INTERIM REPORT

CATHODIC PROTECTION OF TWO CONCRETE BRIDGE DECKS USING TITANIUM-MESH ANODES

Gerardo G. Clemeña
Senior Research Scientist

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

Virginia Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the
Virginia Department of Transportation and
the University of Virginia)

In Cooperation with the U.S. Department of Transportation
Federal Highway Administration

Charlottesville, Virginia

January 1991
VTRC 91-IR5

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INTRODUCTION

Expanded titanium mesh with a layer of precious metal oxides sintered around it has recently been introduced to fulfill the need for a durable anode in the cathodic protection (CP) of concrete bridge decks. In addition to being resistant to chemical attack, the titanium mesh (1) provides relatively high electrical redundancy, (2) requires minimal labor to install, and (3) is compatible with concrete overlays.

To provide the Virginia Department of Transportation with an opportunity to observe and gain experience with the use of this promising type of anode, plans were formulated to use titanium mesh from three different manufacturers in a CP system as part of the rehabilitation of two existing concrete bridge decks that had salt-induced concrete deterioration.

CONSTRUCTION OF THE CP SYSTEM

The bridge decks selected were those of structures 2038 and 2039, which carry the northbound and southbound lanes, respectively, of Interstate 81 over Route 640 in Botetourt County, Virginia. The plans involved installing the three mesh anodes separately in their respective assigned spans (see Table 1) after repair of the deteriorated concrete and prior to the subsequent application of latex-modified concrete (LMC) overlays.

To facilitate remote monitoring of the CP system from any bridge office, an automatic data acquisition system similar to the one being tested in another CP system in Shenandoah County, Virginia, was placed in the rectifier.

Installation of Mesh Anodes and Probes

The repair of the decks started in September of 1989. First, the concrete surface of the slow lanes of the dual-lane bridges was scarified to a depth of at least 1/2 in. This was followed by the removal of the damaged concrete to partial depth (at least 3/4 in below the top-mat rebars) or full depth, if necessary, and sandblasting of the exposed rebars. Then, the construction of the CP system proceeded with the installation of the mesh anodes and corrosion rate probes as follows:

1. Testing for electrical continuity between the rebars in each span.
   This test was conducted while many of the rebars were still exposed to ensure that none of these would be left isolated and unprotected.

2. Survey of concrete cover of the top-mat rebars to locate any rebar or other steel with concrete cover of less than 1/2 in.
   Shallow rebars, steel, or the concrete areas above them were then covered with vinyl-ester resin to prevent shorts between the anodes and these rebars.

3. Installation of corrosion rate probes (a total of two in each span) at locations with the highest rebar potentials.

4. Installation of the mesh anodes, under the guidance of representatives from each manufacturer after all concrete patching was completed.
   After the installation the anode-to-rebar resistance in each span was checked to ensure that none was less than 10 ohms, which would indicate the existence of shorts between the mesh and the rebars. No shorts were found in any span.

5. Placement of LMC overlay.
   During the placement, it is usually impossible to avoid movement of the installed mesh, which may cause the mesh to come in contact with shallow steel or rebars that may have escaped detection, thereby creating shorts. Because of the possibility of this happening, the placement was constantly monitored to ensure that if any short occurred, it could be corrected immediately before the overlay cured.

These procedures, which were conducted by the contractor with the assistance of a corrosion engineer from the Corrpro Companies, Inc., of Medina, Ohio, were repeated on the passing lanes of both decks.

For future comparison, two nearby concrete decks (structures 2026 and 2027) that were also being repaired were similarly instrumented with the rebar corrosion rate probes.

Wiring the System

As specified, all of the lead wires for the anodes and the system grounds in each deck were routed in a PVC conduit to the rectifier that is located in the median at the south end of the two bridges. Similarly, the lead wires for the probes were routed in another conduit. The AC input of the rectifier, which is manufactured by MP Power Company of Houston, Texas, is rated at 115 volt, 60 Hertz, single phase, with a tolerance of 30 amps. The rectifier has six circuits; each has a maximum output of 24 volts at 12 amperes.

All wiring and connecting of the system was conducted by a subcontractor and tested by the engineer from Corrpro before energization of the system. Table 1 shows the designations of the various components of the system.

