SLOVENSKI STANDARD
SIST EN 12696:2000

01-december-2000

Katodna zaščita jekla v betonu

Cathodic protection of steel in concrete

Kathodischer Korrosionsschutz von Stahl in Beton

Protection cathodique de l'acier dans le béton

Ta slovenski standard je istoveten z: **EN 12696:2000**

ICS:

77.060	Korozija kovin	Corrosion of metals
91.080.40	Betonske konstrukcije	Concrete structures

SIST EN 12696:2000 **en**

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 12696

March 2000

ICS 77.060; 91.080.40

English version

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Ref. No. EN 12696:2000 E

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Foreword

This European Standard has been prepared by Technical Committee CEN/TC 219 "Cathodic protection", the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2000, and conflicting national standards shall be withdrawn at the latest by September 2000.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

This European Standard is limited to cathodic protection of steel in atmospherically exposed concrete. Many atmospherically exposed reinforced and prestressed concrete structures incorporate foundations or lower elevations which are buried or submerged. Because the technology for the application of cathodic protection to steel in buried or submerged concrete and the criteria of protection for steel in buried or submerged concrete are both significantly different to those applicable to cathodic protection of steel in atmospherically exposed concrete, these foundations or lower elevations are not addressed in this European Standard.

There are other electrochemical treatments intended to provide corrosion control for steel in concrete. These techniques include re-alkalisation and chloride extraction and are not incorporated into this European Standard. At the time of preparation of this European Standard CEN/TC 219/WG2 were in the process of collecting data on electrochemical re-alkalisation and chloride extraction to prepare European Standards on these techniques at an appropriate time.

Cathodic protection of steel in concrete is a technique that has been demonstrated to be successful in appropriate applications in providing cost effective long term corrosion control for steel in concrete. It is a technique that requires specific design calculations and definition of installation procedures in order to be successfully implemented. This European Standard does not represent a design code for cathodic protection of steel in concrete but represents a performance standard for which it is anticipated, in order to comply with the standard, a detailed design and specification for materials, installation, commissioning and operation will be prepared.

1 Scope

This European Standard specifies performance requirements for cathodic protection of steel in atmospherically exposed concrete, in both new and existing structures. It covers the atmospherically exposed parts of building and civil engineering structures, including normal reinforcement and prestressed reinforcement embedded in the concrete. It is applicable to uncoated steel reinforcement and to organic coated steel reinforcement.

This European Standard does not apply to buried or submerged elements of the buildings or structures.

NOTE Annex A gives guidance on the principles of cathodic protection and its application to steel in concrete.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

ENV 1504-9: Products and systems for the protection and repair of concrete structures – Definitions, requirements, quality control and evaluation of conformity – Part 9: General principles for the use of products and systems

EN 60742: Isolating transformers and safety isolating transformers - Requirements

ISO 8044: Corrosion of metals and alloys - Vocabulary

IEC 60502: Extruded solid dielectric insulated power cables for rated voltages from 1 kV up to 30 kV

IEC 60529: Degrees of protection provided by enclosures (IP Code)

3 Terms and definitions

For the purposes of this European Standard, the terms and definitions given in ISO 8044 and ENV 1504-9 and the following apply.

3.1
zone
a defined part of a cathodic protection system

NOTE Anode systems may be divided into zones to supply current to a fully continuous reinforcement matrix. Alternatively a single anode zone may supply current to separate, electrically isolated, zones within the reinforcement system. Finally zones may comprise an individual anode zone for each reinforcement zone.

As the current provision to each of the zones in each of these alternatives can be separately controlled and measured all are generically called as “cathodic protection zones” and specifically as “anode zones” or “cathode zones”.

4 General

4.1 Quality management systems

The design, the installation, the energising, the commissioning, the long-term operation and the documentation of all of the elements of cathodic protection systems for steel in atmospherically exposed concrete shall be fully documented.

NOTE EN ISO 9001 constitutes a suitable Quality Management Systems Standard which may be utilised.

Each element of the work shall be undertaken in accordance with a fully documented quality plan.

Each stage of the design shall be checked and the checking shall be documented.

Each stage of the installation, energising, commissioning and operation shall be the subject of appropriate visual, mechanical and/or electrical testing and all testing shall be documented.

