CENTER FOR TRANSPORTATION RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

Center for Transportation Research
The University of Texas at Austin

Project Summary Report 7-2945-S
Project 7-2945:
Authors: David Whitney, Leandro Etcheverry, and Harovel Wheat
March 2003

PROJECT SUMMARY REPORT

Cathodic Protection: Coordinating Corrosion to Save State Structures

What We Did...

Research Project 7-2945, *Performance Evaluation of Cathodic Protection Systems for Queen Isabella PR 100*, evaluated the potential for use of cathodic protection for corrosion protection of the splash zone area elements in the substructure of the Queen Isabella Causeway (QIC) connecting Port Isabel, Texas, with South Padre Island, Texas. The splash zone is the area immediately above the water line where the elements go through routine wetting and drying cycles. The elements in that area that were protected by cathodic protection systems (CPSs) included footings and tie beams (Fig. 1).

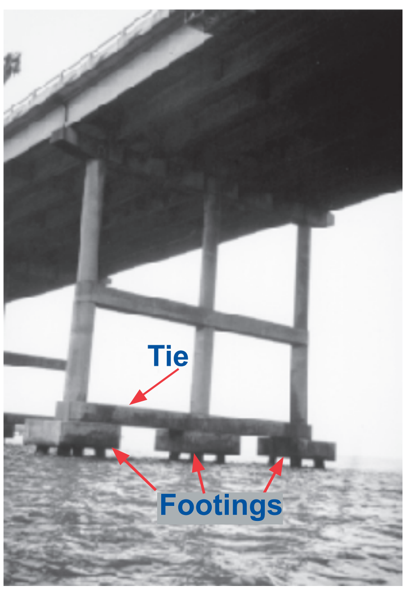

Figure 1 Typical bent showing footing and tie beams protected by CPS in this research.

Researchers selected and instrumented five bents on the QIC with different types of CPS. Care was taken to ensure that the subject bents were typical in their state of corrosion, compared with the other 142 bents, and that each was in a similar state of corrosion and distress as the other subject bents. Additionally, the impressed current bents needed to be far enough into the bay to suffer typical wind and surf exposures, yet close enough to minimize the expense of installing and maintaining electrical cables too far away from the Port-Isabel-shore rectifier and remote monitoring unit installation (Fig. 2). An impressed current, spray-metallized zinc anode-coating system was installed on Bent 19. The gray paint-like coating met application thickness specifications of 10 to 12 mils. Sprayed zinc anode durability is estimated in the literature to range between 10 and 15 years for impressed current systems.

Similar to Bent 19, Bent 20 was also wired for impressed current and monitoring, but it employed a thermally sprayed titanium (2-3 mils plus protective catalyst coating) anode. Although the CPS anodic coating material is significantly more expensive than the zinc, the estimated service life of this system ranges from 20 to 40 years.

Bent 21 employed the last type of impressed current CPS. Its tie bar and footers were covered with the commonly used preformed titanium mesh anode, which was then

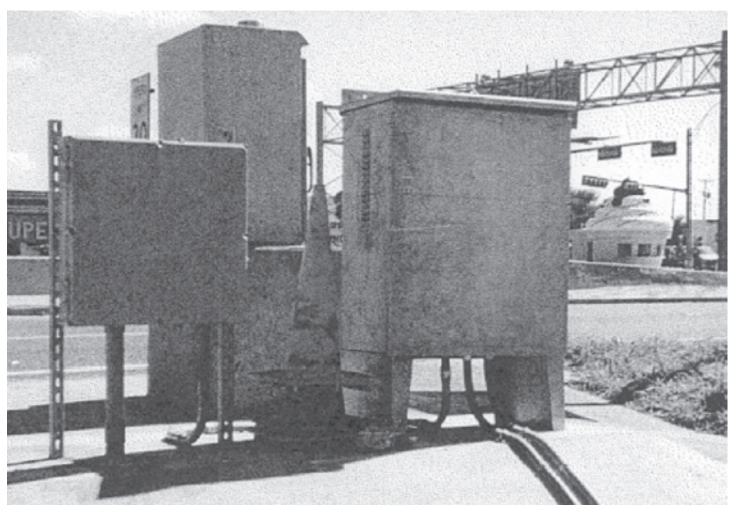

Figure 2 Remote monitoring unit (left) and rectifier (right) installations on Port Isabel shore for cathodic protection systems for the 19th through 23rd bents on QIC.

