SECTION 03800
EMBEDDED GALVANIC ANODES FOR CONCRETE REBUILD

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes:
   1. Supply and installation of embedded galvanic anodes encapsulated in concrete rebuilds or encasements.

1.2 RELATED SECTIONS

A. Following Work items are related to Work in this Specification, but are specified in other Specifications:
   1. Section 03700: Concrete Rebuild

1.3 DEFINITIONS

A. Anode – The electrode in electrolysis at which negative ions are discharged, positive ions are formed, or other oxidizing reactions occur.

B. Carbonation – The conversion of calcium ions in hardened cementitious materials to calcium carbonate by reaction with atmospheric carbon dioxide.

C. Cathode – The electrode at which chemical reduction occurs.

D. Cathodic Protection – A form of corrosion protection for reinforced concrete wherein a sacrificial metal is caused to corrode in preference to the reinforcement, thereby protecting the reinforcement from corrosion.

E. Conductivity – The degree to which a specified material conducts electricity.

F. Electrical Resistivity – A measure of the resistance of a material to flow of electric current.

G. Galvanic Corrosion – Accelerated corrosion of a metal because of an electrical contact with a more noble metal or nonmetallic conductor in a corrosive electrolyte.

H. Reinforcement Continuity – A condition in reinforced concrete in which the reinforcing steel is sufficiently interconnected to provide a path for electrical current.

I. Saturated Surface-Dry – Condition of an aggregate particle or other porous solid when the permeable voids are filled with water and no water is on the exposed surfaces.

1.4 REFERENCE STANDARDS

A. Reference Standards: Latest edition.
   1. American Concrete Institute (ACI):
      a. 222R-01: Protection of Metals in Concrete Against Corrosion
   2. ASTM International (ASTM):
      a. A1064: Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete
      b. B418: Standard Specification for Cast and Wrought Galvanic Zinc Anodes

1.5 SUBMITTALS

A. Pre-Construction: Submitted prior to start of Work
   1. Product Data / Safety Data
      a. For each type of manufactured material and product indicated, including:
         1) Galvanic Anodes.
         2) Conductive Embedding Mortar.

2. Samples: Two galvanic anodes proposed for use.
3. Certification: From anode manufacturer that Installer is trained and approved to install anodes.

1.6 QUALITY ASSURANCE AND QUALITY CONTROL

A. Qualifications:
1. CONTRACTOR and/or subcontractor certified by anode manufacturer as trained and approved for anode installation.

B. Quality Control and Assurance Inspection:
1. Quality Assurance Inspections are to be performed at critical steps throughout the rebuild process. Unless indicated otherwise, the OWNER, ENGINEER and/or Quality Assurance Representative shall perform inspections to verify conformance with Contract Documents.
2. CONTRACTOR's Quality Control Supervisor shall perform initial inspections and correct any items not in conformance with requirements herein and Contract Documents prior to requesting Quality Assurance Inspection.
3. Typical quality control and assurance inspection points are listed below. Quality Assurance Inspection Hold Points are indicated in **bold**. Do not proceed with Work that may make hold point inspections difficult or impossible to perform until inspection has been completed and deficiencies corrected, unless OWNER and/or ENGINEER waives specific inspection requirements.

a. Quality Assurance Checklist

1) _____ **Review and approval of Submittals for conformance with specification requirements.**

2) _____ Reinforcing steel continuity is verified.

3) _____ Proposed layout and spacing of galvanic anodes.

4) _____ Installation of galvanic anodes as specified.

5) _____ **Continuity achieved between installed galvanic anodes and reinforcement.**

6) _____ **Mixing and placement of conductive embedding mortar (if required).**

1.7 DELIVERY, STORAGE AND HANDLING

A. Delivery, store, and handle materials according to manufacturer's recommendations and in such manner as to prevent damage to materials and structure.

B. Remove and replace materials that cannot be installed within stated shelf life.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Source Limitations: Obtain materials through one source from single manufacturer.

