

# Electrochemical realkalization and chloride extraction treatments for reinforced concrete —

## Part 1: Realkalization

The European Standard CEN/TS 14038-1:2004 has the status of a British Standard

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National foreword

This Draft for Development is the official English language version of CEN/TS 14038-1:2004.

This publication is not to be regarded as a British Standard.

It is being issued in the Draft for Development Series of publications and is of a provisional nature as technology in this area is still emerging. It should be applied on this provisional basis, so that information and experience of its practical application may be obtained.

Comments arising from the use of this Draft for Development are requested so that UK experience can be reported to the international organization responsible for the Technical Specification. A review of this publication will be initiated not later than 3 years after its publication by the international organization so that a decision can be taken on its status at the end of its 3-year life. Notification of the start of the review period will be made in an announcement in the appropriate issue of *Update Standards*.

According to the replies received by the end of the review period, the responsible BSI Committee will decide whether to support the conversion into an international standard, to extend the life of the Technical Specification for another 3 years or to withdraw it. Comments should be sent in writing to the Secretary of BSI Technical Committee GEL/603, Cathodic protection, at British Standards House, 389 Chiswick High Road, London W4 4AL, giving the document reference and clause number and proposing, where possible, an appropriate revision of the text.

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Summary of pages

This document comprises a front cover, an inside front cover, the CEN/TS title page, pages 2 to 13 and a back cover.

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English version

## Electrochemical realkalization and chloride extraction treatments for reinforced concrete - Part 1: Realkalization

Ré-alkalinisation électrochimique et traitements d'extraction  
des chlorures applicables au béton armé - Partie 1 : Ré-  
alkalinisation

Elektrochemische Realkalisierung und  
Chloridextraktionsbehandlungen für Stahlbeton - Teil 1:  
Realkalisierung

This Technical Specification (CEN/TS) was approved by CEN on 9 September 2004 for provisional application.

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## Foreword

This document (CEN/TS 14038-1:2004) has been prepared by Technical Committee CEN/TC 219 “Cathodic protection”, the secretariat of which is held by BSI.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to announce this Technical Specification: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

## Introduction

The purpose of realkalization is to provide long-term corrosion protection of steel reinforcement in concrete, which has become carbonated.

There are other electrochemical procedures, which can be used to provide corrosion protection of steel in concrete structures. These include cathodic protection and chloride extraction. There is a European Standard for cathodic protection of steel in concrete (EN 12696).

It is assumed in the drafting of this document that the execution of its provisions is entrusted to appropriately qualified and competent people, for whose use it has been prepared.

## 1 Scope

This document specifies a procedure for carrying out impressed current electrochemical realkalization of carbonated reinforced concrete in existing structures. It is applicable to atmospherically exposed parts of structures with ordinary reinforcement embedded in concrete.

This document does not apply to concrete containing prestressing steel which can suffer hydrogen embrittlement during realkalization, or to concrete containing epoxy-coated or galvanized reinforcement, or if chloride contamination is contributing to reinforcement corrosion.

## 2 Normative references

The following referenced documents are indispensable for the application 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.

prEN 14629:2003, *Products and systems for the protection and repair of concrete structures — Test methods — Determination of chloride content in hardened concrete*

prEN 14630:2003, *Products and systems for the protection and repair of concrete structures - Test methods - Determination of carbonation depth in hardened concrete by the phenolphthalein method*

EN 12696:2000, *Cathodic protection of steel in concrete*

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 use of products and systems.*

EN ISO 8044:1999, *Corrosion of metals and alloys — Basic terms and definitions (ISO 8044:1999).*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN ISO 8044:1999 and the following apply.

### 3.1

#### **realkalization**

electrochemical treatment for restoring to concrete, which surrounds reinforcing bars, a high pH value corresponding to sound, non-carbonated concrete

## 4 Principle

Realkalization of reinforced concrete is performed by applying an electric field between the steel reinforcement embedded in the concrete and an anode surrounded by an alkaline electrolyte solution containing carbonate or hydroxyl ions temporarily placed on the concrete surface.

NOTE 1 The carbonated area treated by realkalization lies beneath the anode.

NOTE 2 Details of the principle underlying this process are given in the European Federation of Corrosion report [1].

NOTE 3 Electrolyte solutions of sodium, potassium and lithium may be used.

