BS EN ISO 12696:2022

BSI Standards Publication

Cathodic protection of steel in concrete

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National foreword

This British Standard is the UK implementation of EN ISO 12696:2022. It is identical to ISO 12696:2022. It supersedes BS EN ISO 12696:2016, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/603, Cathodic protection.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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NORME EUROPÉENNE

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English Version

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Protection cathodique de l'acier dans le béton (ISO 12696:2022)

Kathodischer Korrosionsschutz von Stahl in Beton (ISO 12696:2022)

This European Standard was approved by CEN on 5 May 2022.

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European foreword

This document (EN ISO 12696:2022) has been prepared by Technical Committee ISO/TC 156 "Corrosion of metals and alloys" in collaboration with 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of an identical text or by endorsement, at the latest by November 2022, and conflicting national standards shall be withdrawn at the latest by November 2022.

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Endorsement notice

The text of ISO 12696:2022 has been approved by CEN as EN ISO 12696:2022 without any modification.

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 156, *Corrosion of metals and alloys,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 219, Cathodic *protection of steel in concrete,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 12696:2016), which has been technically revised.

The main changes compared to the previous edition are as follows:

— the scope has been revised to clarify that, in order to comply with this document, it is necessary for the cathodic protection system to have sufficient monitoring provisions to demonstrate that the system meets the criteria of protection specified in 8.6;

— subclause 8.6 has been revised;

— Annex A has been revised and its figures have been updated;

— Clause A.7 has been moved to the new Annex D and a new Clause A.7 “Benefits of cathodic protection current when criteria in 8.6 are not fully met” has been added;

— Annex B has been revised completely;

— a new clause, Clause C.5 “Hybrid anodes”, has been added;

— a new annex, Annex D “Notes on reference electrodes”, has been added;

— the references in the whole document have been revised.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

This document applies to cathodic protection of steel in concrete, with the concrete atmospherically exposed, buried or immersed.

As the criteria of protection for steel in buried or immersed concrete are those applicable to cathodic protection of steel in atmospherically exposed concrete, this revision of ISO 12696:2016 incorporates cathodic protection of steel in buried and immersed concrete. The provision of cathodic protection current can often be more economically provided to steel in buried and immersed concrete by using buried or immersed anode systems detailed in International Standards for buried and immersed steel structures, rather than the anode systems that are suitable for applications to steel in atmospherically exposed concrete. Therefore, reference is made to other International Standards in this respect while the cathodic protection performance criteria for steel in concrete are specified in this document for all exposures.

There are other electrochemical treatments intended to provide corrosion control for steel in concrete. These techniques include re-alkalization and chloride extraction and are not incorporated in this document. See EN 14038-1:2016[10] and EN 14038-2:2020[11] for information on electrochemical treatments.

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 document does not represent a design code for cathodic protection of steel in concrete, but represents a performance standard for which it is anticipated that a detailed design and specification for materials, installation, commissioning and operation will be prepared by experts and experienced persons.

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Cathodic protection of steel in concrete

1 Scope

This document specifies performance requirements for cathodic protection of steel in cement-based concrete, in both new and existing structures. It covers building and civil engineering structures, including carbon steel reinforcement and prestressed reinforcement embedded in the concrete. It is applicable to uncoated steel reinforcement and to organic-coated steel reinforcement. It is not applicable to reinforced concrete containing electrically conductive fibres (e.g. carbon or steel).

This document applies to steel embedded in atmospherically exposed, buried, immersed and tidal elements of buildings or structures.

This document is only applicable to the applications of cathodic protection to steel in concrete which are designed with the intention to, and can be demonstrated to, meet the criteria of protection specified in 8.6. This requires the provision of sufficient performance monitoring systems as specified in 6.3 to all parts of the structure intended to be protected, in order to assess the extent to which the criteria in 8.6 are met.

This document does not apply to galvanic anodes or systems applied into patch repairs to reduce the effects of 'incipient anodes'. This document does also not apply to any form of cathodic protection systems or other electrochemical treatments that either cannot meet the requirements of 8.6 or are not provided with the performance monitoring systems (see 6.3) that are necessary to assess whether the criteria of protection specified in 8.6 are met.

