SLOVENSKI STANDARD
SIST-TS CEN/TS 12390-11:2010

01-junij-2010

Preskušanje strjenega betona - 11. del: Ugotavljanje odpornosti betona proti kloridom, enosmerna difuzija

Testing hardened concrete - Part 11: Determination of the chloride resistance of concrete, unidirectional diffusion

Prüfung von Festbeton -Teil 11: Bestimmung des Chloridwiderstandes von Beton, einseitig gerichtete Diffusion

Essai sur béton durci - Partie 11: Détermination de la résistance du béton à la pénétration des chlorures, diffusion unidirectionnelle

Ta slovenski standard je istoveten z: CEN/TS 12390-11:2010

ICS:

91.100.30	Beton in betonski izdelki	Concrete and concrete products

SIST-TS CEN/TS 12390-11:2010 en,fr,de

TECHNICAL SPECIFICATION

SPÉCIFICATION TECHNIQUE

TECHNISCHE SPEZIFIKATION

CEN/TS 12390-11

January 2010

ICS 91.100.30

English Version

Testing hardened concrete - Part 11: Determination of the chloride resistance of concrete, unidirectional diffusion

Essai sur béton durci - Partie 11: Détermination de la résistance du béton à la pénétration des chlorures, diffusion unidirectionnelle

Prüfung von Festbeton - Teil 11: Bestimmung des Chloridwiderstandes von Beton - Einseitig gerichtete Diffusion

This Technical Specification (CEN/TS) was approved by CEN on 20 June 2009 for provisional application.

The period of validity of this CEN/TS is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the CEN/TS can be converted into a European Standard.

CEN members are required to announce the existence of this CEN/TS in the same way as for an EN and to make the CEN/TS available promptly at national level in an appropriate form. It is permissible to keep conflicting national standards in force (in parallel to the CEN/TS) until the final decision about the possible conversion of the CEN/TS into an EN is reached.

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Ref. No. CEN/TS 12390-11:2010: E

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Foreword

This document (CEN/TS 12390-11:2010) has been prepared by Technical Committee CEN/TC 104 "Concrete and related products", the secretariat of which is held by DIN.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

The drafting of this Technical Specification was delegated to CEN/TC 51/WG 12/TG 5.

This test method is one of a series concerned with testing concrete. At the behest of CEN, RILEM reviewed chloride testing methods [1] and this Technical Specification is based on their recommendations. In addition, this Technical Specification draws on recommendations from the EU-project "Chlortest" 5th Framework Programme (GRD1-2002-71808/G6RD-CT-2002-00855) [2] immersion test recommendation as well as the Nordtest Method NT Build 443 Concrete hardened: Accelerated Chloride penetration [3].

EN 12390, *Testing hardened concrete*, consists of the following parts:

— *Part 1: Shape, dimensions and other requirements for specimens and moulds*

— *Part 2: Making and curing specimens for strength tests*

— *Part 3: Compressive strength of test specimens*

— *Part 4: Compressive strength — Specification for testing machines*

— *Part 5: Flexural strength of test specimens*

— *Part 6: Tensile splitting strength of test specimens*

— *Part 7: Density of hardened concrete*

— *Part 8: Depth of penetration of water under pressure*

— *Part 9: Freeze-thaw resistance — Scaling*[1)]

— *Part 10: Determination of the relative carbonation resistance of concrete*[1)]

— *Part 11: Determination of the chloride resistance of concrete, unidirectional diffusion*[1)]

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

1) For the time being, status of Technical Specification (CEN/TS).

Introduction

Steel reinforced concrete structures exposed to the ingress of chloride, either from seawater or other sources, need to be durable for at least the intended working life. The possibility of reinforcement corrosion is significantly increased as the chloride level at the embedded reinforcement increases. For this reason, the chloride diffusivity or penetrability of the concrete is an important property to measure and this Technical Specification sets out a test method that may be applied to specimens cast to assess the potential chloride resistance properties of a concrete mix.