## 5 Assessment and repair of the structure

### 5.1 General

Prior to undertaking realkalization an assessment of the structure, including its physical condition, its structural integrity and the nature and extent of any repairs, which might be needed, shall be performed in accordance with ENV 1504-9.

The investigations specified in 5.2 to 5.8 shall be carried out in order to:

- a) determine the suitability of the structure for realkalization;
- b) provide information for design.

### 5.2 Review of records

All available drawings, specifications, records and notes shall be reviewed for information on the location, quantity, nature (e.g. mild or high strength steel, smooth or deformed bar, galvanized, epoxy-coated) and continuity of the reinforcement, as well as the constituents and quality of the concrete.

NOTE The possible sensitivity to reduction of bond strength should be evaluated in the case of smooth reinforcement.

### 5.3 Inspection

An inspection shall be carried out to ascertain the type, causes and extent of defects and any features of the structure or of its surrounding environment, which could influence the application and effectiveness of realkalization. All areas of the structure, which require realkalization, shall be checked for delamination of the concrete cover. Defects such as delaminations, cracks, honeycombing or poor construction joints which could permit significant water penetration, or prevent current flow and thereby impair the effectiveness of the realkalization treatment, shall be recorded.

NOTE 1 In areas, which have been previously repaired, the repair methods and materials used should be identified, as far as possible. If the concrete behind the repair is to be realkalized, the electrical resistivity and porosity of the repair media should be considered.

The cause of any deterioration, which is not attributable to corroding reinforcement, shall be determined.

NOTE 2 If any signs of structural distress are evident, an assessment of both the load-bearing capacity of the structure and the need for temporary or permanent strengthening or support should be made.

### 5.4 Carbonation depth measurement

Carbonation depth shall be measured according to prEN 14630 at several locations to ascertain its distribution.

NOTE In selecting locations for concrete sampling, the objective is to identify areas with various carbonation depths for comparison with post-treatment data.

### 5.5 Determination of chloride content

The chloride content of the concrete shall be determined according to prEN 14629 as a proportion of the mass of cement or concrete.

Concrete samples shall be taken from areas expected to have the highest possible chloride content in order to ascertain whether chloride contamination is present.

If chloride contamination is found to be a cause of reinforcement corrosion, chloride content shall be determined in accordance with ENV 1504-9 or EN 12696.

### 5.6 Concrete cover thickness and reinforcement location measurements

Concrete cover thickness and reinforcement location measurements shall be carried out in order to enable a determination to be made of comparative current flow through areas of thick and thin cover, and to identify regions of varying reinforcement density. Any features that could impair the effectiveness of realkalization, such as shielding of the reinforcement, caused by embedded metal mesh, metal fibres, metal plates, plastic sheets or non-conductive repair materials shall be identified. Points at which short circuits between the reinforcing steel and the anodes could occur shall be noted.

### 5.7 Alkali aggregate reaction

If the concrete of the structure, which is to be realkalized, contains aggregates, which can be sensitive to alkali, the risk of provoking an alkali aggregate reaction (AAR) shall be considered prior to any treatment.

NOTE No case of induced AAR has been reported in connection with realkalization.

### 5.8 Reinforcement continuity and size

The reinforcement continuity shall be proven on site by measuring the electrical resistance between reinforcing bars in mutually remote locations across the structure and between all reinforcing bars exposed during concrete repairs (see 5.9.3) or other works following the method and acceptance criteria as specified in EN 12696:2000, 7.1. These measurements shall include the following:

- a) continuity between elements of the structure within each realkalization zone;
- b) continuity of metallic items, other than reinforcement, with the reinforcement itself.

Reinforcement size shall be identified from drawings when available and shall be verified by direct measurements.

## 5.9 Repair

### 5.9.1 General

All operations comprising repair shall be performed in accordance with ENV 1504-9, except where stated otherwise in 5.9.2 to 5.9.3 below.

### 5.9.2 Concrete removal

All delaminated and honeycombed concrete and repair materials with unacceptably high electrical resistivity (> 200 % of parent company resistivity) and/or containing any other materials that may impair the effects of realkalization shall be broken out to achieve a clean, physically sound concrete surface. Any tying wire, nails

or other metal components at the concrete surface that are found in contact with the reinforcement shall be cut back or insulated.