B. Discrete Galvanic Anodes in Concrete Rebuilds:

1. Alkali-activated, Type 1A, consisting of zinc in compliance with ASTM B418 Type II cast around steel tie wires and encased in a highly alkaline cementitious shell with a pH of 14 or greater. The cementitious shell shall contain no chlorides or other corrosive constituents as per ACI Guideline No. 222R-01. Anodes shall be supplied with integral tie wires for tying to the reinforcing steel. Use one of following unless otherwise specified by OWNER and/or ENGINEER:
    a. HRSD System #1: Low-to-Moderate Corrosion:
        1) Galvashield XP (Zinc Mass = 60g); Vector Corrosion Technologies.
        2) Galvashield XPT (Zinc Mass = 60g); Vector Corrosion Technologies.
        3) Sika FerroGard 650 (Zinc Mass = 65g); Sika Corporation.
        4) Sentinel Silver Galvanic Anodes (Zinc Mass = 100g); Euclid Chemical Company.
        5) Approved Equal.
    b. HRSD System #2: Moderate-to-High Corrosion:
        1) Galvashield XP2 (Zinc Mass = 100g); Vector Corrosion Technologies.
        2) Galvashield XP4 (Zinc Mass = 160g); Vector Corrosion Technologies.
        3) Sika FerroGard 670 (Zinc Mass = 105g); Sika Corporation.
        4) Sentinel Gold Galvanic Anodes (Zinc Mass = 200g); Euclid Chemical Company.
        5) Approved Equal.

C. Distributed Galvanic Anodes in Concrete Rebuilds:
1. Alkali-activated consisting of zinc in compliance with ASTM B418 Type II cast around steel tie wires and encased in a highly alkaline cementitious shell with a pH of 14 or greater. The anode unit shall include FRP reinforcing and shall contain no chlorides or other corrosive constituents as per ACI Guideline No. 222R-01. Anodes shall be supplied with integral tie wires for tying to the reinforcing steel. Use one of following unless otherwise specified by OWNER and/or ENGINEER:
    a. HRSD System #3: Low Corrosion:
        1) Galvanode DAS (Zinc Weight = 0.25 lb/ft); Vector Corrosion Technologies.
        2) Approved Equal.
    b. HRSD System #4: Moderate Corrosion:
        1) Galvanode DAS (Zinc Weight = 0.60 lb/ft); Vector Corrosion Technologies.
        2) Approved Equal.
    c. HRSD System #5: High Corrosion:
        1) Galvanode DAS (Zinc Weight = 1.20 lb/ft); Vector Corrosion Technologies.
        2) Approved Equal.

D. Drilled-In Galvanic Anodes
1. Alkali-activated, Type 2A, consisting of zinc in compliance with ASTM B418 Type II cast around steel tie wires and encased in a highly alkaline cementitious shell with a pH of 14 or greater. The cementitious shell shall contain no chlorides or other corrosive constituents as per ACI Guideline No. 222. Anodes shall be supplied with integral tie wires for tying to the reinforcing steel. Use one of following unless otherwise specified by OWNER and/or ENGINEER:
    a. HRSD System #6: Low-to-Moderate Corrosion:
        1) Galvashield CC65; Vector Corrosion Technologies.
        2) Approved Equal.
    b. HRSD System #7: Moderate-to-High Corrosion:
        1) Galvashield CC100; Vector Corrosion Technologies.
        2) Approved Equal.
    c. HRSD System #8: Congested Reinforcement:
        1) Galvashield CC135; Vector Corrosion Technologies.
        2) Approved Equal.

E. Galvanic Anode Spacing:
1. The location and spacing of galvanic anodes shall be determined by the OWNER, ENGINEER and/or Quality Assurance Representative based on field conditions and existing configuration and density of reinforcing steel. The steel density ratio is defined as the ratio of the steel reinforcing surface area to the concrete surface area. Reference Contract Documents or OWNER and/or ENGINEER for specific spacing requirements. The following are minimum requirements unless specified elsewhere:
   a. Discrete Galvanic Anodes
      1) HRSD System #1: Low-to-Moderate Corrosion:
         a) Steel Density ≤ 1.0; Spacing ≤ 18-inches on-center (o.c.).
         b) Steel Density > 1.0; Spacing ≤ 12-inches o.c.
      2) HRSD System #2: Moderate-to-High Corrosion:
         a) Spacing ≤ 12-inches o.c.
   b. Distributed Galvanic Anodes
      1) HRSD System #3: Low Corrosion:
         a) Steel Density ≤ 1.0; Spacing (ties) ≤ 18-inches o.c.
         b) Steel Density > 1.0; Spacing (ties) ≤ 12-inches o.c.
      2) HRSD System #4: Moderate Corrosion:
         a) Spacing (ties) ≤ 12-inches o.c.
      3) HRSD System #5: High Corrosion:
         a) Spacing (ties) ≤ 6-inches o.c.
   c. Drilled-In Galvanic Anodes
      1) HRSD System #6: Low-to-Moderate Corrosion:
         a) Steel Density ≤ 1.0; Spacing ≤ 18-inches o.c.
         b) Steel Density > 1.0; Spacing ≤ 12-inches o.c.
      2) HRSD System #7: Moderate-to-High Corrosion:
         a) Spacing ≤ 12-inches o.c.
      3) HRSD System #8: Congested Reinforcement:
         a) Spacing to be determined by OWNER and/or ENGINEER.

