PUBLISHED DOCUMENT

PD CEN/TR 15177:2006

Testing the freeze-thaw resistance of concrete — Internal structural damage

ICS 91.080.40

British Standards

National foreword

This Published Document was published by BSI. It is the UK implementation of CEN/TR 15177:2006.

The UK participation in its preparation was entrusted by Technical Committee B/517, Concrete, to Subcommittee B/517/1, Concrete production and testing.

A list of organizations represented on B/517/1 can be obtained on request to its secretary.

This publication is a Published Document (PD) and is not to be regarded as a British Standard and therefore should be used for guidance only.

The original document was proposed as a European standard but at the draft for public comment (DPC) stage the project status was changed to a CEN Report as it was not deemed suitable to be published as a European standard. The CEN Report was published so that research laboratories could evolve the test methods and gain some experience of the relevance of such tests to local materials. Therefore, the UK Committee B/517/1 has implemented CEN Report 15177:2006 as PD CEN/TR 15177:2006 but with the following comments.

Whilst there are no performance values given in CEN/TR 15177, the originators of the tests have values they apply in practice and these are known to others. It is accepted that a concrete satisfying these values is likely to perform well in extreme freeze/thaw conditions. However, in the UK there are many concretes that have been shown to perform adequately in the prevailing environmental conditions, but, if tested against these criteria, would fail by a substantial margin. BSI Technical Committee Working Group B/517/1/30 considers that these test methods would not normally be appropriate for evaluating the performance of concrete for UK conditions.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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TECHNICAL REPORT

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English Version

Testing the freeze-thaw resistance of concrete - Internal structural damage

Prüfung des Frost-Tauwiderstandes von Beton - Innere Gefügestörung

This Technical Report was approved by CEN on 31 August 2005. It has been drawn up by the Technical Committee CEN/TC 51.

CEN members are the national standards bodies of Austria, Belgium, 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 United Kingdom.

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Foreword

This document (CEN/TR 15177:2006) has been prepared jointly by Technical Committee CEN/TC 51 "Cement and building limes", the secretariat of which is held by IBN/BIN and by Technical Committee CEN/TC 104 "Concrete and related products", the secretariat of which is held by DIN.

No existing European Standard is superseded.

It is based on the Austrian Standard ÖNORM B 3303 "Testing of Concrete" and on the RILEM recommendation "Test methods of frost resistance of concrete" of RILEM TC 176 IDC. These tests have since been developed by individual countries. This document takes into account those developments.

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 elements or concrete in situ.

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 there are two types of concrete deterioration when a freeze-thaw attack occurs, internal structural damage and scaling. The three test methods in this document describe the testing for internal structural damage. The scaling is dealt with in prCEN/TS 12390-9.

This document contains three different test methods, which are well proved in different parts of Europe. Always they produce consistent results. For that reason no single test method can be established as reference test method. In the case that two laboratories will test the same concrete, they have to agree to only one test method with the same measurement procedure.

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 and still have to be done.

1 Scope

This document specifies three test methods for the estimation of the freeze-thaw resistance of concrete with regard to internal structural damage. 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 concrete i.e. new constituents or new concrete compositions requires an expert evaluation.

NOTE Specification based on these test methods should take into account the behaviour of concrete under practical conditions.

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.

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 206-1, *Concrete – Part 1: Specification, performance, production and conformity*

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

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

EN 12504-4, *Testing concrete – Determination of ultrasonic pulse velocity*

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 surface of concrete due to freeze-thaw attack

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

4 Equipment

4.1 General

4.1.1 Equipment for making concrete specimens according to EN 12390-2.

4.1.2 Moulds for making concrete specimens according to EN 12390-1.

4.1.3 Freezing medium, consisting of de-ionised water and in special cases of 97 % by mass of tap water and 3 % by mass of NaCl (for test with de-icing salt).

4.1.4 A freezing chamber or a freeze-thaw chest with a cooling liquid or a flooding device. The freezing chamber or the freeze-thaw chest are equipped with a temperature and time controlled refrigerating and heating system with a capacity such that the time-temperature curve prescribed in Clauses 7, 8 and 9 can be followed. An automatically controllable frost chest and a water tank with thermostatic control can also be used instead of an automatically controlled freeze-thaw chest with a flooding device.

4.1.5 Thermocouples, or an equivalent temperature measuring device, for measuring the temperature at the appropriate prescribed points in the freezing chest with an accuracy within ± 0,5 K.

4.1.6 2 balances, with an accuracy within ± 1 g and ± 0,05 g.

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

4.1.8 Absorbent laboratory towel.

4.2 Special equipment for beam test

4.2.1 Thermometric frost resistance reference beam according to EN 206-1 with a dimension of 400 mm x 100 mm x 100 mm. A tolerance in length of ≤ 10 % will be permissible. A thermocouple (4.1.5) is installed near the geometric centre of the thermometric reference beam in order to measure the temperature variations during freeze-thaw cycles.

4.2.2 Equipment for ultrasonic pulse transit time (UPTT)

Ultrasonic pulse transit time (UPTT) measurement device which is suitable for determining the transit times of longitudinal waves in porous building materials according to EN 12504-4. The transducers operate in frequency range between 50 kHz and 150 kHz.

4.2.3 Equipment for fundamental transverse frequency (FF)

a) Equipment for measurement the resonance frequency: a Fourier analyser, a modally tuned impact hammer and an accelerometer.

b) Specimens pad consists of a soft and absorbing material (e.g. foam or sponge rubber) to store the specimens planar. The specimens pad uncoupled the specimen of its surroundings, so that the waves run only by the specimen.

4.3 Special equipment for slab test

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

4.3.2 Diamond saw for concrete cutting.

4.3.3 Rubber sheet, (3 ± 0,5) mm thick which is resistant to the freezing medium used and sufficiently elastic down to a temperature of – 27 °C.

4.3.4 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.

4.3.5 Expanded Polystyrene cellular plastic, (20 ± 1) mm thick with a density of (18 ± 2) kg/m^3 or alternative thermal insulation with at least a heat conductivity of 0,036 W/(m·K).

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

4.3.7 Equipment for length change (reference measuring procedure)

a) Length extensometer for measuring length change of specimens with a dial gauge to read in 0,01 mm and an accuracy within ± 0,001 mm. The extensometer is designed to accommodate the size of the specimens.

NOTE In consideration of specimens geometry the dimension of a suitable length extensometer is 170 mm or more.

b) Studs made of stainless steel or other corrosion-resistant materials being designed which secured a good contact with the specimen surface.

c) Invar or an equivalent reverence bar with a length which is comparable to the average specimen length.

4.3.8 Equipment for ultrasonic pulse transit time (alternative measuring procedure)

Ultrasonic pulse transit time (UPTT) measurement device which is suitable for determining the transit times of longitudinal waves in porous building materials according to EN 12504-4. The transducers operate in frequency range between 50 kHz and 150 kHz.

4.3.9 Equipment for fundamental transverse frequency (alternative measuring procedure)

a) Equipment for measurement the resonance frequency: a Fourier analyser, a modally tuned impact hammer and an accelerometer.

b) Specimens pad consists of a soft and absorbing material (e.g. foam or sponge rubber) to store the specimens planar. The specimens pad uncoupled the specimen of its surroundings, so that the waves run only by the specimen.

4.4 Special equipment for CIF-test

4.4.1 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 has to be less than 5 mm.

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

4.4.3 Lateral sealing 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.

4.4.4 Test containers. 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.

Other containers can be used for capillary suction if they assure an equivalent arrangement. 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.

4.4.5 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 bottom.

4.4.6 Unit for adjusting liquid level, i.e. a 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.

4.4.7 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.

