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BSI Standards Publication

Testing hardened concrete

Part 9: Freeze-thaw resistance with de-icing salts — Scaling

bsi.

National foreword

This Published Document is the UK implementation of CEN/TS 12390-9:2016. It supersedes DD CEN/TS 12390-9:2006 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee B/516/12, Sampling & Testing.

A list of organizations represented on this committee can be obtained on request to its secretary.

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English Version

Testing hardened concrete - Part 9: Freeze-thaw resistance with de-icing salts - Scaling

Essais sur béton durci - Partie 9: Résistance au gel dégel-dégel en présence de sels de déverglaçage (écaillage)

Prüfung von Festbeton - Teil 9: Frost- und Frost-Tausalz-Widerstand - Abwitterung

This Technical Specification (CEN/TS) was approved by CEN on 25 April 2016 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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European foreword

This document (CEN/TS 12390-9:2016) has been prepared by Technical Committee CEN/TC 51 "Cement and building limes", the secretariat of which is held by NBN.

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 12390-9:2006.

The following technical modifications have been made in this new edition:

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

— In Clauses 5, 6 and 7,(for all test methods), a prescription measuring the CO_2 content of the air in the storage room has been introduced;

— In Annex A, the alternative applications have been strictly specified;

— In Annex B, a technical specification has been introduced;

— In the Bibliography, the references have been updated.

EN 12390, *Testing hardened concrete*, is currently composed with 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 — Complementary element* [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 secant modulus of elasticity in compression*.

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, 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.

Introduction

Concrete structures exposed to the effects of freezing and thawing need to be durable to have an adequate resistance to this action and, in cases such as road construction, to freezing and thawing in the presence of de-icing agents. It is desirable, especially in the case of new constituents or new concrete compositions, to test for such properties. This also applies to concrete mixes, concrete products, precast concrete, concrete members or concrete *in situ*.

There are two types of concrete deterioration when a freeze–thaw attack occurs, scaling and internal structural damage. Test methods on internal structural damage are described in the CEN Technical Report CEN/TR 15177, *Testing the freeze-thaw resistance of concrete — Internal structural damage*.

Many different test methods have been developed. No single test method can completely reproduce the conditions in the field in all individual cases. Nevertheless, any method should at least correlate to the practical situation and give consistent results. Such a test method may not be suitable for deciding whether the resistance is adequate in a specific instance but will provide data of the resistance of the concrete to freeze–thaw-attack and freeze–thaw-attack in the presence of de-icing agents.

If the concrete has inadequate resistance then the freeze–thaw attack can lead to two different types of damage, namely to scaling (surface weathering) and to internal structural damage. This part of this standard covers only testing for scaling resistance.

This Technical Specification has one reference method and two alternative methods. For routine testing either the reference method or one of the two alternative methods may be used with the agreement of the parties involved. In case of doubt, and if there is no such agreement, the reference method is used.

The testing methods may be used for comparative testing or for assessment against fixed acceptance criteria. The application of limiting values will require the establishment of the correlation between laboratory results and field experience. Due to the nature of the freeze–thaw action, such correlation would have to be established in accordance with local conditions, reflected in the national application documents.

1 Scope

This Technical Specification describes the testing of the freeze–thaw scaling resistance of concrete both with water and with sodium chloride solution. It can be used either to compare new constituents or new concrete compositions against a constituent or a concrete composition that is known to give adequate performance in the local environment or to assess the test results against some absolute numerical values based on local experiences.

Extrapolation of test results to assess different concretes, i.e. new constituents or new concrete compositions, requires an expert evaluation.

NOTE In some cases the test methods may not be suitable for testing special concretes e.g. high strength concrete or permeable concrete. In these cases the result needs to be treated with caution. Also, the testing methods included in this document may not identify aggregates that are subject to occasional 'pop-outs'.

There is no established correlation between the results obtained by the three test methods. All tests will clearly identify poor and good behaviour, but they differ in their assessment of marginal behaviour. The application of different acceptance limits for test results enables assessment for different degrees of exposure severity. In case of justified modifications of the test parameters, precautions might apply. Some alternative applications are described in Annex A.

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*

ISO 5725 (all parts), *Accuracy (trueness and precision) of measurement methods and results*

3 Terms and definitions

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

3.1
freeze-thaw resistance
resistance against alternating freezing and thawing in the presence of water alone

3.2
freeze-thaw resistance with de-icing salt
resistance against alternating freezing and thawing in the presence of de-icing salt

3.3
scaling
loss of material at the testing surface of concrete due to freeze-thaw attack

3.4
internal structural damage
cracks inside concrete which cannot be seen on the surface, but which lead to an alteration of concrete properties, e. g. reduction of the dynamic modulus of elasticity

4 Making of test specimens

Except where details are specified in Clauses 5, 6 and 7 (e.g. the curing) prepare the test specimens in accordance with EN 12390-2. Concrete that requires vibrating for compaction is compacted on a vibrating table. The pre-storage conditions concerning temperature and moisture are documented.

The maximum aggregate size D_{upper} is restricted to one third of the mould length. D_{upper} is the upper permitted value of D for the coarsest fraction of aggregates in the concrete.

5 Slab test (reference method)

5.1 Principle

Slab specimens, sawn from concrete test specimens (Figure 1), are subjected to freeze–thaw attack in presence of a 3 mm deep layer of de-ionized water or 3 % sodium chloride (NaCl) solution. The freeze–thaw resistance is evaluated by the measurement of mass scaled from the testing surface after 56 freeze–thaw cycles.

5.2 Equipment

5.2.1 Equipment for making 150 mm concrete cubes according to EN 12390-2.

5.2.2 Climate controlled room or chamber with a temperature of (20 ± 2) °C, a relative humidity of (65 ± 5) % and an evaporation rate from a free water surface of (45 ± 15) g/(m² h)[1)].

Normally this evaporation rate is obtained with a wind velocity ≤ 0,1 m/s. The evaporation rate is measured from a bowl with a depth of approximately 40 mm and a cross section area of (225 ± 25) cm². The bowl is filled up with water to (10 ± 1) mm from the brim.

The CO_2 content level shall be measured, recorded and kept at a daily average in the range of (300 – 1 000) ppmv to allow for carbonation [2)]

5.2.3 Diamond saw for concrete cutting.

5.2.4 Rubber sheet, (3 ± 0,5) mm thick which is resistant to the salt solution used and elastic down to a temperature of –27 °C, or any alternative moisture retaining lining arrangement.

5.2.5 Adhesive for gluing the rubber sheet to the concrete specimen.

The adhesive is resistant to the environment in question.

NOTE Contact adhesive has proved to be suitable.

5.2.6 Expanded Polystyrene cellular plastic, (20 ± 1) mm thick with a density of (18 ± 2) kg/m³ or alternative thermal insulation with at least a heat conductivity of 0,036 W/(m·K).

5.2.7 Polyethylene sheet, 0,1 mm to 0,2 mm thick.

5.2.8 Freezing medium, consisting either of 97 % by mass of tap water and 3 % by mass of NaCl (for test with de-icing salt) or of de-ionized water only (for test without de-icing salt).

1) Increased rate of surface evaporation and carbonation influences the microstructure. Different types of concrete will be affected in different ways and to a different extent, having impact on moisture exchange and ranking of the performance.

2) Under ambient (indoor/outdoor) and normal working conditions, adequate CO_2 level will automatically be maintained. For smaller, separate rooms or cabinets, the CO_2 level may drop significantly, and the level needs to be re-established by introducing fresh air or by other means adding of CO_2.

5.2.9 Freezing chamber with temperature and time controlled refrigerating and heating system with a capacity such that the time-temperature curve presented in Figure 4 can be obtained in specimen, regardless of its position in the chamber.

The freezer has a good air circulation. The open-mesh shelves in the freezer are level. No deviation from the horizontal plane shall exceed 3 mm per metre in any direction.

5.2.10 Thermocouples, or an equivalent temperature measuring device, for measuring the temperature in the freezing medium on the test surface (see Figure 3) with an accuracy within ± 0,5 K.

5.2.11 Vessel for collecting scaled material.

The vessel is suitable for use at temperatures up to 120 °C without mass loss and is resistant to attack by sodium chloride.

5.2.12 Suitable paper filter for collecting scaled material, optional.

5.2.13 Synthetic brush, resembling a cloth brush, with semi- soft polyamide (nylon) hairs (see specification in Annex B).

5.2.14 Spray bottle, containing tap water for washing off scaled material.

5.2.15 Drying cabinet, controlled at a temperature of (110 ± 10) °C.

5.2.16 Balance, with accuracy within ± 0,05 g.

5.2.17 Vernier callipers, with accuracy within ± 0,1 mm.

5.2.18 CO_2 measurement apparatus.

5.3 Preparation of test specimens

The test requires four specimens, one from each of four cubes.

During the first day after casting the cubes are stored in the moulds and protected against drying by use of a polyethylene sheet. The air temperature is (20 ± 2) °C.