NOTE 1 Annex A gives guidance on the principles of cathodic protection and its application to steel in concrete.

NOTE 2 This document, while not specifically intended to address cathodic protection of steel in any electrolyte except concrete, can be applied to cathodic protection of steel in other cementitious materials such as are found, for example, in early 20th century steel-framed masonry, brick and terracotta clad buildings. In such applications, additional considerations specific to these structures are required in respect of design, materials and installation of cathodic protection; however, the requirements of this document can be applied to these systems.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 8044, *Corrosion of metals and alloys — Vocabulary*

ISO 15257, *Cathodic protection — Competence levels of cathodic protection persons — Basis for a certification scheme*

IEC 60502-1, *Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) to 30 kV (Um = 36 kV) — Part 1: Cables for rated voltages of 1 kV (Um = 1,2 kV) and 3 kV (Um = 3,6 kV)*

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

IEC 61558-1, *Safety of power transformers, power supplies, reactors and similar products — Part 1: General requirements and tests*

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IEC 61558-2-1, *Safety of power transformers, power supplies, reactors and similar products — Part 2-1: Particular requirements and tests for separating transformers and power supplies incorporating separating transformers for general applications*

IEC 61558-2-2, *Safety of power transformers, power supplies, reactors and similar products — Part 2-2: Particular requirements and tests for control transformers and power supplies incorporating control transformers*

IEC 61558-2-4, *Safety of transformers, reactors, power supply units and similar products for supply voltages up to 1 100 V — Part 2-4: Particular requirements and tests for isolating transformers and power supply units incorporating isolating transformers*

IEC 61558-2-13, *Safety of transformers, reactors, power supply units and similar products for supply voltages up to 1 100 V — Part 2-13: Particular requirements and tests for auto transformers and power supply units incorporating auto transformers*

IEC 61558-2-16, *Safety of transformers, reactors, power supply units and similar products for supply voltages up to 1 100 V — Part 2-16: Particular requirements and tests for switch mode power supply units and transformers for switch mode power supply units*

IEC 62262, *Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)*

EN 1504 (all parts), *Products and systems for the protection and repair of concrete structures — Definitions, requirements, quality control and evaluation of conformity*

EN 14629, *Products and systems for the protection and repair of concrete structures — Test methods — Determination of chloride content in hardened concrete*

EN 14630, *Products and systems for the protection and repair of concrete structures — Test methods — Determination of carbonation depth in hardened concrete by the phenolphthalein method*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8044 and EN 1504 (all parts) and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
zone
part of a cathodic protection system

Note 1 to entry: Anode systems can be divided into separate zones to supply current to a fully continuous reinforcement mesh. Alternatively, a single anode zone can supply current to separate, electrically isolated, zones within the reinforcement system. Zones can comprise an individual anode zone for each reinforcement zone or exposure condition. As the current provision to each of the zones in each of these alternatives can be separately measured, all of them are generically called “cathodic protection zones” and specifically “anode zones” or “cathode zones”.

3.2
humectant
hygroscopic material that promotes the retention of moisture

Note 1 to entry: It can be applied to the surface of a galvanic anode to keep the concrete-anode interface moist.

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4 General

4.1 Quality management

The design, the installation, the energizing, the commissioning and the long-term operation of all of the elements of cathodic protection systems for steel in concrete shall be fully documented. For further information, see Annex B.

NOTE ISO 9001 constitutes a suitable quality management systems standard which can be utilized.

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, energizing, commissioning and operation shall be the subject of either appropriate visual, mechanical or electrical testing, or all, and all testing shall be documented.

All test instrumentation shall have valid calibration certificates traceable to National or International standards concerning calibration.

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

4.2 Persons

Each aspect of the cathodic protection system design, installation, testing of the installation, energizing, commissioning and long-term operational control shall be under the supervision of persons with appropriate qualifications, training, expertise and experience in the particular element of the work for which they are responsible.