F. Conductive Embedding Mortar
1. Conductive embedding mortar shall be compatible with galvanic anodes to be used and accepted for use by anode manufacturer. Use one of the following:
   a. Galvashield Embedding Mortar; Vector Corrosion Technologies.
   b. Eucopatch; Euclid Chemical Company.
   c. SikaRepair 222 or 223; Sika Corporation.
   d. Approved Equal.

G. Epoxy for Distributed Galvanic Anode
1. Epoxy shall be 100% solids, non-conductive unless otherwise specified. Use one of the following:
   a. Sikadur 32, Hi-Mod; Sika Corporation.
   b. Approved Equal.

PART 3 - EXECUTION

3.1 GENERAL

A. Prepare substrate and rebuild area in accordance with Section XXXX *{Engineer to specify}*.
1. Remove sufficient concrete at anode locations to permit anode installation.
2. Clean exposed reinforcing steel of rust, mortar, and other inhibiting materials to provide sufficient electrical connection and mechanical bond.

B. Install galvanic anodes in accordance with requirements herein with spacing as specified by the Contract Documents, OWNER and/or ENGINEER. Anode spacing will vary with changes in the reinforcing steel density, the level of chloride in the concrete, and the corrosivity of the local environment. Representative spacing requirements are provided herein and are based on existing conditions and exposure. Reference Drawing 01-08 through 01-14 *{Engineer to specify}* for representative discrete and distributed galvanic anode layout, spacing and installation requirements.

C. Provide minimum 1-1/2 inch concrete cover over anodes unless otherwise specified by OWNER and/or ENGINEER.

D. Electrically connect anodes to clean reinforcing bars.
   1. Wrap anode wires around reinforcing bar and twist tight to allow no free movement.
   2. Confirm electrical continuity of reinforcing steel in removal area and of anodes with reinforcing steel by measuring DC resistance with a multi-meter. Resistance shall be less than 1 ohm.
   3. If continuity of reinforcing steel is not acceptable, add additional steel tie wires or supplemental reinforcing until continuity is acceptable.
   4. If continuity of anode to reinforcing steel is not acceptable, modify wrapping of anode tie wires until acceptable.
   5. If continuity cannot be achieved after implementing additional measures as specified above, notify OWNER and/or ENGINEER for additional direction.

E. Install conductive embedding mortar (if required).

F. Install concrete rebuild material per Section XXXX *{Engineer to specify}*, exercising care to avoid disturbing anodes.

3.2 INSTALLATION OF DISCRETE GALVANIC ANODES

A. Discrete galvanic anodes shall be installed along the perimeter of the repair or interface with spacing as specified.

B. Position anodes as close to rebuild perimeter as possible. Locate at intersections of bars if possible.

C. Position anodes to provide at least 1-1/2 inches of clear cover. If necessary, position anodes next to, or underneath, reinforcing bars.

D. Provide at least 1-inch clearance between anodes and existing concrete substrate sufficient to allow repair material to encase anode.

E. Electrically connect anodes to clean reinforcing bars as close as possible to edge of removal area.
   1. Confirm electrical continuity of reinforcing steel in removal area and of anodes with reinforcing steel by measuring DC resistance with a multi-meter. Resistance shall be less than 1 ohm.

F. Encapsulate anodes in conductive embedding mortar and fill gaps between anodes and concrete substrate with conductive mortar as recommended by anode manufacturer. Encapsulation of anodes with conductive embedding mortar is not required for anodes to be placed within concrete material with measured resistivity values less than 15,000 ohm-cm.

G. Pre-soak anodes prior to placement of concrete rebuild material. Do not soak anodes for greater than 20 minutes unless otherwise specified by anode manufacturer.

H. Install concrete rebuild material per Section XXXX *{Engineer to specify}*, exercising care to avoid disturbing anodes.

3.3 INSTALLATION OF DISTRIBUTED GALVANIC ANODES

A. Distributed galvanic anodes shall be installed along the perimeter of the repair, or at locations as specified by Contract Documents, OWNER and/or ENGINEER.

B. Position anodes to provide at least 1-1/2 inches of clear cover.

C. Provide at least 1-inch clearance between anodes and existing concrete substrate sufficient to allow repair material to encase anode.

D. Electrically connect anodes to clean reinforcing bars. Space ties at locations as specified by Contract Documents, OWNER and/or ENGINEER. At a minimum, spacing shall be in accordance with requirements herein.
   1. Confirm electrical continuity of reinforcing steel in removal area and of anodes with reinforcing steel by measuring DC resistance with a multi-meter. Resistance shall be less than 1 ohm.