NOTE This test method takes a minimum of 119 days comprising a minimum age of the specimen prior to testing of 28 days, a minimum of one day to prepare and condition the specimen and then 90 days to expose the specimen to the chloride solution.

1 Scope

This Technical Specification is a method for determining the unidirectional non-steady state chloride penetration parameters of conditioned specimens of hardened concrete. The test method enables the determination of the chloride penetration at a specified age, e.g. for ranking of concrete quality by comparative testing. Since resistance to chloride penetration depends on the ageing, including the effects of continual hydration, then the ranking may also change with age.

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.

EN 12390-2, *Testing hardened concrete — Part 2: Making and curing specimens for strength tests*

EN 12504-1, *Testing concrete in structures — Part 1: Cored specimens — Taking, examining and testing in compression*

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

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
as-cast surface
surface of a concrete element exposed in the construction works to a chloride environment

3.2
chloride content
amount of acid-soluble chloride expressed in percent by mass of concrete

3.3
chloride penetration
ingress of chlorides into concrete due to exposure to external chloride sources

3.4
diffusion
movement of molecules or ions under a concentration gradient, that is movement from a zone of high concentration to a zone with a lower concentration

3.5
diffusion coefficient
proportionality between the molecular flux (e.g. rate of flow of chloride ions) and the concentration gradient in the diffusion equation

NOTE 1 In this Technical Specification Fick's Law is adopted.

NOTE 2 See Annex A.

3.6
initial chloride content
C_i
chloride content at a distance sufficiently remote from the surface as to not have been influenced by penetration of the chloride exposure solution

NOTE It reflects the initial chloride content that came from the constituents when the concrete was mixed.

3.7
non-steady state diffusion coefficient
D_{nss}
diffusion coefficient that takes into account simultaneous chloride binding

NOTE 1 This reflects the rate of diffusion of chloride into a concrete when part of the chloride is being bound by the cement.

NOTE 2 See Annex A.

NOTE 3 The steady-state chloride diffusion coefficient is measured on water saturated samples where chloride diffuses through a thin specimen between two reservoirs of chloride solution, where one reservoir is at a higher concentration than the other. This steady state chloride diffusion is not covered by this test method. The steady-state chloride diffusion coefficient only reflects the ionic transport diffusion through concrete, as the concrete is unable to bind any more chloride ion.

3.8
profile grinding
dry process grinding a concrete specimen in thin successive layers

3.9
vacuum saturated condition
specimen that is vacuum saturated with water

4 Principle

A specimen, either a cylinder or cube, is cast and cured in accordance with EN 12390-2, with a minimum curing period of not less than 28 days.

Annex B gives guidance on the testing of core specimens, where the core may be sampled from a test element, a precast concrete element or a structure.

The specimen is divided into two sub-specimens, a "profile specimen" that is used to determine the chloride profile after exposure to unidirectional chloride ingress, and an initial chloride sub-specimen that is used to determine the initial chloride level, C_i. This initial figure is taken as the chloride level of the cast concrete.

The profile specimen is vacuum saturated with distilled or demineralised water, coated on all sides but one and then the uncoated face is exposed to a chloride exposure solution. The exposure is achieved by complete immersion, ponding the uncoated face or inverting the specimen and having the uncoated face immersed in the chloride exposure solution. The reference solution is a 3 % by mass sodium chloride (NaCl) solution, for a period of 90 days (other concentrations or solutions, e.g. artificial seawater, are permitted as are different exposure periods). The use of large fully immersed specimens is described in Annex D.

After 90 days of exposure, at least eight parallel layers of the chloride exposed surface are ground off the profile specimen. The acid-soluble chloride content of each layer and the average depth of the layer from the surface of the concrete exposed to the chloride solution are determined. The initial chloride content is determined by grinding a sample from the other sub-specimen and the acid-soluble chloride content determined.

By non-linear regression analysis by least squares curve fitting, the surface chloride content (C_s) and the non-steady state chloride diffusion coefficient (D_{nss}) are determined.