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

Persons who undertake the design, supervision of installation, commissioning, supervision of operation, measurements, monitoring and supervision of maintenance of cathodic protection systems shall have the appropriate level of competence for the tasks undertaken. ISO 15257 specifies a suitable method which may be utilized in the assessement of the competence of cathodic protection persons.

The competence of cathodic protection persons to the appropriate level for tasks undertaken should be demonstrated by certification in accordance with ISO 15257 or by another equivalent prequalification procedure.

4.3 Design

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

Cathodic protection systems for steel in concrete shall be the subject of detailed design.

The design shall, as a minimum, include and document the following:

a) detailed calculations;

b) detailed installation drawings;

c) detailed material and equipment specifications;

d) detailed method statements or specifications for installation, testing, energizing, commissioning and operation;

e) structures containing prestressing shall be assessed for their susceptibility to hydrogen embrittlement and for risk of stray currents.

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The detailed design shall be undertaken by persons who meet the requirements of 4.2. Annex B gives respective information about the design. Annex B provides information for the detailed design which should be undertaken by persons who meet the requirements of 4.2. If ISO 15257 is used to demonstrate their competence, they shall be certificated to Level 4 or above in the sector 'reinforced concrete structures'.

5 Structure assessment and repair

5.1 General

For cathodic protection (or cathodic prevention) of new structures, see 5.12.

The assessment of an existing structure, including its material condition, its structural integrity and whether and how to repair it, shall be performed in accordance with EN 1504 (all parts).

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, and

b) provide system-design input information (for further information, see Annex B).

These investigations shall include, but shall not be limited to, those given in 5.2 to 5.10.

5.2 Records

All available drawings, specifications, records and notes shall be reviewed to assess the location, quantity, nature (e.g. normal, galvanized, epoxy-coated, prestressed) and continuity of the reinforcement and any additional steel, 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 can 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 can permit significant water penetration, and which can in turn impair the effectiveness or durability of the cathodic protection system, shall be recorded.

Where necessary, the inspection and survey of buried or immersed elements will be facilitated by excavation and/ or cofferdams.

5.4 Chloride analysis

If required, values and distributions of the chloride content of the concrete shall be determined in accordance with EN 14629.

5.5 Carbonation depth measurement

If required, the distribution of carbonation depths shall be measured in accordance with EN 14630.

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5.6 Concrete cover and reinforcement location

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

For buried or immersed structures or zones, the concrete cover can be less significant if the anode system comprises anodes buried or immersed and located some distance from the structure.

5.7 Reinforcement electrical continuity

Drawings of reinforcement and other steel elements shall be checked for size, distribution, laps and continuity. The last shall then be proven on site by measuring either the electrical resistance or potential difference, or both, between bars in locations remote from each other across the structure. Testing shall be 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 and other steel size, distribution, laps and 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 reinforcing steel 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 and any other steel 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.

Measurements in any areas identified as delaminated, in the survey specified in 5.3, should be interpreted with caution, because delamination can produce readings inconsistent with the level of corrosion of the reinforcement or other embedded steel.

NOTE 2 References [12], [13] and [14] provide guidance with respect to steel/concrete potential measurements and interpretation.

5.9 Concrete electrical resistivity

The impact of variations in concrete resistivity on the cathodic protection system shall be considered. There is no firm guidance on limits of electrical resistivity with respect to cathodic protection, but the designer shall consider whether full protection can be achieved where required for the ranges of concrete resistivity found on the structure.

NOTE References [14] and [15] provide guidance with respect to concrete electrical resistivity measurements and interpretation.

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5.10 Repair

5.10.1 General

All operations comprising repair shall be performed in accordance with EN 1504 (all parts), except where stated otherwise in 5.10.

NOTE Installation of cathodic protection to an existing structure can be associated with other forms of repair work, such as strengthening, patching or coating, as determined in accordance with EN 1504 (all parts). In this subclause, the term "repair" signifies reinstatement of the damaged/deteriorated concrete 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 and other steel, to install cable connections and monitoring sensors.