All test instrumentation shall have valid calibration certificates traceable to national or European Standards of calibration.

The documentation shall constitute part of the permanent records for the works.

4.2 Personnel

Each aspect of the cathodic protection system design, installation, testing of the installation, energising, commissioning and long-term operational control shall be under the supervision of personnel with appropriate qualification, training, expertise and experience in the particular element of the work for which he is responsible.

NOTE Cathodic protection of steel in concrete is a specialist multidiscipline activity. Expertise is required in the fields of electrochemistry, concrete technology, civil and/or structural engineering and cathodic protection engineering.

4.3 Design

This Standard does not represent a design code but is a performance standard.

Cathodic protection systems for steel in atmospherically exposed concrete shall be the subject of detailed design.
The design shall, as a minimum, include the following:

a) detailed calculations;
b) detailed installation drawings;
c) detailed material and equipment specifications;
d) detailed method statements or specification for installation, testing, energising, commissioning and operation.

NOTE Annex B lists items that should be considered in the detailed design.

5 Structure assessment and repair

5.1 General

The assessment of a structure, including its material condition, its structural integrity, and whether and how to repair it, shall be performed in accordance with ENV 1504-9.

NOTE This assessment will normally be undertaken prior to a decision to use cathodic protection and will not normally be undertaken by personnel, trained in cathodic protection procedures.

When cathodic protection is proposed as the repair/protection method, or part of it, for a structure, additional investigation shall be undertaken in order to:

a) Confirm the suitability of cathodic protection.
b) Provide system design input information. See annex B.

These investigations shall include but shall not be limited to those in 5.2 to 5.10 below:

5.2 Records

All available drawings, specifications, records and notes shall be reviewed to assess the location, quantity, nature (e.g. normal, Zn-galvanised, epoxy-coated, prestressed) and continuity of the reinforcement, and the constituents and quality of the concrete.

The available information shall be confirmed and supplemented by site survey and laboratory tests as specified in 5.3 to 5.8.

5.3 Visual Inspection and Delamination Survey

Visual survey data shall be collected to ascertain the type, causes and extent of defects, and any features of the structure or its surrounding environment, which could influence the application and effectiveness of cathodic protection. Areas which have been previously repaired and the repair methods and materials shall be identified .

All areas of the structure which require to be cathodically protected shall be checked for delamination of the concrete cover.

Defects such as cracks, honeycombing, or poor construction joints which could permit significant water penetration and which could in turn impair the effectiveness of the cathodic protection, shall be recorded.

5.4 Chloride analysis

The chloride content of the concrete shall be determined, in accordance with ENV 1504-9.

5.5 Carbonation depth measurement

Distribution of carbonation depths shall be measured in accordance with ENV 1504-9.

5.6 Concrete cover and reinforcement location

Concrete cover, and reinforcement size and position measurements shall be carried out in order to assess whether the anode/cathode spacing will be adequate for the particular anode system envisaged and to identify dense regions of reinforcement which may require high current density. Shielding of the reinforcement to be protected, caused by embedded metal meshes, metal fibres or plates, plastic sheets or non-conductive repair materials, which could impair the efficiency of cathodic protection shall be assessed. Possible short circuits between reinforcing steel and anode shall be assessed.

5.7 Reinforcement electrical continuity

Drawings of reinforcement and other steel elements shall be checked for continuity which shall then be proven on site by measuring the electrical resistance and/or potential difference between bars in locations remote from each other across the structure as specified in 7.1 for the purpose of confirming cathodic protection feasibility and providing design information. This shall include at least an assessment of the following on a representative basis:

a) electrical continuity between elements of the structure within each zone of the cathodic protection system.
b) electrical continuity of reinforcement within elements of the structure.
c) electrical continuity of metallic items, other than reinforcement, to the reinforcement itself.

At the subsequent repair and installation stage, reinforcement electrical continuity shall be further checked in accordance with the methods, and to the extent, specified in 7.1.

5.8 Steel/concrete potential

Representative areas, both damaged and apparently undamaged, shall be surveyed for reinforcement corrosion activity, using portable reference electrodes conforming to 6.3.2. Measurements shall be taken, preferably on an orthogonal grid, at a maximum spacing of 500 mm.

