SLOVENSKI STANDARD
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Preskušanje strjenega betona - 10. del: Določevanje odpornosti proti karbonatizaciji betona pri atmosferski koncentraciji ogljikovega dioksida

Testing hardened concrete - Part 10: Determination of the carbonation resistance of concrete at atmospheric levels of carbon dioxide

Prüfung von Festbeton - Teil 10: Bestimmung des Karbonatisierungswiderstandes von Beton bei atmosphärischer Konzentration von Kohlendioxid

Essai pour béton durci - Partie 10: Détermination de la résistance à la carbonatation du béton à des niveaux atmosphériques de dioxyde de carbone

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English Version

Testing hardened concrete - Part 10: Determination of the carbonation resistance of concrete at atmospheric levels of carbon dioxide

Essai pour béton durci - Partie 10: Détermination de la résistance à la carbonatation du béton à des niveaux atmosphériques de dioxyde de carbone

Prüfung von Festbeton - Teil 10: Bestimmung des Karbonatisierungswiderstandes von Beton bei atmosphärischer Konzentration von Kohlendioxid

This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 104.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Contents

European foreword

This document (prEN 12390-10:2017) has been prepared by Technical Committee CEN/TC 104 “Concrete and related products”, the secretariat of which is held by DIN.

This document will supersede CEN/TS 12390-10:2007.

This document is currently submitted to the Enquiry.

The drafting of this European standard has been delegated to CEN/TC 51/WG 12.

The series EN 12390, *Testing hardened concrete,* includes 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 10: Determination of the carbonation resistance of concrete at atmospheric levels of carbon dioxide*
- *Part 11: Determination of the chloride resistance of concrete, unidirectional diffusion*
- *Part 13: Determination of the secant modulus of elasticity in compression*

and the following Technical Specifications:

- *Part 9: Freeze–thaw resistance – Scaling*

Introduction

In reinforced and prestressed concrete structures, conventional steel reinforcement needs to be protected by sufficient concrete cover to ensure that the intended working life will be achieved. Corrosion of reinforcement induced by carbonation can play a significant role in a structure's serviceability and consequently carbonation resistance of concrete, in particular of the cover zone, is an important property to be quantified.

This test may be used to measure the carbonation rate of any freshly cast concrete. It may be used to assess the impact of a change of a constituent, e.g. cement type, addition, or the impact of a change in mix proportions, e.g. w/c ratio, cement content, fines content.

The rate of carbonation determined by this test procedure may be used as an input into a model that estimates the start of corrosion of reinforcement.

When assessing the durability performance of a concrete with unknown carbonation resistance or a concrete with one or more unfamiliar constituents, it may be necessary to determine if this concrete/constituents gives a similar or better carbonation resistance than currently accepted concretes/constituents. CEN/TR 16563 [1] sets out basic principles to be followed by equivalent durability procedures. From a European perspective, it makes sense to have common test procedures and common assessment procedures. This European Standard is the European method for determining carbonation resistance at natural levels of carbon dioxide and it is recommended as a method to be used when determining the 'equivalent durability' with respect to carbonation.

Concrete may also be classified on the basis of its carbonation resistance. As this Standard provides test procedures, it only describes the production of standardized test results; how these test results are used to determine a class is not within the scope of this Standard.

For standardization purposes, the carbon dioxide concentration in the storage chamber test is fixed at 400 ppm, which is an increase of 50 ppm over the value used in the previous version of this Standard; however, atmospheric levels of carbon dioxide are not constant in location or time. Carbon dioxide concentration in some urban and industrial areas may exceed 400 ppm.

1 Scope

This European Standard describes the procedures used to determine the carbonation rate of a concrete expressed in mm/√year.

This European Standard describes the procedure where a standardized storage chamber is used and where specimens are placed on a natural, but protected from direct rainfall exposure site. The standardized storage chamber procedure is the reference method.

These procedures are suitable for the initial testing of concrete, but they are not appropriate for factory production control.

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 12390-1, *Testing hardened concrete - Part 1: Shape, dimensions and other requirements for specimens and moulds*

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

EN 12390-3, *Testing hardened concrete - Part 3: Compressive strength of test specimens*

3 Principle

Pairs of beams of concrete (or two cubes per test age) are stored in a storage chamber as specified in 4.4 or on a natural exposure site as specified in 4.5. After defined periods of exposure, an approximately 50 mm slice of the beam is broken off at each test age and tested for its carbonation depth. Alternatively if cubes are being used, they are broken halfway and one half of each cube is used to measure the carbonation depth, the other half being discarded. The carbonation depth is measured at three locations on each face of each beam/cube giving a potential total of 12 measurements per specimen and potentially 24 measurements for the two specimens. The mean carbonation depth of all measurements is calculated. The remains of the beams are returned to the storage chamber for testing at other pre-defined ages. Using at least three sets of measurements taken at 3 months, 6 months and 1 year, the rate of carbonation expressed as mm/√years is determined.

