CONSTRUCTION AND FIRST YEAR OPERATING REPORT

FEDERAL HIGHWAY ADMINISTRATION
DEMONSTRATION PROJECTS DIVISION
PROJECT NO. 34

Work Order DTFH71-85-34-IA-15
Iowa DOT Project HR-1044

IOWA SYSTEM OF BRIDGE DECK REHABILITATION WITH CATHODIC PROTECTION

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BACKGROUND

Bridge deck and substructure deterioration due to the corrosive effects of deicing chemicals on reinforcing steel is a problem facing many transportation agencies. The main concern is protection of older bridges with uncoated reinforcing steel.

Many different methods have been tried over the past years to repair bridge decks. The Iowa system of bridge deck rehabilitation has proven to be very effective. It consists of scarifying the deck surface, removing any deteriorated concrete, and overlaying with low slump dense concrete.

Another rehabilitation method that has emerged is cathodic protection. It has been used for many years in the protection of underground pipelines and in 1973 was first installed on a bridge deck. Cathodic protection works by applying an external source of direct current to the embedded reinforcing steel, thereby changing the electrochemical process of corrosion. The corroding steel, which is anodic, is protected by changing it to a cathodic state.

The technology involved in cathodic protection as applied to bridge decks has improved over the last 12 years. One company marketing new technology in cathodic protection systems is Raychem Corporation of Menlo Park, California. Their system utilizes a Ferex anode mesh that distributes the impressed direct current over the deck surface. Ferex mesh was selected because it seemed readily adaptable to the Iowa system of bridge deck rehabilitation. The bridge deck would be scarified, deteriorated concrete removed, Ferex anode mesh installed, and overlaid with low slump dense concrete.

The Federal Highway Administration (FHWA) promotes cathodic protection under Demonstration Project No. 34, "Cathodic Protection for Reinforced Concrete Bridge Decks."

The Iowa Department of Transportation submitted a proposal to the FHWA to participate in the demonstration project and to research an installation that combined the Iowa system with cathodic protection.

PROJECT LOCATION AND CONDITION

The Raychem Corporation cathodic protection system was installed on the eastbound bridge on U.S. 30, 1.3 miles east of the junction with U.S. 69 (Station 1303 + 20.00 U.S. 30, Story County). The bridge was built in 1963 and is a continuous welded girder with a 7-1/4-inch reinforced concrete deck. It has approximately 9600 square feet (skewed 320' x 30') of deck surface.

The Iowa Department of Transportation performed a bridge deck survey prior to the installation of the cathodic protection system. The survey included the following: (1) visual survey of the deck, (2) delamination map of the deck, (3) chloride content at the top mat of reinforcing steel, (4) concrete cover over the top mat of reinforcing steel, and (5) corrosion potential map of the deck.

The visual survey showed several asphaltic concrete patches in the deck. The delamination map (Appendix A) showed 635 square feet of delaminated area. Cores of the deck were taken and the chloride contents (Appendix B) at one and two inches were determined. A Pachometer was used to make a map of the concrete cover over the reinforcing steel (Appendix C). Corrosion potentials were determined by a copper - copper sulfate half-cell and a map (Appendix D) was made. The results obtained showed a correlation between the areas of delamination and the areas with shallow concrete cover, high chloride contents, and high corrosion potentials.

CONTRACTS AND CONTRACTORS

On January 23, 1985, the Iowa Department of Transportation let a contract (Appendix E) for the bridge deck rehabilitation. A work plan was written on May 1, 1985, and sent to the Demonstration Projects Division of the Federal Highway Administration to incorporate a cathodic protection system into the rehabilitation work. A Cooperative Work Order Agreement was entered into on May 22, 1985, between the Iowa Department of Transportation and the Federal Highway Administration. The Iowa Department of Transportation then issued an Extra Work Order (Appendix F) on July 22, 1985, for the cathodic protection system.

Waterloo Construction Company, Inc. of Waterloo, Iowa, was the successful bidder for the bridge deck rehabilitation. Cathodic protection system was installed by Waterloo Construction. The electrical work involved in the cathodic protection system installation was subcontracted to Dickenson Electric Company, Inc. of Oskaloosa, Iowa. The cathodic protection system was supplied by Raychem Corporation of Menlo Park, California.

BRIDGE DECK PREPARATION

The bridge deck was rehabilitated under traffic so that one lane was open to traffic at all times. The deck was prepared in accordance with 1984 Iowa Standard Specifications for Highway and Bridge Construction, Section 2413.05 (Appendix G). The deck required only Class A bridge floor repair. Approximately 1250 square feet or 13% of the deck surface and unsound concrete was removed down to the level of the top mat of reinforcing steel (Appendix H).

Other preliminary work included construction of a cast-in-place concrete barrier wall on top of the curb. Epoxy-coated reinforcing steel was used in the barrier wall. Special care was taken so that the epoxy-coated steel did not make contact with any embedded steel in the curb. This kept the barrier wall isolated from the cathodic protection system.

INSTALLATION OF CATHODIC PROTECTION SYSTEM

The design of the cathodic protection system was accomplished by Raychem Corporation. A key factor in the design was that the installation had to be done in two phases so that one lane of the bridge could be open to traffic at all times. Raychem furnished complete plans for the installation to the contractors and also provided trained personnel to supervise the installation.

On July 24, 1985, preparation of the south lane was completed. The skies were overcast with light showers developing. Bill Green, Raychem's Application Engineer, decided to complete the steel continuity testing (Appendix I) and wait for the weather to clear. The testing revealed that the steel drains in the gutter were discontinuous and would have to be electrically connected to the other steel.

The next day, July 24, 1985, installation of the cathodic protection system began. To have access to the connections and wirings, three holes, each three inches in diameter, were drilled through the deck. The holes were located near the curb with one at each end of the bridge and at the midpoint. These holes were used to run wiring through the deck to conduit located on the underside.

Silver/silver chloride reference cells and rebar probes were placed in the predetermined excavated areas. Also, system negative and instrument negative ground connections were made. The wiring for these components was run along each edge of the pour to protect the No. 10-AWG wire from the construction traffic. The metal drains were made electrically continuous by cadwelding a wire between the exposed reinforcing steel and the drain.

The next step was to ready the panel mounting rods. Dual cleats were snapped on the rods at premarked eight-inch intervals. The rods were then laid out end to end two inches from the gutter down the length of the bridge. They were fastened down at every third dual cleat by drilling a 1/4-inch diameter hole one inch deep and inserting a plastic push pin through the dual cleat.

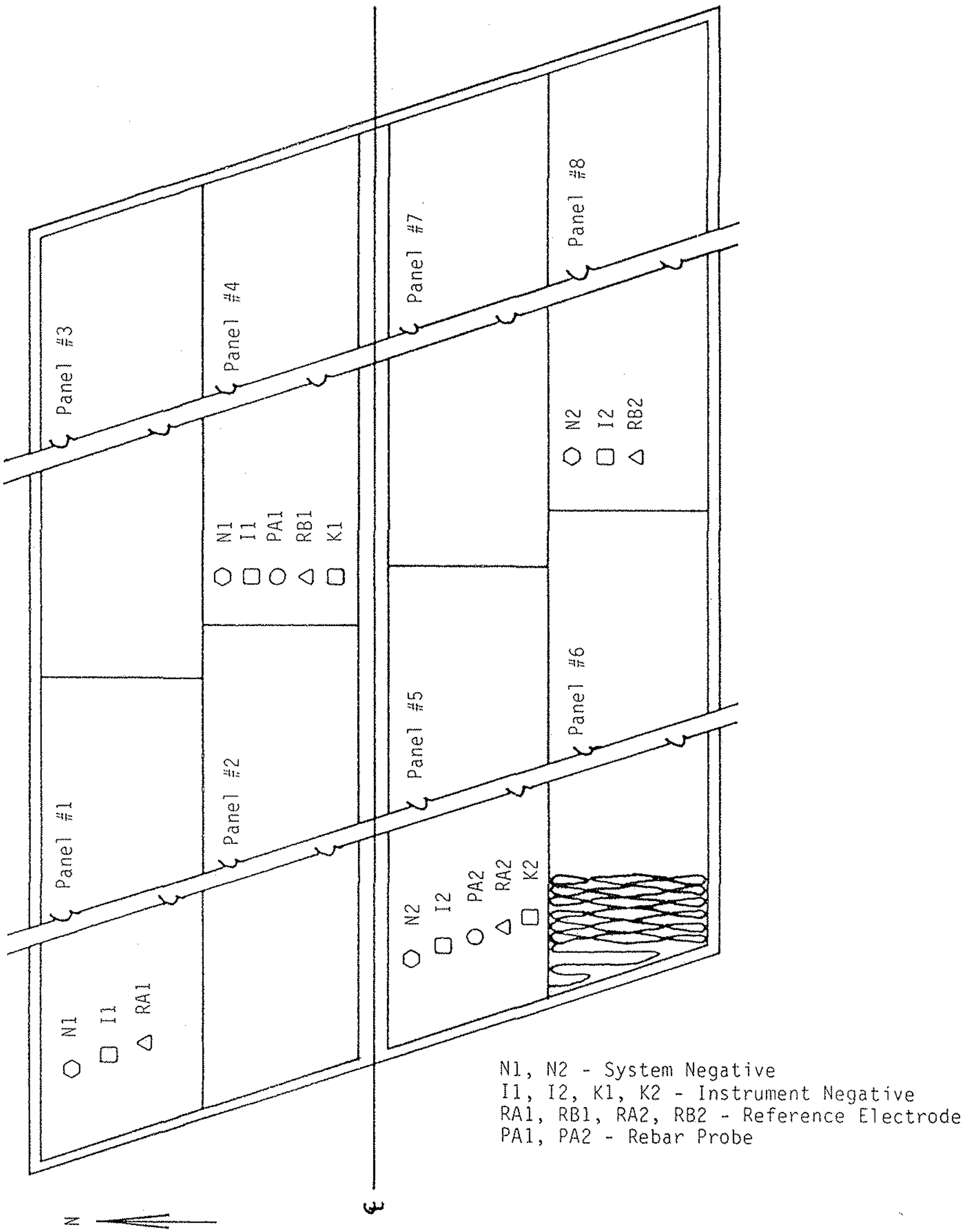
The Ferex anode mesh came rolled in a mat that was seven feet wide and 167 feet long. Four mats would be placed (See Diagram 1) in the lane arranged with two mats side by side to cover the 15 feet wide and 320 long deck surface.