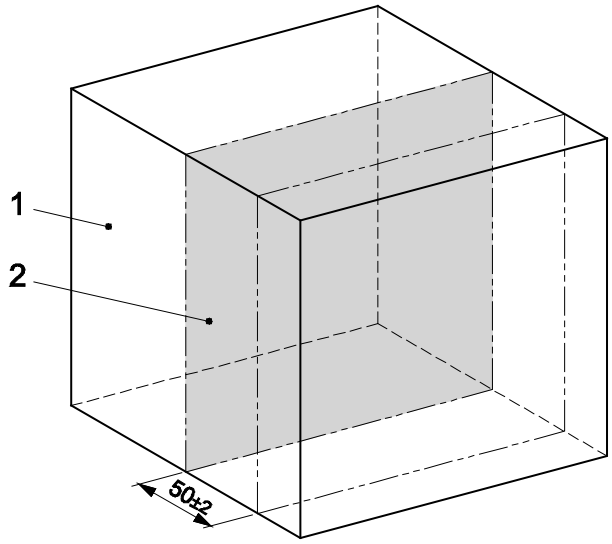
After (24 ± 2) h, the cubes are removed from the moulds and placed in a bath with tap water having a temperature of (20 ± 2) °C.

When the cubes are 7 d old, they are removed from the water bath and placed in the climate chamber (5.2.2), where they are stored until the freeze–thaw testing starts.

At (21 ±1) d [3)] (50 ± 2) mm thick specimen is sawn from each cube perpendicular to the top surface so that the saw cut for the test surface is located in the centre of the cube, see Figure 1. The variation in thickness within a specimen shall not exceed 2 mm.

3) If for any reason (e.g. difficulties in delivery of samples, …), the cutting date is not strictly 21 d, it is vital to strictly keep the following step for pre-conditioning in the seven days and the re-saturation in the consecutive three days. As a consequence, the final age of the sample may vary accordingly.

Dimensions in millimetres



Key

1 top surface at casting

2 test surface

Figure 1 — Location of test specimen and test surface in sawn cube

Directly after sawing, wash the specimen in tap water and wipe off the excess water with a moist sponge. Measure all dimensions of the specimen to an accuracy of ± 0,5 mm by using vernier callipers (5.2.17). Without delay, return it to the climate chamber ensuring that the test surface is vertical with a space between the specimens of at least 50 mm.

When the concrete is (25 ± 1) d[4)] old, rubber sheet, or any alternative moisture retaining lining arrangement, is glued to all surfaces of the specimen except the test surface (the bottom surface rubber does not necessarily need to be glued, see 5.5)[5)]. Place a string of glue or silicone rubber around the test surface in the joint between the concrete and the rubber. The edge of the rubber sheet reaches (20 ± 1) mm above the test surface. After fixing the rubber sheet the specimen shall be returned to the climate chamber.

NOTE 1 The adhesive is normally spread on the concrete surfaces as well as on the rubber surfaces. The manner of gluing the rubber sheet illustrated in Figure 2 has been proved suitable.

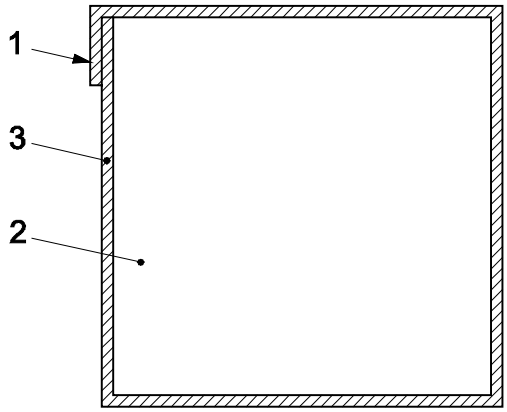
When the concrete is 28 d old, pour a layer about 3 mm deep of de-ionized water at a temperature of (20 ± 2) °C on the top surface. This re- saturation continues for (72 ± 2) h at (20 ± 2) °C during which time the liquid layer shall be maintained at about 3 mm.

NOTE 2 For a specimen with the test area of 150 mm x 150 mm, 67 ml de-ionized water gives an approximately 3 mm thick layer.

During the freeze-thaw cycling, all surfaces of the specimen except the test surface are thermally insulated with (20 ± 1) mm thick polystyrene cellular plastic (5.2.6) according to the test set-up in Figure 3. Another material or thickness providing equivalent thermal insulation can be used instead.

4) If for any reason (e.g. difficulties in delivery of samples, …), the cutting date is not strictly 21 d, it is vital to strictly keep the following step for pre-conditioning in the seven days and the re-saturation in the consecutive three days. As a consequence, the final age of the sample may vary accordingly.

5) The objective of the glued rubber sheet is to ensure one-dimensional moisture exchange of the specimen prior to and during the freeze-thaw exposure.



Key

(top view)

1 overlap

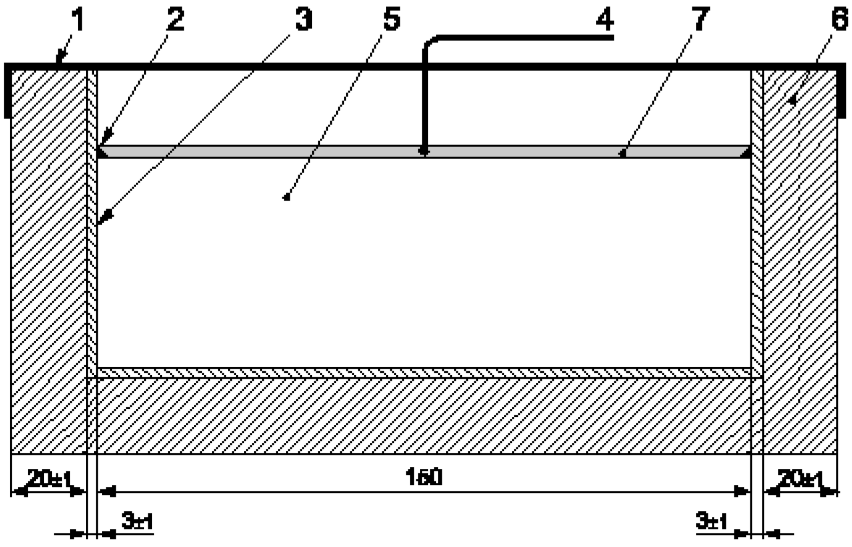
2 test surface

3 rubber sheet

Figure 2 — Sealing the test specimen

Start the test when the specimens are 31 d old, including 3 d of re-saturation. Not earlier than 15 min before the specimens are placed in the freezing chamber (5.2.9), replace the de-ionized water on the test surface with 3 mm of the freezing medium (5.2.8), at a temperature of (20 ± 2) °C.

Dimensions in millimetres



Key

(side view)

1 polyethylene sheet

2 glue string

3 rubber sheet

4 temperature measuring device in contact with the test surface

5 specimen

6 thermal insulation

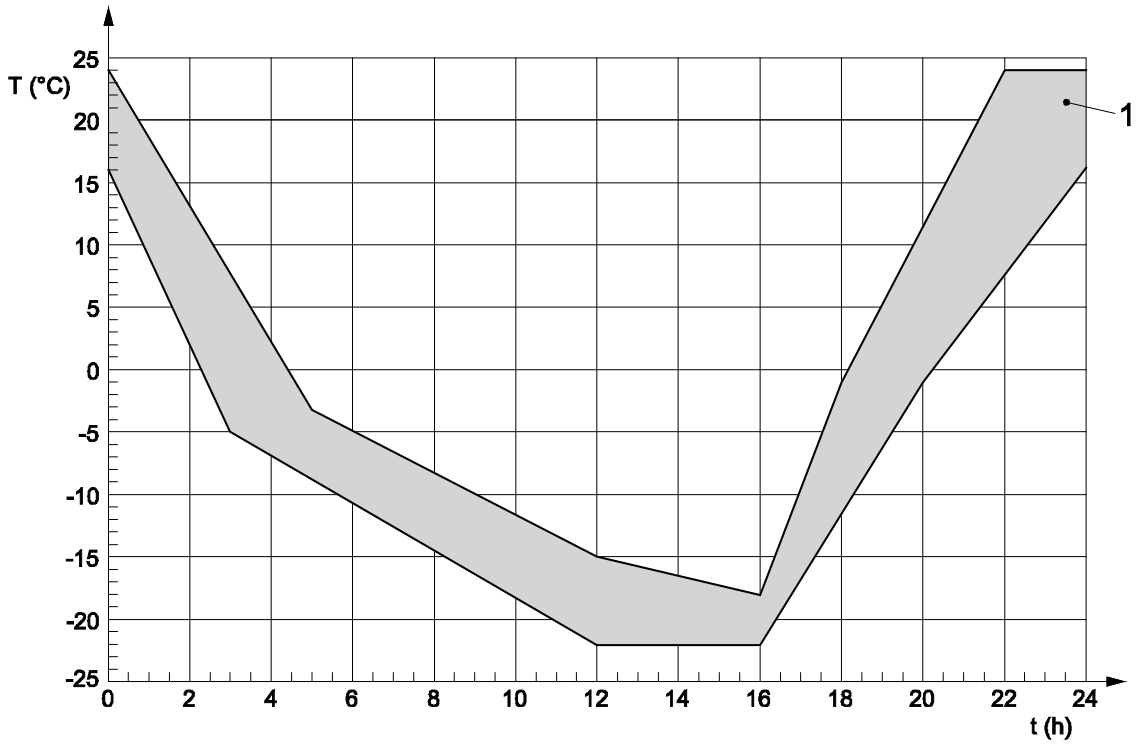
7 freezing medium

Figure 3 — The test set-up used for the freeze–thaw test

The freezing medium is prevented from evaporating by applying a nearly flat, horizontal polyethylene sheet (5.2.7) as shown in Figure 3. The polyethylene sheet remains flat throughout the test so that the distance between the sheet and the surface of the freezing medium is at least 15 mm.