5.10.2 Concrete removal

Any repair material detrimental to the performance of the cathodic protection (CP) system shall be broken out.

For example, predominantly epoxy-based repair materials have very high resistivity values and can shield reinforcement within or behind them from cathodic protection. Concrete reinforced with metallic fibres can have very low electrical resistivity and the fibres can form an electrical short-circuit path between the anode and the steel.

For impressed-current cathodic protection systems, any tying wire, nails or other metal components visible on the concrete, that can contact the anode system or that can 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 can corrode and can 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 the exposed reinforcement or other steel to ensure good contact between the steel and the repair material, but there is no need to clean the reinforcement or other steel, to be embedded in concrete, to bright metal. However, the designer shall consider the impacts of any significant corrosion products on the steel surface on the bonding of concrete repairs to the reinforcement.

NOTE Retained corrosion products are likely to be high in chlorides. If these coincide with voids in the concrete repairs these areas are likely to continue to corrode.

The designer shall consider the effect of primers or coatings used as part of the repair system, having consideration for the possible shielding of CP current from the steel to which, or behind which, the primers or coatings are applied.

5.10.4 Concrete reinstatement

Concrete reinstatement shall be in accordance with EN 1504 (all parts), except where stated in this subclause.

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 compatible with the original concrete. Proprietary curing membranes shall not be used prior to subsequent anode installation over the repair area. Alternative curing methods shall be used.

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The electrical resistivity of concrete repair materials shall be similar to that of the parent concrete.

NOTE Typically, these repair materials have an electrical resistivity within the range approximately half to twice that of the parent concrete when measured under the same conditions as the parent concrete. However, the electrical resistivity of the parent concrete is that of an aged material (age > 20 years), whereas the electrical resistivity of the repair material reflects the properties at a relatively young age; it is anticipated that there is a significant ageing effect over time. Also, measurements made in the laboratory on prisms do not represent the conditions of the structure. A good quality repair made with materials known to be compatible with cathodic protection installations has been found to be more important than arbitrary resistivity limits.

5.11 Cementitious overlay

For cathodic protection systems employing anode systems as outlined in 6.2.3.2, following a 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 EN 1504 (all parts). Bond strength between the existing concrete and overlay shall be tested according to EN 1542. A series of tests shall consist of three single tests. The average bond strength shall be greater than 1,5 MPa for all test series and greater than 1,0 MPa for all single tests. For example, bond strength should be tested with one test series for each started 100 m^2.

If the substrate concrete cohesive strength fails at lower values than 1,5 MPa average and 1,0 MPa minimum, the use of a cementitious overlay may be inappropriate.

Overlay application may be combined with concrete repair.

The electrical resistivity of anode overlays can significantly exceed that of the parent concrete subject to the anode within the overlay being able to pass its design current at the design voltage, in an overlay of this resistivity, in all atmospheric and exposure conditions applicable to the structure.

The selected material, thickness and placement method shall be compatible with each other, with the anode material and the exposure of the structure. Curing membranes shall be removed from the parent concrete/substrate or shall have sufficiently degraded to avoid adversely influencing the performance of the cathodic protection system.

The potential between the anode and reinforcement/steel (cathode) shall be monitored to detect short-circuits.

5.12 New structures

In the case of a new structure, if cathodic protection as a preventive system (cathodic prevention) 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 document and of the standards governing the design and construction of the new structure:

a) provision and checking of reinforcing steel 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 prevention 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 the creation of short-circuits during concrete placement and vibration. Monitoring of potential between anode and reinforcement/steel (cathode) shall be used to detect any short-circuits during concrete placement.

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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 surfaces of the embedded steel to be protected. Impressed current cathodic protection systems shall further incorporate positive and negative direct current cables between the anode and the steel, respectively, and the DC power supply, which is the source of the cathodic protection current.

For galvanic anode systems, direct permanent metallic connections shall be provided between the anode and the steel, except where monitoring that requires current interruption is installed.