The first mat panel number 6, was rolled out over the deck along the panel mounting rods. Because the bridge has a skewed end, the mat was left long to cover that area. The loops on the edge of the mat were fastened to the dual cleats on the panel mounting rods. This gave the proper spacing to the serpentine weave of the mat.

Another series of mounting rods were run down the other edge of the mat at the centerline of the lane. Again, the loops on the edge of the mat were fastened to the dual cleats. The rod was pulled tight causing the mat to lay flat. The rods were fastened down through the dual cleats using the same procedure as before with the plastic push pins. Approximately every four square feet the mat was fastened down with the push pins. Also, areas where the mat did not lay flat were fastened down.

The second mat, panel number 8 was placed as a continuation from panel number 6 from the midpoint of the bridge to the other end. The same procedure was used in installing this panel.

Diagram 1 - Layout of Anode Panels and Electrical Components



With this completed, the next two mats could be installed along side the other two. The panel mounting rods that were fastened down on the centerline of the lane were then used to fasten the loops on the edges of the third and fourth mats, panels number 5 and 7, respectively. Another series of mounting rods were run on the other side of the mats at the centerline of the bridge. The same procedure as before was followed to fasten them down.

The next day, July 26, 1985, work began on supporting the anode mats over the Class A repair areas. The anode mat must not come in contact with any exposed steel. It is necessary to have a 1/2" minimum clearance, and more desirable to have 3/4" clearance, between the anode and the steel. Much consideration was given to filling repair areas ahead of time to avoid any possibility of the anode contacting the exposed steel. It was decided that special rebar clips could be used to act as stands to support the mat over repair areas. After a trial installation of these special clips, it was determined that these clips were not capable of supporting the mesh. The concept as described below was used to install mesh over repair areas.

Small repair areas of five square feet or less were bridged by fastening down the cleats around the perimeter of the excavated area. This gave enough tension so that the mat would not sag and contact the exposed steel.

In larger repair areas it was decided not to bridge them but to alter the mat's weave and run the anode strands between the exposed transverse reinforcing steel. The transverse reinforcing steel was located on top of the longitudinal reinforcing steel. By placing the anode this way, there was 3/4" clearance of concrete between the anode and the longitudinal steel. As an added precaution, cleats were snapped onto the anode where it crossed any exposed reinforcing steel to prevent contact. These same procedures for small and large repair areas were repeated across the bridge.