NOTE 1 It is not necessary to carry out a steel/concrete potential survey of the entire structure. It is appropriate to survey in more detail those areas where reference electrodes are planned to be permanently installed in order to place them in most anodic and other suitable locations.

Continuity of the reinforcement within any steel/concrete potential survey area is essential and shall be checked, using the method in 7.1 before the steel/concrete potential survey.

NOTE 2 It is essential that measurements in any areas identified as delaminated, in the survey specified in 5.2, have to be treated with caution, because delamination can produce readings inconsistent with the level of corrosion of the reinforcement.

5.9 Concrete electrical resistivity

The impact of variations in concrete resistivity on the cathodic protection system shall be considered.

5.10 Repair

5.10.1 General

All operations comprising repair shall be performed in accordance with ENV 1504-9 except where stated otherwise in this clause.

NOTE Installation of cathodic protection to an existing structure may be associated with other forms of repair work such as strengthening, patching or coating, as determined in accordance with ENV 1504-9. In this clause the term 'repair' signifies reinstatement of the damaged/deteriorated concrete substrate to provide an uninterrupted path for the flow of cathodic protection current prior to the installation of cathodic protection, as well as reinstatement at locations where concrete has been removed to provide access to reinforcement, install cable connections and monitoring sensors, and such like.

5.10.2 Concrete removal

All repair materials from previous installations with an electrical resistivity outside the range 50 % to 200 % of the nominal parent concrete electrical resistivity shall be broken out to achieve a clean concrete surface.

Any tying wire, nails or other metal components visible on the concrete, that might contact the anode system or might be too close to the anode for optimum anode/cathode spacing shall be cut back and the concrete shall be repaired.

NOTE Any metallic objects electrically isolated from the cathodic protection cathode circuit may corrode and may require to be electrically bonded to the reinforcement or removed

The removal of physically sound chloride contaminated or carbonated concrete prior to applying cathodic protection is not necessary.

5.10.3 Reinforcement preparation

Any loose corrosion product particles shall be removed from exposed reinforcement to ensure good contact between the steel and the repair material, but there is no need to clean reinforcement to bright metal.

Neither primers or coatings on the steel nor insulating/resistive bonding agents shall be used;.

5.10.4 Concrete reinstatement

Concrete reinstatement shall be in accordance with ENV 1504-9.

Subject to the need to provide adequate cover to avoid short circuits, concrete shall be reinstated using cementitious materials. Repair materials containing metal (either fibre or powder) shall not be used. The electrical resistivity characteristics and mechanical properties of the repair materials shall be similar to the original concrete. Proprietary curing membranes shall not be used prior to subsequent anode installation over the repair area.

The electrical resistivity of concrete repair materials shall be within the range 50 % to 200 % of the nominal parent concrete electrical resistivity.

5.11 Cementitious Overlay

Following repair as specified in 5.10, and anode installation in accordance with 7.5, 7.6 and 7.7 a cementitious overlay shall be applied over appropriate types of installed anode. All materials and application methods shall be in accordance with ENV 1504-9. The average bond strength between existing concrete and overlay shall be greater than 1,5 N/mm² and the minimum shall be greater than 1,0 N/mm², or the test failure shall be within the existing concrete.

Overlay application may be combined with concrete repair.

In such cases the electrical resistivity of concrete repair materials shall be within the range 50 % to 200 % of the nominal parent concrete electrical resistivity. Anode overlays may exceed 200 % of parent concrete electrical resistivity subject to a maximum of 100 kΩ cm at ambient conditions and subject to the anode within the overlay being able to pass its design current at the design voltage in an overlay of this resistivity.

The selected material, thickness and placement method shall be compatible with each other and with the anode material.

Electrical resistance between anode and reinforcement (cathode) shall be monitored to detect short circuits.

Curing membranes shall be removed or shall have sufficiently degraded to avoid adversely influencing the performance of the cathodic protection system.

