



SLOVENSKI STANDARD
SIST-TS CEN/TS 12390-10:2008
01-januar-2008

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Testing hardened concrete - Part 10: Determination of the relative carbonation resistance of concrete

Prüfung von Festbeton - Teil 10: Bestimmung des relativen Karbonatisierungswiderstandes von Beton

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Essai pour béton durci - Partie 10: Détermination de la résistance relative a la carbonatation du béton

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Ta slovenski standard je istoveten z: CEN/TS 12390-10:2007

ICS:

91.100.30 Beton in betonski izdelki Concrete and concrete products

SIST-TS CEN/TS 12390-10:2008 **en,de**

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ICS 91.100.30

English Version

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Prüfung von Festbeton - Teil 10: Bestimmung des relativen Karbonatisierungswiderstandes von Beton

This Technical Specification (CEN/TS) was approved by CEN on 9 June 2007 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.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Foreword

This document (CEN/TS 12390-10:2007) 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.

This test method has been prepared by CEN TC 51/WG12/TG5

This method is one of a series on testing hardened concrete comprising:

EN 12390 Testing hardened concrete

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 – Scaling¹

Part 10: Determination of the relative carbonation resistance of concrete 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, 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 These documents are published as CEN/TC for the time being.

1 Scope

This is a method for evaluating the carbonation resistance of concrete mixes by comparison with a concrete mix with known carbonation resistance. It is not a method for the determination of carbonation depths in existing concrete structures. The test is carried out under controlled exposure conditions using natural levels of carbon dioxide or under natural conditions protected from direct rainfall.

If the carbonation depth of the unknown mix is equal or less than the known mix, it is assumed that the risk of reinforcement corrosion for the new mix is equivalent to the known mix (with the same cover required for the known mix). The “reference” concrete may be any concrete with known performance in the intended place of use (environment).

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 932-1, *Tests for general properties of aggregates – Part 1: Methods for sampling*

EN 1097-5, *Tests for mechanical and physical properties of aggregates – Part 5: Determination of the water content by drying in a ventilated oven*

EN 1097-6, *Tests for mechanical and physical properties of aggregates – Part 6: Determination of particle density and water absorption*

EN 12350-2, *Testing fresh concrete – Part 2: Slump test*

EN 12350-3, *Testing fresh concrete – Part 3: Vebe test*

EN 12350-4, *Testing fresh concrete – Part 4: Degree of compactability*

EN 12350-5, *Testing fresh concrete – Part 5: Flow table test*

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

A concrete mix with known performance under classified exposure conditions in the place of use is chosen as the reference concrete.

From previous information or by trial mixes on the concrete under investigation, determine the mix proportions to give an equal compressive strength as the reference concrete. Two prisms and at least six compression test specimens of both reference concrete and concrete under investigation are manufactured with these mix proportions. In addition two concretes are manufactured using an 8% higher and 8% lower cement content, giving a total of 12 prisms and (at least) 36 compression test specimens. All prisms are sealed-cured until the concrete has reached 50% of the reference strength. The prisms are then exposed to one of the two storage conditions. At defined periods up to at least two years, slices are split from the prisms and the freshly split

surface is sprayed with a phenolphthalein solution. The mean depth of the reacted surface layer is calculated and called the depth of carbonation. The mean depths of carbonation for the pairs of prisms are used to interpolate the depth of carbonation at the reference strength.

The three mixes of the reference concrete and the three mixes of the concrete under investigation are made, ideally, on the same day. The days on which they are placed in the storage chamber may vary as this depends on their relative rates of strength development. Testing for carbonation depth should be on the same days.

The relative performance of the two concretes should be compared with the objective of determining if the unknown concrete gives a carbonation depth equal to or lower than that of the known concrete. Such an approach is not dependent on the repeatability or reproducibility of the test and any failure of the storage chamber is unlikely to be significant, as both concretes will have been subjected to the same exposure.