4 Reagents and apparatus

4.1 A solution of 1g of phenolphthalein powder[1)] dissolved in a solution of 70 ml ethanol and 30 ml of deionised water or an alternative indicator giving a colour change in the range pH 8 to 11 that gives a sufficiently clear colour change in concrete to differentiate the neutralized zone, e.g. thymolphthalein.

4.2 Where used, a fixing solution to permanently fix the colour change in the concrete specimen, see 6.1.

NOTE Suppliers of some indicator solutions also provide a fixing solution that permanently fixes the colour change.

[1)] WARNING: Phenolphthalein is listed in REACH appendix 2 and its lists of substances of very high concern. Phenolphthalein powder should be handled with the greatest care using safety gloves in a fume cupboard fitted with an extractor.

4.3 A magnifier and a gauge to measure the depth of carbonation perpendicular to the exposed concrete surface with a precision of 0,5 mm.

4.4 A storage chamber controlling the average over the test duration carbon dioxide concentration at 0,040 % ± 0,001 % by volume with no variation outside 0,040 % ± 0,005 %, temperature at 20 °C ± 2 °C and a relative humidity at 65 % ± 2 %, see Annex A for details of a suitable chamber.

4.5 Alternatively to 4.4, a natural exposure site where specimens are protected from direct precipitation (rain, hail and snow), see Annex B for details of a suitable arrangement. The site shall be equipped with instruments to measure frequently the relative humidity, temperature and carbon dioxide concentration.

4.6 Apparatus for recording the relative humidity with a precision of ± 1,0 % and the temperature with a precision of ± 0,5 °C.

4.7 Apparatus for recording CO_2 concentration with a precision of ± 0,001 % by volume. If a storage chamber is being used, it shall be fitted with an audible/visual alarm to signify breaching of limits.

4.8 Fan to provide a homogeneous CO_2 concentration in the air. Type, dimensions and power of the fan has to be adapted to the dimension of the chamber.

5 Production of specimens

5.1 General

Representative samples of the constituents, e.g. cement, aggregates, shall be used for making the test specimens. Either a sample of concrete is taken from the concrete production plant or the concrete mixes shall be produced using the laboratory's standard procedures. The specimens for one test shall be cast from a single batch of concrete.

A minimum batch volume of 50 l is recommended.

Each test shall comprise at least two prismatic beams each being at least 360 mm long and the other dimensions at least three times the maximum aggregate size or two cubes per test age with a side length of at least three times the maximum aggregate size. Beams are the reference specimens.

Avoid or minimize the use of mould release agents on the moulds as they may influence the carbonation depth.

All compressive strength specimens, either cubes or cylinders, are made and cured in accordance with EN 12390-1 and EN 12390-2 and tested in accordance with EN 12390-3.

5.2 Procedure when using storage chamber

After finishing the test specimens, cover the exposed concrete surface with polythene or similar impermeable sheeting to prevent drying. After (24 ± 2) h, the moulds shall be stripped and the test specimens transferred without delay into the EN 12390-2 standard curing condition. After 27 days of standard curing, the test specimens shall be exposed to laboratory air for (16 ± 2) h and then they are placed in the storage chamber.

NOTE 1 The reason for the 27 day wet curing is to allow slowly reacting cements to hydrate prior to carbonation testing as further hydration under the test conditions will be minimal.

NOTE 2 In storage chambers that do not have the facility to reduce the relative humidity, if the test specimens are placed immediately in the storage chamber, there is a risk that the relative humidity will temporarily exceed the limit and this higher relative humidity will slow the rate of carbonation. If the storage chamber is fitted with facilities to reduce the relative humidity (not the normal situation), the test specimens can be placed directly in the storage chamber.

The test specimens shall be positioned in the storage chamber in a way that permits air to circulate freely around all the four faces that will be tested. This is either by horizontal storage or vertical storage, but ensuring a 50 mm gap between adjacent specimens. The temperature shall be measured at least once per day at a constant time.

The relative humidity and carbon dioxide concentration shall be measured and recorded at least once every two hours. The average carbon dioxide concentration in the storage chamber over the duration of the test shall be 0,040 % ± 0,001 % with no variation outside 0,040 % ± 0,005 %.