4.4.8 Equipment for ultrasonic pulse transit time (reference measuring procedure)

a) Ultrasonic pulse transit time (UPTT) measurement device which is suitable for determining the transit times of longitudinal waves in porous building materials according to EN 12504-4. The transducers operate in frequency range between 50 kHz and 150 kHz.

b) A rectangular measuring container (e.g. PMMA) is used for UPTT measurement. The transducers are mounted in recesses in two opposite faces of the container so that the transit axes lies parallel to and at a distance of (35 ± 1) mm from the test surface. The size of the container is so large that the total thickness of the coupling medium (l_{c1} + l_{c2} see Figure 13) is approximately 10 mm.

c) A stainless steel plate for collecting scaled particles of the specimens during the measurement of the UPTT. The size of the steel plate is sufficient large and the edges are bent up approximately 5 mm to ensure that all scaled particles can be collected.

4.4.9 Equipment for fundamental transverse frequency (alternative measuring procedure)

a) Equipment for measurement the resonance frequency: a Fourier analyser, a modally tuned impact hammer and an accelerometer.

b) Specimens pad consists of a soft and absorbing material (e.g. foam or sponge rubber) to store the specimens planar. The specimens pad uncoupled the specimen of its surroundings, so that the waves run only by the specimen.

4.4.10 Equipment for length change (alternative measuring procedure)

a) Length extensometer for measuring length change of specimens with a dial gauge to read in 0,01 mm and an accuracy within ± 0,001 mm. The extensometer is designed to accommodate the size of the specimens.

b) Studs made of stainless steel or other corrosion-resistant materials being designed which secured a good contact with the specimen surface.

c) Invar or an equivalent reverence bar with a length which is comparable to the average specimen length.

5 Making of test specimens

Except where details are specified in Clauses 7, 8 and 9 the test specimens, cubes or beams, have to be prepared in accordance with EN 12390-2.

The inner surfaces of the moulds are lightly greased with mould oil and wiped with an absorbent towel (4.1.8) immediately before filling so that the test results are not affected by a thick layer of mould oil.

Concrete that requires vibrating for compaction is compacted on a vibrating table.

The prestorage conditions concerning temperature and moisture are documented.

The maximum aggregate size Dmax is restricted to one third of the mould length.

6 Principle of measurement the internal structural damage

6.1 Relative dynamic modulus of elasticity

Generally the dynamic modulus of elasticity is defined according to Equation 1.

Equation 1: $E_{dyn} = (X)^2 \times l^2 \times \rho \times C$

where

E_{dyn} is the dynamic modulus of elasticity in kN/mm²;

X is the measured value;
- fundamental transverse frequency: natural frequency in Hz;
- ultrasonic pulse transit time: reciprocal of the ultra sonic pulse transit time in µs;

l is the length of the specimen in mm;

ρ is the density in kg/m³;

C is a correction factor contains the Poisson's ratio µ.

The value of the internal structural damage is calculated as relative dynamic modulus of elasticity (RDM). For this reason the specimens length l, the density ρ and the correction factor C can be neglected so that the RDM_{UPTT} is calculated according to Equation 2.

Equation 2: $RDM_n = \left(\frac{X_n}{X_0}\right)^2 \times 100\ [\%]$

where

RDM is the relative dynamic modulus of elasticity in %;

index n characterise the measure after a number of freeze-thaw cycles;

index 0 characterise the initial measure.

6.2 Length change

The internal structural damage due to repeated freeze-thaw cycles can be proofed by measuring the length change. The relative length change is the change in length after n freeze-thaw cycles based on the initial length according to Equation 3.

Equation 3: $\varepsilon_n = \frac{\Delta l}{l_0} \times 100\ [\%]$

where

ε_n is the dilation of the specimen after n freeze-thaw cycles in %;

Δl is the change in length after n freeze-thaw cycles in mm;

l_0 is the initial length in mm.

7 Beam test

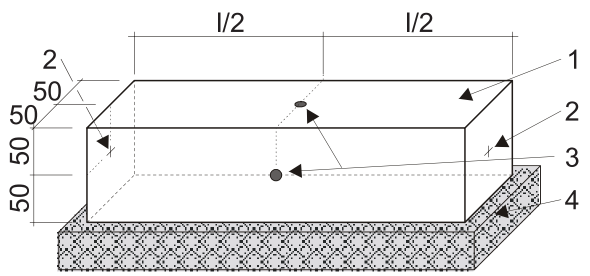
7.1 Principle

Beams with a dimension of 400 mm x 100 mm x 100 mm and a tolerance in length of ≤ 10 % are subjected to freeze-thaw attack in presence of de-ionised water. The freeze-thaw resistance is measured either as relative dynamic modulus of elasticity by using ultrasonic pulse transit time or as fundamental transverse frequency respectively after 56 freeze-thaw cycles.

7.2 Preparation of test specimens

The test requires at least three beams.

During the first day after casting the specimens are stored in the moulds at a temperature of (20 ± 2) °C and a relative humidity of (95 ± 5) %. The specimens are removed from the moulds after (24 ± 2) h. Directly after demoulding, the specimens are weighed. The mass is rounded to the nearest 1 g. Following they are wrapped in plastic film (without any additional water) so that they are substantially moisture-tight and stored for six days in atmospheric air at (20 ± 2) °C. When the specimens are 7 d old, they are removed from the plastic film and weighed. The mass is rounded to the nearest 1 g. Without delay the specimens are placed in a water bath having a temperature of (20 ± 2) °C. They are stored for 21 d under water until the selected freeze-thaw test starts.



Key

1 specimen

2 spots for measuring UPTT

3 spots for measuring FF

4 specimens pad (4.2.3 b)

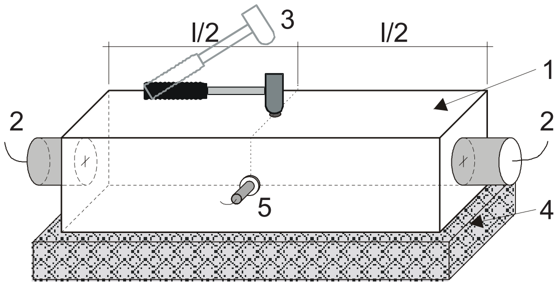
Figure 1 - Location of the spots for measuring the ultrasonic pulse transit time

Analogues to the chosen measurement procedure the spots which are used to determine the ultrasonic pulse transit time or the fundamental transverse frequency are marked on the specimen surface in the middle of the fronts as shown in Figure 1. The spots are used for each measuring occasion.

7.3 Measurement procedure

7.3.1 Fundamental transverse frequency (FF)

The equipment is calibrated according to the instruction manual.



Key

1 specimen

2 ultrasonic pulse transducer

3 modally tuned impact hammer

4 specimens pad (4.2.3 b)

5 accelerometer

Figure 2 - Measurement set-up for determination the internal structural damage

The specimen is placed on a thick pad (4.2.3 b). The accelerometer is hold by hand or by another suitable means, such as a rubber band, in good contact to the concrete test surface. The specimen is taped with a suitable tool (preferably a instrumented hammer) and the fundamental transverse frequency is recorded by the nearest 10 Hz. The tapping is repeated at least three times to obtain an average value with a standard deviation less than 100 Hz.

The relative dynamic modulus of elasticity RDM_{FF} after n freeze-thaw cycles is calculated in percentage according to Equation 4.

Equation 4: $$RDM_{FF,n} = \left(\frac{f_n}{f_0}\right)^2 \times 100 \ [\%]$$

where

RDM_{FF} is the relative dynamic modulus of elasticity in % determined by using FF;

f_n is the fundamental frequency measured after n freeze-thaw cycles in Hz;

f_0 is the initial fundamental frequency in Hz;

7.3.2 Ultrasonic pulse transit time (UPTT).

The ultrasonic equipment is calibrated according to the instruction manual.