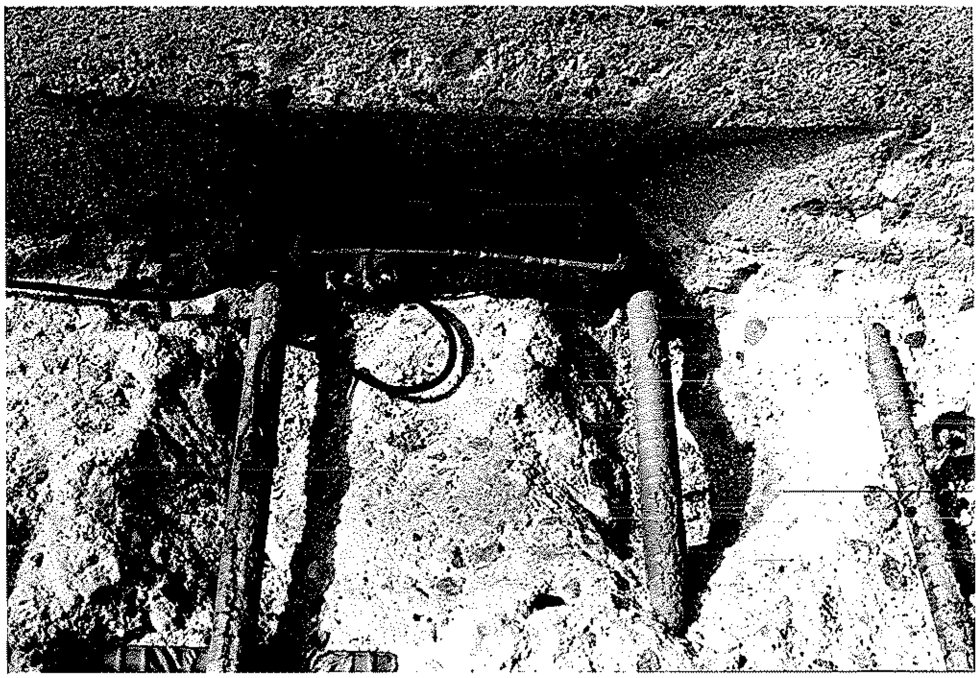


Figure 2 - Discontinuous drains being connected

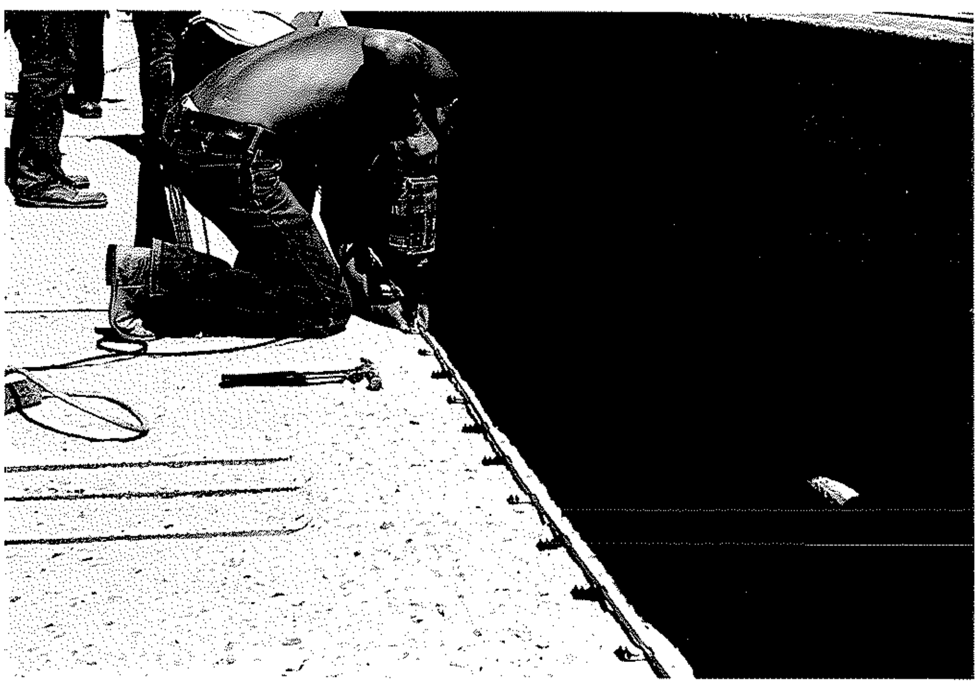


Figure 3 - Installing panel mounting rods

Figure 4 - Rolling out first anode mat

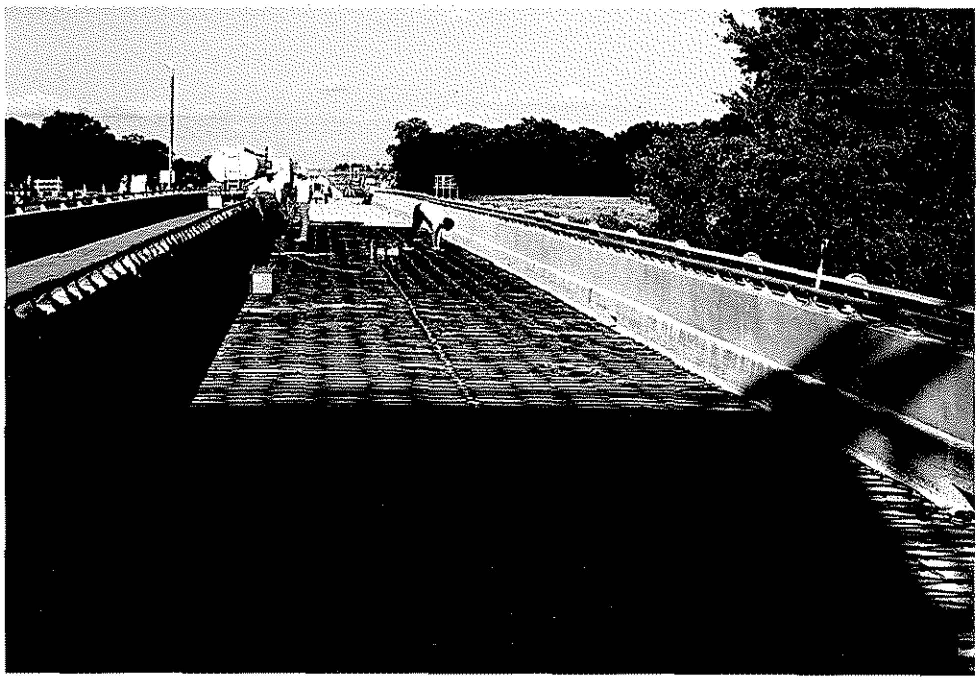


Figure 5 - Overview of entire deck with mats

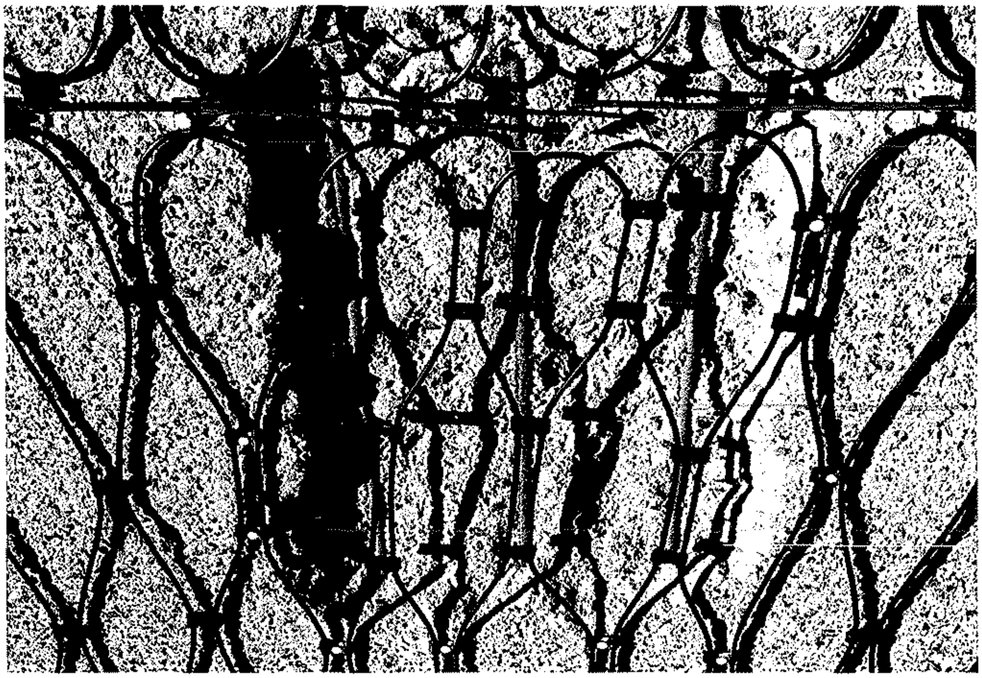


Figure 6 - Small repair areas

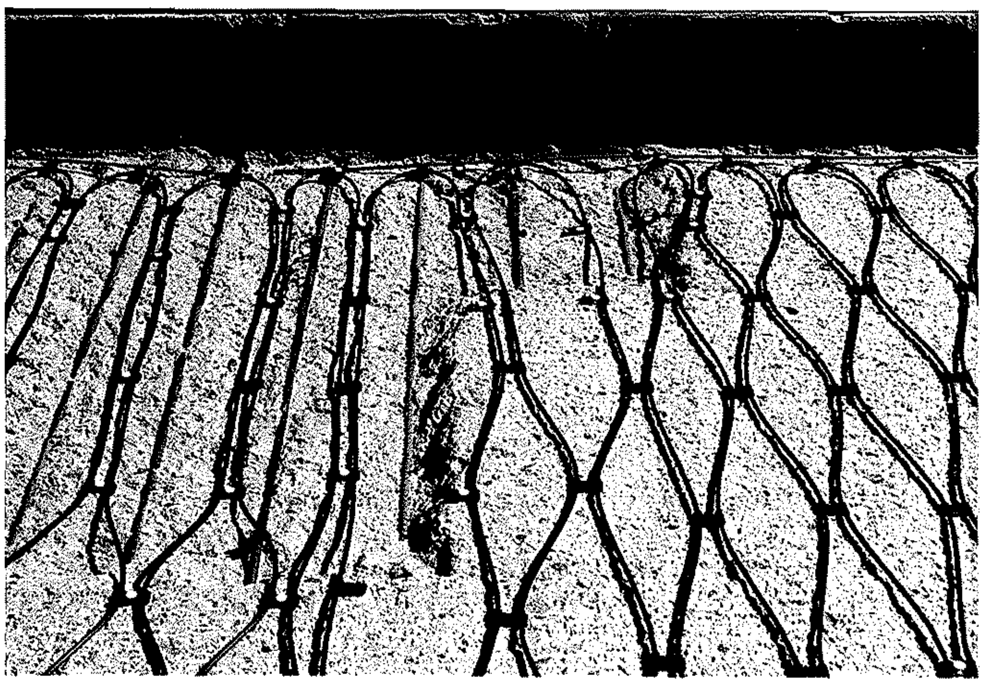


Figure 7 - Large areas - altered pattern

Figure 8 - Hand woven ends at raised plates

Figure 9 - Heat shrink tubing splices

OVERLAY PROCESS

In the afternoon of July 26, 1985, the overlay process began. The 1984 Iowa Standard Specifications for Highway and Bridge Construction, Section 2413 (Appendix J) were followed.

Installation of the anode mats was completed to prevent conflicts with the contractor's normal operations. Some modifications had to be made. A plywood runway was placed over the anode for the concrete delivery buggies. This was to protect the anode mats from the weight of the loaded buggies. Orange cones were set up along the runway to identify areas to be avoided.

Normally, bonding grout is applied to the deck by brooming. It was not practical to use the brooms to apply the grout because of the anode mats on the deck. The contractor was permitted to apply the grout by spraying. A sprayable portland cement and water slurry was used.

The overlay process began with the buggies traveling down the runway and depositing the concrete. Workmen leveled out the concrete in front of the Bidwell finishing machine. Special care was used not to knick or sever the anode mat with the shovels.

The smaller repair areas with free spanning anode mats were filled with a few scoops of concrete and hand vibrated just in front of the paver. This was done to prevent depression of the anode mat and contact with the steel. Once filled, workmen could walk over them without concern. This operation really didn't require extra workmen for the contractor since by specification they are already required to hand vibrate repair areas with concrete 3 inches or more in thickness.

The same procedure of spraying on the bonding grout, depositing and shoveling the concrete, filling and vibrating small repair areas with concrete, and coming over with the finishing machine was repeated the length of the bridge. The larger repair areas which had the mat unwoven and fastened down also required, by specification, hand vibrating.

As a precaution, the resistance in the anode mat was monitored during construction so that if contact with the steel was made, the work could be stopped and the problem located.

To satisfy concerns of how the vibratory action of the finishing machine effected the anode mat, a small finished area of approximately three square feet was removed behind the paver. It was found that the bonding grout had flowed underneath the anode strands and the mat had not shifted from its intended location. No evidence of the anode mat floating up in the overlay was found.

On August 6, 1985, the north lane of the bridge was placed. The same procedures were used except that a layer of burlap was used as a runway instead of the plywood. This is the contractor's normal procedure on deck overlays to catch any spills from the buggies. Raychem assured us that the anode mat would not be damaged. The underside of the anode, after the buggies had run over it numerous times, developed very small abrasions which were not considered detrimental to the performance of the anode.