5.3 Procedure when using a natural exposure site

For each concrete mix, cast at least two beams or at least six cubes for carbonation testing and at least 2 or if the strength development is not known, at least 5 compressive strength specimens from a single batch of concrete. The test specimens shall be cast horizontally in accordance with EN 12390-2. After finishing the test specimens, cover the exposed surface with polythene or similar impermeable sheeting to prevent drying. After (24 ± 2) h, the moulds shall be stripped and the carbonation test specimens transferred without delay into close-fitting, sealed polythene bags or similar storage material and stored at (20 ± 2) °C until they have reached 50 % of the reference strength. If the temperature range is from 15 °C to 25 °C, 50 % of the reference strength may be assumed to have been achieved after 2 days for rapid, 4 days for medium and 7 days for slow concrete strength development [2]. If the strength development is not known at least three cubes or cylinders shall be tested at different ages to ascertain when 50 % of the reference strength has been achieved. Two cubes or cylinders shall be tested 28 days after casting to confirm the reference strength.

NOTE 1 The curing procedures are different to those used for the storage chamber test. The procedures in this clause reflect practice on site and the 'natural environment' will determine if the concrete continues to hydrate.

NOTE 2 The curing periods have been taken from EN 13670 [2] for the curing class 3 and the temperature range from 15 °C to 25 °C.

Once 50 % of the reference strength has been achieved by the cubes/cylinders, the test specimens shall be removed from their polythene bags and placed in the natural exposure site. The test specimens shall be positioned in a way that permits air to circulate freely around all longitudinal faces.

The relative humidity, carbon dioxide concentration and temperature shall be measured and recorded at least once every day at a constant time.

6 Carbonation depth measurements

6.1 Testing age and generation of colour change

Prior to the commencement of the tests, the ages at which the carbonation depth is to be measured shall be defined. These times shall be from the date at which the specimens are placed in the storage chamber or on the natural exposure site. The carbonation depth should be measured at least after three months, six months and one year of storage. If the measured depth of carbonation is less than 5 mm at one year, the testing should be extended to two years

NOTE 1 The measured depth of carbonation is influenced by the time of measuring after application of the indicator solution.

NOTE 2 If the average natural level of relative humidity is greater than 65 %, the rate of carbonation is usually slower (depending upon cement type and w/c ratio) than in the storage chamber test and consequently the period over which measurements is likely to be longer.

In all cases, the exact ages of testing shall be recorded and used in the calculation of the carbonation rate. The date at which the specimens are placed in the storage chamber or on the natural exposure site ($t = 0$), the carbonation depth shall be taken as zero.

At each test age a slice approximately 50 mm thick is broken off each beam or at least two cubes are split in half perpendicular to the trowelled face. The depth of carbonation is measured on the freshly broken surface of the 50mm slice or on one half of the split cube.

NOTE 3 Cutting with a saw is not permitted.

NOTE 4 Measurements need only be taken on one half of a split cube.

Clear the broken surface immediately of dust and loose particles after breaking, and then spray with a fine mist of indicator solution2). Avoid the formation of flow channels on the test surface. If only a weak colouration or none at all appears on the treated surface, repeat the spray test after 1/2 h.

The taking of measurements should be started 1 h ± 15 min after spraying and completed without delay. If the readings cannot be started within this period, use a fixing solution to retain the colour without change. Where a fixing solution has been used, the timing of the depth measurements is not critical.

6.2 Determination of the carbonation depth

6.2.1 General

The carbonation depth shall be determined by the colour change in accordance with the method given below.

6.2.2 Measuring the depth of carbonation

The position of the carbonation front shall be measured at three points on each face. To locate these points the edge length shall be divided into four equal distances. The three central points, i.e. the points at 0,25, 0,5 and 0,75 of the edge length, should be used as the measuring points. With the help of a ruler or a sliding gauge and a magnifier, the carbonation depth (d_k) shall be determined perpendicular to the surface of the beam or cube with a precision of 0,5 mm per measured point.

It is recommended that each freshly broken surface after spraying and the resulting colour change is photographed (inclusive of a scale and specimen reference).

The carbonation depth shall be measured on all four sides of the freshly broken surfaces of the 50 mm slice or on one half of the split cube giving a potential total of twelve measurement points. This procedure is repeated with the second beam or cube specimen.

If the edges of the uncarbonated square cross sectional area are rounded off within the outer measuring points, move the measuring point towards the centreline of the edge until it is within the straight section of the carbonation front. Record that this action has been taken.

The mean depth of carbonation shall be calculated and recorded for each face and the arithmetical mean of all the points used in the assessment shall be calculated and recorded with a precision of 0,1 mm.

NOTE The purpose of recording the mean of each face is to give an indication if one face (often the trowelled face) has significantly deeper carbonation than the other faces.

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2) WARNING: The phenolphthalein indicator solution is flammable. Ingestion, or contact with skin or eyes should be avoided, as should breathing the vapour. Possible effects on the human body include kidney damage and cancer. Use nitrile gloves and safety goggles and use in a well-ventilated space or when wearing a suitable mask.