A little amount of sonic grease is applied to the contact surface of the transducers and the marked points of the specimens. In each case the transducers are arranged on the two opposite marked points of the specimens as shown in Figure 2.

The transducers are pressed against the concrete surfaces so that a constant minimum value is reached. The transmission time is read with an accuracy of 0,1 µs. It is required that the transducers are squeezed to the concrete surface with the same pressure for each measuring occasion.

The relative dynamic modulus of elasticity RDM_{UPPT} is calculated in percentage according to Equation 5.

Equation 5: $$RDM_{UPTT,n} = \left(\frac{t_{S,0}}{t_{S,n}} \right)^2 \times 100 \ [\%]$$

where

RDM_{UPTT} is the relative dynamic modulus of elasticity after n freeze-thaw cycles in %;

$t_{S,0}$ is the initial ultrasonic pulse transit time through the specimen in µs;

$t_{S,n}$ is the ultrasonic pulse transit time through the specimen after n freeze-thaw cycles in µs.

7.4 Test procedure

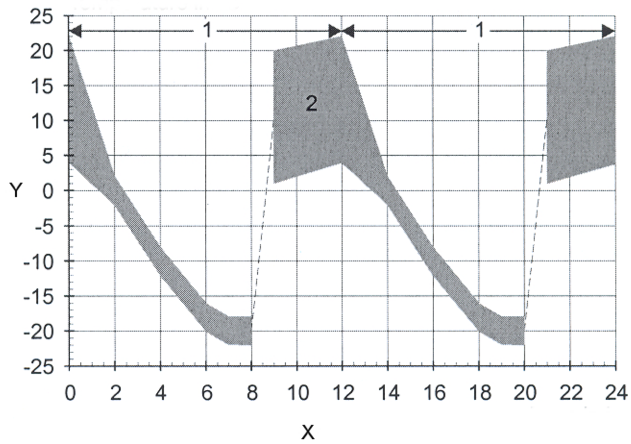
The freeze-thaw test starts after 28 d. The specimens are removed from the water bath and their surfaces are dried with an absorbent towel (4.1.8). The weight of each specimen is measured and rounded to the nearest 1 g.

The initial value for the measurement of the internal structural damage is determined for each specimen according to 7.3. Immediately after this measurement the specimens are placed vertically in the freeze-thaw chest. The freeze-thaw cycles begin 2 h at the latest after the concrete prisms are removed from water storage.

The temperature of the freeze-thaw chest is controlled so that the temperature in the centre of the concrete prism corresponds substantially to the temperature range in Figure 3. The temperature shall not deviate from the shaded area in the diagram by more than 1 K for any specimen whereas the temperature difference between 2 beams shall be ≤ 1 K. The temperature pattern of each cycle differs from that of the first cycle by less than ± 1 K. The air temperature in the freeze-thaw chest shall not fall below – 25 °C. The break points of the shaded area in Figure 3 are listed in Table 1.

Once a week the prisms are turned through 180° so that the former top surface of the prism is placed on the floor of the chest. The prisms shall also be placed in different positions in the chest in accordance with some appropriate cyclic positioning plan. The distances of the concrete prisms from one another and from the wall are at least 60 mm.

NOTE The number of specimens in the freezing chamber or frost chest is always the same. If only few specimens are to be tested, the empty places in the freezer are filled with blanks, unless it has been shown that the correct temperature cycle is achieved without this precaution.



Key

1 freeze-thaw cycle

2 temperature range in the reference prism (7.2.1)

Y temperature in ºC

X time in h

Figure 3 - Time-temperature curve in the centre of the concrete prism

Immediately after the 8 h freezing phase the freeze-thaw chest is flooded with water at (13 ± 8) °C within a maximum time span of 15 min, or else the concrete prisms are placed in a water bath at (13 ± 8) °C in which the surface of the water covers the concrete prisms by at least 15 mm. The thawing phase lasts a total of 4 h. The water is kept in motion for the entire time and is heated or cooled so that for the entire thawing period the water temperature is (13 ± 8) °C in all parts of the freeze-thaw chest or the water tank. 15 min before the end of the 4 h thawing phase the water is pumped out of the freeze-thaw plant in a maximum time of 15 min. If a water bath is used the specimens are taken out of the water bath.

Table 1 - Points specifying the shaded area in Figure 3

time in h	Temperature in °C	
	upper limit	lower limit
0	+ 22	+ 4
2	+ 2	- 2
4	- 8	- 12
6	- 16	- 20
7	- 18	- 22
8	- 18	- 22
9	+ 20	+ 1
12	+ 22	+ 4

The temperature in the centre of the reference prism, and the air and water temperatures, are measured and recorded during a freeze-thaw cycle before the first use of the freeze-thaw chest or the frost chest and water tank, and after about every 56 freeze-thaw cycles.

If, in exceptional cases, it is necessary to interrupt the freeze-thaw cycles during the night and/or at weekends (e.g. with non-automatic test equipment) the specimens are stored under freezing conditions at (- 20 ± 2) °C during this period.

After (7 ± 1), (14 ± 1), (28 ± 1), (42 ± 1) and 56 cycles, the following procedure is carried out for each specimen (1 ± 1) h before the start of the next freeze-thaw cycle.

a) The prisms are removed from the water bath and the surfaces dried with an absorbent towel (4.1.8). During the period when the samples are out of the water bath and are not being tested they are covered with moist towels. The weight of the specimens is determined with an accuracy of 1 g.
b) Depending on which measurement procedure has been used for determining the initial values for the internal structural damage the ultrasonic pulse transit time or the fundamental transverse frequency of the specimens is measured according to 7.3.

The specimens are returned vertically to the freeze-thaw plant.

7.5 Expression of results

Depending on which measurement procedure has been used the value of the internal structural damage is calculated as relative dynamic modulus of elasticity RDM after n freeze-thaw cycles in percentage for each measurement and each specimen. The RDM is rounded to the nearest 1 %.

The mean value, the individual values for each specimen as well as the standard deviation after 56 cycles are used for evaluating the freeze-thaw resistance.

NOTE The water uptake is a good additional information to evaluate the internal structural damage. The water uptake is calculated as change in mass Δm_n after n freeze-thaw cycles in percentage according to Equation 6. The water uptake is rounded to the nearest 0,1 wt.-%.

Equation 6: $$\Delta m_n = \frac{m_n - m_{28d}}{m_{28d}} \times 100 \ [\%]$$

where

Δm_n is the water uptake of the specimen after n freeze-thaw cycles in %;

m_n is the mass of the specimen after n freeze-thaw cycles in g;

m_{28d} is the mass of the specimen at 28 d in g (after storage under water).

7.6 Test report

The test report shall contain at least the following information:

a) reference to this document;
b) origin and marking of the specimens;
c) concrete identification;
d) mean value and the individual values of the change in mass after (7 ± 1), (14 ± 1), (28 ± 1), (42 ± 1) and 56 freeze-thaw cycles;
e) relative values of the freeze-thaw resistance determined by using one of the two measuring procedures for each specimen as well as the mean value in percentage rounded to the nearest 1 %, after (7 ± 1), (14 ± 1), (28 ± 1), (42 ± 1) and 56 freeze-thaw cycles;
f) visual assessment (cracks, scaling from aggregate particles) before the start and after (7 ± 1), (14 ± 1), (28 ± 1), (42 ± 1) and 56 cycles;

g) any deviations from these test method;

h) optional: Composition of the concrete.

7.7 Alternative application

The method applies to prisms with a cross-section of 100 mm × 100 mm and a length of (400 ± 40) mm. The test starts after 28 d with the preliminary storage as specified in 7.2. The same test principle can, however, also be used for other conditions. It is normally the method of making and curing specimens that differs from these test method. Examples of alternative applications are:

a) Other sample dimensions can be used provided that d = (100±20) mm and h:d ≥ 2,0 for the test specimens. For example, the method is suitable for testing slices from cores drilled from structures or for testing precast units.

b) Other curing conditions can be used and the concrete age may differ from 28 days at the start of the freeze-thaw testing.

c) The number of freeze-thaw cycles may exceed 56.

