ITEM 01634.8101 M - CATHODIC PROTECTIVE SYSTEM FOR NEW REINFORCED CONCRETE BRIDGE DECKS

DESCRIPTION

The work shall consist of furnishing, installing, and designing an electrically fed cathodic protection system for a new concrete deck slab. The anode system shall consist of a catalyzed titanium ribbon mesh, which is cast monolithically into the new deck slab. The purpose of the cathodic protection system is to protect the reinforcing steel embedded in the concrete from corroding by passing a low voltage direct current from the anode to the steel.

MATERIALS

The cathodic protection system shall consist of an anode system, rectifier, corrosion rate probes, reference electrodes, DC wiring, conduit, AC power supply to the rectifier, and all associated electrical connections.

Materials for this work shall conform to the following requirements:

1. **Anode System.** The anode system shall consist of catalyzed titanium anode ribbon mesh, current distributors, and plastic rebar clips. The specifications for each of these components is given below:

   a. **Catalyzed Titanium Anode Ribbon Mesh.** The specified anode shall consist of ELGARD 100 Anode Ribbon Mesh, as supplied by Corrpro Companies, Inc., Medina, Ohio, or approved equal. The anode shall have the following properties:

      - Width ......................... 13 mm
      - Thickness ....................... 0.6 mm
      - Substrate composition ........... Titanium, Grade 1 per ASTM B265
      - Anode coating .................... Precious metal oxide catalyst

      The anode material to be used on this project shall have a life expectancy of at least 75 years in accordance with National Association of Corrosion Engineers (NACE) Standard Test Method TM0294-94 “Testing of Embeddable Anodes for Use in Cathodic Protection of Atmospherically Exposed Steel-Reinforced Concrete.” Anode shall have a proven track record of at least 10 years for cathodic protection of bridge deck reinforcing steel.

   b. **Current Distributor.** The current distributor shall be a solid Grade 1, 12.7 mm wide uncoated titanium bar. Thickness shall be 0.9 mm.

   c. **Insulated Titanium Connector.** The connector shall consist of a titanium rod, 3.175 mm diameter, 400 mm long, with a 300 mm length of current distributor factory welded to the rod. The current distributor shall overlap the rod by approximately 50 mm, with spot welds at three locations. The spot welds shall be made at the factory using a high powered resistance welder. The exposed rod shall be insulated with heat shrink connector for approximately 300 mm, leaving 50 mm uncovered.

   d. **Plastic Rebar Clips.** The rebar clips shall be injection molded plastic clips suitable for this application. Plastic ties for securing the anode ribbon to the rebar clips shall be nylon locking cable ties 2.5 mm in width, 99 mm long, and 1.1 mm in thickness. Rebar clips must position the anode material a minimum of 13 mm above the bottom bar of the top mat of the reinforcement.

2. **Rectifier (Power Supply).** The rectifier shall be a manual voltage control tap-switch rectifier with filtered DC output and silicon diodes. The power supply shall have a non-conductive front panel with a digital panel meter for monitoring the rectifier DC voltage and current for each zone. The rectifier shall
have an individual circuit for each anode zone. DC voltage and current output ratings shall be as recommended by the anode system supplier.

Variation in the AC input from 5% below to 10% above rated line values shall not damage any components nor alter the rated DC output. The rectifier shall have a fuse in each positive output and a quick acting magnetic breaker rated at 120% of the circuit capacity. A relay shall be installed in the AC input to permit interruption of the rectifier. Three spare fuses of the same rating shall be provided with the rectifier, which shall be secured inside the enclosure. DC shunts shall be provided for each circuit. The shunts shall be mounted on the front panel of the rectifier. The unit shall be furnished with upgraded lightning arresters (high joule MOVs) on both the AC and DC sides. Test jacks, suitable for connecting No. #18 AWG wire, shall be provided to terminate two instrumentation lead wires per zone.