Figure 10 - Bridging over large repair area

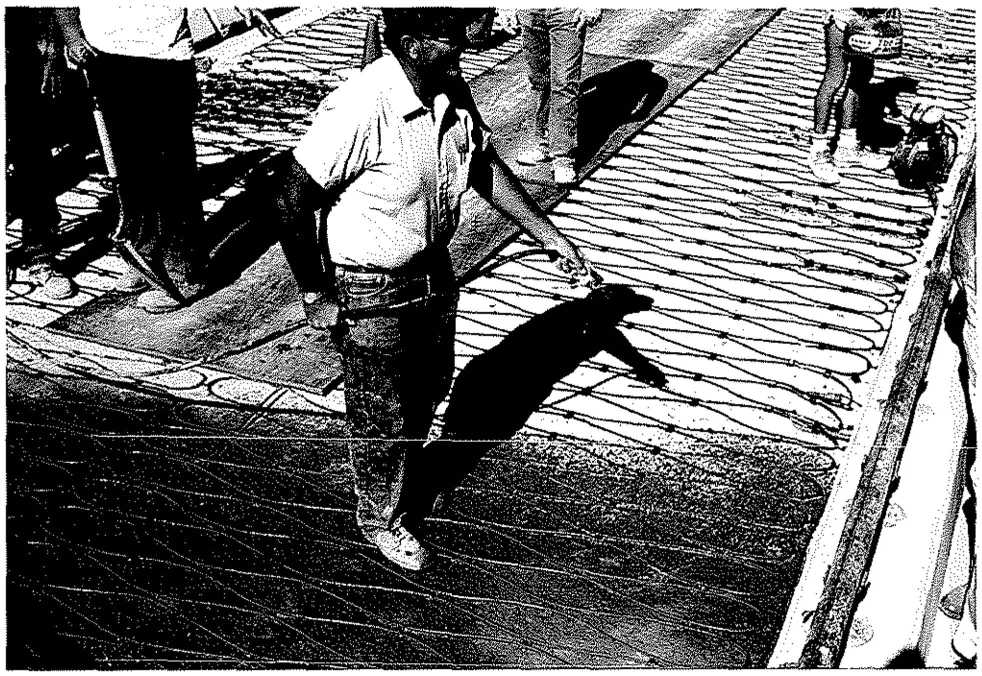


Figure 11 - Grout spraying

Figure 12 - Puddling in front of paver

Figure 13 - Filling and vibrating small repair area

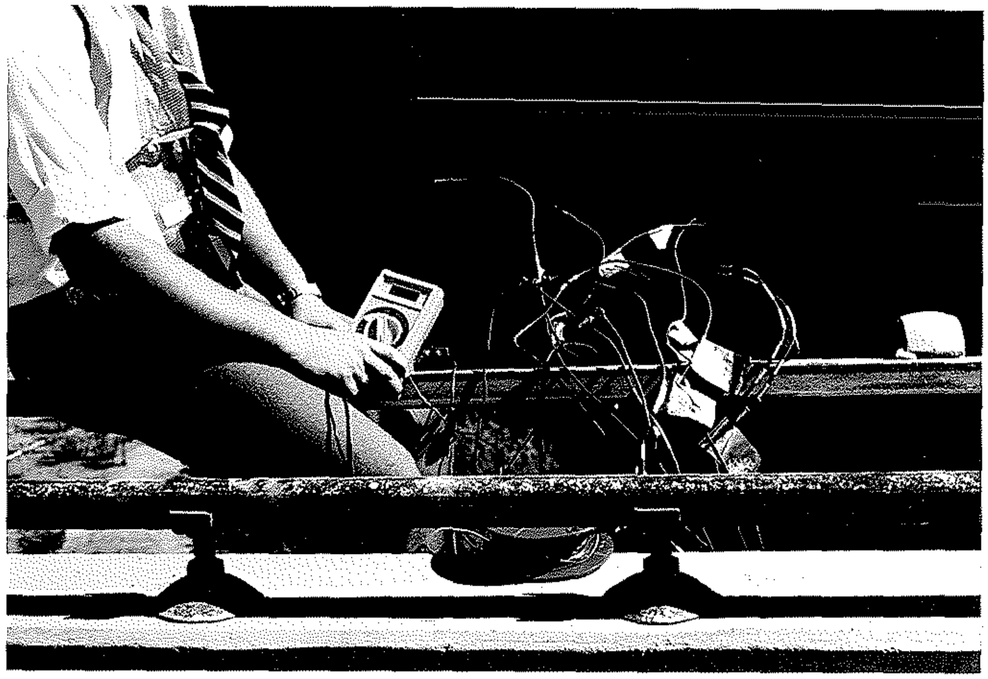


Figure 14 - Monitoring resistance

Figure 15 - Excavated area behind paver

POST CONSTRUCTION AND SYSTEM START-UP

Subsequent electrical work was completed by running the wiring through conduits to the control boxes located on the inside of the northeast wing wall. There was one conduit on both sides of the bridge along the outside of the girder. The south conduit came across the east abutment to the control boxes.

The rectifier is a 25 volt, 24 amp constant current unit with two outputs each rated at 25 volts and 12 amps. The control resistance box (CRB) is a four circuit output unit. The units were mounted on the inside of the wingwall to help protect them from the weather. A steel cage was placed around them to prevent vandalism.

The electrical power needed for the system was obtained from an overhead power line servicing a billboard sign approximately 800 feet east of the bridge. A power line was trenched in down the right-of-way and under the twin bridges to the control boxes.

Start-up of the system was initiated on September 25, 1985. Raychem personnel were present to adjust the system to the theoretical values calculated for adequate protection. The system was monitored every week for the next four weeks for a stabilization period. On October 23, 1985, a four-hour depolarization test was conducted to check for the 100 millivolt shift.

Figure 16 - Conduit runs

Figure 17 - Control boxes on wing wall

COSTS

The costs associated with the cathodic protection system were as follows:

Contractor's Labor	$ 6,479.74
Raychem Corp. - Materials (Ferex anode mats, cleats, push pins, mounting rods, and splices)	32,448.00
Electrical Materials and Labor (Conduit and wiring)	26,800.00
Bonding Grout Sprayer	800.00
Small Tools and Incidental Materials	2,680.00
Plywood for Runway	1,044.00
Contractor's Overhead	7,335.76
	==========
TOTAL	$77,587.50

The cost of cathodic protection system calculates to be $8.08 per square foot of deck surface. These costs do not include deck preparation and concrete overlay or traffic control.

FIRST YEAR MONITORING

During this first year, investigations were carried out to determine the affect on bonding of overlay due to the presence of anode mats. A Delamtect was used shortly after the bridge was opened to survey for delaminations. No delaminations were detected. After one year, another delamination survey was conducted revealing no delaminations.

During the summer of 1986, the bridge was painted under a maintenance contract. To protect the control boxes from fugitive sandblasting dust, the system was shutoff and the control boxes covered with plastic. However, when the system was restarted after two weeks a circuit board in the rectifier burned up. It was speculated that dust or moisture may have been present and caused the circuit board to spark. A new circuit board was obtained from the manufacturer at no cost since it was still under warranty.

The system performance was monitored regularly as indicated in Appendix K. Six depolarization tests were conducted during the year to detect the 100 mV shift. The system was adjusted to insure adequate protection.

The average monthly power consumption was 69 kilowatts. The monthly cost of power was $10.10. Monthly data for consumption and cost is in Appendix L.

CONCLUSIONS

1. Raychem's Ferex anode system of cathodic protection is readily adaptable to construction methods used in the Iowa System of bridge deck repair.

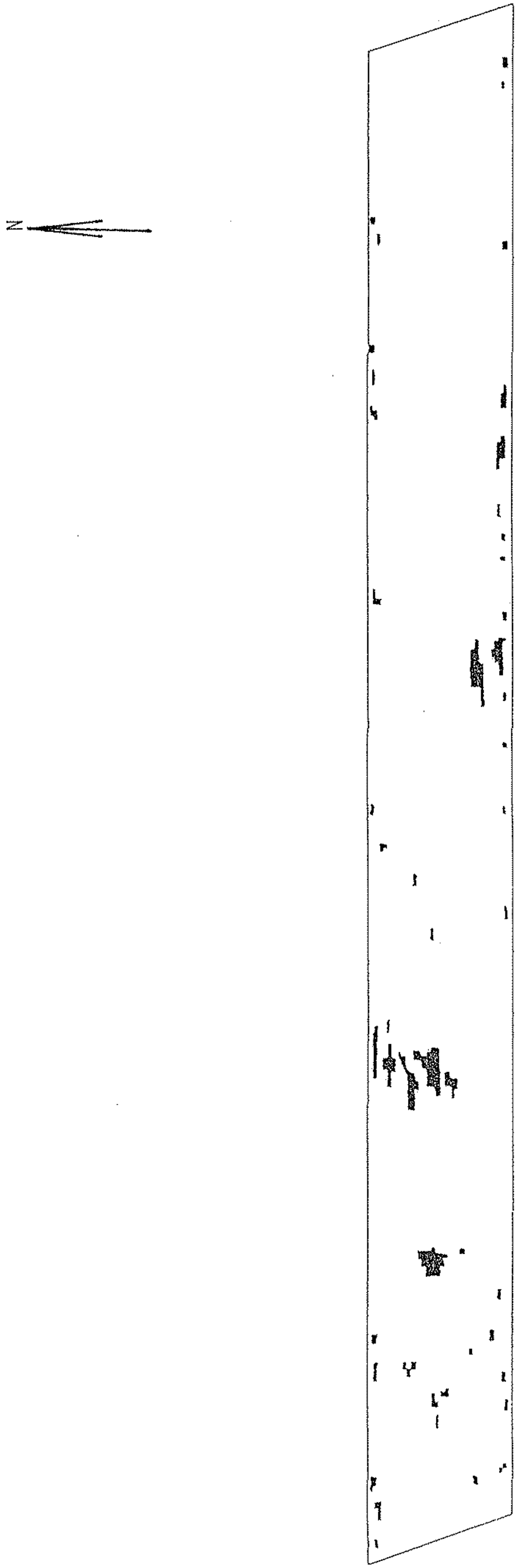
2. After one year, the anode mats have not affected the bonding of the overlay as evidenced by delamination surveys.

