a technique for its use, and made it available for general application. The technique

Testing Laboratory
U of M 1913

Research Laboratory
MSU 1939

Investigation and Research Division
1924

Testing and Research Division
1933

Materials and Technology Division
1985

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is to cut longitudinal slots in the bridge deck at approximately one foot intervals and place conductive wire in those slots (Platinum, copper and even carbon strands have been used). The electrically conductive polymer is mixed at the site and poured into the slots covering the wire. When the protective current is applied to the system the wire carries the current to the polymer which then distributes it to the surrounding concrete. Problems with this technique include the fact that it is very labor intensive and that the polymer can only be mixed in small batches since it has a very short life before setting, installation quality is difficult to control, and service life has not been adequate.

Several changes and improvements have been achieved since the slotted system. The type considered best at present distributes the current by means of a manufactured mesh-type grid. This mesh system is easily installed by a contractor or by DOT personnel by unrolling and fastening it evenly over the deck, and covering it with a concrete overlay. The current is applied directly to the mesh grid anode which distributes it to the concrete deck.

Current MDOT Activity

In the fall of 1987, one of the mesh-type systems was chosen by the Department for its first cathodic protection project. It was installed in conjunction with a standard overlay and railing replacement on the bridge carrying Verona Rd over I 94 between Battle Creek and Marshall. The usual method for repairing this type of structure is to remove the salt contaminated concrete and then apply an overlay to provide a new riding surface. The high salt content of this particular deck precluded the use of MDOT's standard repair methods since the salt would cause corrosion to continue beneath the new overlay. This left as the only options either a total replacement of the deck or cathodic protection.

MDOT's research laboratory was one of the first to install a CP system with microcomputer based remote monitoring and control (via telephone line). Probes for monitoring the system (up to 16 of each type) include: thermocouples for checking temperature; reference electrodes that are indicators of corrosion; rebar probes that are indicators of instantaneous corrosion current; four-point resistance probes that indicate how much corrosion current has occurred; and resistivity probes to indicate changing moisture and chloride content of the deck. Remote control can increase or decrease the voltage (and thus the current), and turn the system on and off.

Remote monitoring of appropriate probes within the deck should provide a continuous and accurate indication of corrosion rates at various locations as well as maintain a cumulative record. Since it is the corrosion of the reinforcement within the concrete that results in much of the deterioration of the deck, an evaluation of corrosion rates can aid greatly in predicting the performance of the cathodic protection system long before there are any visual signs of bridge deck deterioration.

New Activities

Cathodic protection for highway application was initially used exclusively on bridge decks. More recently there have been experimental projects that make use of this technology on piers, retaining walls, and abutments. Although the methods used in this area are not as well developed as those used for bridge decks, this area of application will continue to grow.

In the Future

An FHWA study indicates that extensive cathodic protection usage on moderately salt damaged interstate bridge decks could save tens of billions of dollars over the next several decades. Present cathodic protection systems are lower in cost than earlier systems. The project just installed cost \$5.28/sq ft beyond the cost of scheduled overlay and railing replacement (about \$10,000, total). It is possible that a properly installed and maintained CP system could extend the life of a bridge deck for an additional 20 years or more. Cathodic protection has moved beyond the experimental stage and if prices continue to fall, CP systems will be used more and more by the transportation industry. One type of bridge that seems to be especially suited for CP treatment is the reinforced concrete 'T-beam' type, where support from below is needed if major removal of concrete is required. In locations where freeways pass under the bridges, supports would interfere with traffic. CP treatment of these structures before they are badly deteriorated may avoid considerable problems later.

In our Department (Bureau of Highways) the M&T Division is now putting together a presentation for the Engineering Operations Committee, that will recommend increasing the use of cathodic protection on structures scheduled for rehabilitation.

-Bard Lower

TECHADVISORIES

The brief information items that follow here are intended to aid MDOT technologists by advising or clarifying, for them, current technical developments, changes or other activities that may affect their technical duties or responsibilities.

MDOT RESEARCH PUBLICATIONS

Static and Dynamic Properties of Anchor Bolts for Sign Supports - Final Report, Research Report No. R-1283, by B. R. Lower and L. J. Pearson. Fatigue tests on sign support anchor bolts were made in order to answer some questions raised by prior work in the area. Further tests were run on galvanized and plain bolts, as well as solid stainless steel and stainless steel clad bolts. This report confirms the results of the earlier research, that galvanizing does reduce the fatigue life of the bolt. Although this study shows that the fatigue lives of solid stainless and stainless steel clad bolts exceeded that of the galvanized bolts by more than an order of magnitude, they are not cost competitive even if small diameter bolts could be substituted for our current 2-in. galvanized bolts. Design stresses for such anchor bolts have been reduced as a result of the study.

Load Tests of the Zilwaukee Bridge, Research Report No. R-1285, by S. R. Kulkarni. This report describes the tests performed by MDOT on five spans of the bridge. The spans

were selected to represent spans constructed under both contracts, spans damaged by spalling, undamaged spans, and the span involved in the 1982 construction accident. A 258-ton test load was applied to the spans, and the response of each span to this load was determined by measuring deflections and strains. The entire testing program was conducted under the review and observation of Construction Technology Laboratories, Inc. of Skokie, Ill. The theoretical structural responses of the selected spans to the test loads were determined by a second consulting firm, Howard Needles Tammen and Bergendoff, and compared with the responses measured by M&T on the bridge. Conclusions based on the test program and analysis, showed that the measured performance of the bridge was superior to, or at least equal to, that specified by the design of the bridge.

NEW MATERIALS ACTION

Approved: Set 45 DOT, a new formulation of Set 45, has been reinstated to the approved material status as a concrete patching product.

This document is disseminated as an element of MDOT's technical transfer program. It is intended primarily as a means for timely transfer of technical information to those MDOT technologists engaged in transportation design, construction, maintenance, operation, and program development. Suggestions or questions from district or central office technologists concerning MATES subjects are invited and should be directed to M&T's Technology Transfer Unit.

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