### 5.9.3 Reinforcement preparation

Exposed reinforcement shall have any loose scale removed to ensure good contact between the steel and the repair material.

NOTE 1 There is no need to clean reinforcement to bright metal.

Primers or coatings and insulating/resistive bonding agents shall not be applied to the steel.

NOTE 2 Continuity assessment, bonding and installation of all connections to reinforcement should be performed only after reinforcement preparation.

## 6 Materials and apparatus

### 6.1 Calibration of instrumentation

All instrumentation used to carry out the measurements specified in Clauses 5, 7 and 8 shall have valid calibration certificates traceable to a national or European Standard of measurement.

### 6.2 Anode system

#### 6.2.1 General

The anode system shall consist of an anode submerged in an alkaline electrolyte solution on the concrete surface.

#### 6.2.2 Anode

The anode shall be capable of distributing and sustaining the current required for the realkalization treatment.

#### 6.2.3 Anode zone

Each anode zone should be designed to provide uniform current density to the reinforcing steel. Typically one anode zone has a size not exceeding 50 m<sup>2</sup> of concrete surface or a current output not exceeding 100 A.

NOTE This is also referred to in the text as a "realkalization zone".

#### 6.2.4 Alkaline electrolyte solution

The alkaline electrolyte solution shall be capable of:

- a) conducting the current between the anode and steel reinforcement; and
- b) providing alkalinity to the carbonated concrete.

### 6.3 Electric cables

All cables shall be insulated.

All cables shall be uniquely identified by colour of insulation and by zone number. The following colour code shall be used:

- a) cables to anodes (positive cables): red;
- b) cables to reinforcement (negative cables): black.

Cables shall be dimensioned to:

- 1) carry the design current +25 % within a permissible temperature range allowed under national or European Standards;
- 2) be of adequate mechanical strength.

## 6.4 Power supply

The impressed current power supply shall be limited to 50 V DC with a ripple content not exceeding 100 mV rms with a minimum frequency of 100 Hz.

The AC power supply and its cabling shall conform to the requirements of an applicable national or European electrical safety standard.

The DC outputs shall be constant current.

All fuses shall be labelled with circuit designation and fuse characteristics.

All output terminals shall be fully insulated from any metal within the box. The terminals shall be clearly marked “+ ANODE” and “– Reinforcement”.

The DC power supply unit shall be rated for continuous short circuits, and be suitable for the environment in which it is to operate.

## 7 Installation procedures

### 7.1 Electrical continuity

The electrical continuity of reinforcement shall be tested in accordance with 5.8 before applying realkalization treatment.

Each zone to be realkalized shall be provided with multiple connection points to the reinforcement steel.

### 7.2 Performance monitoring

Each anode zone to be realkalized shall be provided with the means necessary to monitor the total charge in ampere hours (A·h) and duration of the treatment.

### 7.3 Installation of anode system

Before installing the anode system, the concrete surfaces shall be free of electrically insulating contaminants.

Particular care shall be taken to avoid short circuits between the anodes and any metallic items at the surface of the concrete.

The anode in each zone to be realkalized shall be provided with multiple anode connections.

### 7.4 Protection of electrolyte solution

The electrolyte solution shall be protected against climatic changes (e.g. sun, rain, wind, frost).

## 7.5 Electrical installation

Installation works shall be undertaken in accordance with applicable national or European electrical safety standards.

## 7.6 Preliminary testing and documentation

Prior to commissioning the installation preliminary testing shall be carried out and the results documented.

Polarity checks shall be carried out on all circuits.

Electrical continuity shall be checked by measuring resistances of all anode connections and all cathode connections within each treatment zone.

Insulation checks shall be carried out on all circuits to check the electrical insulation of the DC positive side from the DC negative side and from any metallic items on or adjacent to the concrete surface (e.g. scaffolding).

After applying the electrolyte solution, anode/cathode resistance and potential shall be measured for each realkalization zone to detect short circuits, which shall be corrected prior to energizing the system.

## 8 Commissioning, operation and termination of treatment

### 8.1 Visual inspection

Before the realkalization installation is energized, the installation and all its component parts shall be subjected to a complete visual inspection to check that all components and cables are properly installed, labelled and protected from environmental, human and animal damage.

### 8.2 Energizing and adjustment of current output

Energizing shall be undertaken only after completion of preliminary testing in accordance with 7.6 and visual inspection in accordance with 8.1.