When alternative applications are used, the specimens are stored 21 d under water having a temperature of (20 ± 2) °C before the start of the freeze-thaw test, unless other curing conditions are of special interest. The test then continues according to these test methods.

All deviations from this test method are noted in the test report.

8 Slab test

8.1 Principle

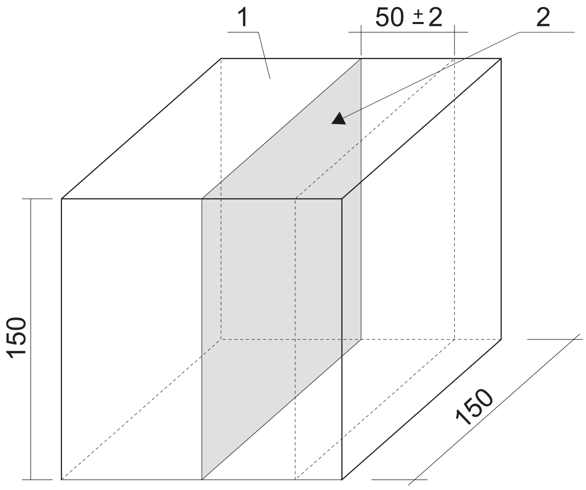
Slab specimens, sawn from concrete test specimens (Figure 1), are subjected to freeze-thaw attack in presence of a 3 mm deep layer of de-ionised water or 3 % sodium chloride (NaCl) solution. The freeze-thaw resistance is measured either as relative length change or as relative dynamic modulus of elasticity by using ultrasonic pulse transit time or fundamental transverse frequency after 56 freeze-thaw cycles.

8.2 Preparation of test specimens

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

During the first day after casting the specimens are stored in the moulds at a temperature of (20 ± 2) °C and a relative humidity of (95 ± 5) %. The specimens are removed from the moulds after (24 ± 2) h. Directly after demoulding, the specimens are placed in a bath with tap water having a temperature of (20 ± 2) °C. When the specimens are 7 d old, they are removed from the water bath and placed in the climate chamber (4.3.1), where they are stored until the selected freeze-thaw test starts.

Dimensions in millimetres



Key

1 top surface of casting

2 test surface

Figure 4 - Location of test specimen in sawn cube

At 21 d a (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 4. The range in mean thickness of a specimen shall not exceed 2 mm. 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 (6.2.17). Without delay, return it to the climate chamber ensuring that the test surface is vertically with a space between the specimens of at least 50 mm.

Dimensions in millimetres

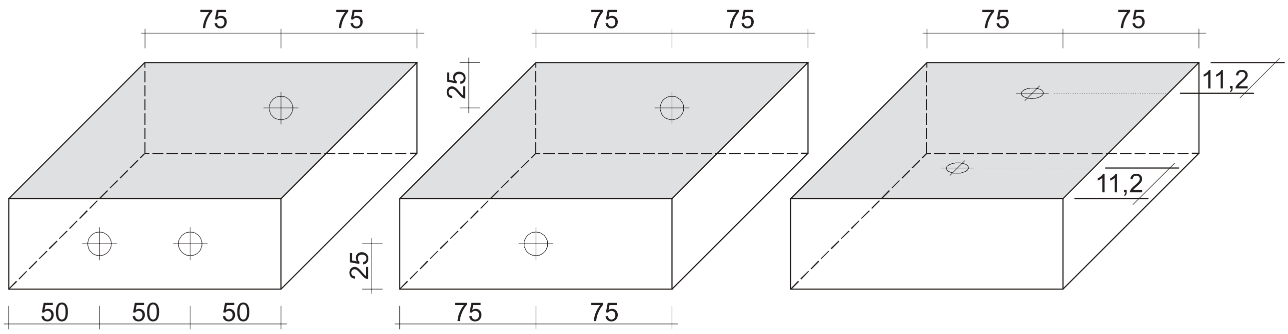
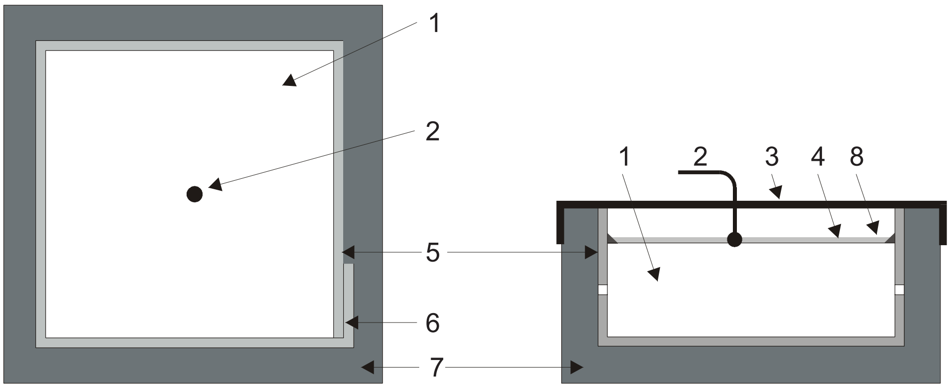


Figure 5 - Location of the spots for measuring a) length change; b) ultrasonic pulse transit time; c) fundamental transverse frequency

Analogues to the chosen measurement procedure the spots which are used to determine the internal structural damage are marked on the specimen surface when the concrete is (25 ± 1) d old (Figure 5). The spots are used for each measuring occasion.

Following rubber sheet is glued to all surfaces of the specimen except the test surface. A string of glue or silicone rubber is placed around the test surface in the join between the concrete and the rubber. The surface area remaining after the application of the glue string shall be not less than 90 % of the original surface area of the specimen. The edge of the rubber sheet reaches (20 ± 1) mm above the test surface.

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 6 has been proved suitable.



Key

1 specimen

2 temperature measuring device

3 polyethylene sheet

4 freezing medium

5 rubber sheet

6 overlap

7 thermal insulation

8 glue string

Figure 6 - The test set-up used for the freeze-thaw test

NOTE 2 The spots for measuring the length change and ultrasonic pulse transit time respectively are marked on the two most parallel side surfaces. They should not show voids or defects and are protected with paper labels having a diameter of (13 ± 1) mm. After gluing the rubber sheet on the surfaces it is punched above the selected and protected points with ∅ (13 ± 1) mm holes. The paper labels are removed. Immediately after punching the holes the specimens are returned to the climate chamber (4.3.1) with the test surface vertically.]

Before starting the test, all surfaces of the specimens except the test surfaces are thermally insulated with (20 ± 1) mm thick polystyrene cellular plastic (4.3.5) according to the test set-up in Figure 6. Another material or thickness providing equivalent thermal insulation can be used instead.

8.3 Measurement procedure

8.3.1 Length change (reference measurement procedure)

The extensometer is calibrated with the invar (4.3.7. c)) according to the instruction manual. The measurement is carried out at (20 ± 2) °C.

Each specimen is placed on to the extensometer with the test surface outwards faced (see Figure 7). The 2 marked points on one side of the specimen are aligned to the two studs on the extensometer.

NOTE A good contact between stud and concrete surface is to be guaranteed. Sticking a poly-label on to the rubber sheet can facilitate the alignment.

The specimen is hold together with the extensometer vertically. The measurement nib of the extensometer is taken onto the marked point of the opposite concrete surface. The length of the specimen is read on the micrometer to the nearest 0,01 mm.

The relative length change is calculated in percentage for each measurement occasion according to Equation 7.

