SLOVENSKI STANDARD
SIST EN 12390-11:2015

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Nadomešča:
SIST-TS CEN/TS 12390-11:2010

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

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

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ICS:

91.100.30	Beton in betonski izdelki	Concrete and concrete products

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EUROPEAN STANDARD

NORME EUROPÉENNE

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English Version

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

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This European Standard was approved by CEN on 19 June 2015.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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Ref. No. EN 12390-11:2015 E

SIST EN 12390-11:2015

Contents

Page

iTeh STANDARD PREVIEW
(standards.iteh.ai)
SIST EN 12390-11:2015
https://standards.iteh.ai/catalog/standards/sist/b6082521-3c35-4bf0-ad0f-81deb3ad02b1/sist-en-12390-11-2015

SIST EN 12390-11:2015

European foreword

This document (EN 12390-11:2015) has been prepared by Technical Committee CEN/TC 104 “Concrete and related products”, the secretariat of which is held by DIN.

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of an identical text or by endorsement, at the latest by February 2016 and conflicting national standards shall be withdrawn at the latest by February 2016.

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.

This document supersedes CEN/TS 12390-11:2010.

In comparison to CEN/TS 12390-11:2010, the following changes have been made:

— In Clause 2, the normative references have been updated;

— In Clause 8, a minimum value of the coefficient of determination has been added and further guidance on the calculations has been added;

— In Clause 9, a graph and details of points included and excluded plus the coefficient of determination have been added;

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— In Clause 10, Table 3 has been added;

— A new Annex E (informative) "Guidance on test procedure" has been added;

SIST EN 12390-11:2015
https://standards.iteh.ai/catalog/standards/sist/b6082521-3c35-4bf0-ad0f-81deb3ad02b1/sist-en-12390-11-2015

— A new Annex F (informative) "Examples for calibration of the calculation procedure for regression analysis" has been added;

— The Bibliography has been reviewed;

— The standard has been revised editorially.

The drafting of this European Standard was delegated to CEN/TC 51(CEN/TC104)/JWG12/TG5.

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 European Standard is based on their recommendations. In addition, this European Standard 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].

The series EN 12390, *Testing hardened concrete* includes the following parts:

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

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

— *Part 3: Compressive strength testing of specimens*

— *Part 4: Compressive strength - Specification of testing machines*

— *Part 5: Flexural strength of test specimens*

SIST EN 12390-11:2015

— *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* (Technical Specification)

— *Part 10: Determination of the relative carbonation resistance of concrete* (Technical Specification)

— *Part 11: Determination of the chloride resistance of concrete, unidirectional diffusion*

— *Part 13: Determination of the secant modulus of elasticity in compression*

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

iTeh STANDARD PREVIEW
(standards.iteh.ai)

SIST EN 12390-11:2015
https://standards.iteh.ai/catalog/standards/sist/b6082521-3c35-4bf0-ad0f-81deb3ad02b1/sist-en-12390-11-2015

SIST EN 12390-11:2015

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 European Standard sets out a test method that may be applied to specimens cast or core specimens to assess the potential chloride resistance properties of a concrete mix.

Specifications regarding the test procedure with core specimens are given in Annex B.

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

iTeh STANDARD PREVIEW
(standards.iteh.ai)
SIST EN 12390-11:2015
https://standards.iteh.ai/catalog/standards/sist/b6082521-3c35-4bf0-ad0f-81deb3ad02b1/sist-en-12390-11-2015

SIST EN 12390-11:2015

1 Scope

This European Standard is a method for determining the unidirectional non-steady state chloride diffusion and surface concentration 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.

The test procedure does not apply to concrete with surface treatments such as silanes and it may not apply to concrete containing fibres (see E.1).

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 14629, *Products and systems for the protection and repair of concrete structures - Test methods - Determination of chloride content in hardened concrete*

3 Term, definitions symbols and abbreviated terms

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

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3.1 Terms and definitions

SIST EN 12390-11:2015
https://standards.iteh.ai/catalog/standards/sist/b6082521-3c35-4bf0-ad0f-81dcb3ad02b1/sist-en-12390-11-2015

3.1.1
as-cast surface
surface of a concrete element exposed in the construction works to a chloride environment

3.1.2
chloride content
amount of acid-soluble chloride expressed in percent by mass of concrete

3.1.3
chloride penetration
ingress of chlorides into concrete due to exposure to external chloride sources

3.1.4
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

3.1.5
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 to entry: In this European Standard Fick’s Law is adopted.