5.4 Test procedure

To begin the test, place the specimens in the freezing chamber at the cycle phase time (0 ± 30) min according to Figure 4. After the specimens have been placed in the freezing chamber, subject them to repeated cycles of freezing and thawing. Monitor the temperature continuously in the freezing medium at the centre of the test surface for at least one specimen in the freezing chamber. During the test, the temperature in the freezing medium shall fall within the shaded area shown in Figure 4. The temperature shall exceed 0 °C during each cycle for at least 7 h but not more than 9 h. The air temperature in the freezer shall never fall below –27 °C.



Key

1 temperature range at the centre of the test surface

Figure 4 — Time (t) -temperature (T) cycle in the freezing medium at the centre of the test surface

The points specifying the shaded area in Figure 4 are given in Table 1 below:

Table 1 — Points specifying the shaded area in Figure 4

Upper limit		Lower limit	
t in h	*T* in °C	*t* in h	*T* in °C
0	+ 24,0	0	+ 16,0
5	- 3,0	3	- 5,0
12	- 15,0	12	- 22,0
16	- 18,0	16	- 22,0
18	- 1,0	20	- 1,0
22	+ 24,0	24	+ 16,0

To obtain the correct temperature cycle for all the specimens it is necessary to have a good air circulation in the freezing chamber.

It is recommended that the number of specimens in the freezer is always the same. If only few specimens are to be tested, the empty places in the freezer should be filled with dummies, unless it has been shown that the correct temperature cycle is achieved without this precaution.

After (7 ± 1), (14 ± 1), (28 ± 1), (42 ± 1) and 56 cycles, depending on the duration of the test, carry out the following procedure for each specimen during the thawed phase of the solution between 20 h to 24 h according to Figure 4:

a) Check the thickness of the remaining freezing medium. If the testing surface, partly or completely, is no longer covered by at least 1 mm of the freezing medium due to evaporation, leaking or permeation, this shall be noted for the report and the test specimen shall be discarded from further testing.

b) Collect the material which has scaled from the test surface by rinsing the test surface using the spray bottle (5.2.14) and brushing it with the brush (5.2.13). Ensure that both the liquid and the scaled material are collected in the vessel (5.2.11).

c) Apply 3 mm of fresh freezing medium to the test surface (67 ml are required for 150 mm x 150 mm testing area).

d) Return the specimen to the freezer.

e) Carefully pour out the liquid in the vessel. It is recommended to pour the liquid through a suitable paper filter, especially where small amounts of scaled material are concerned.

f) The vessel containing the scaled material and the filter, if used, are dried to constant mass at (110 ± 10) °C and weighed to the nearest 0,1 g. The cumulative mass of the dried scaled material after n freeze–thaw cycle is determined by Formula (1). Record the value rounded to the nearest 0,1 g:

$$m_{s,n} = m_{s,before} + (m_{v+s(+f)} - m_{v(+f)}) \quad (1)$$

where

$m_{s,n}$ is the cumulative mass of dried scaled material after n freeze–thaw cycles rounded to the nearest 0,1 g;

$m_{s,before}$ is the cumulative mass of dried scaled material calculated at the previous measuring occasion;

$m_{v+s(+f)}$ is the mass of the vessel containing the dried scaled material and of the paper filter, if used, rounded to the nearest 0,1 g;

$m_{v(+f)}$ is the mass of the empty vessel and the clean dry paper filter, if used, rounded to the nearest 0,1 g.

g) Assess the specimens visually with regard to cracks, scaling from aggregate particles, evaporation or drying of the testing surface, leakage or water or salt solution.

After completion of the test, inspection of the test specimen bottom, with or without removal of the rubber, may prove useful for assessing cracks or permeation of the freezing medium, causing inadequate scaling test results.

5.5 Expression of results

For each measurement and each specimen calculate S_n, the cumulative amount of scaled material per unit area after n cycles, in kilograms per square metre, by the formula:

$$S_n = \frac{m_{s,n}}{A} \cdot 10^3 \quad (2)$$

where

S_n is the mass of scaled material related to the test surface after the n-th cycle in kg/m^2,

$m_{s,n}$ is the cumulative mass of dried scaled material after n freeze–thaw cycle determined by Formula (1);

A is the effective area of the testing surface, calculated from the length measurements after the glue string is applied and rounded to the nearest 100 mm^2.

The mean value and the individual values for each specimen after 56 cycles are used for evaluating the scaling resistance. The bottom surface of the test specimen, i.e. the opposite one of that subjected to exposure to the freezing medium, shall be inspected for damages e.g. by removing the bottom rubber sheet - and the observations reported.

Some concrete qualities are vulnerable to permeation of moisture that may accumulate at the bottom. This may lead to dry top surface and inadequate scaling test result, bottom surface damage and/or internal cracking. Observations of this phenomenon shall be reported. The test specimen should be discarded in such cases when calculating the average scaling value.

5.6 Test report

The test report shall contain at least the following information:

a) reference to this Technical Specification;

b) any deviations from the reference test procedure;

c) origin and marking of the specimens;

d) concrete identification;

e) composition of the freezing medium (5.2.8);

f) amount of cumulative scaled material for each specimen as well as the mean value in kilograms per square metre rounded to the nearest 0,02 kg/m^2, after (7 ± 1), (14 ± 1), (28 ± 1), (42 ± 1) and 56 freeze–thaw cycles;

g) visual assessment: (cracks, scaling from aggregate particles, evaporation or drying of the testing surface, leakage of water or salt solution) before the start and after (7 ± 1), (14 ± 1), (28 ± 1), (42 ± 1) and 56 cycles, bottom surface damages after completion of the test;

h) optional: Composition of the concrete.

6 Cube test (alternative method)

6.1 Principle

Cube specimens, immersed in de-ionized water or 3 % sodium chloride (NaCl) solution, are subjected to freeze–thaw attack. The freeze–thaw resistance is evaluated by the measurement of mass loss of the cubes after 56 freeze–thaw cycles.

6.2 Equipment

6.2.1 Equipment for making 100 mm concrete cubes according to EN 12390-2.

6.2.2 Climate controlled room or chamber with a temperature of (20 ± 2) °C and an evaporation rate of (45 ± 15) g/(m^2 h)[6].

Normally this is obtained with a wind velocity ≤ 0,1 m/s and a relative humidity of (65 ± 5) %.

The evaporation is measured from a bowl with a depth of approximately 40 mm and a cross section area of (225 ± 25) cm^2. The bowl is filled up to (10 ± 1) mm from the brim. CO_2 content level to allow for carbonation[7], the level shall be measured, recorded and kept at a daily average in the range of (300 – 1 100) ppmv.

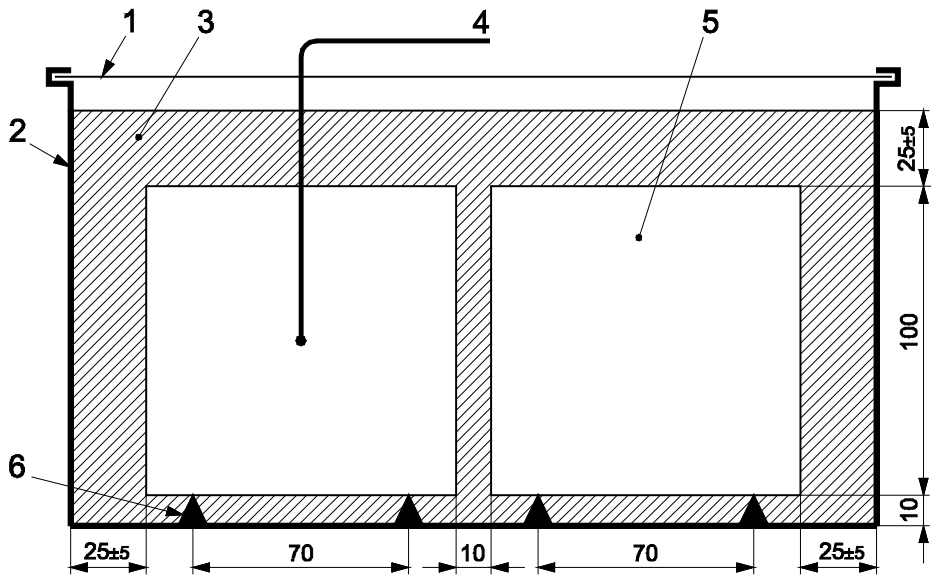
6.2.3 Containers for the freeze–thaw test: Brass (semi hard brass 63:37) or stainless steel watertight containers with a width of (120 ± 15) mm, a length of (260 ± 15) mm and a height of (150 ± 15) mm (see Figure 5).