3. Data to date indicates that the reinforcing steel is being adequately protected.

ACKNOWLEDGEMENTS

A special thanks to Ron Risting, Gary Evans, and Terry Tuloff, all of Waterloo Construction; to Dave Dickenson of Dickenson Electric, and to Bill Green, Joe Brick, and Bruce Rodgers all of Raychem. Also thanks to the many people in the Iowa DOT and the FHWA for their help.

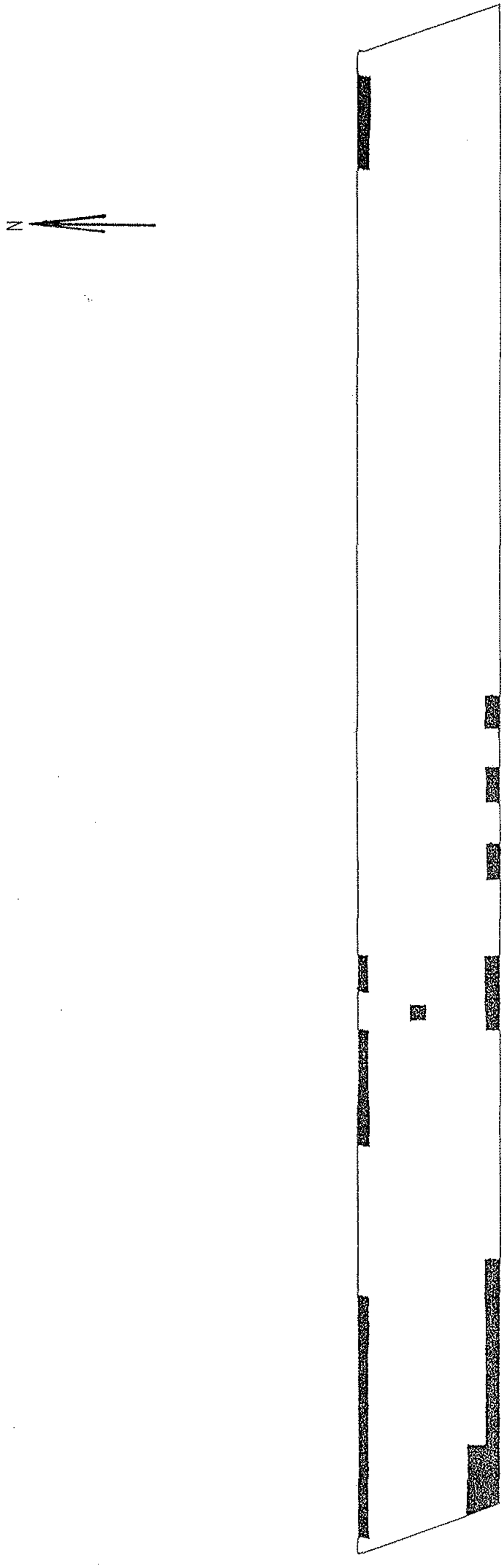
Appendix A
Delamination Map



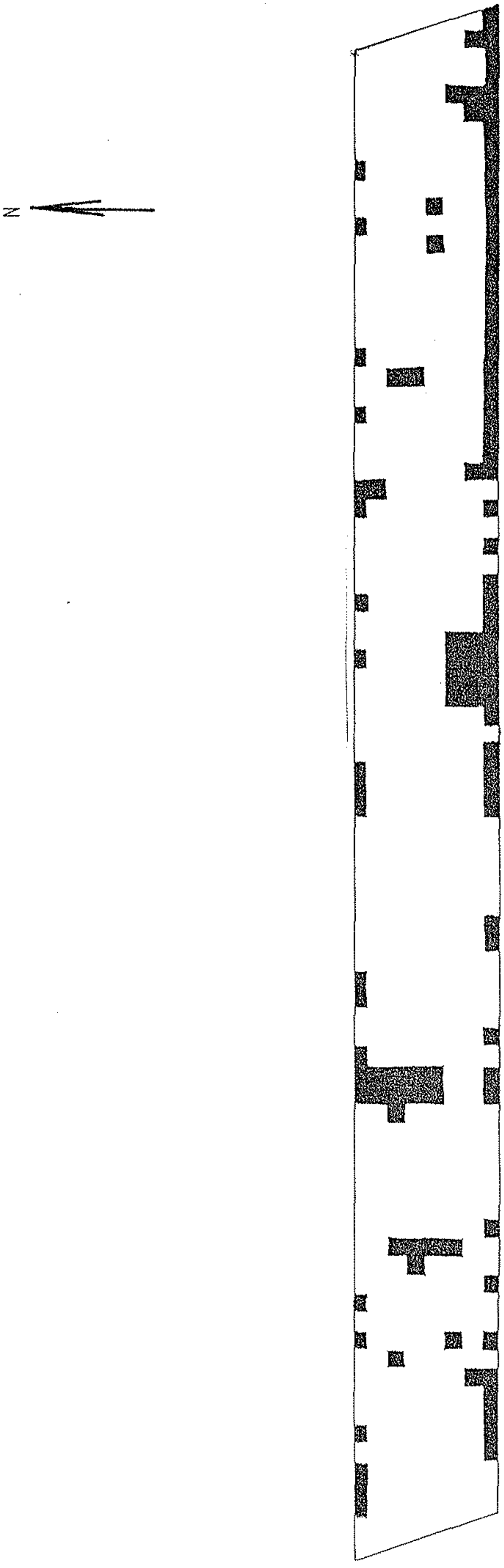
CHLORIDE CONTENTS

Sample No.	0-1 inch depth	1-2 inch depth
1	7.3 lbs./yd^3	2.7 lbs./yd^3
2	12.4 lbs./yd^3	4.9 lbs./yd^3
3	12.9 lbs./yd^3	6.2 lbs./yd^3
4	17.7 lbs./yd^3	1.4 lbs./yd^3
5	22.8 lbs./yd^3	13.0 lbs./yd^3
6	7.9 lbs./yd^3	2.4 lbs./yd^3
AVERAGE	13.5 lbs./yd^3	5.1 lbs./yd^3

Appendix C
Shallow Concrete Cover Over Reinforcing Steel (1-3/8" or less)



Appendix D
Corrosion
Potential Map
(Copper - Copper
Sulfate Half Cell
-0.35 Volts or more)



Appendix E
Rehabilitation
Contract
(Page 1 of 3)

COST CENTER 611000 OBJECT 885

PROJ NO. FN-30-5(55)--21-85 COUNTY STORY
RES. ENGR TOM CACKLER 521100 ADDRESS AMES
LETTING DATE JANUARY 23, 1985 LIQUIDATED DAMAGES #1 $125.00 #2 $225.00
SPECIAL PROV 11/6/84 #970, 1/23/85 #973, 7/31/84 #963,
7/31/84 #966, 5/11/82 #900, 12/12/84 #983,
8/31/84 #975, 7/31/84 #969, 1/23/85 #987

DATE STARTED ______ FIELD COMP. ______ CERT. COMP ______

FORM 650019 8-77 H-384

CONTRACT NO. 23528

TYPE OF WORK STRUCTURES PROJECT NO FN-30-5(55)--21-85
MILES ______ COST CENTER 611000 OBJECT 835
COUNTY STORY
ON U S 30 APPROX. 1.3 MILES EAST OF JCT. U S 69 OVER
SKUNK RIVER

THIS AGREEMENT MADE AND ENTERED BY AND BETWEEN THE IOWA DEPARTMENT OF TRANSPORTATION
ROBERT R RIGLER, DARRELL RENSINK, DENNIS VOY, DEL VAN HORN,
MOLLY SCOTT, AUSTIN TURNER & C ROGER FAIR PARTY OF THE FIRST PART, AND
WATERLOO CONSTR. CO., INC. OF WATERLOO, IOWA 47630
PARTY OF THE SECOND PART.