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 can be interrogated and displayed by portable instrumentation or by permanently installed instrumentation of either the 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.

Both impressed current and galvanic anode cathodic protection systems require monitoring provisions in order to determine the performance and comply with this document.

NOTE Galvanic anode systems can be used without monitoring systems or methods to measure their performance. Such systems do not comply with this document.

6.2 Anode systems

6.2.1 General

See Annex C.

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 into the design, with, where necessary, planned maintenance or replacement of the anode system or parts of the system at periods designated in the design.

For anodes embedded into or applied to the surface of the concrete, 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.

For anodes embedded into or applied to the surface of the concrete, the maximum short-term current density at the anode surface shall not exceed 220 mA/m^2 and the maximum long-term current density at the anode surface shall not exceed 110 mA/m^2. These values may only be exceeded if the designer can demonstrate and document within the design report that a higher current density can be reliably accommodated within the design life of the cathodic protection system for that combination of anode material, its cementitious surround and its method of installation (e.g. a mesh anode within an overlay, a ribbon or ribbon mesh anode within slots or chases, or discrete anodes within drilled holes). The anode manufacturer's recommended current densities shall not be exceeded.

Either the design or the selection, or both, of the anode material shall consider likely variations in cathode current density requirements, steel distribution, concrete electrical resistivity and any other

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factors likely to result in uneven distribution of current demand or current discharge from the anode and the possibility of this resulting in an 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 embedded in concrete or applied to the concrete primarily (but not exclusively) in the cathodic protection of steel in atmospherically exposed concrete. The requirements for such anodes are unique for use in cathodic protection of steel in concrete, as the anodes must be installed or applied and 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 oxidizing, producing acidity.

NOTE 2 Anodes are listed non-exclusively in Annex C.

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

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

NOTE 3 There is an established test method for accelerated life testing of mixed metal oxide coated titanium anodes embedded in concrete, ISO 19097-1[5]. There is also a procedure for comparative testing of carbon based conductive-coating anodes[16].

Anode systems used for the protection of steel in buried or immersed concrete are detailed in EN 12954[9], EN 12495[7], ISO 15589-2[4], ISO 12473[2] and ISO 19097-2[6] and ISO 13174[3].

6.2.2 Conductive coating anode systems

6.2.2.1 Conductive coatings

These coatings are used as impressed current anodes.

The anode system shall comprise a conductive coating containing carbon and a series of conductors (current distributors) 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, for example, 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 current distributors shall be demonstrated by trials or past projects to enable the design anode performance to be achieved. The spacing of current distributors 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 current distributors, 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 either the wet or dry, or both, film thickness requirements to achieve the required dry film conductivity.

See Annex C for further information.

6.2.2.2 Thermally sprayed metallic coatings

The anode system shall comprise a thermally sprayed metallic coating of Zn, Al-Zn, Al-Zn-In or Ti.

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The Zn coatings are used both as impressed current anodes and as galvanic anodes; the Al-Zn and Al-Zn-In alloy anodes are used as a galvanic anode. Ti is used as an impressed current anode with a catalytic spray to lower the anode-to-concrete interfacial resistance.

When thermal sprayed metallic coatings are used as galvanic anodes, they may be applied directly to the reinforcement/steel where it is exposed, as well as predominantly to the sound concrete surface, subject to the requirements of being able to monitor the performance of the CP system as in this document.

A humectant may be applied to thermal sprayed metallic coatings used as galvanic anodes to enhance their performance.

To avoid atmospheric corrosion and prolong the lifetime of the anode, a top-coating with suitable properties may be applied to the thermal sprayed metallic layer.

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 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 for determining the application process requirements to achieve the required film thickness and conductivity.

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

See Annex C for further information.

6.2.3 Activated titanium anode systems

6.2.3.1 General

These anodes are used as impressed current anodes.

The anode system shall comprise a substrate of titanium[17] 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.

NOTE 1 These anodes are frequently described as mixed metal-oxide-coated titanium (MMO/Ti) anodes or inert anodes.