Because of the high coefficient of variation, ~ 15 % for D_{nss} for the test, it is required to test at least two specimens and report the results separately.

NOTE 1 The chloride diffusion coefficient varies with the age of the concrete and the period of exposure.

NOTE 2 The diffusion test described in this Technical Specification is only valid for a constant initial chloride content.

NOTE 3 When precision information is available for this test, a check on the validity of the two or more results will be introduced plus the determination of the average value.

5 Reagents and apparatus

5.1 Reagents

Reagents of analytical quality shall be used.

NOTE Unless otherwise stated "percent" means percent by mass.

5.1.1 Calcium hydroxide, $Ca(OH)_2$.

5.1.2 Chloride Exposure Solution

5.1.2.1 Reference solution

Dissolve 30 g of analytical quality NaCl in 970 g of distilled or demineralised water having an electrical conductivity ≤ 0,5 mSm^{-1} at 20 °C to produce a 3 % by mass NaCl solution. Store it in a clean container.

NOTE This NaCl solution has a similar chloride concentration to that of Atlantic seawater.

5.1.2.2 Other exposure solutions

Where the concentration of the chloride exposure solution is other than that in 5.1.2.1, the concentration shall be recorded and reported. Where a different solution is used, the composition of the solution shall be recorded and reported.

NOTE 1 Natural and artificial seawater have been used to reflect the exposure of the construction works.

NOTE 2 Higher concentrations of NaCl, such as 16,5 %, and shorter exposure periods (e.g. 35 days) have been used to accelerate the development of a chloride profile.

5.1.3 Chloride ion diffusion proof two-component polyurethane or epoxy-based paint or other equivalent barrier system

5.1.4 Chemicals for chloride analysis, to EN 14629.

5.1.5 Distilled or demineralised water, having an electrical conductivity ≤ 0,5 mSm^{-1}.

5.2 Apparatus

5.2.1 Water cooled diamond saw

5.2.2 Balance for weighing NaCl and water, capable of weighing to an accuracy of ± 0,1 g.

5.2.3 Thermometer, capable of measuring to an accuracy of ± 1 °C.

5.2.4 Temperature controlled chamber, capable of keeping a temperature of (20 ± 2) °C.

5.2.5 Where used, a polyethylene container with airtight lid for immersion of the profile specimen. The volume of the exposure solution shall exceed the volume of the specimen by not less than 12,5 millilitres per square centimetre of exposed surface. A container may contain more than one sample provided the ratio of exposure solution to exposed surface shall be recorded and reported.

NOTE During the test, the chloride concentration of the chloride exposure solution reduces and if the ratio of the volume of chloride exposure solution to exposure surface varies, the rate of reduction will vary with nominally identical concrete. For this reason if a direct comparison of results from different specimens is required, the ratio of the volume of chloride exposure solution to exposed surface should be constant.

5.2.6 Where used, pond to be attached to profile specimen. The ponds shall have a constant diameter and initial depth not less than 125 mm.

5.2.7 Equipment for grinding off and collecting concrete powder in layers 1 mm or more deep, capable of grinding a surface area of at least 40 cm^2 and not grinding within 10 mm of the edge of the test area.

5.2.8 Compressed air or air blower, to clean dust from specimen and equipment between grinding layers.

5.2.9 Dust collecting bags

5.2.10 Equipment for chloride content testing, in accordance with EN 14629.

5.2.11 Calliper, measuring to an accuracy of ± 0,1 mm.

5.2.12 Vacuum container, capable of containing at least three specimens.

5.2.13 Vacuum pump, capable of maintaining an absolute pressure of less than 50 mbar (5 kPa) in the container, e.g. a water-jet pump.