The rectifier enclosure shall be air cooled, NEMA type 3R, constructed from 12 ga. mill galvanized steel, finished in 3-5 mils fusion bonded polyester powder paint, with a hinged weatherproof door with gasket. All openings shall be screened. The top of the cabinet shall be equipped with a green light which will be on when the system is operating properly. The light shall be visible from a minimum distance of 20 meters. The housing door shall be lockable and shall have a bronze padlock and three keys. The inside of the front door shall have a tray to hold the maintenance manual.

Each power supply shall have a digital panel meter for monitoring the rectifier DC voltage and current output for each zone. Meters and indicators shall be capable of withstanding temperatures between -40°C and 66°C. Each power supply shall have an individual circuit for each anode zone and one spare anode power circuit.

3. **Corrosion Rate Probe.** The corrosion rate probe shall consist of a Rohrback Cosasco Model 650 Corrosometer Probe, or equal. The measurement element shall be carbon steel and the thickness shall be type T-20; 10 mils (250:m) Life. Probe shall be provided with a separate lead at the probe end for connection to rebar. Cable length shall be sufficient to extend to a junction box or the rectifier enclosure without splicing, as shown on the plans or in the proposal. A Model CK-3 instrument shall be furnished with cathodic protection system to enable measurement of the corrosion rate data from the Corrosometer probe(s).

4. **Reference Electrodes.** Reference electrodes shall be silver/silver chloride (Ag/AgCl) suitable for installation in reinforced concrete structures. Each reference electrode shall have a No. 10 AWG copper conductor with HMWPE insulation attached at the factory. The ground wire shall also be No. 10 AWG HMWPE.

Store reference electrodes at room temperature (i.e. between 10° and 35°C). Avoid excessive heat and sunlight. Keep cap secured and tight until use.

Prior to installation, each reference electrode shall be calibrated to a laboratory-type “standard” silver/silver reference cell of known quality. Remove cap and submerge reference electrode(s) in a non-metallic container with potable water. The potential difference between the “standard” cell and the reference electrode(s) under test shall be measured using a voltmeter capable of resolving a potential difference of 1 millivolt. For each reading, the negative or common lead on the voltmeter shall be connected to the “standard” cell and the polarity of the reading noted. Acceptable reference electrodes will have stable readings of 0 ± 3 millivolts. All data shall be tabulated and the serial numbers indicated where applicable. The data shall be provided to the Engineer for approval. Each reference electrode shall be approved for use prior to installation.

All thermite welds shall be coated with a dielectric coating conforming to §721-03.

5. **Electrical.** The junction boxes if separate from the rectifier enclosure, shall be molded PVC and suitably
weatherproofed for outdoor installation. The minimum size shall be 203 mm x 203 mm x 102 mm. Stainless steel bolts shall be provided to secure the junction box to the soffit of the deck. Anchors shall be encased in a nonmetallic expansion shield and the hole filled with epoxy. A weep hole shall be provided in each junction box.

The conduit for the DC circuitry shall be PVC Schedule 80. The conduit shall be sized in accordance with the latest revision of the National Electrical Code (NEC) for wire fill. Exposed conduit shall be mounted securely by suitable nonmetallic hangers or straps with the maximum spacing of supports not greater than indicated by Article 347(8) of NEC. Expansion joints shall be installed in accordance with the manufacturer's recommendations for temperature change of 38° C. Weep holes shall be provided in the at all low points in the conduit run. Stainless steel bolts shall be provided to secure the conduit to the soffit of the deck. Anchors shall be encased in a nonmetallic expansion shield and the hole filled with epoxy.

A transformer, as required, shall be supplied and installed by the power company.

6. **Wiring.** Wiring which will be encased in the concrete shall be No. 10 AWG with HMWPE insulation. Power wiring in conduit shall be at least No. 10 AWG with THHN insulation. Instrumentation wiring in conduit shall be No. #18 AWG shielded twisted pair communication wire with PVC outer jacket. All wiring shall be labeled at the junction box and rectifier to identify its function and location. The power wiring shall be sized according to the National Electric Code. The power cable for the anode and the power cable for the system ground shall be taken into consideration.

7. **Connections.** The system negative and working electrode (corrosion rate probe) connections to the reinforcing steel shall be made by thermit welding method. No mechanical connections will be permitted. All thermite weld connections shall be coated with a dielectric coating conforming to §721-03.