Equation 7: $\varepsilon_{L,n} = \frac{l_n - l_0}{L_0} \times 100 \ [\%]$

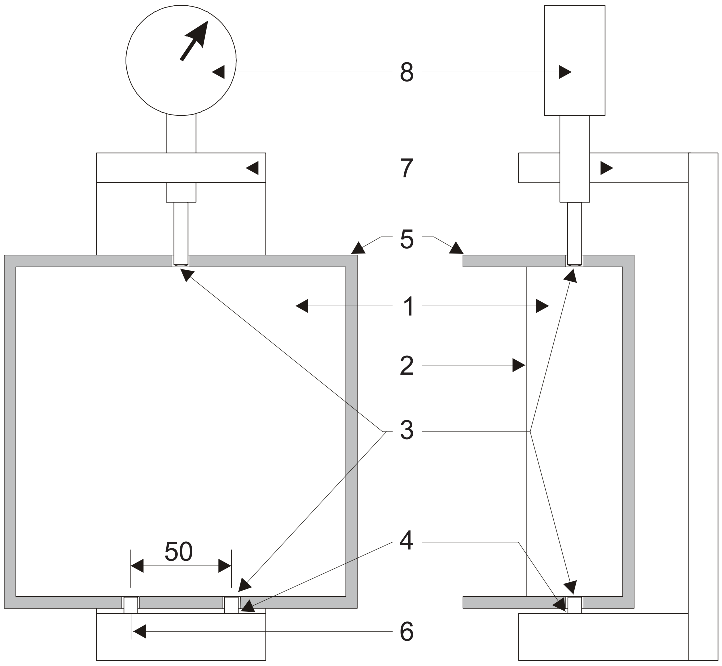
where

$\varepsilon_{L,n}$ is the dilation of the specimen after n freeze-thaw cycles in %;

l_n is the length reading after n freeze-thaw cycles in mm;

l_0 is the initial length reading in mm;

L_0 is the initial length of the specimen $L_0 = 150 + l_0$ in mm.



Key

1 specimen

2 test surface

3 marked spots

4 Flad stuts

5 rubber sheet

6 alignment mark

7 steel frame

8 micrometer gauge

Figure 7 - Specimen on the three points extensometer

8.3.2 Fundamental transverse frequency FF (alternative measurement procedure)

The equipment is calibrated according to the instruction manual.

The specimen is placed on a thick pad (4.3.9 b)). The accelerometer is hold by hand or by another suitable means, such as a rubber band, in good contact to the concrete test surface. The specimen is taped with a suitable tool (preferably a instrumented hammer) and the fundamental transverse frequency is recorded by the nearest 10 Hz. The tapping is repeated at least three times to obtain an average value with a standard deviation less than 100 Hz.

The relative dynamic modulus of elasticity RDM_{FF} is calculated in percentage according to Equation 8.

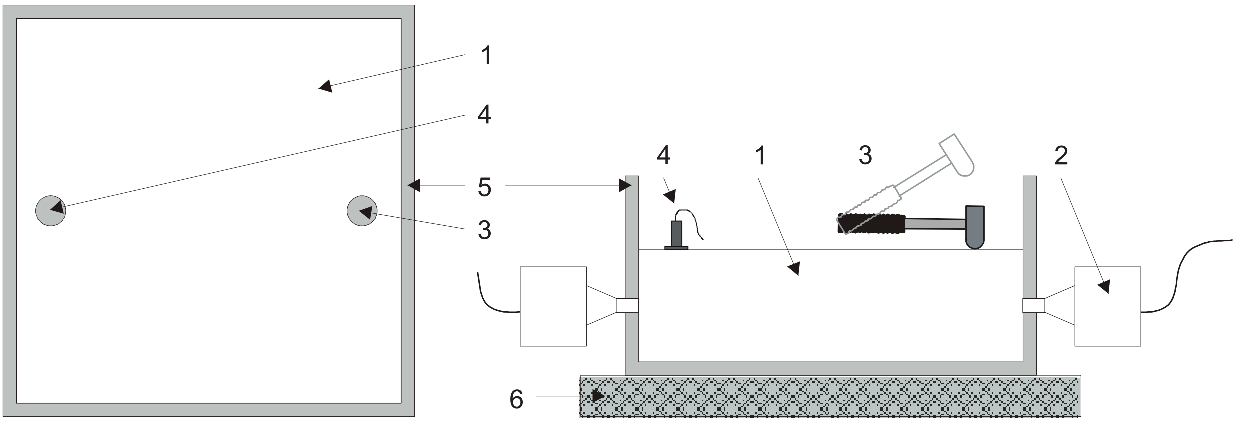
Equation 8: $$RDM_{FF} = \left(\frac{f_n}{f_0}\right)^2 \times 100\ [\%]$$

where

RDM_{FF} is the relative dynamic modulus of elasticity in % determined by using FF;

f_n is the fundamental frequency measured after n freeze-thaw cycles in Hz;

f_0 is the initial fundamental frequency in Hz.



Key

1 specimen

2 UPTT transducer

3 modally tuned impact hammer

4 accelerometer

5 rubber sheet

6 specimens pad (4.3.9 b))

Figure 8 - Test set-up for measuring the fundamental transverse frequency or ultrasonic pulse transit time

8.3.3 Ultrasonic pulse transit time UPTT (alternative measurement procedure)

The ultrasonic equipment is calibrated according to the instruction manual.

A little amount of sonic grease is applied to the contact surface of the transducers and the marked spots of the specimens. In each case the transducers are arranged on the two opposite marked spots of the specimens as shown in Figure 8.

The transducers are pressed against the concrete surfaces so that a constant minimum value is reached. The transmission time is read to the nearest 0,2 µs. It is required that the transducers are squeezed to the concrete surface with the same pressure for each measuring occasion.

The relative dynamic modulus of elasticity RDM_{UPTT} is calculated in percentage according to Equation 9.

Equation 9: $$RDM_{UPTT} = \left(\frac{t_0}{t_n}\right)^2 \times 100 \; [\%]$$

where

RDM_{UPTT} is the relative dynamic modulus of elasticity in % determined by using UPTT;

t_0 is the initial transit time in µs;

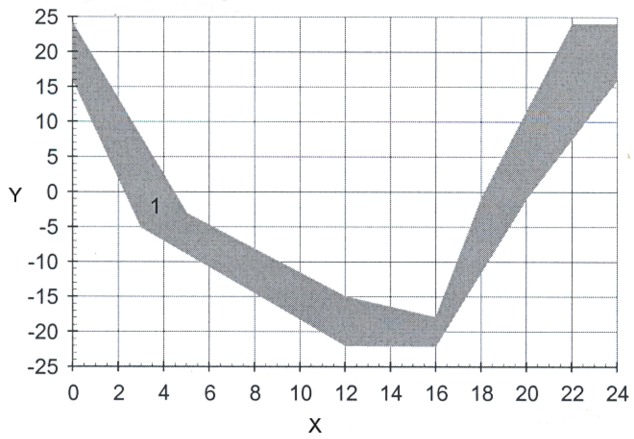
t_n is the transit time measured after n freeze-thaw cycles in µs.

8.4 Test procedure

The freeze-thaw test starts after 28 d with the re-saturation of the specimens. A 3 mm deep layer of de-ionised water is poured onto the test surface of each specimen at a temperature of (20 ± 2) °C. This re-saturation is continued for (72 ± 2) h at (20 ± 2) °C during which time the layer is to be maintained at about 3 mm.

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

Not earlier than 15 min before the specimens are placed in the freezing chamber, the de-ionised water on the test surfaces is removed and the initial value for the measurement of the internal structural damage is determined for each specimen according to 8.3. Immediately after the measurement, 67 ml of the freezing medium (4.1.3) at (20 ± 2) °C is poured onto the test surface so that an average 3 mm thick liquid layer is achieved. The freezing medium is prevented from evaporating by applying a flat, horizontal polyethylene sheet (4.3.6) as shown in Figure 6. It comes never in contact with the freezing medium (4.1.3).