5.12 New structures

In the case of a new structure, if cathodic protection as a preventive system is to be included in the original construction, the following issues shall be assessed in the design, specification and construction procedures, in addition to the requirements of the remainder of this standard and of the standards governing the design and construction of the new structure:

a) Provision and checking of reinforcement electrical continuity, in accordance with 7.1.
b) Adequate securing and protection of monitoring sensors and all cables and their connections, to avoid damage or disturbance during concrete placement and vibration.
c) Connection, location or insulation of other metallic fixtures, fixings, or other items, so as to avoid undesirable influences from the cathodic protection system.
d) In the case of anodes cast into the concrete structure, provision of sufficient rigid insulating spacers and attachments to secure the anodes in position and prevent creation of short circuits during concrete placement and vibration. Electrical resistance monitoring between anode and reinforcement (cathode) shall be used to detect short circuits during concrete placement.

6 Cathodic Protection System Components

6.1 General

The cathodic protection system shall include an anode system intended to distribute the cathodic protection current to the relevant surfaces or parts of the concrete, to facilitate its conversion from electronic to ionic current at the anode/concrete interface and to allow its distribution to the surfaces of the embedded steel in the concrete. The cathodic protection system shall further incorporate positive and negative d.c. cables between the anode and steel respectively and the d.c. power supply, which for impressed current systems is the source of the cathodic prevention current. Reference electrodes, other electrodes and other sensors are key elements of cathodic protection systems and constitute the performance monitoring system within cathodic protection systems. The data from the electrodes and sensors may be interrogated and displayed by portable

instrumentation, permanently installed instrumentation of either automatic or manual type. The entire cathodic protection system shall be designed, installed and tested to be suitable for its intended life in its intended environment.

6.2 Anode systems

The anode system shall be capable of supplying the performance required by the cathodic protection design (see 4.3). The anode system's calculated or anticipated life shall be sufficient for the design life incorporated in to the design, with, where necessary, planned maintenance or replacement of the anode system or parts of the system at periods designated in the design.

The anode current density shall conform to the design and shall not exceed such values resulting in a performance reduction of either:

a) the concrete at the anode/concrete interface; or
b) the anode;

during the design life of the anode.

The design and/or the selection of the anode material shall consider likely variations in cathode current density requirements, steel distribution, concrete electrical resistivity and any other factors likely to result in uneven distribution of current demand or current discharge from the anode and the possibility of this resulting in early failure of isolated parts of the anode system.

NOTE 1 A variety of anode systems have been developed, tested and demonstrated in long-term field applications to be suitable for use in the cathodic protection of steel in atmospherically exposed concrete. The requirements for such anodes are unique for usage of cathodic protection in concrete as the anodes have to be installed or applied distributed across the concrete surface or within the concrete as required to meet the design distribution and magnitude of current. The anode is therefore in close contact with the highly alkaline concrete pore water. In operation the anodic electrochemical reactions at the anode/concrete interface are oxidising, producing acidity.

NOTE 2 The anode systems described in this standard are in two categories. Anode systems which have been in use for a minimum of 5 years and which have extensive, generally successful, track records are covered by this standard in 6.2.1 and 6.2.2. It is not intended that the use of other, perhaps newer or less well proven, anode materials is to be precluded as this would restrict the necessary and advantageous development of new, possibly improved, anode materials. These are listed in C.1.4.

NOTE 3 It is likely that new and effective anode materials will be developed for cathodic protection of steel in atmospherically exposed concrete. It is not the purpose of this standard to preclude their use. It is recommended that the use of any anode should only be undertaken where performance can be demonstrated by laboratory testing, trials and/or past projects.

NOTE 4 It is suggested that new anode materials for cathodic protection of steel in atmospherically exposed concrete should be the subject of rigorous laboratory testing and, wherever possible, extended and/or accelerated field trials prior to commercial non-trial applications.

6.2.1 Conductive Coating Anode Systems

6.2.1.1 Organic Coatings

The anode system shall comprise an organic conductive coating (solvent based or water soluble, containing a carbon conductor) and a series of conductors (primary anodes) fixed to the concrete surface or integrated into the coating in order that the conductors can distribute current within the coating. The conductors shall be of material able to resist anodic reactions, e.g. platinum coated or platinum clad titanium or niobium which may be copper cored, or mixed metal oxide coated titanium.