The realkalization current density shall not exceed  $4 \text{ A/m}^2$  of reinforcement surface.

The charge shall be delivered over a minimum period of 100 h.

### 8.3 Routine inspection and maintenance

Routine inspection shall be carried out at least once a day. The following checks shall be carried out and the data recorded:

- a) confirmation that all realkalization zones are functioning;
- b) confirmation that the current and time (A·h) monitoring system specified in 8.4 is correctly monitoring all realkalized zones;
- c) measurement of output voltage to each realkalization zone;
- d) visual checks of cable insulation and anode connections, to confirm their proper functions;
- e) control of electrolyte solution and supply to ensure that the entire realkalization zones are fully encapsulated in electrolyte solution.

## 8.4 Realkalization process monitoring

In each zone of realkalization treatment the current and time of current discharge shall be measured and recorded at intervals not exceeding 2 h or continuously using an A·h meter.

## 8.5 Termination of treatment

Realkalization treatment shall be terminated when a total charge of 200 A·h/m<sup>2</sup> has been delivered to the reinforcement surface. The effectiveness of the realkalization process shall be demonstrated by phenolphthalein pH testing in each anode zone.

NOTE 1 In phenolphthalein pH testing, the extent of realkalization is indicated by pink colouration around the reinforcement to a minimum of 10 mm or the bar diameter whichever is smaller.

NOTE 2 prEN 14630 is in preparation and should be utilized when published.

The steel reinforcement surface area, which shall receive the charge of 200 A·h/m<sup>2</sup>, shall incorporate all of the reinforcement closest to surface being treated and due allowance shall be made for current discharged to other reinforcement.

If the extent of carbonation is beyond the reinforcement closest to the surface, all reinforcement within the areas of carbonation shall be incorporated into the calculation.

NOTE 3 The allowance for current discharge to other reinforcement may be by calculation of all reinforcement surface area within a particular depth of concrete, typically 200 mm, which should all receive 200 A·h/m<sup>2</sup>. Alternatively, the allowance may be of the reinforcement surface area of deeper layers and the assumption that second and subsequent reinforcement layers will receive typically 30 % of the current density received by the reinforcement layer above it.

## 9 Final report

Upon completion of realkalization a final report shall be issued. It shall include the following information:

- a) a general description of the structure, its location and physical condition;
- b) details of the parties associated with the refurbishment works (e.g. client, design engineer, supervising engineer, contractor, subcontractors) and their respective responsibilities;
- c) details of the design of the realkalization treatment including:
  - 1) the surface area calculation for the reinforcement, in order to demonstrate conformity with the requirements of 8.5;
  - 2) a copy of the specification for the works, including definition of acceptance criteria; and
  - 3) drawings in accordance with which the system was installed and energized, indicating variations and key dates;
- d) a description of the preparation prior to treatment, including surface preparation, repairs, reinforcing bar continuity tests and selected test locations for concrete sampling;
- e) process monitoring data: A·h charge records for each zone and additional current and voltage values recorded during treatment as specified in 8.3 and 8.4;
- f) analysis of the results, including a consideration of any local abnormalities or variations in results followed by a statement of treatment effectiveness;
- g) other relevant documents.

## 10 Post-treatment coating and monitoring

Where required, aesthetic or anti-carbonation coating shall be applied to realkalized concrete.

NOTE 1 Caution should be exercised in the selection of the coating and in the drying and surface preparation of the concrete prior to coating application.

Where required, devices shall be installed to enable post-treatment monitoring of the effectiveness of the treatment.

NOTE 2 Several suitable devices exist. For example, cast-in probes for potential and corrosion rate measurements.

## Bibliography

- [1] Mietz, J ed. *Electrochemical rehabilitation methods for reinforced concrete structures — A state of the art report*. European Federation of Corrosion, Publication 24. London: IOM Communications Ltd, 1998.
- [2] Hondel, A. W. M. van den and R. B. Polder, Laboratory investigation of electrochemical realkalisation of concrete. *Eurocorr '98*, Working Party 11, Reinforcement Corrosion, Utrecht, NL, 1998. European Federation of Corrosion.
- [3] Poliet, V., 1999 & 2000, COST 521 project reports B-2. Office for Official Publications of the European Communities.

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