The system negative and positive connections in the junction boxes shall require the use of a mechanical crimp connection, which is subsequently sealed from the environment with a suitable insulating material. The mechanical and crimp connections shall be Lisco Part No. CT-8 or equivalent. The insulating material shall be a heat-shrinkable material such as Alpha FIT-700 or 3M E-Z Seal.

**CONSTRUCTION DETAILS**

1. **General Requirements.** The contractor shall be responsible for the design of the cathodic protection system. The design shall include all provisions of this specification. Thirty (30) days prior to the installation, the Contractor shall submit to the Engineer for approval, three (3) sets of shop drawings and material catalog cuts which completely detail the system layout, design, and materials to be supplied. The submission shall include AC current requirements, power supply weight, dimensional outline drawings in SI units, electrical schematics, and bound manual for installation, operation, and maintenance of the system.

A technical representative from the CP supplier shall be on site during placement of the system, and placement of the concrete deck. The representative shall also be required to attend the preplacement meeting as described in Subsection 557-3.06 of the standard specifications, unless ordered otherwise by the Engineer.

The bridge deck shall be subdivided into separately controlled cathodic protection zones, with a maximum anode zone size of 500 square meters. The zone dimensions shall correspond with the deck slab concrete placement schedule on the drawings. Maximum allowable anode current density shall be 107.6 mA/m². In order to assure uniform current distribution to the bridge deck, the anode voltage drop shall not exceed...
300 mV from the power feed point to the furthest point from the power feed. The design current density per unit deck surface area shall not be less than 0.2 mA/m². Two current distributors shall run lengthwise for the full length of each zone. Each zone shall also contain two system negative connections, one reference electrode, and one corrosion rate probe, placed as recommended by the CP manufacturer.

2. **System Requirements.**

   a. **Utilities.** The Contractor shall install a complete electrical service, with associated equipment and terminations, as indicated on the plans or as directed. AC input for the rectifier shall be 120 Volts, 60 Hertz, single phase. The service shall have a minimum 30 Amp rating. A fused disconnect switch shall be provided in a separate enclosure. If a transformer is required at the site it shall be supplied and installed by the power company. Electric service shall be metered as approved by the power company.

   b. **Anode System.** The spacing between the anode and reinforcing steel in the deck shall be a minimum of 12 mm. The anode shall be securely attached to the reinforcing steel using plastic rebar clips and tie wires, so that the construction activity associated with the concrete pour does not cause the anode to shift or come in contact with any part of the structural steel assembly.

   A 150 mm length of PVC pipe shall be provided in the deck for passing the insulated titanium connector, system negative, and instrumentation wiring to the junction box if required. The pipe shall be schedule 80 PVC heavy wall conduit.

   The anode shall be installed in accordance with the manufacturer’s instructions. A general procedure for installing the anode ribbon mesh is given below:

   The anode ribbon mesh and current distributor bar shall be placed on the deck as recommended by the CP manufacturer. Ribbon sections shall be cut to match the width of the deck. The first length of ribbon mesh shall be installed in the transverse direction at the edge of the anode zone. The anode strips shall be spaced no greater than 300 mm on center. The anode ribbon shall be attached to the longitudinal rebars on the top mat using plastic rebar clips and cable ties. Each longitudinal bar shall have a rebar clip where the anode ribbon mesh passes over. The ribbon mesh and rebar clips shall be installed between the transverse bars and shall face upwards. The ribbon mesh shall be tensioned slightly during installation. Additional plastic cable ties may be used to secure the anode in place. Each successive width of ribbon mesh shall be placed adjacent to the last until the entire zone is covered.

   Care shall be taken to make sure that the anode does not come in contact with the reinforcing steel. The Contractor shall take special precautions to ensure that the anode is not damaged or pushed into the steel during the concrete pour.