Key

1 temperature range at the centre of the test surface, whereby the time of temperature > 0°C is 7 to 9 h

Y temperature in ºC

X time in h

Figure 9 - Time-temperature curve in the freezing medium at the centre of the test surface

The specimens are placed in the freezing chamber and the freeze-thaw cycles are started. During the test, the temperature of the freezing chamber is controlled so that the temperature in the freezing medium at the centre of the test surface corresponds to the shaded area in Figure 9. The points specifying the shaded area in Figure 9 are given in Table 2.

Table 2 - Points specifying the shaded area in Figure 9

Upper limit		Lower limit	
time [h]	temperature [°C]	time [h]	temperature [°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

The temperature cycle is monitored continuously for at least one specimen. 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. To obtain the correct temperature cycle for all the specimens there has to be a good air circulation in the freezing chamber.

NOTE 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 blanks, 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, the following procedure is carried out for each specimen during the thawed phase of the solution between 20 h to 24 h according to Figure 9:

a) The excess freezing medium is poured and the scaled material is washed away[1], if there is any, from the test surface with tap water using a spray bottle.

b) Depending on which measurement procedure has been used for determining the initial values for the internal structural damage the length change, the fundamental transverse frequency or the ultrasonic pulse transit time of the specimens is measured according to 8.3.

c) Apply fresh freezing medium onto the test surfaces. 67 ml are required for each specimen.

d) The specimens are returned to the freezing chamber at the point of cycle phase time (0 ± 30) min.

8.5 Expression of results

Depending on which measurement procedure has been used the value of the internal structural damage is calculated after n freeze-thaw cycles in percentage for each measurement and each specimen according to 8.3. The relative length change is rounded to the nearest 0,01 % and the RDM to the nearest 1 % respectively.

The mean value, the individual values for each specimen as well as the standard deviation after 56 cycles are used for evaluating the freeze-thaw resistance.

[1] If the scaling resistance is simultaneously tested the scaled material is collected according to prCEN/TS 12390-9, Clause 5.

8.6 Test report

The test report shall contain at least the following information:

a) reference to this document;

b) origin and marking of the specimens;

c) concrete identification;

d) composition of the freezing medium (4.1.3);

e) value of the internal structural damage for each specimen as well as the mean value in percentage rounded to the nearest 1 %, after (7 ± 1), (14 ±1), (28 ± 1), (42 ± 1) and 56 freeze-thaw cycles;

f) any deviations from these test method;

g) optional: Visual assessment (cracks, scaling from aggregate particles, leakage of freezing medium) before the start and after (7 ± 1), (14 ± 1), (28 ± 1), (42 ± 1) and 56 cycles;

h) optional: Composition of the concrete.

8.7 Alternative applications

The test method is restricted to specimens with dimensions of approximately 50 mm x 150 mm x 150 mm, where a sawn surface is tested. The test starts after 28 d with the (72 ± 2) h re-saturation of the test specimen. The same test principle can, however, also be used for other conditions. It is normally the method of making and curing specimens that differs from these test method. Examples of alternative applications are:

a) Other specimen geometries can be used but the thickness should always be (50 ± 2) mm. For example, the method is suitable for testing slices from cores drilled from structures or for testing precast units.

b) Top surfaces and surfaces cast against formwork can be tested instead of sawn surfaces.

c) Other curing conditions can be used and the concrete age may differ from 28 d at the start of the freeze-thaw testing.

d) Other de-icing agents than NaCl can be used.

e) The number of freeze-thaw cycles may exceed 56.

When alternative applications are used, the specimens are sawn to a thickness of (50 ± 2) mm 7 d before the start of the freeze-thaw test. During these 7 d the specimens are stored in the climate chamber (4.3.1), unless other curing conditions are of special interest. The freeze-thaw test starts with the (72 ± 2) h re-saturation. The test then continues according to these test method.

All deviations from these test method are noted in the test report.

9 CIF-test

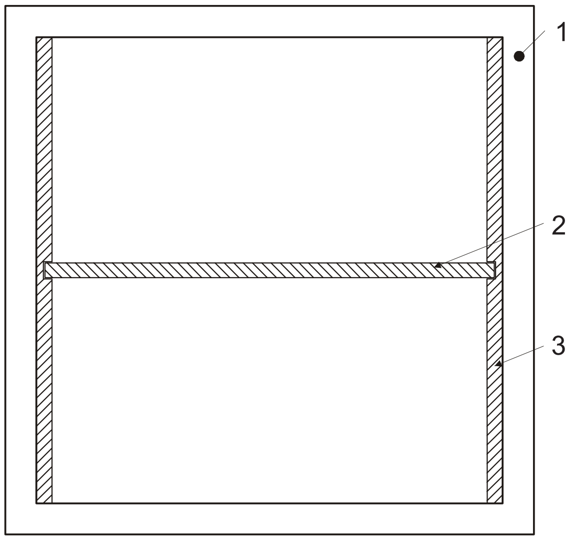
9.1 Principle

CIF specimens, obtained by splitting a 150 mm cube mould with a centralised Polytetrafluorethylene plate, are subjected to freeze-thaw attack in presence of de-ionised water or 3 % sodium chloride (NaCl) solution. The freeze-thaw resistance is measured either as relative length change or as relative dynamic modulus of elasticity by using ultrasonic pulse transit time or fundamental transverse frequency after 56 freeze-thaw cycles.

9.2 Preparation of test specimens

The test requires at least five specimens with a total test surface area of ≥ 0,08 m². The base of the specimens is rectangular and the height is restricted to (70 ± 2) mm.

To obtain the specimens the 150 mm³ moulds are separated into halves with the PTFE plate (4.4.1). The centred plate can be fixed by two other plates which are placed vertically (see Figure 10). The concrete surface at the PTFE plate is the test surface. The PTFE plate is not treated with any demoulding agent.



Key

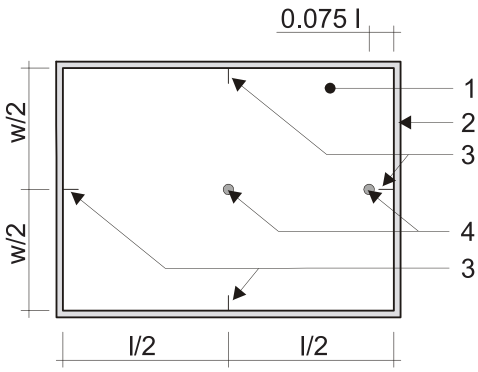
1 form work 150 mm x 150 mm x 150 mm

2 Centred PTFE disk

3 Lateral PTFE disk

Figure 10 - Arrangement of PTFE plates

During the first day after casting the specimens are stored in the moulds at a temperature of (20 ± 2) °C and a relative humidity of (95 ± 5) %. The specimens are removed from the moulds after (24 ± 2) h. Directly after demoulding, the specimens are placed in a bath with tap water having a temperature of (20 ± 2) °C. When the specimens are 7 d old, they are removed from the water bath and placed in the climate chamber (4.4.2), where they are stored until the selected freeze-thaw test starts.



Key

1 specimens top

2 lateral sealing

3 spots for measuring UPTT

4 spots for measuring FF

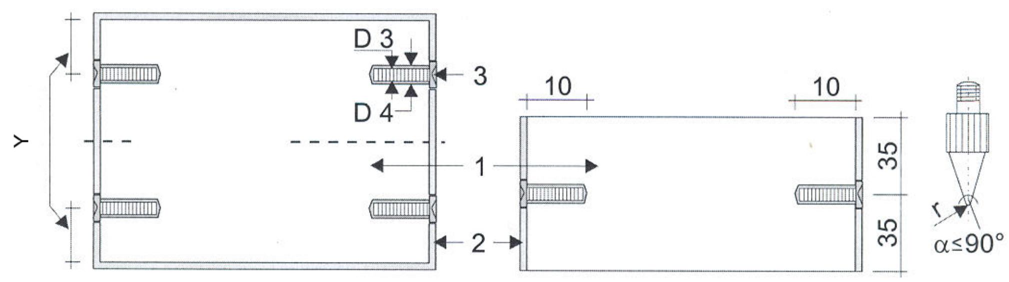
Figure 11 - Location of the sound wave propagation axes

Analogues to the chosen measurement procedure the specimens are prepared for the determination of the internal structural deterioration between 21st and 26th day after casting the specimens.