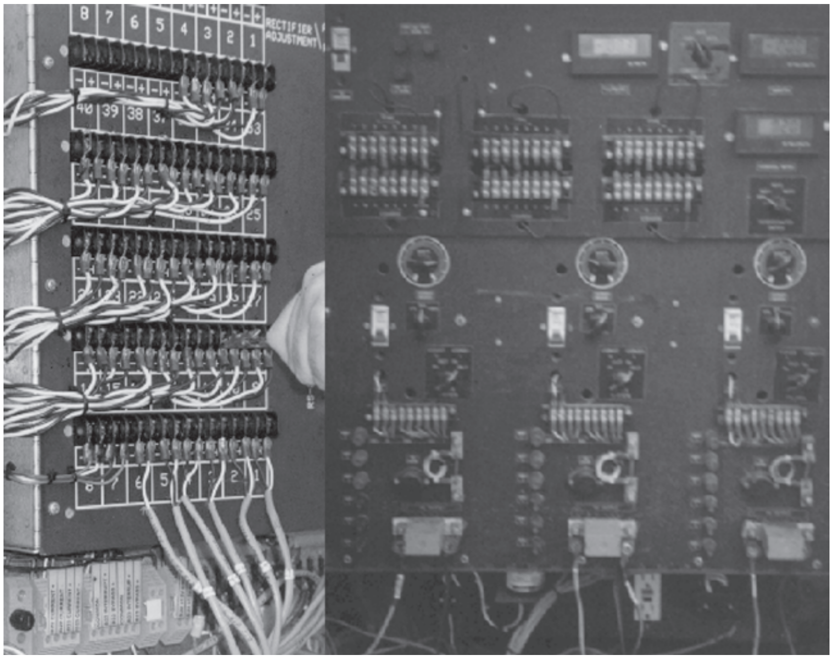

Figure 3 The RMU on the left served as the data logger and the modem port for data transfer from the QIC to Pharr District office more than 90 miles away, while the rectifier at the right provided the necessary power for impressed current CPS bents and data retrieval from each bent.

covered with a thin protective concrete overlay. This CPS, too, is more expensive, with the estimated service life ranging from 20 to 35 years.

Bent 22 employed the first of two galvanic systems, another thermally applied zinc coating for the anode. It is the same material and was applied the same as on Bent 19, but no power supply lines were installed here, as this passive or galvanic system relies on the approximately one-volt differential between the natural electrical potentials of the rebar and the zinc coating to drive the protective current. The predicted life of this passive system was the same as for the impressed current on the zinc anode at Bent 19.

The last system applied on Bent 23 in the comparison is a galvanic, thermally applied special aluminum-zinc alloy coating. Like the passive system described in the previous paragraph, the difference in natural voltage potentials of the special alloy coating versus the structural steel reinforcement is expected to drive the protective current. The difference in electrical potential between this coating and the rebar is a little more than that on Bent 22; so a little higher protection current is expected, perhaps providing a little better protection. This special alloy anode that costs significantly more than the zinc anode was in the developmental stage at the time of installation.

Finally, Bent 24 had no CPS installed, but it was wired for remote monitoring and inspected like the other five in order to monitor the relative progress of corrosion in a normal unprotected bent.

Data loggers and a remote monitoring modem communication system were connected electrically to the anodes and reinforcement in the protected footings and tie beams to provide the research team with regular station reports indicating corrosion activity and relative protection capabilities of the protection systems (Fig 3). Additionally, researchers visually inspected the protected structural elements and each CPS for problems on an annual basis or more often as indicated by monthly station report data.

Table 1 is a list of cost comparisons based upon the actual installations for each system at the QIC. Unit costs per bent will be much lower with the volume of materials and repeatable application processes associated with such a large number of bents in final TxDOT implementation, when compared to these single bent installations for the research study.

What We Found...

Findings of the research indicated that durability of the systems was challenged much more by the harsh marine environment than by the normally anticipated electrical consumption of the anode systems. In addition, the researchers encountered many problems trying to maintain the impressed current systems and would not recommend this approach

Table 1 Cost comparison of CPS evaluated on the Queen Isabella Causeway during this project

1.2 CP System	Sprayed Zinc Imp. Current	Sprayed Titanium Imp. Current	Titanium Mesh with Overlay Imp. Current	Sprayed Zinc Galv. Current	Sprayed Alloy Galv. Current
Location	Bent 19	Bent 20	Bent 21	Bent 22	Bent 23
Installed Cost	$68,400*	$121,400	$104,400	$74,400*	$84,400

*TxDOT records indicate the above totals, but researchers suspect that the costs for bents 19 and 22 may be reversed. Since the anodes are the same, any significant cost difference should be due to the rectifier used with the impressed current system in 19.