The sheet metal is about 1 mm thick. The containers are closed with lids which are designed so that they cannot be lifted off when the containers are flooded; containers with sliding lids as shown in Figure 5 and Figure 6 have proved successful. The lid of one container has an opening which can be closed (see Figure 6) for measuring the temperature in the centre of one cube.

6) Increased rate of surface evaporation and carbonation influences the microstructure. Different types of concrete will be affected in different ways and to a different extent, having impact on moisture exchange and ranking of the performance.

7) Under ambient (indoor/outdoor) and normal working conditions, adequate CO2 level will automatically be maintained. For smaller, separate rooms or cabinets, the CO_2 level may drop significantly, and the level needs to be re-established by introducing fresh air or by other means adding of CO_2.

Dimensions in millimetres



Key

(side view)

1	sliding lid	4	temperature measuring device in the centre of a cube
2	container for specimens	5	specimen
3	freezing medium	6	spacers 10 mm high

Figure 5 — Container with specimens

6.2.4 Freezing medium, consisting either of 97 % by mass of tap water and 3 % by mass of NaCl (for test with de-icing salt) or of de-ionized water only (for test without de-icing salt).

6.2.5 Spacer (10 ± 1) mm high placed on the container bottom to support the specimen and to guarantee a defined thickness of the liquid layer between the test surface and the container (see Figure 5).

6.2.6 Automatically-controlled freeze–thaw chest with a flooding device.

Instead of the automatically-controlled chest a freezer and a water bath or a freeze–thaw chest with a secondary cooling circulation can be used.

The performance of the freeze–thaw chest or the freezer and the water bath is designed so that it is possible to maintain the temperature cycle in Figure 7 for each of the cubes placed in it.

6.2.7 Thermocouples, or an equivalent temperature measuring device, for measuring the temperature in the centre of the cube (see Figure 6) with an accuracy within 0,5 K.

NOTE A continuous recording device is particularly suitable for logging the temperature with which the temperature can be measured and recorded at least every 10 min over a period of 24 h.

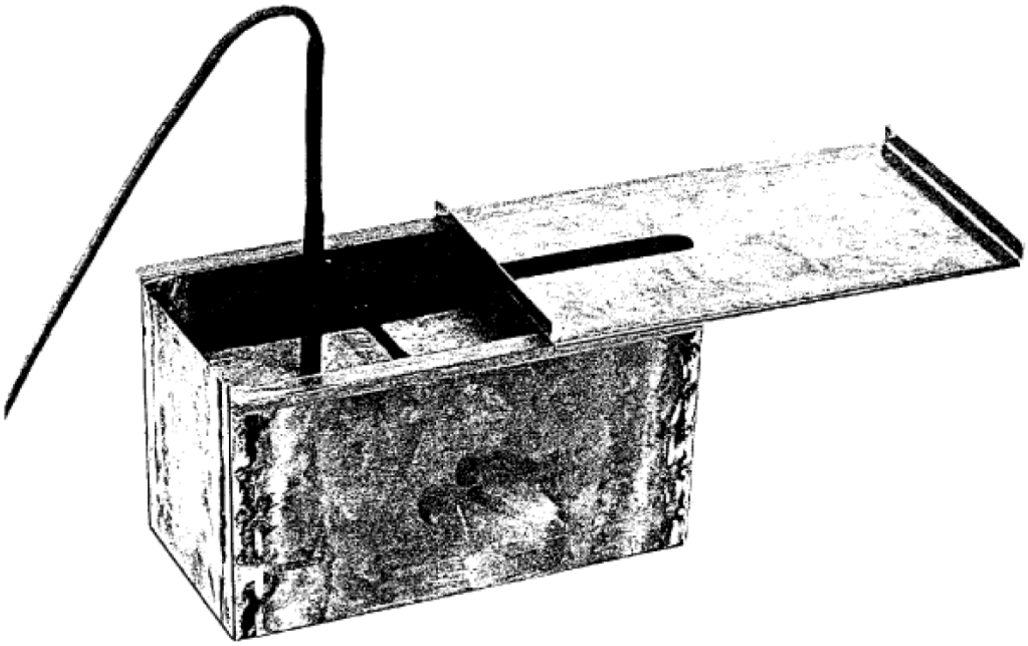


Figure 6 — Container with cubes and temperature sensor

6.2.8 Suitable paper filter for collecting scaled material, optional.

6.2.9 Semi- soft rush, as specified in Annex B.

6.2.10 Spray bottle, containing tap water for washing off scaled material.

6.2.11 Drying cabinet, controlled at a temperature of (110 ± 10) °C.

6.2.12 Balance, with an accuracy within ± 0,05 g.

6.3 Preparation of test specimen

The test requires four 100 mm cubes (2 containers with 2 cubes each).

Lightly apply a demoulding agent to the internal surfaces of the cube moulds and wipe them with a dry sheet directly before they are filled with concrete so that the test results are not affected by excessive residues of the release agent.

During the first day after casting the cubes are stored in the moulds and protected against drying by use of a polyethylene sheet. The air temperature is (20 ± 2) °C.

After (24 ± 2) h, the cubes are removed from the moulds and placed in a bath with tap water having a temperature of (20 ± 2) °C.

When the cubes are 7 d old, they are removed from the water bath and placed in the climate chamber (6.2.2), where they are stored for 20 d.

6.4 Test procedure

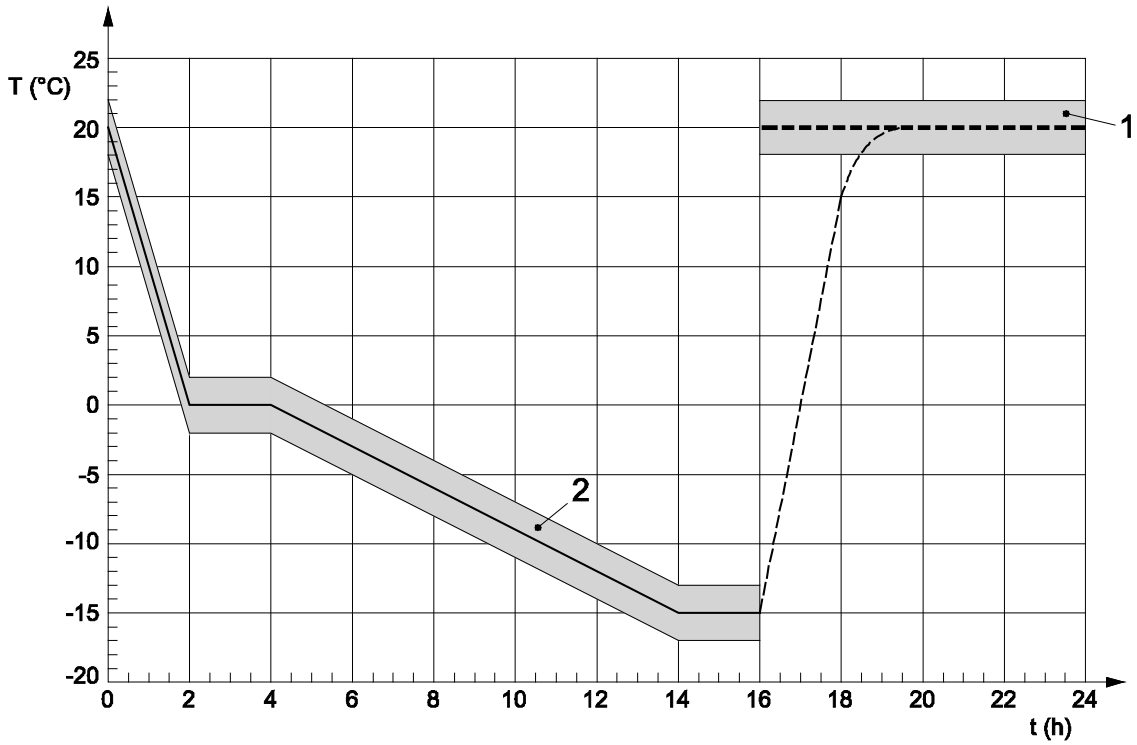
At 27 d, 1 d before the start of freezing test, determine the mass of the four cubes to an accuracy of 1 g. Then place the four cubes provided for the freezing test in two containers (6.2.3) so that the faces which were uppermost during casting are perpendicular to the base of the container and that there is about 10 mm distance between the cubes. Pour in freezing medium (6.2.4) until it covers the cubes by (25 ± 5) mm.

