***SPECIFICATION***

*This specification series is intended to cover construction activities related to galvanic anodes for control of incipient anode affect and general corrosion control of steel in concrete.*

***I. Discrete or drilled in galvanic anodes to provide steel in concrete corrosion control*.**

***1. General***

1. *Steel reinforcement in concrete elements can be electrochemically protected from the risk of corrosion to areas adjacent to repair patches (incipient anode effect), chloride initiated corrosion and carbonated concrete by using galvanic anodes.*

*Use of galvanic anodes within repair patches may reduce the extent of sound but contaminated concrete that needs to be broken out in accordance with the international guidelines.*

*Galvanic anodes attached to steel reinforcement generate a protective current because the steel and the metal used in the galvanic anode have different electrochemical potentials.*

*Galvanic anodes should only be assumed to provide protection to the existing reinforcement within the repair patch and up to 300mm beyond the edge of the repair patch. Protection to other contaminated areas of concrete beyond this limit will not be provided.*

*Discrete galvanic anodes are fixed directly to reinforcement within the repair areas and should be located near to and inside the perimeter of the repair.*

*Drilled in galvanic anodes are installed in holes drilled into the substrate and connected to the reinforcement within the repair area.*

1. *If there is a definite need to monitor the current being supplied by the installed anodes, monitoring points can also be used to check for indicators that protection is being achieved and reference electrodes will be needed. Monitoring by reference electrode can only confirm the steel reinforcement being polarised.*

***2. Performance requirements***

1. *The metallic core of the galvanic anode will sacrificially corrode to protect the steel reinforcement to which it is connected. It is important that products of corrosion from the anode and any resulting reactions with activating agents and backfill do not generate chemicals which are themselves a corrosion risk to the existing reinforcement or expand so much during service that adjacent concrete is damaged.*
2. *The galvanic anode shall contain NO alkali-activated with an alkaline cementitious shell with a pH of 14 or greater such as calcium hydroxide, lithium hydroxide, potassium hydroxide or sodium hydroxide due to their carbonation properties as these products are used in the industry as carbon dioxide scavangers. High carbonation rates of these activating agents will reduce the pH to levels around a pH of 11 passivating the zinc anode.*
3. *The galvanic anode shall contain NO chloride or halide-activated cementitious shell, adhesive or paste such as sodium-, lithium- or potassium- chlorides or bromides in accordance with EN 1504 and EN 1015-17.*
4. *Reference electrodes should remain useable for at least 20 years, and during that time it should be possible to reliably interrogate the system potential or corrosion current. Readings should remain stable regardless of variations in concrete temperature and moisture. More information can be obtained from ISO 12696 (monitoring sensors).*

***3. Acceptance of products***

1. *Galvanic anodes are proprietary products. Their manufacture is not currently covered by an international standard. As a result, the contractor is required to provide evidence that the proposed anode has performed satisfactorily in service, and examples of installations where the product has achieved the minimum life required by the contract.*

***4. Contractor design***

1. *Where the Contractor is required to design the galvanic anode system, the compiler should specify this in contract specific Appendix 1.*

*The compiler should include in the contract appropriate supporting information e.g. the existing reinforcement drawings, concrete testing reports. The minimum free chloride content of the adjacent existing concrete, and maximum reinforcement density to be assumed in the design should be specified in contract specific Appendix 1.*

1. *Where a longer service life than 10 years is required, the compiler should specify this in contract specific Appendix 1.*
2. *Where permanent reference electrodes are required, the compiler should specify requirements in contract specific Appendix 1.*

***II. Products and materials***

***1. Galvanic anodes***

1. *The metals and metallic alloys used for proprietary galvanic anodes are more active than steel in the electrochemical series. Zinc and its alloys are currently the principal materials used for manufacturing galvanic anodes. The specification requires zinc or zinc alloy metals to have high percentage purity to ensure a reasonably consistent protective current.*
2. *The design of galvanic anodes relies on the sacrificial zinc element achieving an adequate efficiency/ utilisation factor. High quality zinc is specified for this.*
3. *The galvanic anodes will be embedded or coated with an electrochemically active paste or adhesive and produce galvanic current to the steel in concrete reinforcement for a minimum of 10 years from the date of anode installation.*
4. *Galvanic anodes and reference electrodes rely for their operation on the free flow of electrons within the electrochemical circuit consisting of the anodes, concrete and reinforcement. The circuit relies on a durable electrical connection between the anode or reference electrode and the existing steel reinforcement, so electrical continuity of the connecting wires should be confirmed.*

***2. Reference electrodes***

1. *When required for an installation of galvanic anodes connected in series, the type, number and location of permanent reference electrodes for monitoring of the installation should be specified in contract specific Appendix 1.*

***III. Installation of galvanic anodes and reference electrodes***

***1. Electrical continuity of reinforcement***

1. *If galvanic anodes are specified within a concrete repair patch, it is very important to check there is electrical continuity between existing reinforcing bars. Continuity should be established if not present at the intersection of bars.*

***2. Electrical potential survey***

1. *Results of the electrical potential survey will provide initial readings to compare against future readings of electrical potential and may later provide some indication of anode performance. It may take a short time period for the current developed by galvanic anodes to distribute itself throughout the reinforcement cage, achieve polarisation and provide full protection to reinforcement outside the repair patch.*