SYSTEM ENERGIZATION

Prior to energization of the system, the resistances between the different components of the CP system were measured for use as baseline data. The initial rebar potentials and corrosion rates of the rebars, adjacent to the embedded probes in each span, were also measured. The results are presented in Table 2.

After these measurements, the system was energized on March 8, 1990. Attempts by Corrpro's engineer to obtain an E-vs-log I curve for each circuit failed. Without the benefit of these curves, the rule-of-thumb of 0.75 to 1.5 mA/ft^2 of concrete area was used by the engineer. Therefore, the DC output of each circuit was adjusted to provide an initial current density of approximately 1.5 mA/ft^2 of concrete area. Table 3 shows the corresponding settings on the rectifier and the resulting rebar potentials.

ACCEPTANCE TESTINGS AND FINAL SYSTEM ADJUSTMENTS

After its energization, the system was left to operate for 30 days before conducting the acceptance tests and the final adjustment of the system (all as required in the specifications). On April 30, 1990, an attempt was made by the engineer from Corrpro to conduct these procedures. However, it was found that all six circuit controller boards in the rectifier were damaged.

Subsequent investigation at the site by a representative from the manufacturer of the rectifier indicated that the rectifier was damaged by lightning. Further investigation revealed that these decks, contrary to the assumption that bridges are naturally grounded through their reinforcement, were not grounded to earth. It is, therefore, believed that lightning had struck one of the decks and caused a subsequent electrical surge in the rectifier. All the controller boards were repaired, and the system was re-energized on June 28, 1990, to the original current settings (see Table 3).

Depolarization Tests

Depolarization tests were specified as part of the final testing of the CP system before its acceptance by VDOT. The tests, which were performed on July 30, 1990, indicated that the resulting average polarization decays ranged from 172 to 455 mV within 4 hours after the current outputs to all six circuits were interrupted (see Table 4). The magnitude of these decays indicated that, based on the minimum of 100-mV shift recommended in the National Association of Corrosion Engineers (NACE) Standard No. RP0290-90, the decks were more than sufficiently polarized (or protected) at the current settings shown in Table 3.

Table 4 also shows that the current settings on circuits 1, 4, 5, and 6 were polarizing the rebars probably more than necessary. Consequently, the current output settings for these circuits were reduced accordingly by the Corrpro engineer on July 31, 1990 (see Table 5). The system was left to operate overnight before another set of depolarization tests were conducted. The results of these tests (Table 4) showed the intended reductions (although not as much as aimed for) in the polarization decays for the aforementioned circuits. Further, there was a reduction in the decay of polarization in circuit 3. Based on these results, the system was further fine tuned on August 1, 1990 (see Table 5).

Measurement of the Resistances of Components

The electrical resistances of some of the components were measured again during the final testings. The results, which are presented in Table 6, showed that the anode-to-structure resistances in all circuits had increased since the start of the operation. It is expected that this resistance would increase during the first several months of the operation of a CP system. Meanwhile, the resistance between each reference electrode and its ground had decreased with the exception of that for reference electrode 2 in span B.

SUMMATION

Based on the data obtained during the pre-energization and final acceptance testings, the CP system appeared to be functioning as it was designed to. As expected, the titanium-mesh anodes were simple to install. No definitive differences between the three anodes have been observed yet. The remote monitoring unit is functioning properly. It allows readings of the current and voltage outputs of all circuits and the rebar potentials from anywhere in the country through the telephone number that is assigned to the system by the local telephone company.

In view of the damage that had occurred to the circuit controller boards in the rectifier as a result of the absence of natural grounding in the structures, a simple and effective way to ground these structures to earth should be considered. Further, when preparing specifications for future CP systems, it may be necessary to require that the structures involved be grounded, just as grounding of the rectifier is required.

ACKNOWLEDGMENT

Appreciation is extended to the Federal Highway Administration for funding this demonstration project and to Dow Chemical, Elgard Corporation, and Imperial Chemical Industries for providing their titanium-mesh anodes free of charge.