   Two lengths of current distributor bar shall be installed along the centerline of the bridge in the longitudinal direction. The distance between the current distributor bars shall be approximately 150 mm. The current distributor bar shall be spot welded to the anode ribbon mesh where it crosses over. Two spot welds shall be provided at each intersection between the anode ribbon mesh and current distributor. Non-metallic spacers shall be used to prevent the current distributor from contacting the reinforcing steel. After the entire ribbon mesh and current distributor has been installed, additional clips shall be installed as directed by the Manufacturer’s technical representative. The ribbon mesh shall be fastened sufficiently to prevent significant movement during placement of the concrete.
All titanium-to-titanium connections shall be metallurgical bonds made by resistance welding with
equipment supplied by the anode manufacturer and used in accordance with the manufacturer’s
instructions. Prior to commencing welding, the equipment settings shall be tested by welding
current distributor test strips, to ensure that a satisfactory weld will be obtained.

Any embedded steel besides the reinforcing steel (i.e., scuppers, conduit, piping, support bolts, etc.)
shall be made electrically continuous with the reinforcing steel by means of thermite weld
connections, or completely isolated from the cathodic protection system, as determined by the
Engineer.

c. **Corrosion Rate Probe Installation.** The corrosion rate probes shall be installed as indicated by
the Cathodic Protection Technical Representative. One corrosion rate probe shall be installed in each
anode zone. The probes shall be attached to the top mat of reinforcing steel using non-
metallic spacers and secured in place using plastic cable ties. The corrosion rate probe wires shall
be secured to the reinforcing steel bars with plastic cable ties and protected from any
physical damage. The wires shall extend to the parapet junction box without splices.

d. **Reference Electrode Installation.** The reference electrodes shall be installed at the
predetermined locations as shown on the plans. The reference electrodes shall be placed at the
level of, and parallel to the top mat of reinforcing steel. Plastic cable ties or non-metallic straps
shall be used to secure the precast element(s) to the reinforcement. At this location, a reference cell
negative connection shall be provided and connected to the steel in a manner as described above.
Plastic cable ties shall be used to secure the cabling to the reinforcing steel so that it is not damaged
during the concrete placement. Remove cap prior to concrete pour.

e. **Rebar Ground Connections.** The system negative and ground cables shall be connected to the
reinforcing steel by the thermite welding method. Approximately 12 mm of insulation shall be
removed from the end of the wire. The steel surface shall be wire brushed to remove any
material, which could interfere with a good bond. The batting is placed over the cleaned area and the
sleeved wire located in the hollow. The mold is placed over the hollow such that 3 mm of the wire
is exposed. The thermite charge is loaded and ignited. The thermite charge used shall be
an Erico CA-25 or equivalent. All thermite weld connections shall be coated with a 100%
solids non-conductive epoxy. The system negative and reference electrode ground cables shall
pass through the PVC conduit access hole to the junction box.

f. **Current Distributor.** The current distributors are installed below the transverse rebar on the top
mat using an inverted plastic rebar clip and cable tie. To obtain a desired length of current
distributor, or to make splices between strips, the strips can be resistance welded together. The weld is
made by overlapping the ends approximately 75 mm and making spot welds every 12 mm.
If the resulting length is longer than required, the current distributor can be cut to fit with tin snips.

A factory fabricated anode connector with 3.175 mm diameter titanium rod may be installed on the
deck to facilitate connection between the current distributor and positive anode cable in the junction
box. Two anode connectors shall be installed in each zone as indicated on the plans. The anode lead
connector is spot welded to the titanium rod in the factory and then spot welded to the current
distributor in the field. At least six spot welds shall be provided between the anode connector and
the current distributor. Once the titanium rods, system negative and instrumentation wires are
inserted through the PVC access hole conduit, the conduit shall be filled with a non-conductive,
waterproofing material, such as acrylic latex caulking.

g. **Rectifier.** The rectifier shall be installed at the location indicated in the plans or proposal.
installed on the bridge seat, galvanized steel anchor bolts, inserts and washers shall be used to secure the enclosure to the concrete floor. Grounding rods and cable shall be sized and installed such that the power supply to ground resistance is less than 25 ohms. Tests shall be conducted to verify this criterion.