Figure 4 Even during calm seas, wave action attacks CPS anode margins at the bottom of the footers.

in the future. Estimates of service life for the systems had originally been based upon the normal sacrificial consumption of the anodes, but wave action and strong winds, pigeon and pelican droppings acting predominantly on the ends facing the Gulf of Mexico, and possibly excessive current being imposed on the system deteriorated all anode systems much faster than manufacturers expected (Figs. 4 and 5). Within the first year of activation bubbles developed under the anodes, especially at the margins, and soon many small pieces of anode cracked and peeled off. Performance monitoring indicates that a system of regular maintenance would be desirable to gauge the actual rate of anode deterioration. Because the non-impressed current sprayed zinc anode system and the non-impressed current sprayed aluminum-zinc alloy system both performed reasonably well, they are recommended for the Queen Isabella PR 100. The zinc anode system is less expensive, but the aluminum-zinc alloy appears to provide better protection in dryer conditions and more uniform protection overall.

Figure 5 Pelicans, pigeons, and boats may contribute to premature anode deterioration.

The Researchers Recommend...

An itemized listing of implementation recommendations resulting from this research is provided below.

1. All subject bents showed minimal deterioration of their protected concrete elements, while unprotected bents have clearly shown progressive deterioration. Due to the crucial importance of installing and activating CPS before significant structural deterioration results from progressive corrosion, and due to the harshness of the marine exposure on this only bridge between the island and mainland, TxDOT must immediately act to design and install the CPS for the remaining footers and tie beams of the QIC. Because the technology is unfamiliar to most of the local TxDOT personnel and the local contractors, special considerations must be made in the drafting of the specifications and in pre-qualifying the contractors responsible for the installation and verification of the CPS effectiveness. It is crucial that TxDOT employ a corrosion engineer well experienced with cathodic protection of steel-reinforced concrete structures in marine environments to oversee the drafting of the specifications and to inspect the actual installation and subsequent verification of the CPS.
2. Additionally, any bidder for the job must have a similarly experienced corrosion engineer (i.e., proof of a minimum of two years field experience with installation and performance testing of CPS on steel-reinforced concrete structures in marine environments) employed in the design review before bidding, as well as on the jobsite, to direct the processes of electrical continuity assurance of the reinforcing steel, quality control of the anode thickness and its bulk resistivity, proper installation of connector plates, and any other quality control testing or verification required.
3. Using initial cost and predicted whole life estimates, including maintenance as described in the comprehensive first report for this research project, the recommended CPS for this TxDOT application is a spray applied zinc anode galvanic system or a spray applied aluminum-zinc alloy galvanic system, both systems without impressed current.
4. A detailed plan for annually monitoring and maintaining the anode and CPS circuitry on each bent must be established before the anodes are installed. A regular inspection schedule of the CPS and the bents must be maintained. This schedule should probably be coordinated with biennial BRINSAP inspections to minimize effort and expense normally associated with substructure evaluations of a marine structure. Maintenance planning should include anticipation of contracts for annual reapplications of the sprayed zinc or aluminum-zinc anode to any bents where anode loss is significant enough to compromise adequate protection of the bent.
5. It is also recommended that cellular-modem remote-reporting units be strategically installed at the most critical bents (wherever damage due to wind and wave action, pelicans, pigeons, or boats is most likely). These modems would allow data transfer to a remote office where effectiveness of the CPS on those bents could be reviewed monthly or as needed.
6. The anode manufacturers, who would bid to supply anodes for this construction contract, offer one additional recommendation for consideration. Since the electrochemical technology has advanced sufficiently to produce relatively reliable equipment and connections, even for marine applications, it would follow, then, that in order to make CPS for this type of application more economically attractive, manufacturers should aggressively pursue bond improvements for the anodic coatings and surface protection methods and materials for more durable anodes placed in waterline applications on steel reinforced concrete structures.

For More Details...

Research Supervisor: Harovel Wheat, Ph.D., P.E., (512) 471-1451
email: hwheat@mail.utexas.edu
TxDOT Project Director: Robin L. Longwell, P.E., (956) 702-6130
email: rlongwel@dot.state.tx.us

The research is documented in the following reports:

2945-1 *Evaluation of Cathodic Protection Systems for Marine Bridge Substructures*, December 1998

To obtain copies of a report: CTR Library, Center for Transportation Research,
(512) 232-3126, email: ctrlib@uts.cc.utexas.edu

TxDOT Implementation Status December 2003

The Pharr District presently has a contract underway for Cathodic Protection of the Queen Isabella Causeway, the structure which served as the focus of this research project. A galvanic zinc anode system is being installed as the primary protection system, along with some galvanic aluminum-zinc indium for cost and performance comparisons.

For more information, contact: Tom Yarbrough, P.E., Research and Technology Implementation Office, (512) 465-7403 or e-mail tyarbro@dot.st.tx.us.

Your Involvement Is Welcome!

Disclaimer

Center for Transportation Research
The University of Texas at Austin

The University of Texas at Austin
Center for Transportation Research Library
3208 Red River #115
Austin, TX 78705-2650