4 Reagents and apparatus

4.1 A solution of 1 % phenolphthalein in 70 % ethanol.

4.2 A magnifier and a gauge to measure the depth of carbonation perpendicular to the exposed concrete surface with a precision of 0,2 mm.

4.3 A storage chamber controlling the carbon dioxide concentration at $(0,035 \pm 0,005)$ %, temperature at (20 ± 2) °C and a relative humidity at (65 ± 5) %, see Annex A for details of a suitable chamber.

4.4 A natural exposure site where specimens are protected from direct rainfall, see Annex B for details of a suitable arrangement.

4.5 Apparatus for recording the relative humidity with a precision of $\pm 2,0$ % and the temperature with a precision of $\pm 0,5$ °C.

4.6 Apparatus for recording CO₂ concentration with a precision of $\pm 0,001$ % by volume fitted with an audible/visual alarm to signify breaching of limits.

4.7 Fans to facilitate circulation of air within the storage chamber.

5 Production of specimens

5.1 General

Prior to production and testing, the following shall be specified or agreed:

- reference strength at a given age under the conditions of the test method;
- consistence class.

Prior to testing, the following may be specified or agreed:

- some or all of the constituent materials;
- maximum nominal upper aggregate size;
- other performance requirements for the concrete to be tested;
- environment for the test

either Environment A — 20 °C, 65 % relative humidity, 0,035 % carbon dioxide

or Environment B — outside and protected from direct rainfall.

For each concrete to be tested, 3 mixes with constant free water content shall be cast to allow the normalisation procedure detailed in clause 6 to be carried out:

— one primary mix containing the cement content judged to give the reference strength;

— two secondary mixes: one containing 8 % by mass more cement than the primary mix and the other with 8 % by mass less cement than the primary mix.

NOTE When preparing concrete to have a given property, such as consistence or air content, it may be necessary to prepare and test trial mixes of varying composition to establish the required mix quantities.

Prisms shall be at least 400 mm long with a cross-section of 100 mm x 100 mm from which slices approximately 50 mm thick can be split off at each date of carbonation testing. The shortest dimension of the prism shall not be less than 4 times the maximum nominal upper aggregate size. Avoid or minimise the use of mould release agents on the prism moulds as they may influence the carbonation depth.

5.2 Constituent materials

5.2.1 Sampling

If bulk samples of aggregates are supplied, sub-samples for the test portions shall be taken in accordance with EN 932-1. Where required, samples shall be accompanied by a certificate of sampling in accordance with relevant European or national standards. Otherwise use the materials in the proportions supplied or specified for the concretes.

5.2.2 Cement and addition

Upon their arrival at the laboratory, store the materials in separate airtight containers of appropriate size in a dry place. Before use, thoroughly stir each separate material, either using a hand tool or in a suitable mixer, in such a manner as to ensure the greatest possible uniformity, taking care to avoid the intrusion of foreign matter or loss of material.

5.2.3 Aggregate

The aggregate shall be in one of the following conditions:

- oven-dry;
- air-dried to (20 ± 5) °C;
- water-saturated surface-dry;
- saturated by soaking in water for at least 24 h.

Where necessary, determine the water content in accordance with EN 1097-5 and the water absorption in accordance with EN 1097-6.

The aggregates for each concrete batch shall be used either in separate size fractions or with an all-in grading.

5.3 Batching

The quantity of concrete shall be at least 10 % more than that required for the proposed tests. Where feasible, the concrete shall be made in a single batch.

For each concrete batch, weigh and batch the cement to an accuracy of at least 0,5 %, the admixtures to an accuracy of 5 % and the aggregates to an accuracy of 1%.

Where admixtures are used, the manufacturer's instructions for use shall be followed.

5.4 Mixing

5.4.1 General

Mix the concrete in a room having an ambient temperature of (20 ± 5) °C and a relative humidity of not less than 50 %.

If the aggregate is in a dry condition, soak it with some of the mixing water, while avoiding water loss by evaporation, to allow the aggregate to take up most of the water it will ultimately absorb. Where admixtures are used, they shall be added with the second portion of the mixing water.