After 24 h, determine the mass of each cube to an accuracy of 1 g and calculate the quantity of freezing medium absorbed in 24 h from the increase in mass.

At 28 d place the containers with closed lids containing the cubes immersed in the freezing medium, evenly distributed, in the freeze–thaw chest (6.2.6) or the freezer. Start the freeze–thaw cycle. Change the containers around once a week; turn them through 180° and inter-change them on a cyclic basis.

Control the temperature of the freeze–thaw chest so that the temperature at the centre of the cube corresponds to the solid line in Figure 7 and shall not leave the shaded area in the diagram. The air temperature in the cooling chest should not fall below –25 °C. Table 2 contains the mean value, the upper and the lower limit of the temperature curve as function of time.

The number of containers in the chest or freezer should always be the same. If only a few cubes are to be tested, containers with blanks (cubes) are put in for this purpose. The containers are not stacked on top of one another.



Key

1 temperature of the water bath

2 temperature in the centre of a 100 mm cube

Figure 7 — Temperature behaviour pattern in the centre of a cube

The points specifying the shaded area in Figure 7 are given in Table 2.

Immediately after the 16 h cooling phase if a freeze–thaw chest with air cooling is used, flood the chest with water or put the containers into a water bath at (20 ± 2) °C so that the water stands (20 ± 5) mm below the brims of the containers. The thawing phase lasts a total of 8 h. Keep the water moving at all times, and heat or cool so that the water temperature at all points in the chest or water bath is (20 ± 2) °C during the entire thawing process. If a freeze–thaw chest with secondary cooling is used, the freezing and the thawing of the specimens will be carried out by the cooling liquid.

Check the water temperature during the thawing process when first using the chest or the water bath and after approximately every 56 freeze–thaw cycles. Fifteen minutes before the end of the 8 h thawing phase, pump the water out of the chest over a maximum time of 15 min. Where a water bath is used, remove the containers from the bath.

Table 2 — Points specifying the shaded area in Figure 7

t in h	*T* in °C		
	Upper limit	Nominal value	lower limit
0	+ 22,0	+ 20,0	+ 18,0
2	+ 2,0	0,0	- 2,0
4	+ 2,0	0,0	- 2,0
14	- 13,0	- 15,0	- 17,0
16	- 13,0	- 15,0	- 17,0

If, in exceptional cases, it is necessary to interrupt the test or during the weekend, if non-automatic test equipment is used, the containers with the cubes remain in frozen state at (−15 ± 2) °C.

After (7 ± 1), (14 ± 1), (28 ± 1), (42 ± 1) and 56 freeze–thaw cycles, carry out the following procedure during the thawed state of the specimens:

a) Check the cubes visually to determine whether cracks or other substantial changes have occurred and whether the loss is on the surfaces or has occurred at the edges.

b) Brush the cubes with the brush (6.2.9) using a light pressure in such a way that the pieces which have already been loosened are detached and can be collected. Pour the liquid carefully out of the container (and through a suitable filter).

c) Before the start of the next cooling phase, fill the container with the cubes with fresh freezing medium (6.2.4) at (20 ± 2) °C. Return the container to the chest.

d) Dry all the pieces which have been detached by the freezing action (from the container, from the filter and the above-mentioned brushings) to a constant mass at (110 ± 10) °C. The cumulative mass of dried scaled material is determined to an accuracy of 0,1 g by Formula (3):

$$m_{s,n} = m_{s,before} + m_{c+f+b} \tag{3}$$

where

$m_{s,\,n}$ is the cumulative mass of dried scaled material after n freeze–thaw cycle rounded to the nearest 0,1 g;

$m_{s,\,before}$ is the cumulative mass of dried scaled material calculated by the measuring occasion before;

m_{c+f+b} is the mass of dried scaled material in the container, filter and obtained by brushing rounded to the nearest 0,1 g.

6.5 Expression of the results

Calculate the liquid absorption *L* for each cube before the start of the freeze–thaw cycles as a percentage by mass to the nearest 0,1 % by the formula:

$$L = \frac{m_{28\mathrm{d}} - m_{27\mathrm{d}}}{m_{27\mathrm{d}}} \cdot 100 \qquad (4)$$

where

$m_{27\mathrm{d}}$ is the mass of the air dry cube at 27 d, in grams;

$m_{28\mathrm{d}}$ is the mass of the saturated cube at 28 d, in grams

and determine the mean value of the four cubes to the nearest 0,1 %.

For each measurement calculate the loss P of two cubes in each container as a percentage by mass to the nearest 0,1 % by the formula:

$$P = \frac{m_{\mathrm{s,n}}}{m_{\mathrm{o}}} \cdot 100 \ \% \qquad (5)$$

where

m_{o} is the mass of two air dry cubes (for one container) at 27 d, in grams;

$m_{\mathrm{s,\,n}}$ is the cumulative mass of the dried scaled material calculated by Formula (3)

and determine the mean value for the two containers to the nearest 0,1 %.

The mean value and the individual values for loss in mass after 56 cycles are used for evaluating the scaling resistance.

6.6 Test report

The test report shall contain at least the following information:

a) reference to this Technical Specification;

b) any deviations from this alternative test procedure;

c) origin and marking of the specimens;

d) concrete identification;

e) composition of the freezing medium (6.2.4);

f) loss of mass of the cubes for each container as well as the mean value in percentage by mass to the nearest 0,1 %, after (7 ± 1), (14 ± 1), (28 ± 1), (42 ± 1) and 56 freeze–thaw cycles;

g) visual assessment (notes on cracks, substantial changes in the cube and type of loss - loss of material at the surfaces or edges) after (7 ± 1), (14 ± 1), (28 ± 1), (42 ± 1) and 56 freeze–thaw cycles. Unevenly distributed deterioration of the cubes should be mentioned;

h) optional: Liquid absorption by the cubes (mean) during the 24 h water or NaCl-solution storage before the start of the freezing test in percentage by mass to the nearest 0,1 %;

i) optional: Composition of the concrete.

7 CF/CDF-test (alternative method)

7.1 Principle

CF/CDF specimens, obtained by splitting a 150 mm cube mould with a centralized PTFE plate, are subjected to freeze–thaw attack in presence of de-ionized water (CF-test) or 3 % sodium chloride (NaCl) solution (CDF-test). The freeze–thaw scaling resistance is evaluated by the measurement of mass scaled from specimens after 28 freeze–thaw cycles (CDF test using 3 % sodium chloride (NaCl) solution) or after 56 freeze–thaw cycles (CF test using de-ionized water).

7.2 Equipment

7.2.1 Equipment for making 150 mm concrete cubes according to EN 12390-2.

7.2.2 PTFE plate (Polytetrafluorethylene) or other materials with an equivalent hydrophobic surface serving as mould for the test surface.

The geometry of the plate is adapted to the 150 mm cube mould and the thickness is less than 5 mm.

7.2.3 Climate controlled room or chamber with a temperature of (20 ± 2) °C and an evaporation rate of (45 ± 15) g/(m² h)[8].

Normally this is obtained with a wind velocity ≤ 0,1 m/s and a relative humidity of (65 ± 5) %. The evaporation is measured from a bowl with a depth of approximately 40 mm and a cross section area of (225 ± 25) cm². The bowl is filled up to (10 ± 1) mm from the brim. CO_2 content level to allow for carbonation[9], the level shall be measured, recorded and kept at a daily average in the range of (300 – 1 100) ppmv.

7.2.4 Lateral sealing which consists of solvent-free epoxy resin or aluminium foil with butyl rubber, durable to temperatures of −20 °C and resistant against the attack of the de-icing solution.

7.2.5 Freezing medium, consisting either of 97 % by mass of tap water and 3 % by mass of NaCl (for test with de-icing salt) or of de-ionized water only (for test without de-icing salt).

7.2.6 Unit for adjusting liquid level, i.e. by suction device.

The suction device may consist of a capillary tube with a spacer of (10 ± 1) mm that is connected with e.g. a water jet pump to suck up the excessive liquid in the test containers.

7.2.7 Test containers (see Figure 8).

The specimens are stored in stainless steel containers during the freeze–thaw cycles. The stainless sheet metal is (0,7 ± 0,01) mm thick. The size of the test container is selected in such a way that the thickness of the air layer between the vertical side of the specimen and the test container is restricted to (30 ± 20) mm.

The same test containers can be used for capillary suction. Other containers can be used if they ensure an equivalent arrangement for capillary suction. During the capillary suction the test container is closed with a cover. The cover has an incline to prevent any possible condensation water from dripping onto the specimens.