WITNESSETH, THAT THE PARTY OF THE SECOND PART, FOR AND IN CONSIDERATION OF $ ****186,466.64 PAYABLE AS SET FORTH IN THE SPECIFICATIONS CONSTITUTING A PART OF THIS CONTRACT, HEREBY AGREES TO CONSTRUCT VARIOUS ITEMS OF WORK AND, OR, VARIOUS MATERIALS OR SUPPLIES IN ACCORDANCE WITH THE PLANS AND SPECIFICATIONS THEREFORE, AND IN THE LOCATIONS DESIGNATED IN THE NOTICE TO BIDDERS, AS FOLLOWS

FLOOR REPAIR ON 320' X 30' CONTINUOUS WELDED GIRDER BRIDGE (E.B.)

GRP 1 DESIGN 684

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	BRIDGE FLOOR OVERLAY	1,123	SQ. YDS.	23.27	25,079.21
2	BRIDGE FLOOR REPAIR, CLASS A	70.600	SQ. YDS.	29.00	2,047.40
3	STEEL, STRUCTURAL	2,823	LBS.	1.70	4,799.10
4	TEMPORARY BARRIER RAIL, FURNISH ONLY	530	LIN. FT.	5.00	2,650.00
5	TEMPORARY BARRIER RAIL, PLACE ONLY	1,060	LIN. FT.	2.50	2,650.00
6	SEALER, CONCRETE - AS PER PLAN	1,214	SQ. FT.	.70	849.80
7	PAVEMENT MARKINGS	82.800	STAS.	45.00	3,726.00
8	TEMPORARY FLOODLIGHTING		LUMP SUM		1,500.00
9	TRAFFIC CONTROL		LUMP SUM		2,500.00
10	RAIL, CONCRETE BARRIER (CAST-IN-PLACE)	638	LIN. FT.	24.00	15,312.00
11	GUARDRAIL, FORMED STEEL BEAM	168.750	LIN. FT.	10.00	1,687.50
12	GUARDRAIL, POSTS, BEAM	54	ONLY	50.00	2,700.00
13	GUARDRAIL, END ANCHORAGES, BEAM				

PARTY OF THE SECOND PART CERTIFIES BY HIS SIGNATURE ON THIS CONTRACT, UNDER PAIN OF PENALTIES FOR FALSE CERTIFICATION, THAT HE HAS COMPLIED WITH 324.17(8) OF THE 1975 CODE OF IOWA AS AMENDED IF APPLICABLE
SAID SPECIFICATIONS AND PLANS ARE HEREBY MADE A PART OF AND THE BASIS OF THIS AGREEMENT, AND A TRUE COPY OF SAID PLANS AND SPECIFICATIONS IS NOW ON FILE IN THE OFFICE OF THE PARTY OF THE FIRST PART UNDER DATE OF JANUARY 17, 1985

THAT IN CONSIDERATION OF THE FOREGOING, THE PARTY OF THE FIRST PART HEREBY AGREES TO PAY THE PARTY OF THE SECOND PART, PROMPTLY AND ACCORDING TO THE REQUIREMENTS OF THE SPECIFICATIONS THE AMOUNTS SET FORTH, SUBJECT TO THE CONDITIONS AS SET FORTH IN THE SPECIFICATIONS.
THE PARTIES HERETO AGREE THAT THE NOTICE AND INSTRUCTIONS TO BIDDERS, THE PROPOSAL FILED HEREIN, THE GENERAL SPECIFICATIONS OF THE IOWA DEPARTMENT OF TRANSPORTATION FOR 1984 TOGETHER WITH SPECIAL PROVISIONS ATTACHED, TOGETHER WITH THE GENERAL AND DETAILED PLANS, IF ANY, FOR SAID PROJECT FN-30-5(55)--21-85, TOGETHER WITH SECOND PARTY'S PERFORMANCE BOND, ARE MADE A PART HEREOF, AND TOGETHER WITH THIS INSTRUMENT CONSTITUTE THE CONTRACT BETWEEN THE PARTIES HERETO.
THAT IT IS FURTHER UNDERSTOOD AND AGREED BY THE PARTIES OF THIS CONTRACT THAT THE ABOVE WORK SHALL BE COMMENCED OR COMPLETED IN ACCORDANCE WITH THE FOLLOWING SCHEDULE:

	APPROX. OR SPECIFIED STARTING DATE OR NUMBER OF WORKING DAYS	SPECIFIED COMPLETION DATE OR NUMBER OF WORKING DAYS
GROUP 1	25 WORKING DAYS	SEPT.13, 1985
GROUP 2	25 WORKING DAYS	SEPT.13, 1985

THAT TIME IS THE ESSENCE OF THIS CONTRACT AND THAT SAID CONTRACT CONTAINS ALL OF THE TERMS AND CONDITIONS AGREED UPON BY THE PARTIES HERETO
IN WITNESS WHEREOF THE PARTIES HERETO HAVE SET THEIR HANDS FOR THE PURPOSE HEREIN EXPRESSED TO THIS AND THREE OTHER IDENTICAL INSTRUMENTS AS OF THE ______ DAY OF ______, 19 ______

IOWA DEPARTMENT OF TRANSPORTATION

BY ______
PARTY OF THE FIRST PART

WATERLOO CONSTR. CO., INC. OF WATERLOO, IOWA

BY ______
PARTY OF THE SECOND PART

CONTRACT NO. 23523 PROJECT FN-30-5(55)--21-85 PAGE 2

ITEM NO	ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	RE-52	1	ONLY	400.00	400.00
14	GUARDRAIL, END ANCHORAGES, BEAM RE-53	1	ONLY	400.00	400.00
15	REMOVAL OF FORMED STEEL BEAM GUARDRAIL	62.500	LIN. FT.	4.00	250.00
16	REMOVAL OF POSTS	34	ONLY	4.00	136.00
17	REMOVAL OF GUARDRAIL END ANCHORAGE	2	ONLY	40.00	80.00
18	REMOVE & REINSTALL FORMED STEEL BEAM GUARDRAIL	175	LIN. FT.	6.00	1,050.00
19	DELINEATORS, SINGLE WHITE	7	ONLY	10.00	70.00
20	REMOVE AND REINSTALL OBJECT MARKERS	4	ONLY	20.00	80.00
21	OBJECT MARKER, TRIPLE YELLOW AS PER PLAN	3	ONLY	20.00	60.00
22	EMBANKMENT-IN-PLACE	730	CU. YDS.	11.00	8,030.00
23	HOLES (FOR PRESSURE GROUTING)	85	ONLY	24.00	2,040.00
24	PORTLAND CEMENT (FOR PRESSURE GROUTING)	.800	TONS	2,059.33	1,647.46
25	JOINT, PRESSURE RELIEF	48	LIN. FT.	20.00	960.00
26	BASE, TYPE B CLASS 1 ASPHALT CEMENT CONCRETE	114	TONS	70.00	7,980.00
27	MOBILIZATION	100.00%			8,000.00
			GRP 1	TOTAL	$96,614.47

FLOOR REPAIR ON 320' X 30' CONTINUOUS WELDED GIRDER BRIDGE (W.B.)

GRP 2 DESIGN 784

ITEM NO	ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
28	BRIDGE FLOOR OVERLAY	1,236	SQ. YDS.	22.19	27,426.84
29	BRIDGE FLOOR REPAIR, CLASS A	85.600	SQ. YDS.	29.00	2,482.40
30	STEEL, STRUCTURAL	2,823	LBS.	1.70	4,799.10
31	TEMPORARY BARRIER RAIL, FURNISH ONLY	530	LIN. FT.	5.00	2,650.00
32	TEMPORARY BARRIER RAIL, PLACE ONLY	1,060	LIN. FT.	2.50	2,650.00
33	SEALER, CONCRETE - AS PER PLAN	1,214	SQ. FT.	.70	849.80
34	PAVEMENT MARKINGS	82.800	STAS.	45.00	3,726.00
35	TEMPORARY FLOODLIGHTING		LUMP SUM		1,500.00
36	TRAFFIC CONTROL		LUMP SUM		2,500.00
37	RAIL, CONCRETE BARRIER (CAST-IN-PLACE)	638	LIN. FT.	24.00	15,312.00
38	GUARDRAIL, FORMED STEEL BEAM	106.250	LIN. FT.	10.00	1,062.50
39	GUARDRAIL, POSTS, BEAM	42	ONLY	50.00	2,100.00
40	GUARDRAIL, END ANCHORAGES, BEAM RE-52	1	ONLY	400.00	400.00
41	GUARDRAIL, END ANCHORAGES, BEAM RE-53	1	ONLY	400.00	400.00
42	REMOVAL OF FORMED STEEL BEAM GUARDRAIL	75	LIN. FT.	4.00	300.00
43	REMOVAL OF POSTS	34	ONLY	4.00	136.00
44	REMOVAL OF GUARDRAIL END ANCHORAGE	2	ONLY	40.00	80.00
45	REMOVE & REINSTALL FORMED STEEL BEAM GUARDRAIL	162.500	LIN. FT.	6.00	975.00

Appendix E
Rehabilitation
Contract
(Page 3 of 3)