Mix the concrete by machine. The size of the batch shall be between 50 % and 90 % of the rated capacity of the mixer to avoid incomplete mixing and spillage.

Before using the mixer, clean off any fresh concrete remaining from a previous batch. Ensure that no free water remains in the mixer. If using a pan mixer and it is dry, wipe the pan with a damp cloth immediately prior to use. If using a tilting drum mixer, place a small preliminary batch of similar proportions to the main batch into the mixer immediately before the main batch in order to coat the mixer. Discharge this priming mix and proceed with batching the main batch.

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5.4.2 Mixing procedure

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5.4.2.1 Using dry aggregates

Add the all-in aggregate in one amount. If separate fine and coarse aggregates are used, add in the following order half the coarse aggregate, the fine aggregate and the remaining coarse aggregate and start the mixer and run it for 15 s to 30 s. Continue mixing and add about half the water during the next 15 s. After mixing for a total of 2 min to 3 min, stop the mixer and leave the contents covered for 5 min to 15 min.

NOTE With some aggregates, this will be insufficient time to approximate to a saturated condition.

Add the cement, addition, pigment and fibres by spreading them in an even layer over the aggregates. Start the mixer and mix for 30 s. Stop the mixer and immediately clean off any material adhering to the mixer blades into the pan. Without delay, recommence mixing and add the remaining mixing water into which the admixture has been poured. Where more than one admixture is used follow the manufacturer's instructions, but do not incorporate them into the water used for pre-soaking the aggregates. Continue mixing after all the materials have been added for at least 2 min and not more than 3 min.

After completing mixing in a pan mixer without a discharging gate, turn the concrete over in the pan a few times using a hand tool to ensure uniformity before sampling. After completing mixing in a drum mixer, discharge the concrete onto a clean non-absorbent surface and turn it over using a hand tool to ensure uniformity before sampling.

5.4.2.2 Using saturated aggregates

If all-in aggregate is used, add half before the other materials and the remainder after them. If separate fine and coarse aggregates are used, add in the following order, half the coarse aggregate, the fine aggregate, the

cement, additions, pigments and fibres, and the remaining coarse aggregate. Start the mixer and add all the mixing water during the first 30 s of mixing. Continue mixing after all the materials have been added for at least 2 min and not more than 3 min.

After completing mixing in a pan mixer without a discharging gate, turn the concrete over in the pan a few times using a hand tool to ensure uniformity before sampling. After completing mixing in a drum mixer, discharge the concrete onto a clean non-absorbent surface and turn it over using a hand tool to ensure uniformity before sampling.

5.5 Production of prisms and making and testing compression test specimens

Measure the consistence using EN 12350-2, EN 12350-3, EN 12350-4 or EN 12350-5 as appropriate. For each mix, cast two prisms and at least 6 cubes or cylinders from a single batch of concrete. Cast the prisms horizontally following EN 12390-2, **5.1**, **5.2**, **5.3** and **5.4**. After finishing the prisms, cover the exposed surface with polythene or similar impermeable sheeting to prevent drying. After 24 h, the moulds shall be stripped and the prisms transferred without delay into a close-fitting, sealed polythene bag or similar storage material and stored at (20 ± 2) °C until they have reached 50 % of the reference strength. All cubes or cylinders shall be made and cured in accordance with EN 12390-1 and EN 12390-2, and tested in accordance with EN 12390-3. Three cubes or cylinders shall be tested 28 d after casting. The other three cubes or cylinders shall be tested at different earlier ages to ascertain when 50 % of the reference strength has been achieved. Where the primary mix is designed to give the reference carbonation resistance, the cubes or cylinders shall be tested to ascertain when 50 % of the 28 d strength of the primary mix is achieved.