Ultrasonic pulse transit time: The spots, by which the two sound wave propagation axis run are marked on the specimen surface (Figure 11).

Fundamental transverse frequency: The spots, by which the specimen is tapped and the frequency is recorded are marked on the specimen surface (Figure 11).

Length change: The reference studs are glued with solvent-free epoxy resin in drilled holes (Figure 12) if the length change measurement is used. The holes are drilled so low that the studs extends 3 mm beyond the specimens surface.



Key

1 specimen

2 lateral sealing

3 studs, allen screw M3x10

Y 0,02 width

Figure 12 - Preparation of the specimens for measuring the length change

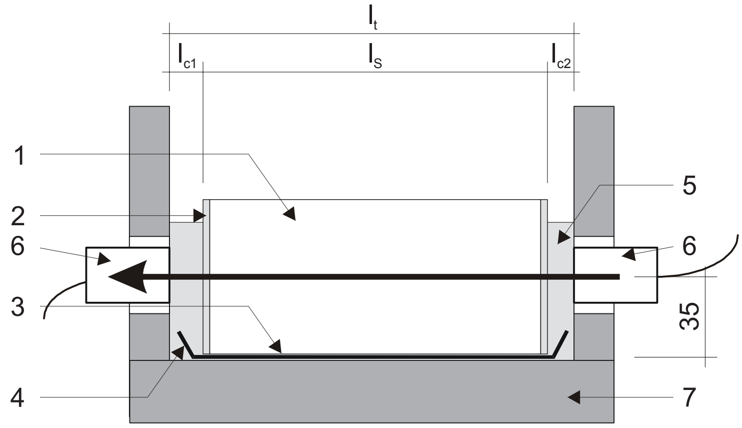
The lateral surfaces are either covered with aluminium foil glued with butyl rubber or sealed with a solvent-free epoxy resin. Before and after the specimens are sealed the weight of each specimen is determined to an accuracy of ± 0,1 g. Immediately after it the specimens are returned to the climate chamber (4.4.2).

9.3 Measurement procedure

9.3.1 Ultrasonic pulse transit time UPTT (reference measurement procedure)

The ultrasonic equipment is connected with the transducers of the measuring container. The length l_t between the transducers is measured with an accuracy of ± 0,5 mm. The measurement of the UPTT is done with an accuracy of ± 0,1 µs, without any air blisters being allowed on the transducers.

Before each measuring occasion the steel plate (4.4.8 c) is placed in the measuring container. The coupling medium of approximately 20 °C corresponds to the freezing medium (0) and is filled in up to 10 mm above the transducers. The total transit time t_{cm} is measured through the coupling medium without the specimen.



Key

1 specimen

2 lateral sealing

3 test surface

4 steel plate

5 coupling medium

6 transducer

7 measuring container

Figure 13 - Test set-up for CIF test

The specimens are placed on the steel plate. The sound wave propagation axes always run through the marked spots on the specimen. The coupling medium is filled in up to 10 mm above the transducers. The upper side of the specimen may not be wetted. Then the total transit times t_t are determined with an accuracy of ± 0,1 µs. The measures are taken in parallel to the testing surface in 2 orthogonal axes at a height of 35 mm above the testing surface (Figure 13).

The relative dynamic modulus of elasticity RDM_{UPTT} is calculated in percentage according to Equation 10.

Equation 10:

$$RDM_{UPPT,n} = \left(\frac{l_{t,n}}{l_{t,0}} \times \frac{t_{t,0} \times l_{t,0} - t_{cm,0} \times l_{t,0} + t_{cm,0} \times l_S}{t_{t,n} \times l_{t,n} - t_{cm,n} \times l_{t,n} + t_{cm,n} \times l_S} \right)^2 \times 100 \ [\%]$$

where

RDM_{UPTT} is relative dynamic modulus of elasticity in %;

t_t is the total transit time (specimen + coupling medium) in µs;

t_{cm} is the transit time through the coupling medium without specimen in the container in µs;

l_t is the total length between the transducers in mm;

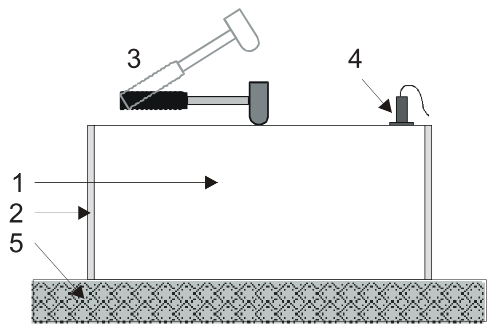
l_S is the length of the specimen before sealing the lateral surfaces in mm;

index n characterise the measure after a number of freeze-thaw cycles;

index 0 characterise the initial measure after the capillary suction period.

9.3.2 Fundamental transverse frequency (alternative measurement procedure)

The equipment is calibrated according to the instruction manual.



Key

1 specimen

2 lateral sealing

3 modally tuned impact hammer

4 accelerometer

5 specimens pad

Figure 14 - Test set-up for measuring the fundamental transverse frequency

The specimen is placed on a thick pad (4.4.9 b)). The accelerometer is hold by hand or by another suitable means, such as a rubber band, in good contact to the concrete test surface. The specimen is taped with a suitable tool (preferably a instrumented hammer) and the FF is recorded by the nearest 10 Hz. The tapping is repeated at least three times to obtain an average value with a standard deviation less than 100 Hz.

The relative dynamic modulus of elasticity RDM_{FF} is calculated in percentage according to Equation 11.

Equation 11: $$RDM_{FF} = \left(\frac{f_n}{f_0}\right)^2 \times 100 \; [\%]$$

where

RDM_{FF} is the relative dynamic modulus of elasticity in % determined by using FF;

f_n is the fundamental frequency measured after n freeze-thaw cycles in Hz;

f_0 is the initial fundamental frequency in Hz.

9.3.3 Length change (alternative measurement procedure)

The extensometer is calibrated with the invar (4.4.10 c)) according to the instruction manual. The measurement is carried out at (20 ± 2) °C.

The specimens are placed in the extensometer with the same end up each time. The specimen or the extensometer is rotated slowly while the measurement is made. The minimum reading is recorded if the rotation causes a change in the dial reading.