E. Encapsulate anode wires and reinforcing steel at connection points with 100% solids, non-conductive, epoxy coating.

F. Install concrete rebuild material with resistivity values less than 15,000 ohm-cm, unless otherwise approved by OWNER and/or ENGINEER, per Section XXXX *{Engineer to specify}*, exercising care to avoid disturbing anodes.

3.4 INSTALLATION OF DRILLED-IN GALVANIC ANODES

A. General
   1. Reference Drawing 01-11 *{Engineer to specify}* for plan and section details of typical drilled-in galvanic anode installations.
   2. Using a rebar location device (pachometer or equivalent), locate all existing reinforcing steel within the area designated for protection and clearly mark reinforcing layout on exterior concrete surface for examination by OWNER and/or ENGINEER.
      a. In areas where known, or potential, embedded conduit or other obstructions may be present, utilize ground penetrating radar (GPR) or other means for determining the location of rebar and embedded obstructions.
   3. Drill a minimum of four 1/2-inch diameter holes at rebar locations to verify continuity of existing underlying reinforcing steel. It is recommended that locations be consistent with presumed reinforcing steel connection (tie-in) points to the furthest extent possible. Continuity shall be measured using DC resistance with a multi-meter. Continuity measurements shall be deemed acceptable for resistance of 1 ohm or less. Should resistance exceed 1 ohm, OWNER and/or ENGINEER to determine recommended course of action.
   4. Based on layout of located rebar and embedded obstructions, OWNER and/or ENGINEER to designate locations for anode placement and rebar connection.
      a. Anodes shall be installed 4-inches (min) from reinforcing grid designated for protection unless otherwise specified by Anodes shall be installed 4-inches (min) from reinforcing grid designated for protection unless otherwise specified by ENGINEER.
   5. Drill anode unit holes to specified diameter and depth in accordance with manufacturer recommendations based on anode unit size. Do not enlarge holes.
   6. Thoroughly clean reinforcing steel connection and anode drilled-hole locations utilizing a stiff wire brush, or equivalent. Remove dust, debris and contaminants utilizing compressed air or pressurized water.
   7. Connection to reinforcing steel shall be made using manufacturer approved methods and shall utilize manufacturer specified connection kit units (if applicable). Continuity shall be measured using DC resistance with a multi-meter. Continuity measurements shall be deemed acceptable for resistance of 1 ohm or less.
   8. Saturate Surface Dry (SSD) drilled holes for 2-hours (min) prior to installation of anodes and conductive embedding mortar.
      a. Pre-soak anode units as required by manufacturer.
   9. Install conductive embedding mortar into bottom two-thirds (by depth) of drilled SSD anode unit holes, unless otherwise specified by manufacturer.

10. Install anode units by slowly pressing units into the embedding mortar, allowing the mortar to fill the annular space around the units. Ensure no air voids exist between the unit anode and parent concrete. Ensure minimum anode unit concrete cover depth of 3/4-inch.
    a. Interconnect anode unit wiring with reinforcing steel connection wiring and place wiring securely into saw-cut grooves. Connect wiring in accordance with manufacturer recommendations and utilizing manufacturer recommended installation kits (if applicable). Top off anode unit holes and fill saw-cut grooves with embedding mortar.
    b. Wet cure embedding mortar for minimum 24-hours and as recommended by manufacturer.

B. For Series Connection
    1. A single circuit shall contain no more than 10 anode units.
    2. Drill two (min) 1/2-inch reinforcing steel connection holes per string of anodes.
    3. Saw-cut a single continuous groove approximately 1/4-inch wide by 1/2-inch deep into the concrete along the proposed anode series arrangement to interconnect reinforcing steel connection holes with the anode connection holes.

C. For Individual Connection
    1. Drill one 1/2-inch rebar connection hole per anode unit location.
    2. Saw-cut a groove approximately 1/4-inch wide by 1/2-inch deep into the concrete to interconnect the reinforcing steel connection hole with the anode connection hole.

3.5 DRAWINGS

A. The following figures represent typical or representative conditions and may not be indicative of actual field conditions. The OWNER and/or ENGINEER should review the conditions as necessary for applicability. *{Engineer to review Series 600 of Standard Details in Section 34 of HRSD Design and Construction Standards for applicability and inclusion}*
    1. Standard Detail 600: Installation of Discrete Galvanic Anodes
    2. Standard Detail 601: Installation of Distributed Galvanic Anodes
    3. Standard Detail 602: Distributed Galvanic Anodes at Top of Wall
    4. Standard Detail 603: Installation of Drilled-In Galvanic Anodes
    5. Standard Detail 604: Conductive Mortar Bridge for Use with High Resistivity Repair Mortars
    6. Standard Detail 605: Typical Galvanic Anode Layout
    7. Standard Detail 606: Typical Galvanic Anode Connections

END OF SECTION