Note 2 to entry: See Annex A.

SIST EN 12390-11:2015

3.1.6
initial chloride content
C_i
chloride content at a distance sufficiently remote from the exposed surface as to not have been influenced by penetration of the chloride exposure solution

Note 1 to entry: It reflects the initial chloride content that came from the constituents when the concrete was mixed.

3.1.7
non-steady state diffusion coefficient
D_{nss}
diffusion coefficient that takes into account simultaneous chloride binding

Note 1 to entry: The steady-state chloride diffusion coefficient is measured on water saturated specimens 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.

Note 2 to entry: See Annex A.

3.1.8
profile grinding
dry process grinding a concrete specimen in thin successive layers

3.1.9
vacuum saturated condition
specimen that is vacuum saturated with water

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3.2 Symbols and abbreviated terms

SIST EN 12390-11:2015
https://standards.iteh.ai/catalog/standards/sist/b6082521-3c35-4bf0-ad0f-81deb3ad02b1/sist-en-12390-11-2015

C_i	Initial chloride content, % by mass of concrete;
$C_{m,j}$	Measured chloride content of concrete layer j, % by mass of concrete
$C_{r,j}$	Chloride content of layer j calculated according to Formula (1) using the most suitable combination of Cs and Dnss, % by mass of concrete
C_s	Calculated chloride content at the exposed surface, % by mass of concrete
C_x	Chloride content measured at average depth x and exposure time *t*, % by mass of concrete
D_{nss}	Non-steady state chloride diffusion coefficient, $m^2 s^{-1}$;
F	Sum of squares of the residuals
FR	Flow rate (flux) in mol m^{-2}·s
j1 to jn	Ground layer defined in terms of the number of layers from the exposed surface, the surface layer being j1
r	Repeatability
R	Reproducibility
R^2	Coefficient of determination

SIST EN 12390-11:2015

sr	Repeatability standard deviation
sR	Reproducibility standard deviation
S	Sum of squares
t	Exposure time, seconds.
u	Variable of the integral with no units
x	Depth below the exposed surface to the mid-point of the ground layer j, m;
z	Adimensional parameter with no units
$\partial c / \partial x$	Gradient of concentration with the concentration expressed in mol/m^3

4 Principle

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

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.

iTeh STANDARD PREVIEW
(standards.iteh.ai)
SIST EN 12390-11:2015
https://standards.iteh.ai/catalog/standards/sist/b6082521-3e35-4bf0-ad0f-81deb3ad02b1/sist-en-12390-11-2015

The profile specimen is vacuum saturated with distilled or demineralized water, coated on all sides but one and then the uncoated face is exposed to a chloride exposure solution. The exposure is achieved by either 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 d (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 d of exposure, at least 8 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 – 30 % for D_{nss} for the test, the number of specimens should be increased until the required precision is achieved. The results shall be reported separately and the average value.

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 European Standard is only valid for a constant initial chloride content.

5 Reagents and apparatus

5.1 Reagents

Reagents of analytical quality shall be used.

SIST EN 12390-11:2015

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 demineralized 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 d) 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.

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5.1.4 Chemicals for chloride analysis, to EN 14629.

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

SIST EN 12390-11:2015
https://standards.iteh.ai/catalog/standards/sist/b6082521-3c35-4bf0-ad0f-81deb3ad02b1/sist-en-12390-11-2015

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 °C ± 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 ml per cm^2 of exposed surface. A container may contain more than one specimen provided at least the minimum ratio of exposure solution to exposed surface is achieved. The ratio of exposure solution to exposed surface shall be recorded and reported.

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.

SIST EN 12390-11:2015

5.2.7 Equipment for grinding off and collecting concrete powder in layers less than 2 mm 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 (5kPa) 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 °C ± 2 °C in accordance with EN 12390-2, where the curing period is not less than 28 d.

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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 ground granulated blastfurnace slag, 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 d.

SIST EN 12390-11:2015
https://standards.iteh.ai/catalog/standards/sist/b6082521-3c35-4bf0-ad0f-81deb3ad02b1/sist-en-12390-11-2015

After at least 28 d of standard curing, each cylinder, cube or prism 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. The tested surface should be free of voids and visible cracks. 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 variations in the concentration of cement paste and chloride at the formed surface. The use of this approach will be reported under sub-clause 9 m), as it is a non-standard test condition.