RESEARCH
Oregon Department of Transportation

Research Notes

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Zinc Anodes to Protect Coastal Bridges

Oregon is blessed with a beautiful coastline. Unfortunately, transportation structures on the coast must withstand an aggressive marine environment that causes corrosion problems. Many reinforced concrete bridges, some having historical significance, have been damaged by corrosion to the point where they must be replaced. In the late 1980s, the Oregon Department of Transportation (ODOT) began testing two methods to protect bridges – impressed current cathodic protection (ICCP) and sacrificial anode cathodic protection (SACP).

ICCP works by forcing electrical current through the concrete into the reinforcing steel to stop the corrosion. In SACP, no external current is provided; rather, dissimilar metals on the structure create a protective current, much like a battery. For both methods, a conductive material, or anode, is applied to the surface of the bridge so that the electric current can penetrate evenly through the concrete to protect all the reinforcing steel.

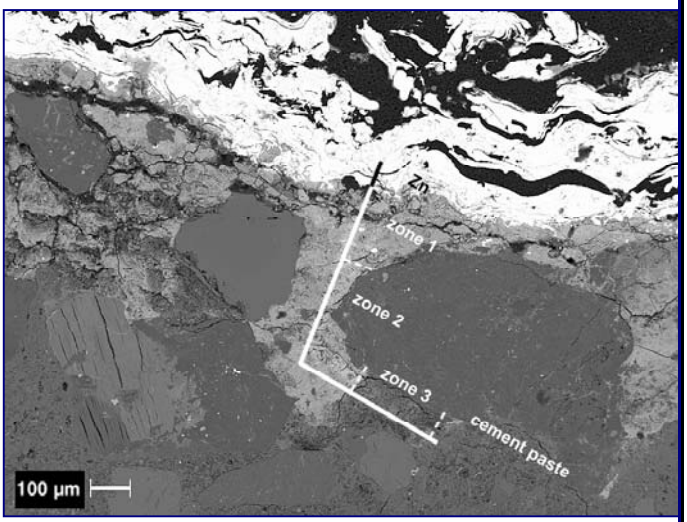
ODOT used a thermal-sprayed zinc metal for most of its anodes. The zinc wire was continuously melted in an electric arc, and the molten metal was propelled onto the concrete at high velocity. Although these systems were proven to work, the life of the anode and the operating characteristics of the cathodic protection systems over the life of the anode were unknown.

Laboratory and Field Studies

ODOT asked the Department of Energy's Albany Research Center to conduct laboratory experiments and field studies to determine the expected life and performance of thermal-sprayed zinc anodes. Laboratory studies were performed on test slabs that were exposed to accelerated aging to simulate up to 24 years of ICCP based on ODOT's electrical operating parameters. Cathodic protection systems that had been in service on bridges up to 12 years were also evaluated. Analyses and measurements were made of anode bond strength, amounts and location of chemical constituents, acidity, and electrical characteristics.

Results

The research documents the performance and requirements of the cathodic protection systems. The service life of thermal-sprayed zinc anodes operating under ODOT's parameters for ICCP is estimated at 27 years. The research shows that over time, changes in interfacial chemistry, as illustrated in the image below, decrease the effectiveness of an ICCP system and reduce the strength of the bond between the zinc coating and



Photomicrograph showing the zinc anode (white) and the substrate. The light-colored gray below the zinc delineates zones within the concrete that have undergone changes in chemistry during cathodic protection.

the concrete. Though accelerated aging tests are not possible with SACP, evidence indicates that the extent of degradation at the interface is much less than in ICCP. However, the amount of protective current decreases over time, and the anode is consumed in the process of protecting the steel.

The findings show that light sandblasting prior to applying the anode is necessary, but preheating the concrete has no beneficial effect. Moisture at the anode-concrete interface is critical for anodes to operate efficiently under both ICCP and SACP.

The results of the research have been used to develop models of zinc anode operation that incorporated bond strength, circuit resistance, interfacial chemistry, and anode condition.

During service, the cathodic protection changes the local conditions around the steel to a less-corrosive environment. Research is ongoing to investigate switching off cathodic protection systems while the steel is in a non-corrosive condition to prolong the anode life.

In addition, the zinc anode research has shown that circuit resistance, calculated from operating voltage and current data routinely collected for ICCP systems, can be used to monitor the condition of the zinc anode. Researchers are investigating the use of circuit resistance for an ICCP anode condition rating that could be incorporated into the Bridge Management System.

Further research will determine the effectiveness of SACP in the Pacific Northwest climate.

Benefits

The specification for preparing the concrete surface prior to thermal spraying was modified as a result of the research. Quantifying the expected life of anodes improved the long-term cost estimates used in planning structure preservation.

By clarifying the degradation and performance mechanisms, ongoing research projects may develop operational procedures to prolong the life of cathodic protection systems and techniques to monitor anode condition.

Request a copy of the report

"Performance of Zinc Anodes for Cathodic Protection of Reinforced Concrete Bridges"

from the Research Group by phone, e-mail, or in person. Or view the report on the Research web page listed below. For more information, contact

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For more information on ODOT's Research Program and Projects, check the website at
http://www.odot.state.or.us/tddresearch/