The relative length change is calculated in percentage according to Equation 12

Equation 12:

$$\varepsilon_L = \frac{l_{C,0} - l_{C,n} + l_n - l_0}{L_0} \times 100 \ [\%]$$

where

ε_L is the dilation of the specimen in percentage;

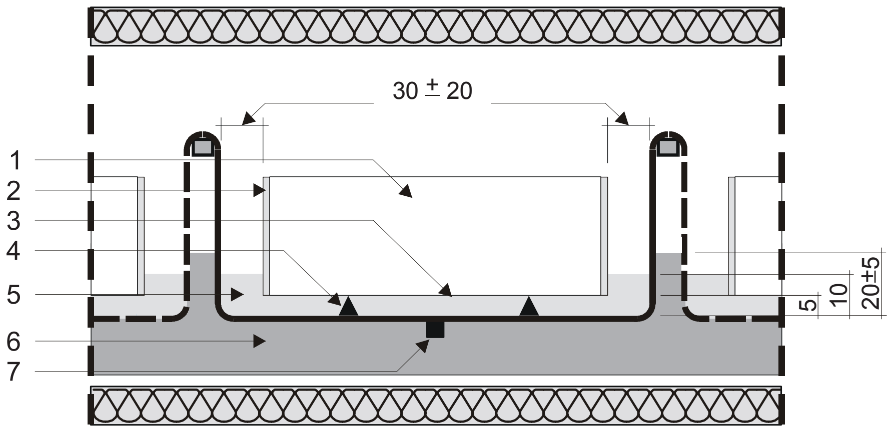
$l_{C,0}$ is the length of the calibration bar before the first freeze-thaw cycle in mm;

$l_{C,n}$ is the length of the calibration bar after n freeze-thaw cycles in mm;

l_n is the length of the specimen after n freeze-thaw cycles in mm;

l_0 is the initial length of the specimen before the first freeze-thaw cycle in mm;

L_0 is the length of the specimen before sealing the lateral surfaces in mm.



Key

1 specimen

2 lateral sealing

3 test surface

4 spacer (4.4.5)

5 freezing medium (0)

6 cooling liquid

7 reference point

Figure 15 - Test set-up of the CIF-test in the middle of the chest during the freeze-thaw cycles

9.4 Test procedure

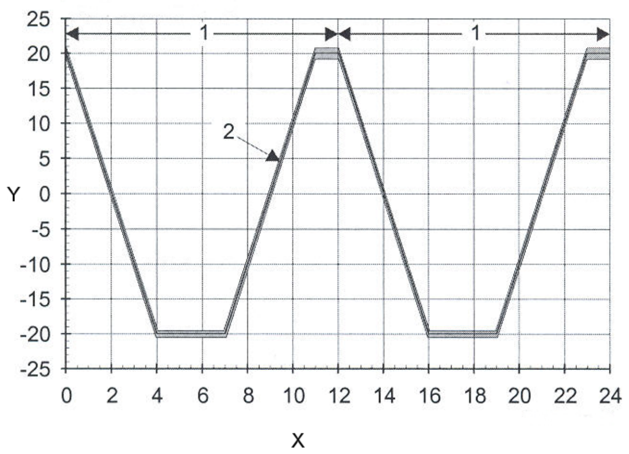
The freeze-thaw test starts after 28 d with the re-saturation of the specimens. Following dry storage, each specimen is placed in one container (4.4.4) on the (5 ± 0,1) mm high spacers (4.4.5) with the test surface downwards (Figure 15). Subsequently, the freezing medium is poured into the container to a height of (10 ± 1) mm without wetting the specimen's top.

NOTE This can be achieved by filling to approximately 13 mm and removing the surplus solution by means of suction device (4.4.6).

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

Immediately before the specimens are placed in the freeze-thaw chest, the initial value for the measurement of the internal structural damage is determined for each specimen according to 9.3. Immediately after this measurement the containers with the specimens are placed in the freeze-thaw chest on supports which ensure an immersion depth of the bottom of the test containers in the cooling liquid of (20 ± 5) mm (Figure 16).

A 12 h freeze-thaw cycle is applied. The points specifying the temperature curve in Figure 16 are given in Table 3.The reference temperature is measured in the cooling bath liquid below the bottom of the test container in the middle of the chest. The temperature is monitored continuously. 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.



Key

1 freeze-thaw cycle

2 temperature at the reference point

Y temperature in ºC

X time in h

Figure 16 - Time-temperature curve in the cooling liquid at the reference point

Table 3 - Points specifying the shaded area in Figure 16

time [h]	temperature [°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 (7 ± 1), (14 ± 1), (28 ± 1), (42 ± 1) and 56 freeze-thaw cycles, the following procedure is carried out 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 (0) and subjected to ultrasonic cleaning for 3 min.

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 μ_b is weighed to 0,1 g. The mass of the empty filter μ_f is determined before with the same accuracy. The mass of the scaled material μ_s is then: $\mu_s = \mu_b - \mu_f$.

c) All surfaces of the specimens are carefully dried with an absorbent laboratory towel (0). The mass of each specimen is determined and rounded to the nearest 1 g.

d) Depending on which measurement procedure has been used for determining the initial values for the internal structural damage the ultrasonic pulse transit time, the fundamental transverse frequency or the length change is measured according to 9.3.

e) Before the start of the next freeze-thaw cycle the containers with the specimens are filled with fresh freezing medium (0) to a height of (10 ± 1) mm without wetting the specimen's top. The containers are returned to the chest.

9.5 Expression of test results

Depending on which measurement procedure has been used the value of the internal structural damage is calculated after n freeze-thaw cycles in percentage for each measurement and each specimen according to 9.3. The RDM is rounded to the nearest 1 % and the relative length change to the nearest 0,01 % respectively.

The mean value, the individual values for each specimen as well as the standard deviation after 56 cycles are used for evaluating the freeze-thaw resistance.

NOTE The water uptake is a good additional information to evaluate the internal structural damage. The water uptake is calculated as change in mass w_n after n freeze-thaw cycles in percentage according to Equation 13. The water uptake is rounded to the nearest 0,1 wt.-%.

Equation 13:

$$w_n = \frac{m_{S,n} - m_{S,1} + \mu_{S,n}}{m_{S,0}} \times 100 \ [\text{wt.}-\%]$$

where

w_n is water uptake after n freeze-thaw cycles in wt-%;

$m_{S,n}$ is the mass of each specimen after n freeze-thaw cycles in g;

$m_{S,1}$ is the mass of each specimen including the sealing mass before re-saturation in g;

$\mu_{S,n}$ is the cumulative mass of scaled material after n freeze-thaw cycles in g;

$m_{S,0}$ is the mass of each specimen without the sealing mass before re-saturation in g.

9.6 Test report

The test report shall contain at least the following information:

a) reference to this document;

b) origin and marking of the specimens;

c) concrete identification;

d) composition of the freezing medium (4.1.3);

e) value of the internal structural damage for each specimen as well as the mean value in percentage rounded to the nearest 1 %, after (7 ± 1), (14 ± 1), (28 ± 1), (42 ± 1) and 56 freeze-thaw cycles;

f) any deviations from these test method;

g) optional: The mean value and the individual values of the water uptake after (7 ± 1), (14 ± 1), (28 ± 1), (42 ± 1) and 56 freeze-thaw cycles;

h) optional: Visual assessment (cracks, scaling from aggregate particles) before the start and after (7 ± 1), (14 ± 1), (28 ± 1), (42 ± 1) and 56 cycles;

i) optional: Composition of the concrete.

9.7 Alternative application

The test method is restricted to at least 5 specimens with height of approximately 70 mm and a total test surface of ≥ 0,08 m², where the test starts at an age of 28 days. The same test principle can, however, also be used for other conditions. It is normally the method of making and curing specimens that differs from the standard test procedure. Examples of alternative applications are:

a) Other specimen geometries may be used but the total test surface area is ≥ 0,08 m² and the height is (70 ± 5) mm. For example, the method is suitable for testing slices from cores drilled from structures, paving blocks or for testing precast units.

b) It is permissible to insert two PTFE plates (4.4.1) 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 lager aggregate size the PTFE plate can be placed only at one side of the mould.

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

d) Other curing conditions can be used and the concrete age may differ from 28 d at the start of the freeze-thaw testing.

e) Other de-icing agents than NaCl can be used.

f) The number of freeze-thaw cycles may exceed 56.

When alternative applications are used, the specimens are stored for surface drying in the climate chamber (4.4.2) for 21 d and then re-saturated for 7 d in the freezing medium as in this test method, unless other curing conditions are of special interest. The test then continues according to this test method.

All deviations from this test method are noted in the test report.

Bibliography

[1] EN 12350-1, Testing fresh concrete – Part 1: Sampling

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