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

NOTE 2 A suitable test procedure is given in ISO 19097-1[5] for anodes encased in concrete and ISO 19097-2[6] for buried and immersed anodes

6.2.3.2 Surface installed

The activated titanium shall take the form of a mesh or grid, distributed in accordance with the cathodic protection system 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.

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

See Annex C for further information.

6.2.3.3 Installation into recesses in cover 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 onto exposed reinforcement prior to concrete placement.

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

See Annex C for further information.

6.2.3.4 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 cathodic protection system 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 utilized, the graphite shall be considered as the anode in calculating the minimum anode/reinforcement or other steel spacing.

See Annex C for further information.

6.2.4 Titania ceramic anodes

See Annex C for further information.

6.2.5 Conductive cementitious anodes

Galvanic systems shall be wired to enable current interruption between the anode and the cathode for monitoring purposes in accordance with the requirement of this document.

See Annex C for further information.

6.2.6 Embedded galvanic anodes

These consist of zinc anodes in an activating encapsulation.

NOTE 1 Galvanic anodes can be used to enhance the durability of localized patch repairs and, in particular, to limit the likely acceleration of corrosion rate around patch repairs (sometimes called the ‘incipient anode effect’). These systems are not typically subject to performance monitoring and are not addressed in this document.

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NOTE 2 Galvanic anodes can be used more extensively in a structure and if provision is made to include performance monitoring provision into the system such that the requirements of 8.6 can be demonstrated and if one or more of the criteria of 8.6 a), b) or c) are met, such systems are addressed in this document.

Anode types consists of zinc encased in proprietary activating encapsulation with connections to the reinforcing bar (rebar). One or more galvanic anodes are installed within the concrete repair, or into drilled or cored holes in, or surrounding the concrete repair and are attached to the reinforcement.

Other anode types consist of a "string" of zinc anodes in a proprietary activating encapsulation to be embedded into drilled or cored holes within the concrete repair or surrounding undamaged parent concrete, which are then attached to the reinforcement either directly or via monitored cable connection for assessment purposes.

Galvanic systems shall be wired to enable current interruption between the anode and the cathode for monitoring purposes in accordance with the requirement of this document.

See Annex C for further information.

6.2.7 Surface-mounted galvanic anodes

6.2.7.1 Zinc mesh in overlay

This anode is designed for splash and tidal zone applications. It consists of an expanded zinc metal sheet or mesh, mechanically fixed and grouted to the prepared concrete surface. It may use a permanent form (or jacket) containing the expanded mesh zinc anode which is clamped to a concrete pile in the splash and tidal zone. This is filled with a cementitious grout. Cast zinc anodes may be attached below the low-water line.

Galvanic systems shall be wired to enable current interruption between the anode and the cathode for monitoring purposes in accordance with the requirement of this document.

See Annex C for further information.

6.2.7.2 Adhesive zinc-sheet anode

A "glue on" anode system has been developed that can be applied directly to a prepared concrete surface. The adhesive is a hydrogel, as used in attaching electrodes to the skin for medical applications. The anode is supplied in rolls of adhesive covered zinc sheet and is attached to the structure. The rolls are then soldered together and attached directly to the steel.

Galvanic systems shall be wired to enable current interruption between the anode and the cathode for monitoring purposes in accordance with the requirement of this document.

See Annex C for further information.

6.2.8 Buried and immersed anodes

6.2.8.1 General

For structures that are either buried or immersed, anodes do not have to be in direct physical contact with the concrete. Traditional anode systems, for example, as used in cathodic protection schemes for buried and immersed pipelines, tanks, marine structures and as described in EN 12495[7], EN 12954[9], ISO 12473[2] and ISO 15589-2[4] can be used. In these cases, the anodes are located away from the structure but are buried or immersed in the same electrolyte in which the reinforced concrete structure is buried or immersed.

The type of anode composition, shape, location and method of installation varies for the different systems and also varies between buried and immersed conditions. Further information is given in Annex C.

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