Concrete Solutions, 4th International Conference on Concrete Repair, Dresden, Germany, 26 – 28 September 2011

Galvanic corrosion protection of steel in concrete with a zinc mesh anode embedded into a solid electrolyte (EZA)

CAS
COMPOSITE - ANODE - SYSTEMS GMBH

Galvanic corrosion protection of steel in concrete with a zinc mesh anode embedded into a solid electrolyte (EZA)

W. Schwarz, F. Müllner
CAS Composite Anode Systems GmbH, Austria

A. van den Hondel
Eco Remain, Capelle aan den Ijsse, Nederland

ABSTRACT: The efficiency of the galvanic corrosion protection (GCP) of the steel reinforcement of a novel Embedded Zinc Anode (EZA) is evaluated on three types of civil structures – a road bridge (cantilevers, part of the underside the bridge deck and an abutment) in the Styrian Alps in Austria, concrete abutments of a steel bridge and support-beams for the bearings of a road bridge in the Netherlands. The EZA is applied to the surface of concrete members whose steel is to be protected from corrosion by embedding a zinc mesh (2 – 4 kg/m^2) into a proprietary mortar that hardens to a solid electrolyte. The efficiency of the GCP was monitored with embedded reference cells, concrete resistivity – and macro cell sensors. The macro cell sensors allow the quantification of the galvanic protection efficiency. Data collected over a period of up to nearly 4 years show that the EZA protects the steel reinforcement efficiently and reliably.

1 INTRODUCTION

Galvanic corrosion protection of steel in concrete is based on the formation of a galvanic element if a metal less noble than cast iron steel, in direct contact with the concrete overlay, is electrically connected to the steel rebars. The reinforcing steel is protected from corrosion as long as sufficient galvanic current flows between the galvanic anode and the steel reinforcement. Most commonly, zinc is used as the sacrificial anode material. The galvanic element formed corresponds to a conventional zinc/air battery that is becoming popular again as an alternative source of energy.

Galvanic corrosion protection was first employed to protect a bridge deck in Illinois in 1977 within the cooperative highway research program, with mixed results (Kepler et al. 2000). A problem with the initially applied sacrificial anodes was that their protection current decreases with time, and they eventually become passive, so most systems have a relatively short useful life (Virmani & Clemena 1998).

In the 1990’s, sacrificial anode systems based on sprayed zinc anodes, zinc foil glued to the concrete surface (zinc hydrogel system), zinc mesh pile jackets around bridge columns filled with sea water were starting to be evaluated and used for the protection of bridge structures (Virmani & Clemena 1998, Kessler, Powers & Lasa 2004; Szabo & Bakos 2006, Bullard, Cramer & Covinho 2009).

To a limited extent, zinc anodes embedded into the concrete overlay, are used to protect the steel reinforcement especially accompanying concrete repair.

The efficiency of galvanic corrosion protection depends on the lasting activity of the zinc anode. Deposition and agglomeration of the anodic products like zinc hydroxide and zinc hydroxychlorides or contact with calcium hydroxide in the pore solution may passivate the zinc anode surface. Service time of the zinc anode may be limited by self corrosion that increases with the activation of the zinc anode and may reach up to 70% of the zinc consumed during operation.

The driving voltage is set by the properties of the anode, the interface of the anode to the concrete and by the electrolytic conductivity of the concrete overlay. Sprayed zinc anodes require sufficient humidity and high chloride contents to operate satisfactorily (Bäßler et. al.). Galvanic systems are not suitable for the protection of steel in carbonated concrete members.

For the galvanic systems evaluated so far, efficient corrosion protection for steel in concrete has been provided. Expected service times are in the range of 40 years and more.

Experience showed that most failures of galvanic systems occurred due to the failure of the adhesion of the anode to the concrete overlay and due to passivation of the anode exposed to frequent wet dry cycles. Zinc-Hydrogel anodes are especially sensitive to exposure to high humidity with subsequent delamination.

A novel galvanic zinc anode system, composed of a zinc mesh embedded into a proprietary mortar that solidifies into a solid electrolyte, was developed by CAS. The solid electrolyte of the embedded zinc anode system (EZA) is based on a tecto-alumosilicate-binder containing additives that prevent passivation of the zinc anode, assure high and durable galvanic activity of the zinc anode and high and durable adhesion towards the concrete overlay.