Once this strength has been achieved by the cubes/cylinders, the prisms shall be removed from their polythene bags and placed in the storage chamber (environment A; see Annex A) or under local environmental conditions (environment B; see Annex B). If outside conditions are chosen, the relative humidity shall be periodically measured. The prisms shall be positioned in a way that permits air to circulate freely around all faces.

5.6 Carbonation depth measurements

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5.6.1 Testing age and generation of colour change

The carbonation depth shall be measured at the following ages: 182 d, 273 d, 365 d, 547 d, 730 d ($\pm 2\%$) after placing in the storage chamber. Where the specimens are stored in Environment B, the ages for measuring the carbonation depth shall be 365 d and 730 d ($\pm 2\%$) after placing on the exposure site and as specified thereafter.

A slice approximately 50 mm thick shall be broken off the beam at each test age. The depths of carbonation on the freshly broken surface shall be measured.

NOTE 1 Saw cuts are not suitable.

Clear the broken surface immediately of dust and loose particles after breaking, and then spray with a fine mist of indicator solution. Avoid the formation of flow channels on the test surface. If only a weak colouration or none at all appears on the treated surface, spray again after 30 min.

The measurements shall begin at $1 \text{ h} \pm 15 \text{ min}$ after spraying and completed without a pause.

NOTE 2 The measured depth of carbonation may be influenced by the time of measuring after application of the indicator solution.

5.6.2 Determination of the carbonation front

5.6.2.1 General

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

5.6.2.2 Measuring the depth of carbonation

The carbonation front shall be measured at five points on each face. To locate these points the edge length shall be divided into eight equal distances. The five central points shall be used. 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 prism with a precision of 0,2 mm per measured point. If the edges of the uncarbonated square are rounded off within the outer measuring points, then only the three central points are recorded.

The depth of the carbonation front shall be measured on all four faces of both prisms giving a total of forty measurement points. The mean depth of carbonation shall be calculated and recorded for each face and the arithmetical average of the forty points shall be calculated and recorded.

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

5.6.2.3 Appreciation of dense aggregates

Dense aggregate particles that lie within the carbonation front will not be coloured by the phenolphthalein and the carbonation front will be interrupted by the particle, Figure 1a). For determining the carbonation depth, the theoretical carbonation front at the intersection of the location point and a line connecting the limits on each side of the particle, Figure 1b), shall be used.

5.6.2.4 Appreciation of pores and porous aggregates and extreme values

When there are pores or particles of porous aggregates lying in the area of the carbonation front, extreme values of the carbonation depth may appear, Figure 2. Where the measured values of Δd_k are less than 4 mm, they shall be used in the calculation of the mean carbonation depth. Higher values of Δd_k shall not be included when calculating the mean carbonation depth, however, the existence of high values of Δd_k shall be recorded in the test report.

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6 Presentation of the results

6.1 Stage 1 Normalisation of Carbonation Depths

For the three mixes cast, plot the depth of carbonation against time up to 2 years as shown in Figure 3. At each test date, the maximum d_k (excluding values where $\Delta d_k \geq 4\text{mm}$, see 5.6.2.4), minimum d_k and the arithmetical mean of all included readings taken from the two prisms shall be plotted and the best fit regression line drawn. For each test age and for each mix, the depth of carbonation given by the regression line shall be determined.

6.2 Stage 2 Normalisation

From the measured 28 d compressive strength for the three mixes, the exact cement content to give a required strength shall be determined by plotting cube/cylinder compressive strength against cement content, an example of which is shown in Figure 4a). From this relationship, the cement content to give the reference strength shall be determined to the nearest 5 kg/m^3 .

The depths of carbonation given by the regression line shall be plotted against cement content at all ages as shown in an example, Figure 4b). A vertical line shall be drawn at the cement content giving the reference strength and from this line, the carbonation depths at the reference strength are determined for all ages of test. Report the depths of carbonation at the reference strength for all test ages. When reporting the results, all cement contents shall be rounded to the nearest 5 kg/m^3 and all depths of carbonation shall be rounded to the nearest 0,5 mm.