CONTRACT NO. 23528 PROJECT FN-30-5(55)--21-85 PAGE 3

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
46	REMOVE AND REINSTALL OBJECT MARKERS	6	ONLY	20.00	120.00
47	DELINEATORS, SINGLE WHITE	7	ONLY	20.00	140.00
48	OBJECT MARKER, TRIPLE YELLOW AS PER PLAN	1	ONLY	20.00	20.00
49	EMBANKMENT-IN-PLACE	19	CU. YDS.	11.00	209.00
50	HOLES (FOR PRESSURE GROUTING)	68	ONLY	24.00	1,632.00
51	PORTLAND CEMENT (FOR PRESSURE GROUTING)	.700	TONS	2,059.33	1,441.53
52	JOINT, PRESSURE RELIEF	48	LIN. FT.	20.00	960.00
53	BASE, TYPE B CLASS 1 ASPHALT CEMENT CONCRETE	114	TONS	70.00	7,980.00
54	MOBILIZATION	100.00%			8,000.00
				GRP 2 TOTAL	$89,352.17
				GRAND TOTAL	$186,466.64

Appendix F
Extra Work Order
(Page 1 of 2)

CHANGE OR EXTRA WORK ORDER

No. 6 BL

☐ Non-Substantial

☒ Substantial

FHWA Concurrence ________

Contract No. 23528

County Story

Group #1 Design #684
(Only one group can be covered by one work order)

Project FN-30-5(55)--21-85

Kind of Work Structure

Date Prepared 7-22-85

To Waterloo Construction Co., Inc.

Contractor:

You are hereby ordered to make the following changes from the plans or do the following extra work on your contract dated 1-17-85.

A - Description of change to be made or extra work to be done:

8003: Contractor to furnish all material, labor and equipment required to install Cathodic protection to Eastbound bridge deck prior to deck overlay as per plan and manufacturer's recommendation.

B - Reason for ordering change or extra work:

8003: The cathodic protection system will be installed as FHWA demonstration project No. 34 in order to decrease the amount of delamination on the bridge deck. This will be performed as per FHWA work order No. DTFH71-85-34-IA-15 with FHWA funds in the amount of $60,000.

(Continued on reverse side)

Approved ________ 8/2, 1985
Kenneth Meeks Asst. Dist. Engr.

Thomas R. Jacobson 7-30, 1985
Thomas R. Jacobson Res. Engr.

Receipt is acknowledged of this change or extra work and terms of settlement are hereby agreed to

Approved contingent upon funds being available under the existing project agreement or upon additional Federal-aid funds being made available by a modified project agreement.

Waterloo Construction Co., Inc.
Contractor

By Roland Risting 7-29, 1985

________ Date

________ For the Division Administrator Federal Highway Administration

Approved ________ AUG 05 1985
Construction Engineer

DISTRIBUTION: 1. White Copy - Iowa Department of Transportation Main Office, 2. Canary Copy - Federal Highway Administration, 3. Pink Copy - Resident Engineer, 4. Green Copy - Contractor, 5. Blue Copy - Office of Construction or Maintenance, 6. Buff Copy - District Engineer.

ESTIMATED OVER-RUN OR UNDER-RUN INVOLVED FOR CONTRACT

2 0 5 2 8 (1 2 3 4 5) GRP. ___ (6)

CHANGE/WORK ORDER NO. 6 BL

Appendix F
Extra Work Order
(Page 2 of 2)

C - Settlement for cost of work to be made as follows:

Lump Sum Agreement

Labor	$6,479.74
Ray-Chem Materials	32,448.00
Plywood sheeting	1,044.00
Subtotal	39,971.74
15% Overhead	5,995.76
Electrical work (26,800 + 5%)	28,140.00
Grout sprayer	800.00
Small tools and incidental equipment	2,680.00
	$77,587.50

Lump sum price agreed to by Central Construction Office.

D - ITEMS INCLUDED IN CONTRACT

7 -- 10

ITEM NO.	ITEM DESCRIPTION	FUNCTION CODE	UNIT PRICE .XXX	QUANTITY .XXX	AMOUNT .XX
7	APPLIES TO ITEM				
7	APPLIES TO ITEM				
7	APPLIES TO ITEM				
7	APPLIES TO ITEM				
7	APPLIES TO ITEM				
7	APPLIES TO ITEM				
7	APPLIES TO ITEM				
				TOTAL	

E - ITEMS NOT INCLUDED IN CONTRACT

7 -- 10

ITEM NO.	ITEM DESCRIPTION	ITEM CODE	FUNCTION CODE	UNIT PRICE .XXX	QUANTITY .XXX	AMOUNT .XX
8 0 0 3	Cathodic Protection	None	4 3 0	$1.000	77587.500	$77,587.50
8						
8						
8						
8						
8						
8						
					TOTAL	$77,587.50

2413.05 PREPARATION OF SURFACE FOR REPAIR AND OVERLAY. Concrete shall be removed from each area, designated on the plans or by the Engineer, to a depth and in a manner consistent with the classification for that area. Areas as shown on the plans are based on the best information available; actual areas will be determined by the Engineer.

A. Class A Bridge Floor Repair. Concrete may be removed by chipping or by a combination of scarifying and chipping, except that final clean up, in any case, shall be by use of hand tools. Class A repair removal shall be considered to start 1/4 inch below the existing surface, but this shall not preclude removal coincidental with preparation for overlay. Removal for Class A repair shall extend at least to the level of the top of the top reinforcing bars, and the removal shall extend deeper, as necessary, to remove unsound concrete.

All reinforcing bars and newly exposed concrete shall be thoroughly cleaned by sandblasting or shotblasting. Where bond between existing concrete and reinforcing steel has been destroyed, the concrete adjacent to the bar shall be removed to a depth that will permit new concrete to bond to the entire periphery of the bar so exposed. A minimum of 3/4-inch clearance shall be required around the bar. Care shall be exercised to prevent cutting, stretching, or damaging any exposed reinforcing steel. The Engineer may require enlarging a designate portion should inspection indicate deterioration of concrete or corrosion of reinforcing beyond the limits previously designated.

B. Class B Bridge Floor Repair. Within all areas designated for Class B repair, and any designated areas of Class A repair in which the depth of the remaining sound concrete is less than 50 percent of the original depth of the bridge floor, all concrete shall be removed. Designated Class A repair areas shall be measured as Class B Bridge Floor Repair when full-depth removal is required. At the direction of the Engineer, limited areas of removal greater than 50 percent of the floor thickness, such as beneath reinforcing, may be allowed; these limited areas of excess depth will be measured as Class A Bridge Floor Repair. Concrete may be removed by chipping or by a combination of scarifying and chipping, except that the final removal at the periphery of Class B repair areas shall be accomplished by 15-pound chipping hammers or hand tools. Class B repair removal shall be considered to start 1/4 inch below the existing surface, but this shall not preclude removal coincidental with preparation for overlay. All exposed reinforcing bars and newly exposed concrete shall be thoroughly cleaned by sandblasting or shotblasting. Care shall be exercised to prevent cutting, stretching, or damaging exposed reinforcing.

Forms shall be provided to enable placement of new concrete in the full-depth opening. The forms shall preferably be suspended from existing reinforcing bars by wire ties. Forms may, in the case of large-area openings, be supported by blocking from the beam flanges. Forms will in all cases be supported by elements of the existing superstructure unless specifically noted or shown otherwise on the plans.

C. Bridge Floor Overlay. The entire, existing concrete floor area shall be uniformly scarified or prepared to a depth of ½ inch, except over areas of Class A and B repair where the ¼-inch removal may be coincidental with operations for repair removal. Removal to a greater depth will be required at drains and elsewhere, as noted on the plans.

D. General. The thickness of concrete above the prepared surface or reinforcing steel shall be at least 3/4 inch and shall be greater if specified on the plans. The clearance shall be checked in the following manner before concrete is placed. A filler block having a thickness 1/8 inch less than the overlay thickness shall be attached to the bottom of the screed; with screed guides in place, the screed shall be passed over the area to be concreted. As an alternate to passage of the finishing machine, an approved template, supported by the screed guides, may be passed over the overlay area. Where the intended clearance does not allow use of this method, a stringline or other means shall be used, subject to approval of the Engineer. All old concrete which does not have sufficient clearance shall be removed. All reinforcing steel which does not have sufficient clearance shall be depressed and fastened down. It may be necessary to remove concrete beneath some reinforcement to permit depressing the reinforcement adequately. The minimum clear distance around these bars for placement of new concrete shall be 3/4 inch.

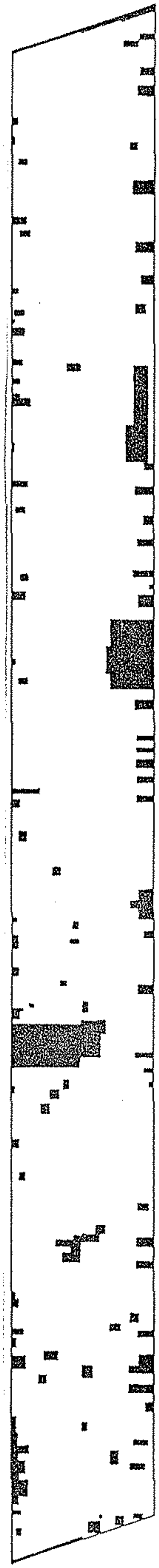
Areas from which concrete has been removed shall be kept free of slurry produced by wet sawing of concrete joints. All such slurry shall be removed from prepared areas before new concrete is placed.