The efficiency of the galvanic corrosion protection (GCP) of the steel reinforcement with a novel embedded zinc anode (EZA) is evaluated on three types of civil structures – a road bridge (cantilevers, part of the underside the bridge deck and an abutment) in the Styrian Alps in Austria, concrete abutments of a steel bridge and support-beams for the bearings of a road bridge in the Netherlands. The results of the evaluation of the performance and of the efficiency of the protection of the steel reinforcement against corrosion are presented.

2 DESCRIPTION OF THE SYSTEM

The galvanic EZA system is composed of a zinc mesh (rhomboedric, mesh size 2 – 4 cm, 2 – 8 kg/m^2) embedded into the proprietary solid electrolyte (figure 1) that ascertains an optimum electrolytic contact between the zinc anode and the concrete overlay.

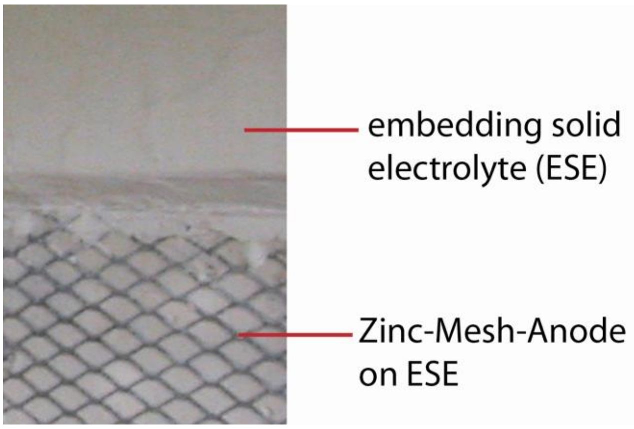

Figure 1. Embedded galvanic zinc anode (EZA): zinc mesh embedded into the TASC mortar from which the embedding solid electrolyte forms.

The solid electrolyte, based on a tectoalumosilicate cement (TASC), prevents the self passivation of the zinc anode and therefore assures an optimum and reliable protection of steel reinforcement endangered by, or already damaged by chloride induced corrosion.

The zinc anode, a zinc mesh, is embedded into the proprietary solid electrolyte that ascertains an optimum electrolytic contact between the zinc anode and the steel reinforcement.

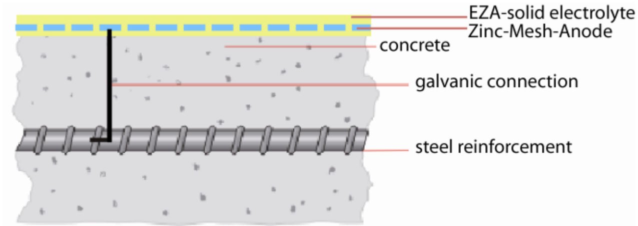

Figure 2.: Scheme of the mode of operation of an EZA

Unlike impressed current CP systems, hydrogen evolution is not possible on an EZA. The EZA is especially suited for the corrosion protection of prestressed concrete structures.

The EZA is placed on the surface of the concrete member in which the steel reinforcement is to be protected from corrosion (figure 2):

The concrete surface has to be prepared with the standard procedures for placing coatings on concrete surface (high-pressure water jetting, sand blasting, etc.). The concrete surface has to be clean and electrolytically conductive as specified in EN 12696. Tie wires embedded into the concrete overlay have got to be removed. Prior to the installation of the EZA, sensors and electrical connections to the steel rebars have to be installed.

The EZA is installed analogous to how tiles are placed: A layer of the TASC-mortar (2 – 3 mm) is placed on the concrete surface. The zinc mesh is pressed onto the mortar layer. If required, the zinc mesh may be fixed with plastic bolts to the concrete. After hardening (after about 12 hours), the individual zinc sheets are mechanically coupled with a crimping tool and electrical connections are installed if depolarisation measurements are required. Otherwise, the zinc mesh may be directly connected to the steel rebars by shooting steel bolts into drilled holes onto steel rebars.

Subsequently, the zinc mesh is embedded into a second layer of the TASC-mortar. After applying the mortar has to be covered with a plastic sheet or foil for at least three days to prevent evaporation of water.

Adhesion strength after 24 hours is in the range of 0.6 – 1.0 MPa, after 7 days > 2 MPa and after 28 days about 2.5 – 3.0 MPa.

The EZA shall be put into operation at least three weeks after installation by connecting the anode to the steel rebars.

The efficiency of corrosion protection by the EZA may be evaluated according to the procedure described in EN 12696 – the 24 h depolarisation criterion. For that purpose, the installation of into the concrete overlay embedded reference cells and an automated monitoring and control system is required.