6 Preparation of specimens

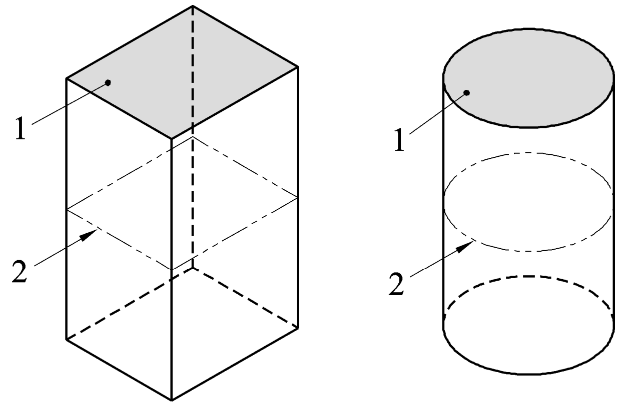
6.1 Preparing sub-specimens

A specimen size shall be selected such that after cutting, the minimum dimension of the sub-specimens used to determine a chloride profile are at least three times the nominal maximum aggregate size. At least two specimens, either 100 mm diameter or more cylinders or 100 mm or more cubes, are cast and cured in a water filled bath with a temperature of (20 ± 2) °C in accordance with EN 12390-2, where the curing period is not less than 28 days.

NOTE 1 The aim of the test will normally be to assess the potential resistance to chloride ingress for a concrete mix. Where the concrete contains secondary cementing materials, such as fly ash or ggbs, then it may be appropriate to increase the minimum age at testing as it is known that chloride resistance may increase significantly at ages greater than 28 days.

After at least 28 days of standard curing, each cylinder or cube is cut into two sub-specimens using the water cooled diamond saw. Cylindrical specimens are cut in the direction parallel to the flat surface and cubical specimens are cut in the direction parallel to the top (trowelled) surface as shown in Figure 1. No dimension of the sub-specimens used to determine a chloride profile shall be less than three times the nominal maximum aggregate size. One sub-specimen (called the "profile specimen") is used to determine the chloride profile, and the initial chloride sub-specimen is used to determine the initial chloride content. This initial chloride content is taken as being the chloride content of the cast concrete. The adjacent sawn faces are used to determine these values.

NOTE 2 Where a chloride profile is required that incorporates the effect of a formed surface then a formed surface from a cube specimen may be specified as the surface for chloride exposure. However, the results from such a procedure are difficult to interpret due to concentrations of cement paste and chloride at the formed surface. The use of this approach should be reported under Clause 9, m), as it is a non-standard test condition.



Key

1 trowelled surface

2 cut to separate specimens and produce exposure surface

Figure 1 — Specimen preparation

After sawing, the sub-specimen to be used to determine the initial chloride content shall be placed in a close fitting sealed plastic bag or tested immediately.

Where needed, the sub-specimens may be cut to reduce their size to aid handling, but the sub-specimen for determining the chloride profile shall not have a dimension less than three times the nominal maximum aggregate size.

6.2 Conditioning and preparation of profile specimen for chloride testing

6.2.1 Vacuum saturation of the profile specimens

After sawing the specimens, vacuum saturate the profile specimens with water. Annex C shows a typical arrangement for vacuum saturation. Place the profile specimens in the vacuum container and reduce the absolute pressure to a value between 10 mbar and 50 mbar (1 kPa to 5 kPa) within a few minutes of closing the container. Maintain this absolute pressure for 3 h and then with the vacuum pump still running, fill the container with distilled or demineralised water so that all the profile specimens are immersed. Maintain the absolute pressure for a further hour before allowing air to re-enter the container.

Leave the profile specimens immersed in water until the process of surface sealing starts.

6.2.2 Sealing surfaces other than the surface to be exposed

Start the sealing within 24 h of completing the vacuum saturation. All surfaces of the profile specimen except for the sawn face shall be sealed, see Annex D for an exception. After sealing the surfaces, place the specimens in saturated calcium hydroxide solution for at least 18 h.

NOTE The purpose of sealing the faces other than the face exposed to the chloride solution is to ensure that the ingress of chloride ions into the concrete is a pure unidirectional diffusion process and not a mixture of diffusion and other processes, e.g. capillary suction.

The requirement to seal the faces may be achieved in a number of ways. The following techniques have established suitability.

a) Sealing technique for immersion, ponding or inversion