Hand tools shall be used to remove final particles of concrete or to achieve the required depth. The entire surface, including curbs and exposed reinforcement, against which new concrete is to be placed shall be sandblasted or shotblasted. The cleaning shall be of such extent as to remove all dirt, oil, and other foreign material, as well as any unsound concrete. Immediately before applying grout in preparation for placement of new concrete, the surface shall be cleaned with air blast. For the portland cement concrete, it is not intended or desired that existing concrete, prepared for repair or overlay be presaturated with water before grout and new concrete is placed. The prepared surface shall be dry to allow some absorption of the grout.

At the time of placement of either PCC or latex-modified concrete, the area shall be clean and the reinforcement free of rust; rust forming because of dew on clean reinforcement overnight will not be considered objectionable, but reinforcement with a greater amount of rust shall be subject to recleaning before the concrete is placed. The area shall be cleaned by air blast before the concrete is placed.

For latex-modified concrete, the surface shall be flushed with water and kept wet for at least one hour before concrete placement. Puddles of free water shall be removed before covering with concrete.

Appendix H
Class A Repair Map



CONTINUITY TESTING

Procedure

Testing must be performed to verify that the mats of the steel reinforcement and any other steel in the bridge deck are electrically continuous throughout the area to be protected.

1. A D.C. ohm meter capable of resolving 0.1 ohms or less shall be used for all continuity testing.

2. The reinforcing steel must be wire brushed or filed to bright, clean white metal condition at each contact location.

3. The resistance between rebar test locations must be recorded with the ohm meter lead wires connected in one way then the leads reversed and the resistance measurement repeated. The resistance reading should not change if the bars are continuous.

4. Take resistance measurements at several separate locations within each control zone from one edge of the zone to the other edge. Longitudinal and transverse bars as well as top and bottom mats should be checked.

5. Discontinuous rebar is indicated by any one of the following:

   a. Resistance readings that change more than 0.3 ohms when the ohm meter leads are reversed.

   b. Resistance readings that change more than 0.3 ohms in 15 seconds.

   c. Unstable resistance readings on the ohm meter.

   d. Resistance readings greater than 1.0 ohm.

6. The discontinuous steel must be electrically continuous.

Section 2413. Surfacing and Repair and Overlay of Bridge Floors

2413.01 DESCRIPTION. Surfacing bridge floors shall consist of placing a wearing course on a prepared surface, and other necessary work shown on the plans or specified herein.

Repair and overlay of bridge floors shall consist of removing concrete from the existing surface, replacing and overlaying with new concrete, and other necessary work shown on the plans or as specified. When structural repairs are included in the project, Class C or Class D concrete, as specified on the plans, may be mixed using equipment meeting requirements of 2413.03B. The concrete mixture used for the overlay may be used for the repair; the water consistency shall be as specified in 2403.03E. The work shall be done according to the plans and this specification. Unless otherwise provided on the plans, overlay shall accomplish a raise of the existing roadway surface and shall cover the entire concrete floor surface, including those areas to be repaired. Bridge floor repair and overlay shall be classified as follows:

A. Class A Bridge Floor Repair shall consist of removing floor concrete below the level described for Bridge Floor Overlay, but less than full depth; disposing of concrete removed; replacing the excavated volume with concrete to a level bounding the Bridge Floor Overlay classification. Lower limit for Class A Bridge Floor Repair shall be to suitable existing concrete, as determined by the Engineer, but to at least the level of the top of the top reinforcing steel.

B. Class B Bridge Floor Repair shall consist of removing floor concrete below the level described for Bridge Floor Overlay for the full remaining depth of the floor; disposing of concrete removed; replacing the excavated volume with concrete to a level bounding the Bridge Floor Overlay classification.

C. Bridge Floor Overlay shall consist of removing floor concrete to a depth 1/4 inch below the existing, finished surface, except at drains and elsewhere as noted on the plans; disposing of the concrete removed; overlaying with a concrete course of a depth designated on the plans. Thickness of the concrete overlay shall be measured from a level 1/4 inch below the original surface to a final raised surface as shown on the plans. Where removal to a level lower than 1/4 inch below the original surface is necessary because of surface fixtures, the minimum thickness of abutting overlay shall be 3/4 inch and shall be tapered to the full designated thickness.

Unless otherwise specified, the work shall be done using either portland cement concrete or latex-modified concrete, at the Contractor's option.

2413.02 MATERIALS. All materials shall meet requirements for the respective items in Part IV.

Only one brand of cement shall be used during placement of an individual pour. Type III cement will not be permitted.

Sections 4110 and 4115 shall apply to the aggregates. Only those coarse aggregates specifically allowed by 4115.08 for this work shall be used.

A. Portland Cement Concrete shall meet the following requirements:

BASIC ABSOLUTE VOLUMES PER UNIT VOLUME OF CONCRETE

Coarse Aggregate	0.312088
Fine Aggregate	.312088
Air	.060000
Water	.160255
Cement	.155569

APPROXIMATE QUANTITIES OF DRY MATERIALS PER CUBIC YARD OF CONCRETE*

Coarse Aggregate	1,394 lb
Fine Aggregate	1,394 lb
Cement	823 lb

*These quantities are based on the following assumptions: Specific gravity of cement, 3.14; Specific gravity of coarse and fine aggregates, 2.65; Weight of one cubic foot of water, 62.4 pounds.

A water-reducing admixture for improving workability will be required. This admixture shall be approved by the Engineer.

The slump, measured in accordance with AASHTO T 119, shall be 3/4 inch with a maximum of 1 inch and no minimum requirement. Testing for slump of concrete from a continuous mixer shall commence within 2 to 4 minutes after the concrete is discharged.

The intended air entrainment of the finished concrete is 6 percent, but the air content of fresh, unvibrated concrete at the time of placement, as determined by AASHTO T 152, shall be 6.5 percent, with a maximum variation of plus or minus 1.0 percent.

Grout for bonding new concrete to previously placed concrete shall consist of equal parts by weight of portland cement and fine aggregate for concrete mixed with sufficient water to form a stiff slurry. The consistency shall be such that the slurry can be applied with a stiff brush or broom to the previously placed concrete in a thin, even coating that will not run or puddle in low spots. An equivalent grout of portland cement and water, to be applied by pressure spray, may be substituted with approval of the Engineer. For sealing vertical joints between adjacent lanes and at the curbs, this grout shall be thinned to paint consistency.

CATHODIC PROTECTION PERFORMANCE REPORT*

Reporting Period Time After Start-Up	Total Voltage (Volts)	Total Current (Amps)	Polarized Potentials: Section 1 On Reading Instant Off (Volts)	Section 2 On Reading Instant Off (Volts)	Section 3 On Reading Instant Off (Volts)	Section 4 On Reading Instant Off (Volts)	Current Flow To Rebar Probes Zone 1 / Zone 2 (milliAmps)	Circuit Current Minimum / Section # Maximum / Section # (Amps)	Ambient Temp. (°F)	Bridge Deck Condition	Observations
4 weeks	7.91	9.96	-0.972 -0.767	-1.920 -0.684	-0.622 -0.511	-0.970 -0.873	-- / --	2.40 / 2 2.48 / 4	60	Damp	System adjustments still taking place
2 months	9.50	9.00	-1.460 -0.980	-3.620 -0.790	-1.180 -0.620	-1.370 -0.960	-- / --	1.68 / 3 3.03 / 1	14	Snow packed	Still no current flow to the rebar probes
4 months	6.90	9.00	-1.176 -0.902	-1.380 -0.586	-0.790 -0.564	-0.730 -0.583	-- / --	1.61 / 3 2.99 / 1	34	Dry	
8 months	3.93	6.00	-0.660 -0.560	-0.330 -0.190	-0.140 -0.130	-0.120 -0.110	5.3 / 65.9	1.15 / 2 2.04 / 1	60	Dry	
1 year	5.81	5.94	-0.698 -0.494	-1.029 -0.546	-0.118 -0.103	-0.302 -0.266	23.2 / 29.4	1.12 / 3 1.95 / 1	55	Dry	New circuit card in place

* Intermediate readings were taken but not reported here

October 10, 1985	87 kw	$13.04
November 14, 1985	115	13.94
December 16, 1985	141	14.66
January 16, 1986	134	14.20
February 18, 1986	130	14.11
March 17, 1986	60	9.16
April 16, 1986	45	8.12
May 14, 1986	41	7.84
June 16, 1986	49	8.38
July 16, 1986	5	5.57
August 14, 1986	0	5.00
September 16, 1986	28	7.41
October 16, 1986	57	9.90
	===	======
Average/month	69 kw	$10.10