8) Increased rate of surface evaporation and carbonation influences the microstructure. Different types of concrete will be affected in different ways and to a different extent, having impact on moisture exchange and ranking of the performance.

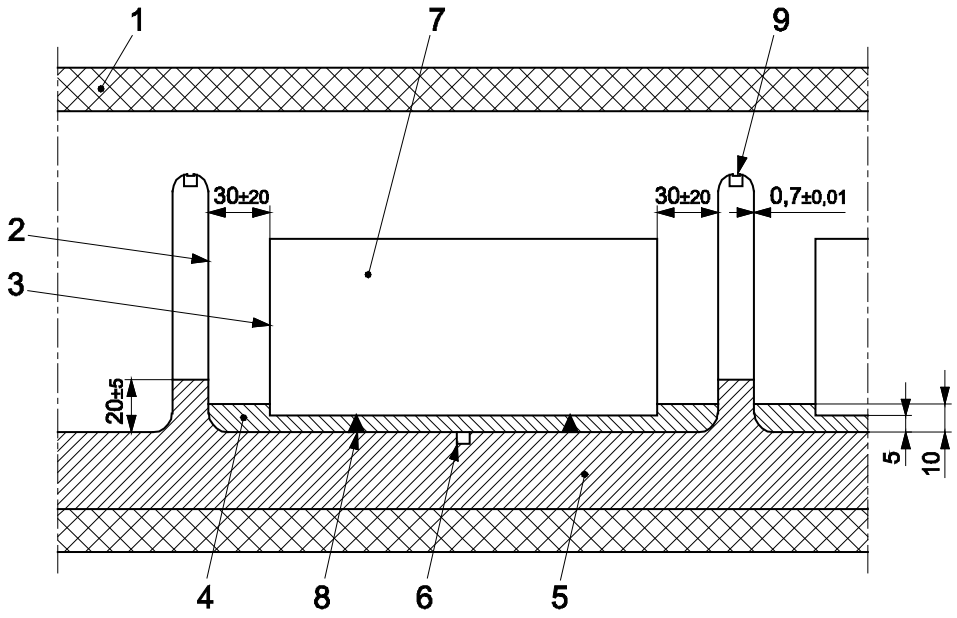
9) Under ambient (indoor/outdoor) and normal working conditions, adequate CO2 level will automatically be maintained. For smaller, separate rooms or cabinets, the CO_2 level may drop significantly, and the level needs to be re-established by introducing fresh air or by other means adding of CO_2.

7.2.8 Spacer (5 ± 0,1) mm high placed on the container bottom to support the specimen and to guarantee a defined thickness of the liquid layer between the test surface and the container (see Figure 8).

7.2.9 Temperature controlled chest (see Figure 8).

For temperature control during the freeze–thaw cycle, a chest with a liquid cooling bath is used. The temperature of the cooling bath is controlled by an appropriate device. The heating and cooling capacity and the control unit is capable of maintaining the temperature regime at the reference point within ± 0,5 K with full loading by the test containers with the test specimens. The temperature deviation of the cooling liquid is limited at ± 0,5 K at the minimum temperature and at ± 1 K at other temperatures. A constant time shift between the test containers is acceptable.

Dimensions in millimetres



Key

(side view)

1 lid of the chest
2 test container
3 lateral sealing
4 freezing medium
5 cooling liquid
6 reference point under the centre of the median container in the chest
7 specimen
8 spacer 5 mm high
9 supports for adjusting the containers

Figure 8 — Principle arrangement of the CF/CDF-test during the freeze–thaw cycles

The chest is equipped with supports for the test containers above the cooling bath to ensure an immersion depth of the bottom of the test containers of approximately (20 ± 5) mm.

7.2.10 Temperature gauge with an accuracy of ± 0,05 K at 0 °C, which is recommended for the measurement.

The reference temperature is measured in the cooling bath liquid below the bottom of the test container. The temperature gauge is in the form of a rectangular container with dimensions ((40 ± 0,2) mm x (5 ± 0,2) mm x (5 ± 0,2) mm). A surface (5 mm x 40 mm) of the temperature gauge is secured so that the long side of the probe lies in the direction flow. The time constant (t –90 %) of the probe (without securing device), determined according to EN 60751 in a flow water bath, should be (6,3 ± 0,8) s. The minimum temperature of –20 °C is used for calibration.

7.2.11 Ultrasonic bath.

The size of the ultrasonic bath is sufficiently large. The test container does not have a mechanical contact to the ultrasonic bath. The minimum distance between the test container and the lower surface of the bath amounts to 15 mm. The bath should provide the following power data: ERS power in the range of 180 W to 250 W; HF peak power under double half-wave operation in the range of 360 W to 500 W; frequency in the range of 35 kHz to 41 kHz.

7.2.12 Suitable paper filter for collecting scaled material, optional.

7.2.13 Drying cabinet, controlled at a temperature of (110 ± 10) °C.

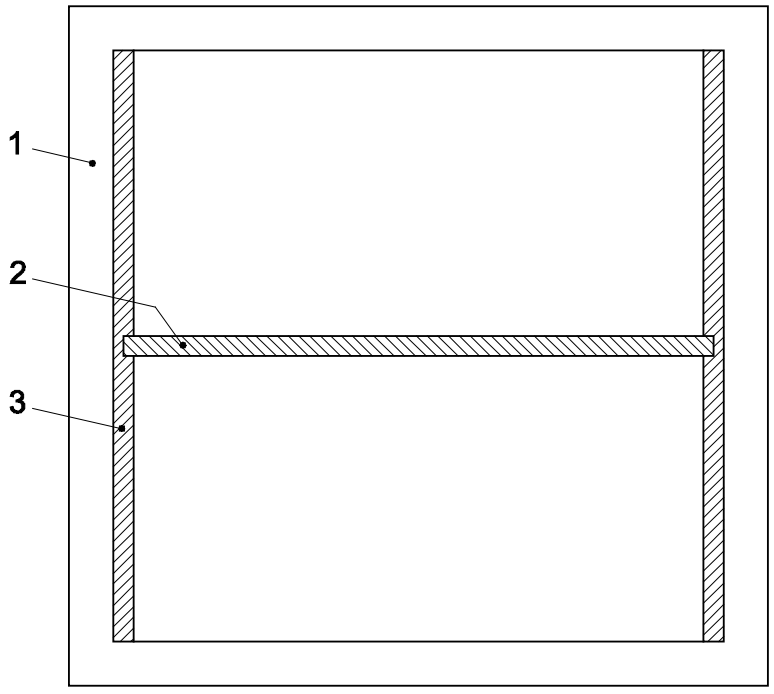
7.2.14 Balance, with an accuracy within ± 0,05 g.

7.2.15 Vernier callipers, with an accuracy within ± 0,1 mm.

7.3 Preparation of test specimens

The test requires five specimens. The test surface of each specimen is approx. 140 mm x 150 mm.

The PTFE plate (7.2.2) is centred in the mould in order to divide the mould into halves. The vertical PTFE plate serves as a mould surface. The centred plate can be fixed by two other plates which are placed vertically (see Figure 9). The concrete surface at the PTFE plate is the test surface. The PTFE plate is not treated with any demoulding agent.



Key

1 form work 150 mm x 150 mm x 150 mm

2 centred PTFE disk

3 lateral PTFE disk

Figure 9 — Arrangement of PTFE plates

During the first day after casting the cubes are stored in the moulds and protected against drying by use of a polyethylene sheet. The air temperature is (20 ± 2) °C.

After (24 ± 2) h, the cubes are removed from the moulds and placed in a bath with tap water having a temperature of (20 ± 2) °C.

When the cubes are 7 d old they are removed from the water bath and placed in the climate chamber (7.2.3), where they are stored for surface drying for 21 d until the freeze–thaw testing starts.