The combination of conductive coating and primary anodes shall be demonstrated by trials or past projects to enable the design anode performance to be achieved. The spacing of primary anodes within the conductive coating shall be such that it can be calculated or demonstrated that the variation in anode current output attributable to the resistance, within the coating, between primary anodes, does not exceed ± 10 % of the average current output measured as a ± 10 % voltage drop.

The particular application technique selected shall be demonstrated by trials or past projects to enable the design anode performance to be achieved.

The adhesion of the coating to the concrete, subject to appropriate surface preparation and the above application technique, shall be suitable to achieve the full design life of the anode system.

Data shall be provided determining the wet or dry film thickness requirements to achieve the required dry film conductivity.

See C.1.1 for further information.

6.2.1.2 Metallic Coatings

The anode system shall comprise a thermally sprayed metallic coating.

> NOTE Metallic coatings of zinc and zinc alloys and of subsequently activated titanium have been used as anodes. The last two do not have a 5 year track record and are categorised as in annex C.1.2 and C.1.3.

The combination of metallic coating and connectors shall be demonstrated by trials or past projects to enable the design anode performance to be achieved. The spacing of connectors within the metallic coating shall be such that it can be calculated or demonstrated that the variation in anode current output attributable to the resistance, within the coating, between connectors, does not exceed ± 10 % of the average current output measured as a ± 10 % voltage drop.

The particular application technique selected shall be demonstrated by trials or past projects to enable the design anode performance to be achieved.

The adhesion of the coating to the concrete, subject to appropriate surface preparation and the above application technique, shall be suitable to achieve the full design life of the anode system.

Data shall be provided determining the application process requirements to achieve the required film thickness and conductivity.

Metallic connectors (of Cu, Cu-Zn-alloys or Ti) electrically insulated from but mechanically bonded to the concrete surface shall be installed prior to metallic coating application.

6.2.2 Activated Titanium Anode Systems

6.2.2.1 General

The anode system shall comprise a substrate of titanium [1] and an electrocatalytic coating containing oxides of platinum group metals, platinum, iridium or ruthenium along with oxides of titanium, zirconium and tantalum together with anode/cable connections and a cementitious overlay or surround.

The coating composition and thickness, or mass per unit area, shall be demonstrated by trials and/or laboratory testing to enable the design anode performance to be achieved.

6.2.2.2 Surface installed

The activated titanium shall take the form of a mesh or grid distributed, in accordance with the design, on the concrete surface. Titanium connectors shall be spot welded to the mesh or grid to distribute current to all component parts of the anode and to facilitate electrical connections to the anode. Where anode/cable connections are to be incorporated into the cementitious overlay, they shall be of a type and installed in a manner that can be demonstrated by trials or past projects to enable the design anode and anode/cable connection performance to be achieved.

Non-metallic fixings shall be utilised to facilitate the fixing of the anode material to the surface of the concrete or to reinforcement prior to pouring concrete and shall ensure that there are no short circuits between anode and reinforcement.

6.2.2.3 Installation into recesses in covering concrete

The anode shall take the form of solid or mesh titanium strips or grids complete with the electrocatalytic coating, suitable for recessing into grooves cut into the cover concrete, or be activated titanium strips and grids with non-metallic fixings to facilitate installation on to exposed reinforcement prior to concrete placement.

The size and distribution of the strips or grids shall conform to the anode design and the maximum anode current density.

6.2.2.4 Embedded within the structure

Activated titanium shall be embedded within the structure in one of the following ways:

a) Electrocatalytically coated titanium in the form of strip, mesh, grid or tubes shall be embedded into a cementitious repair mortar in holes drilled into the concrete.
b) Anodes of a similar form or platinum coated titanium rods shall be used in conjunction with a conductive graphite based backfill.
c) Anodes of a similar form shall be cast into new construction for cathodic prevention or into concrete repairs for cathodic protection.

Where a backfill (e.g. graphite) is part of the anode system, its operating current density based upon the dimensions of the hole drilled in the concrete, and the anode current density within the backfill shall conform to the design (see 4.3) and shall be limited to values which can be demonstrated by trials or past projects to enable the requisite anode, backfill and anode/cable connection performance to be achieved. Where graphite backfill is utilised, the graphite shall be considered as the anode in calculating the minimum anode/reinforcement spacing.

6.2.3 Other Anode Systems

See annex C.1.4.