Table 1

DESIGNATIONS OF COMPONENTS IN THE CATHODIC PROTECTION SYSTEM

Structure	Span	Area (sq ft)	Anode/ Manufacturer	Rectifier Circuit No.	Anode Wire No.*	Corr. Rate Probe No.	Ref. Electrode No.	Lead Wire No.*
2039 (SBL)	A	2016	Lida/ Dow Chemical	1	1,2,3	1987	1	6
						1984	2	7
	B	1974	Elgard 150/ Elgard	2	4	1990	1	3
						1989	2	5
	C	1680	Tectrode S6/ ICI	3	5,6	1994	1	1
						1974	2	2
2038 (NBL)	A	2016	Lida/ Dow Chemical	4	4,5,6	1986	1	7
						1985	2	6
	B	1848	Elgard 150/ Elgard	5	3	1988	1	5
						1991	2	4
	C	1680	Tectrode S6/ ICI	6	1,2	1975	1	2
						1995	2	1

* From the bridges

Table 2

PRE-CATHODIC PROTECTION CONDITIONS OF THE DECKS (MARCH 8, 1990)

Structure	Span	Circuit	Anode	Resistance (ohm) Anode-to-Structure	Resistance (ohm) Ref. Elect. -to-Ground	Resistance (ohm) Ctr. Elect. -to-Ground	Initial Ref. Elect Pot. (mv)	Initial Corrosion Rate (mpy)
2039 (SBL)	A	1	Lida	0.32	170	230	–63	1.85
					190	270	–11	1.78
	B	2	Elgard	0.28	190	340	–209	1.59
					380	300	–174	1.54
	C	3	Tectrode	0.36	260	250	–176	1.47
					130	240	–227	2.82
2038 (NBL)	A	4	Lida	0.28	160	240	–92	2.04
					150	180	–92	2.20
	B	5	Elgard	0.33	190	300	–227	1.32
					170	330	–141	0.74
	C	6	Tectrode	0.45	150	400	–71	1.10
					170	260	–95	0.90

Table 3

INITIAL ENERGIZATION DATA

Structure	Span	Circuit	Current		Voltage	Potential (mV)	
			(A)	(mA/sq ft)	(V)	RC–1	RC–2
2039	A	1	3.0	1.49	2.6	–674	–669
	B	2	3.0	1.52	2.0	–431	–420
	C	3	2.5	1.49	2.0	–452	–444
2038	A	4	3.0	1.49	1.9	–517	–522
	B	5	3.0	1.62	2.4	–702	–648
	C	6	2.5	1.49	2.4	–556	–580

Table 4

POLARIZATION DECAYS OBSERVED IN DEPOLARIZATION TESTS

Circuit	Polarization Decay (mV)					
	07/30/90			08/01/90		
	RC–1	RC–2	AVG.	RC–1	RC–2	AVG.
1	464	445	455	424	407	416
2	199	146	173	200	145	173
3	154	189	172	111	153	132
4	398	365	382	344	338	341
5	376	400	388	311	355	333
6	424	482	453	339	389	364

Table 5

OPERATIONAL SETTINGS IN THE RECTIFIER

			03/08/90		07/31/90		08/01/90	
Structure	Span	Circuit	Amp	V	Amp	V	Amp	V
2039	A	1	3.0	2.6	2.2	1.7	1.5	1.3
	B	2	3.0	2.0	3.2	2.2	3.2	2.0
	C	3	2.5	2.0	2.5	2.3	2.9	2.2
2038	A	4	3.0	1.9	2.2	1.5	1.5	1.2
	B	5	3.0	2.4	2.0	1.9	1.5	1.4
	C	6	2.5	2.4	1.5	1.9	1.0	1.4

Table 6

ELECTRICAL RESISTANCES OF SOME COMPONENTS
(JULY 31, 1990)

			Resistance (ohm)			
Structure	Span	Circuit	Anode-to-Structure	Change* (%)	Ref. Elect. -to-Ground	Change* (%)
2039 (SBL)	A	1	0.33	(3.1)	120	(–29.4)
					150	(–21.1)
	B	2	0.31	(10.7)	150	(–21.1)
					430	(13.2)
	C	3	0.41	(13.9)	240	(–7.7)
					93	(–28.5)
2038 (NBL)	A	4	0.28	(0.0)	120	(–25.0)
					110	(–26.7)
	B	5	0.36	(9.1)	145	(–23.7)
					130	(–23.5)
	C	6	0.47	(4.4)	110	(–26.7)
					130	(–23.5)

*In comparison to the pre-CP conditions.