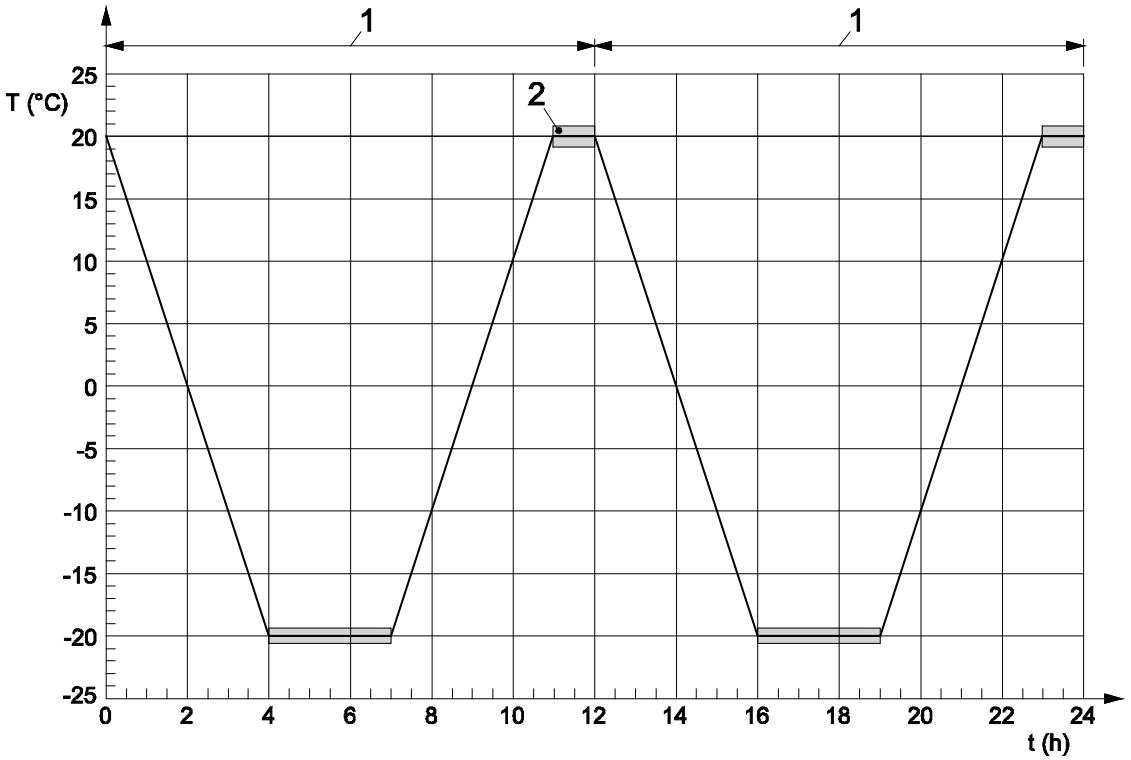
Between 21st and 26th day after casting the specimens the lateral surfaces are either covered with aluminium foil glued with butyl rubber or sealed with a solvent-free epoxy resin. Immediately after this treatment the specimens are returned to the climate chamber.

7.4 Test procedure

The freeze–thaw test starts after 28 d with the re- saturation of the specimens.

Following dry storage, the specimens are placed in the test containers on the (5 ± 0,1) mm high spacers with the test surface downwards (see Figure 8). Subsequently, the freezing medium is poured into the container to a height of (10 ± 1) mm without wetting the specimen's top.

NOTE This can be achieved by filling to approx. 13 mm and removing the surplus solution by means of suction device (7.2.6).



Key

1 freeze–thaw cycle

2 temperature measured at the reference point

Figure 10 — Temperature curve

During the capillary suction the test container is closed. The capillary suction period is seven days at a temperature of (20 ± 2) °C. Check and adjust the liquid level above at regular intervals, depending on the suction capacity of the material during capillary suction. The weight gain of the specimens is measured.

Before starting the freeze–thaw cycles, remove loosely adhering particles and dirt from the test surfaces of the specimens by treatment in the ultrasonic bath (7.2.11) described in 7.4 a). The material removed is discarded.

A 12 h freeze–thaw cycle is applied (see Figure 10). The temperature cycle in the chest (7.2.10) is monitored continuously at the reference point.

The points specifying the temperature curve in Figure 10 are given in Table 3.

Table 3 — Points specifying the shaded area in Figure 10

t in h	T in °C		
	upper limit	nominal value	lower limit
0	+ 21,0	+ 20,0	+ 19,0
4	- 19,5	- 20,0	- 20,5
7	- 19,5	- 20,0	- 20,5
11	+ 21,0	+ 20,0	+ 19,0
12	+ 21,0	+ 20,0	+ 19,0

After (4 ± 1), (6 ± 1), (14 ± 1) and 28 freeze–thaw cycles (CDF-test) or (6 ± 1), (14 ± 1), (28 ± 1), (42 ± 1) and 56 freeze–thaw cycles (CF-test), carry out the following procedure for each specimen while the temperature is above 15 °C.

a) To remove loosely adhering scaled material from the test surface, the test container is dipped into the contact liquid of an ultrasonic bath (7.2.11) and subjected to ultrasonic cleaning for three minutes.

b) The solution comprising the scaled material is filtered. The suitable paper filter is subsequently dried at (110 ± 10) °C for 24 h and cooled for (60 ± 5) min at a temperature of (20 ± 2) °C and a relative humidity of (65 ± 5) %. The mass of the filter containing the dried scaled material m_{s+f} is weighed to 0,1 g. The mass of the empty filter m_f is determined before with the same accuracy. The mass of the dried scaled material $m_{s,n}$ is determined by Formula (6):

$$m_{s,n} = m_{s,before} + (m_{s+f} - m_f) \quad (6)$$

where

$m_{s,n}$ is the cumulative mass of dried scaled material after n freeze–thaw cycle rounded to the nearest 0,1 g;

$m_{s,before}$ is the cumulative mass of dried scaled material calculated by the measuring occasion before;

m_{s+f} is the mass of the dried filter with the scaled material rounded to the nearest 0,1 g;

m_f is the mass of the dry filter rounded to the nearest 0,1 g.

c) Before the start of the next freeze–thaw cycle pour fresh freezing medium (7.2.5) into the container to a height of (10 ± 1) mm without wetting the specimen's top.

d) Return the container to the chest.

7.5 Expression of test results

For each measurement and each specimen calculate S_n, the cumulative amount of scaled material per unit area after n cycles, in kilograms per square metre, by Formula (7):

$$S_n = \frac{m_{s,n}}{A} \cdot 10^3 \quad (7)$$

where

S_n is the mass of scaled material related to the test surface after the n-th cycle in kg/m^2,

$m_{s,n}$ is the cumulative mass of dried scaled material after n freeze–thaw cycle determined by Formula (6),

A is the test surface in mm^2, calculated on the basis of the linear dimensions as the average of at least two measurements determined to the nearest 0,5 mm.

The mean value and the standard deviation of the scaled material are evaluated. The mean value and the individual values for each specimen after 28 cycles (CDF-test) or 56 cycles (CF-test) are used for evaluating the scaling resistance.

7.6 Test report

The test report shall contain at least the following information:

a) reference to this Technical Specification;

b) any deviations from this test procedure;

c) origin, size and marking of the specimens;

d) concrete identification

e) the composition of the freezing medium (7.2.5);

f) amount of cumulative scaled material for each specimen as well as the mean value and the standard deviation in kilograms per square metre rounded to the nearest 0,001 kg/m^2, after (4 ± 1), (6 ± 1), (14 ± 1) and 28 cycles (CDF-test) or (14 ± 1), (28 ± 1), (42 ± 1) and 56 cycles (CF-test);

g) visual assessment (cracks, scaling from aggregate particles) before the start and after (4 ± 1), (6 ± 1), (14 ± 1) and 28 cycles (CDF-test) or (14 ± 1), (28 ± 1), (42 ± 1) and 56 cycles (CF-test);

h) optional: mass of solution sucked up during the capillary suction period for each specimen as well as the mean value and the standard deviation;

i) optional: the composition of the concrete.

8 Precision data

The precision estimates from each of the tests, given as coefficients of variation in Table 5:

a) are derived from data for repeatability and reproducibility determined from inter-laboratory trials carried out in accordance with the ISO 5725- series;

NOTE This is published in: Breit, W.; Siebel, E.: Standard methods for testing the resistance of concrete to freezing and thawing – Round robin test. Milestone Report Work Package 3, European Research Project MAT1-CT94-0055, Forschungsinstitut der Zementindustrie, Report No. B1489/3, Düsseldorf, June 1998.

b) are based on the functional relationships between scaling (general mean m) and coefficients of variation (V_r V_R) given in Table 4 for each of the three test methods described in this document;

c) give an indication of the differences between test results for the reference method at one specific scaling level;

d) apply only to scaling caused by the action of 3 % sodium chloride solution as the freezing medium".

Table 4 — Functional relation between scaling and repeatability and reproducibility of coefficient of variation (scaling with 3 %-sodium chloride solution)

Test method	Units for m	Repeatability coefficient of variation $v_r = a \cdot m^b$			Reproducibility coefficient of variation $v_R = a \cdot m^b$		
		a	b	R^2	a	b	R^2
Slab	kg/m²	17,00	- 0,24	0,99	31,00	- 0,23	0,95
CDF	kg/m²	15,00	- 0,12	0,91	31,00	- 0,18	0,94
Cube	% by mass	27,00	- 0,35	0,89	54,00	- 0,26	0,50

Table 5 — Precision data for appropriate scaling level

Test method	Scaling level	Coefficient of variation [%]	
		repeatability v_r	reproducibility v_R
Slab	1,0 kg/m²	17	31
CDF	1,5 kg/m²	14	29
cube	3 % by mass	18	38

Annex A
(informative)

Alternative applications

The application of these test methods for the performance assessment of concrete under different exposure severity is addressed in this annex. The applied testing conditions are sometimes considered to be extreme compared to practical temperature conditions and degree of saturation. This may cause confusion regarding setting of acceptance limits for local conditions. Also, some regions may experience series of mild winters in a row and suddenly one with extensive use of de-icers, a situation for which it is very difficult to establish a direct laboratory versus field correlation.

