INTERNATIONAL STANDARD

ISO 1920-11

First edition
2013-05-01

Testing of concrete —

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

Essais du béton —

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

Reference number
ISO 1920-11:2013(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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. www.iso.org/directives

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received. www.iso.org/patents

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

The committee responsible for this document is ISO/TC 71, *Concrete, reinforced concrete and prestressed concrete*, Subcommittee SC 1, *Test methods for concrete*.

ISO 1920 consists of the following parts, under the general title *Testing of concrete*:

- *Part 1: Sampling of fresh concrete*
- *Part 2: Properties of fresh concrete*
- *Part 3: Making and curing test specimens*
- *Part 4: Strength of hardened concrete*
- *Part 5: Properties of hardened concrete other than strength*
- *Part 6: Sampling, preparing and testing of concrete cores*
- *Part 7: Non-destructive tests on hardened concrete*
- *Part 8: Determination of drying shrinkage of concrete for samples prepared in the field or in the laboratory*
- *Part 9: Determination of creep of concrete cylinders in compression*
- *Part 10: Determination of static modulus of elasticity in compression*
- *Part 11: Determination of the chloride resistance of concrete, unidirectional diffusion*
- *Part 12: Determination of the carbonation resistance of concrete — Accelerated carbonation method*

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 service 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 chloride penetrability of the concrete is an important property to measure and this International Standard sets out a test method that may be applied to specimens cast to assess the potential chloride resistance 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. Different periods of curing and exposure may be set (and stated in the test report) in order to adjust the test duration.

Testing of concrete —

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

1 Scope

This part of ISO 1920 specifies 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.

NOTE 1 The aim of the test is to assess the potential resistance to chloride ingress for a concrete mix.

NOTE 2 Since resistance to chloride penetration depends on ageing, due to the effects of continual hydration of the concrete, the ranking may also change with age.

2 Normative references

The following referenced documents are essential for the application of this part of ISO 1920. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1920-3, *Testing of concrete — Part 3: Making and curing test specimens*

ISO 1920-6, *Testing of concrete — Part 6: Sampling, preparing and testing of concrete cores*

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
acid-soluble 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, 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 to entry: In this part of ISO 1920, Fick's Law is adopted as a valid mathematical representation of the chloride ingress mechanism.

Note 2 to entry: 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 1 to entry: 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 to entry: This reflects the rate of diffusion of chloride into a concrete when part of the chloride is being bound by the cement.

Note 2 to entry: See Annex A.

Note 3 to entry: 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 ISO 1920-3 (see also amendments of the curing conditions in 6.1), for a standard curing period of 28 days.

NOTE 1 A curing period of less than 28 days may be set, depending on the type of cement and purpose of the test.

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 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 total immersion of the specimen in the chloride exposure solution.

NOTE 2 The test can be performed without vacuum saturating the profile specimen in water; this should be stated in the test report.

NOTE 3 The exposure can be achieved by alternative methods, that are:

a) ponding the uncoated face of the specimen in the chloride exposure solution;

b) inverting the specimen and having the uncoated face immersed in the chloride exposure solution.

NOTE 4 The use of large fully immersed specimens is described in Annex C.

The standard reference solution is a 3 % by mass, sodium chloride (NaCl) solution, for an exposure period of 90 days. The solution concentration will be kept constant during the test.

NOTE 5 Other concentrations or solutions, e.g. artificial seawater, and exposure periods other than 90 days, may be set.

After the specified period 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 having the acid-soluble chloride content determined.

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

Because of the high coefficient of variation, approximately 15 % for D_{nss} for the test, testing of three specimens is required and the results reported separately.

NOTE 6 The chloride diffusion coefficient varies with the age of the concrete and the period of exposure.

NOTE 7 The diffusion test described in this part of ISO 1920 is only valid for a constant initial chloride content.

NOTE 8 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

a) 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 seawater.

b) Other exposure solutions

Where the concentration of the chloride exposure solution is other than that in 5.1.2 a), 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) may be used to accelerate the development of a chloride profile.

5.1.3 Chloride impervious barrier system

A polyurethane or epoxy-based paint or equivalent barrier system highly resistant to chloride diffusion, to be used in sealing the sides of the specimen.

5.1.4 Chemicals for chloride analysis, complying to a national standard valid in the place of use. The reference number of the national standard shall be stated in the test report.

5.1.5 Distilled or demineralized 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 ml 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 4000 mm^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 a national standard valid in the place of use. The reference number of the national standard shall be stated in the test report.

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

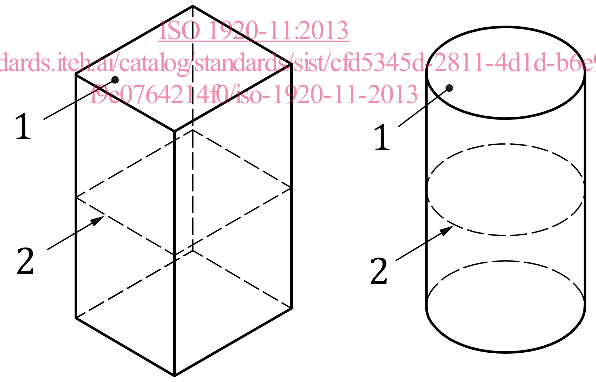
6.1 Preparing sub-specimens

A specimen size shall be selected such that after cutting, the minimum dimension of the sub-specimens used to determine a chloride profile is at least three times the nominal maximum aggregate size. Three specimens, either cylinders, 100 mm or greater in diameter or cubes, 100 mm or greater are cast, and cured for a period of 28 days in a water filled bath with a temperature of (20 ± 2) °C, in accordance with ISO 1920-3. In hot climate locations, the curing conditions after removal of the specimen from the mould can be different from those mentioned in ISO 1920-3. In this case, the specimens may be stored in water at a temperature of (27 ± 2) °C or in a chamber having a temperature of (27 ± 2) °C and a relative humidity of at least 95 %.

NOTE A curing period other than 28 days may be set, depending on the type of cement and purpose of the test.

After 28 days of standard curing or the specified curing period (see the above note), 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.