SPR RESEARCH PROGRAM
SECOND-STAGE PROBLEM STATEMENT
FY 2009

ODOT Research Unit
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I. PROBLEM NUMBER

ST-09-02

II. PROBLEM TITLE

Replacing Thermal Sprayed Zinc Anodes on Cathodically Protected Steel Reinforced Concrete Bridges

III. RESEARCH PROBLEM STATEMENT

ODOT has historic reinforced concrete bridges at the coast that employ impressed current cathodic protection (CP) to greatly reduce the corrosion of the embedded steel reinforcement. The cathodic protection systems rely on passing an electric current into the concrete through zinc metal anodes that have been sprayed onto the surface of the concrete. Some of these zinc anodes are nearing the end of their design lives, while others are beginning to separate from the concrete prematurely possibly due to erratic current controllers or initial contractor inexperience during installation. Anode sections that have debonded no longer protect the underlying steel reinforcement. When the natural rate of corrosion resumes, the unprotected sections are on the path to concrete spalling and steel section loss - the conditions that required ODOT to undertake expensive repairs and protection schemes.

Currently, there is no procedure established by ODOT to remove old anodes, prepare the concrete surface, and install new anodes. In addition, alternative materials such as carbon, titanium, or zinc hydrogel can be used as anodes, but there is no comparison of these alternatives that definitively shows which one would be the most cost-effective replacement.

IV. RESEARCH OBJECTIVES

The objectives of the research are the following: 1) To determine the most cost-effective method to remove existing zinc anodes; 2) To develop a protocol to prepare the concrete surface for the new anode; and 3) To provide lifetime cost analysis for the various anode materials options.

V. WORK TASKS, COST ESTIMATE AND DURATION

To accomplish the proposed objectives, this research will consist of the tasks described below. The Yaquina Bay Bridge had a CP system installed in 1994, and several sections have prematurely failed. One of these sections is the entire surface of Pier 9 on the South end of the bridge. It is anticipated that Pier 9 will be used for the field evaluations listed in the tasks.

Task 1. Survey of the current practice (cost estimated at $10,000; month 1- month 3). A comprehensive literature review will be conducted near the beginning of this project to obtain the state-of-the-practice and the-state-of-the-art information relevant to this project. Information related to new materials, innovative methods, and recent advancements in CP used by other states and other countries will be sought. Publications and reports published by TRB, SHRP, FHWA, NCHRP, UTCs, and state highway agencies will be targeted in the review process. A detailed Internet search will also be conducted using TRIS online, Google Scholar, and SCIFinder Scholar as a starting point. Other DOTs will be contacted to document their experiences with using various materials and methodologies. In addition, the WTI research team will meet with ODOT personnel to determine Oregon's CP field experience and knowledge base from previous research including those in collaboration with the U.S. Department of Energy Albany Research Center.

Task 2. Investigation of zinc anode removal methods (cost estimated at $47,000; month 2- month 6). This task will utilize findings from Task 1 to identify, investigate and compare the various methods used to remove the thermal-sprayed zinc anode. Previous ODOT studies showed zinc anodes reacted with the concrete during cathodic protection. A thin, relatively low pH layer (relative to cement paste) consisting primarily of ZnO and $Zn(OH)_2$ formed at the interface, and a second layer of calcium and zinc aluminates and silicates formed under the first. Both layers contained elevated concentrations of sulfate and chloride ions. Various zinc removal methods (e.g. sandblasting, shotblasting, and high-pressure water blasting) will be evaluated in the field and the laboratory to determine removal performance.

Task 3. Investigation of concrete surface preparation options (cost estimated at $48,000; month 3- month 8). This task will utilize findings from Task 1 to identify, investigate and compare the various methods used to further treat the concrete surface subsequent to the zinc anode removal and prior to the new anode application. Surface preparation is a critical factor for the CP system, as it affects the bond strength and interfacial chemistry of the anode-concrete system and ultimately the performance and service life of the anode. Various surface preparation methods (e.g. chemical cleaning, mechanical cleaning, and flame cleaning) will be evaluated in the laboratory and the field.

Task 4. Investigation of anode materials options (cost estimated at $93,000; month 3- month 16). Laboratory tests will be conducted on anode materials (e.g. carbon, titanium and zinc) and their application parameters to quantify anode performance (bond strength, circuit resistance, interfacial chemistry, electrochemical age, etc.). Such data will be used to predict the anode service life which will be inputted into a life-cycle cost analysis model. If possible, the effect of humectants (chemicals shown to improve performance) will be evaluated and included in the cost analysis.

Task 5. Final report (cost estimated at $22,000; month 15- month 18)

ODOT support and project management: $25,000.

Project cost: $245,000 Duration: 24 months

VI. IMPLEMENTATION

The PI will conduct regular meetings with the ODOT bridge preservation engineers to provide updates on findings and to receive input on project direction. The final report will include procedures and recommendations for anode selection, surface preparation, and application that can be incorporated into field specifications.

VII. POTENTIAL BENEFITS

The research will allow ODOT to specify the most cost-effective approach to replace failing and end-of-life cathodic protection anodes. The outcome will ensure that the ODOT CP systems installed on historic coastal structures will continue to protect those structures and extend their service lives.

VIII. SUBMITTED BY

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