The test methods define a set of clearly defined exposure conditions, taking into account the need of reproducibility, and deviating from the fixed procedure may influence test results in a most non-predictable way. When deviations are made from the test methods reported in this Technical Specification (TS), it is difficult to claim the conformity to specified test method. The results may however be reported referring to the test procedure according to this TS and setting out the deviations from its requirements.

However, application of the test methods for particularly mild climates may motivate the use of reduced number of freeze–thaw cycles or of other adequately fixed acceptance criteria. Some motivated applications and modifications are listed below but shall accompany adequate concerns with respect to implications.

Alternative application may be used due to specific objectives, such as but not limited to:

1) adoption of the testing method for concrete product testing, on samples with different geometry

2) investigation of concrete qualities with differing developments of age dependant properties than those for which the testing methods were originally developed;

3) adoption of the testing method for regional application of scaling acceptance limits, and in particular;

4) such adoption with differentiation of severity of exposure conditions;

5) adoption of the basic principles of the testing method but for research on certain mechanistic phenomena;

6) assessment of existing structures, e.g. with the objective of establishing acceptance criteria based on the testing performance of samples from structures with service records and known mix design.

Such objectives leading to modifications of the testing procedure have raised some questions and concerns that shall be considered. In general, sensitivity to ageing, moisture history and carbonation on deterioration level and precision shall be carefully considered. Changes leading to change in scaling level may also influence the precision data: The latter depends on total scaling level, see Clause 8.

Potential changes and related concerns:

a) Geometry and number of samples: The testing methods included in this document are restricted to specimens with dimensions of approximately 50 mm x 150 mm x 150 mm (Slab test), 100 mm (Cube test) and 70 mm x 140 mm x 150 mm (CF/CDF test). Other specimen geometries can be used but the thickness should always be (50 ± 2) mm (Slab), (80 – 100) mm (Cube) or (70 ± 5) mm (CF/CDF) due to the sample heat capacity and conductivity. Other dimensions may change the actual temperature cycle of the testing sample. For example, the method is suitable for testing slices

from cores drilled from structures or for testing precast units (see Point g) below). Note that changing the total mass subjected to testing in a testing cabinet may also change the temperature cycle if not sufficiently controlled. The use of dummy samples (e.g. long life samples of high F-T resistance for re-use) – also with the same type and amount of freezing medium - may compensate for the latter. Total number of specimens or total surface area should also be kept as in the basic methods.

b) Top surfaces and surfaces cast against formwork can be tested instead of sawn surfaces. Their specific binder content and properties compared to that of bulk concrete should be considered, with reference to the – normally – increased damage potential of the surface skin.

c) Standard start of testing is at 31 (Slabs) or 28 (Cubes) d of age. Other curing conditions can be used and the concrete age may differ from 31 d at the start of the freeze thaw testing. Change in moisture history and level of carbonation may implicitly apply.

d) Other de-icing agents than NaCl can be used. Different mechanisms as well as different relationships between temperature level and amount of freezeable moisture content may apply.

e) The number of freeze–thaw cycles may deviate from 56. In some cases, e.g. for testing paving blocks, 28 cycles instead of 56 cycles may be used. The numbers of cycles should always be at least 14.

f) The temperature cycle: Changing the temperature cycle may strongly influence precision data due to the nonlinear relationships between temperature level and amount of freezeable water. For mild climate conditions, it may be overlooked that the application of de-icers on a frozen surface may lead to substantially more severe temperature drops in the concrete surface than without (temperature shock) or in the surrounding air. In order to simulate a defined and reproducible temperature drop in the laboratory, a temperature change as already defined is required. The same is valid for simulating the accumulative moisture pumping effect. Change of temperature cycle should never be applied without extensive documentation and considering consequences of impairment of precision.

g) Extraction of samples from larger blocks, *in situ* structures or concrete products:

   1) For the slab test, the specimens are sawn to the correct thickness 10 d before the start of the freeze–thaw test. During these 10 d the specimens are stored in the climate chamber for 7 d and then re-saturated for 3 d as in the reference method, unless other curing conditions are of special interest. A 3 mm thick layer of the freezing medium is poured on to the test surface before the start of the freeze–thaw test. The test then continues according to the method.

   2) For the cube test, the specimens are stored in the climate chamber for 20 d and then re-saturated for one day in the freezing medium. The test then continues according to the method.

   3) For the CF/CDF test, the specimens are stored for surface drying in the climate chamber for 21 d and then re-saturated for 7 d in the freezing medium. The test then continues according to the method.

h) If samples are extracted from *in situ* structures with the objective of comparing the test results to those of freshly made test specimens for the setting of acceptance limits, it shall be taken into consideration that the *in situ* concrete has undergone structural changes leading to alterations in the pore structure, and thus does no longer exhibit the performance characteristics of that of a corresponding freshly made mix of similar composition. The reasons for such alterations comprise, but are not limited to differences in degree of hydration, carbonation, precipitation of substances, leaching and deterioration - parameters that strongly influence moisture transport and degree of saturation.

i) Special features with the CF/CDF test:

1) It is permissible to insert two PTFE plates (7.2.2) at two opposed vertical sides. In this case, the specimens are cut through the centre between the two test surfaces after storage under water. For larger aggregate size the PTFE plate can be placed only at one side of the mould.

2) If the strength development of the specimens is low the curing time in the mould can be increased. The storage time in tap water is then decreased by the same amount.

All deviations from the reference method shall be noted in the test report.

Annex B
(informative)

Guideline for selection of brush

B.1 General

B.1.1 The brush type, in particular hardness and stiffness of hairs is recognized as an important factor affecting the scattering of data coming from different laboratories.

B.1.2 Standardized criteria for quantitative specifications regarding stiffness and hardness of brush hairs do not exist (EN, or any National Documents). These properties and characteristics are indirectly defined through the specifications of the nature of the material, length and diameter of hairs, the density of hairs by holes and number of holes per brush.

A brush fulfilling the following specification can be considered as semi-soft, as required in 5.2.13. This can be used as a guidance.

B.2 Construction data and characteristics of the brush

B.2.1 Nature of the materials of hair, shore hardness, tip form

Synthetic fibres (Polyamide) with a shore hardness of 75 – 80 D and with rounded tip.

PA 6.12 ø 0,15 mm.

NOTE PA 6.12 is the technical- commercial reference of the requested synthetic fibre. PA means Poly Amide. 6.12 correspond to the number of different chemical groups to make the polymer.

B.2.2 Body dimensions

Polypropylene-body 62 mm × 50 mm × 20 mm

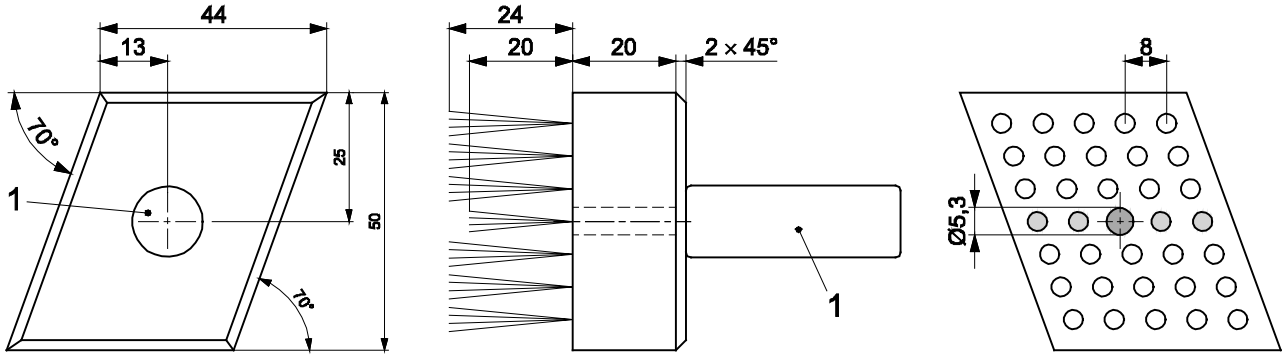
B.2.3 Number of holes per brush, number of hairs per hole

34 holes, 380 ± 6 hairs per hole

30 bundles with H1 = 24 mm

4 bundles with H2 = 20 mm (middle row) as wear indicator

Dimensions in mm



Key

1 angles in degrees

Figure B.1 — Brush characteristics

B.2.4 Shape

The specific shape, which is not mandatory, has been designed in order for the brush to be as efficient as possible in the corners of the specimen.

B.2.5 Wear indicator (recommended, not mandatory)

In order to ensure constant mechanical properties and homogeneous behaviour, the middle row is composed with 4 bundles of hairs shorter than the other bundles. When the length of the longest hairs has reached the length of those of the middle row, the brush shall be changed.

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