***3. Fitting of anodes and electrodes***

1. *The spacing between adjacent anodes should be specified according to the steel reinforcement surface area ratio (steel surface area within a 1 m2 concrete areas), the current output capability of the individual anode and the environmental conditions, including the assumed concentration of chlorides in the neighbouring parent concrete.*
2. *The compiler should show on construction drawings the location, extent and spacing of galvanic anodes fixed to reinforcement within repairs or give details of these in contract specific Appendix 1.*
3. *For fairly sized patch repairs, anodes are fixed around the perimeter of a repair and are not provided in the centre of a patch.*
4. *The location of reference electrodes on a structural element should be shown on construction drawings and the general location should be described in Appendix 1 and referenced to construction drawings.*

***4. Junction boxes***

1. *Where junction boxes are required for monitoring of galvanic anodes within repairs patches or specific zones, the compiler should give requirements in contract specific Appendix 1.*

***5. Particular requirements for discrete galvanic anodes***

1. *The resistivity of mortar or concrete used to reinstate repair patches where discrete galvanic anodes are tied to reinforcement and incorporated within the repair should be limited to the range given in Note 1.*

***6. Particular requirements for drilled in galvanic anodes***

1. *The hole's backfill/surround material should be an electrochemically active paste or adhesive in contact with the zinc to produce galvanic current to the steel in concrete reinforcement for a minimum of 10 years from the date of anode installation.*
2. *The hole's backfill/surround material shall contain NO alkali-activated with an alkaline cementitious shell with a pH of 14 or greater such as calcium hydroxide, lithium hydroxide, potassium hydroxide or sodium hydroxide due to their carbonation properties as these products are used in the industry as carbon dioxide scavangers. High carbonation rates of these activating agents will reduce the pH to levels around a pH of 11 passivating the zinc anode.*
3. *The galvanic anode shall contain NO chloride or halide-activated cementitious shell, adhesive or paste such as sodium-, lithium- or potassium- chlorides or bromides in accordance with EN 1504 and EN 1015-17.*

***8. Particular requirements for reference electrodes***

1. *If reference electrodes are required for monitoring the steel polarisation, they should be located within the existing sound concrete, as required by ISO 12696. The compiler should describe the location of electrodes in contract specific Appendix 1, if locations are not shown on contract drawings.*

***IV. Repairs to structures using galvanic anodes for control of incipient anode effect***

***1. General***

1. *Concrete repair product may be marketed as compatible for use with cathodic protection systems.*
2. *Galvanic anodes generate their own current and drive voltage. The galvanic current needs to draw chloride ions from the existing concrete just outside the repair patch towards the anodes.*
3. *Using a high resistivity repair product for repairs may significantly reduce current flow. The specification includes a range of acceptable electrical resistivities.*
4. *Resin-based repair mortars are not suitable for use in conjunction with electrochemical treatments; neither are repair products containing e.g. steel or carbon fibres. This is because current generated by galvanic anodes is impeded by the high resistivity of polymer resin and current deflection is caused by conductive fibres.*

***V. Testing of Completed Repairs***

1. *ISO 12696 has a general recommendation that repair products should have a resistivity within the range 50 – 200% of the parent concrete, however galvanic anodes generate a limited drive voltage, so a limited resistivity of the repair concrete is more important for galvanic anode systems.*
2. *Published guidance on testing of concrete for electrical resistivity may be found in electrochemical tests for measurement of concrete resistivity using Wenner technique. Methods of measuring the resistivity of concrete both in the laboratory and in-situ are given in RILEM TC-154. Technical Recommendation where 4-pin, 2-pin and surface electrode to reinforcing cage methods are discussed along with temperature compensation. It should be noted that the document states that a coefficient of variation of 30% in resistivity measurements is normal in the field.*

***APPENDIX 1 REQUIREMENTS FOR GALVANIC ANODES***

*Include here the following contract specific requirements and details:*

1. *Requirements for Contractor to design galvanic anode installation.*
2. *Required service life of galvanic anodes if different from 10 years.*
3. *Requirements of reference electrodes for monitoring :*
   1. *Type, size, material.*
   2. *Location.*
4. *Required spacing of galvanic anodes around the perimeter of repair, if not specified on the drawings.*
5. *Requirements for monitoring of galvanic anode installation including:*
   1. *Connections.*
   2. *Junction boxes.*
   3. *Control boxes.*
   4. *Terminals for local or remote monitoring.*

***NOTE 1 CONCRETE REPAIR PRODUCTS FOR GALVANIC ANODES***

1. *The cathodic protection designer should be consulted on how the repair system should be specified and designed to deal with issues that may include varying resistivities due to different exposure conditions, concretes or repairs and the requirement for current to reach steel below repairs.*
2. *The repair material should be cementitious with no electrically conducting admixtures or fibres and it shall not be resin based.*
3. *If a repair material can be shown to have performed well in comparable cathodic protection systems under similar conditions then its resistivity value should not be the overriding determinant in its use.*
4. *When comparing laboratory measurements with resistivity values from the field there will typically be a coefficient of variation of 30% for field measurements as well as further errors and variations due to temperature and relative humidity differences.*
5. *For galvanic anodes the repair material resistivity should be within 50% to 200% of the resistivity of the parent concrete measured in a comparable manner and/or should not exceed 150 ohm.m or any other limit specified by the anode supplier.*