3. **Testing Requirements.** The following tests shall be performed by the Cathodic Protection Technical Representative:

   a. **Anode Steel Isolation Check.** After the anode has been installed in each zone, a check shall be made to ensure that the anode is discontinuous from the steel so that the cathodic protection system will function as intended. Isolation checks shall be made prior to, during, and after the concrete pour. Testing shall be conducted using a digital multimeter and an AC resistance meter. Suggested meters include a Fluke Model 85 multimeter and a Nilsson Model 400 AC resistance meter. Prior to taking the readings, the steel must be cleaned to a bright metal condition at each test location, or a rebar ground connection may be used in that zone. The connection to the anode may be made at any convenient location.

      Prior to the concrete pour, the millivolt drop between the anode and steel shall be measured. A wet sponge shall be used as an electrolyte between a portion of the anode and the reinforcing steel in each zone. Readings of 1 mV or less, are indicative of a short circuit and the contact must be located and cleared.

      The millivolt drop between the anode and steel shall be measured continuously during the anode pour for each zone. A log shall be maintained showing the millivolt readings as a function of time. If the voltage drops to zero immediately, then a short has occurred. Alternatively, a small DC power supply may be used to energize the anode during the pour. The potential of a portable reference cell placed in the wet concrete or the embedded cell in the corrosion rate probe shall be monitored with current on and current off. If the potential shifts more negative when the current is turned off, then a short has occurred and the contact must be cleared before the concrete pour can proceed.

      After the concrete pour has been completed, the DC voltage and AC resistance shall be measured between the anode and steel. The results of this testing will be dependent on the size of the zone as well as other variables.

   b. **Energization Test.** Initial measurements prior to energization shall consist of electrical continuity testing between all rebar ground connections at the rectifier, the static potential and AC resistance of the embedded reference cells, and the open circuit potential and AC resistance between the anode and steel. Additionally, the Cathodic Protection Technical Representative shall obtain corrosion rate probe measurements prior to energizing the cathodic protection system using the CK-3 instrument.

      After the initial system measurements are obtained, the system shall be energized. The potential of the steel is monitored by using the embedded reference cell in the corrosion rate probe. The criterion for adequate current shall be a depolarization of at least 100 mV after a minimum of 4 hours. This test shall be made by measuring the steel potential immediately after the current is turned off and monitoring the change in the potential with time. If the depolarization is less than 100 mV, then the voltage setting on the power supply must be increased. The results of the initial measurements and depolarization testing shall be submitted in writing.

4. **Manual.** The Contractor shall provide the Engineer with three operation/maintenance manuals. Each manual shall document the entire system as installed including all test results, and up-to-date as-built
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drawings. Each manual shall be bound and indexed for use by someone not familiar with the content. Material used for the manufacture of the manual shall be resistant to fading, tearing, smudging, or any other circumstance that would render the information unusable.

5. **Training.** After installation has been completed, the Contractor shall arrange for a training session for State personnel. The training session shall cover all aspects of the system including trouble shooting and repair. It shall be conducted by competent trainers familiar in all respects with the system as installed.

   The training session shall be conducted before contract acceptance, at the convenience of the State and shall be structured such that a maximum of ten people can be trained. The actual number of trainees will be determined by the State. Each person attending the training session shall be supplied with a personal copy of the operation/maintenance manual. This copy shall become the property of the State and the cost of supplying copies shall be included in the price bid.

6. **Certification.** The Contractor shall be required to guarantee the in-service operation of the system in accordance with Subsection 104-08. After all installation and testing are completed the technical representative shall certify, in writing, that the cathodic protection system is functioning as required. This certification shall be submitted to the Engineer for inclusion in the project record.

**METHOD OF MEASUREMENT**

This work will measured on an each basis for each structure cathodically protected under the item Cathodic Protective System for New Reinforced Concrete Bridge Decks.

**BASIS OF PAYMENT**

Payment for this work will be for each location Cathodic Protective System for New Reinforced Concrete Bridge Decks is used, and shall include all materials, equipment, technical representation from the designer-supplier, tools and labor incidental to the completion of this item. The cost of furnishing electrical service to the service cabinet including the cost of conduit and conductors, the service cabinet and foundation, conduit, and wiring from the service cabinet to the cathodic protection system, are to be included in this item.