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Testing of concrete —

Part 7:
Non-destructive tests on hardened concrete

Essais du béton —

Partie 7: Essais non destructifs du béton durci

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Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 1920-7 was prepared by Technical Committee ISO/TC 71, *Concrete, reinforced concrete and pre-stressed concrete*, Subcommittee SC 1, *Test methods for concrete*.

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

— *Part 1: Sampling of fresh concrete*

— *Part 2: Properties of fresh concrete*

— *Part 3: Making and curing test specimens*

— *Part 4: Strength of hardened concrete*

— *Part 5: Properties of hardened concrete other than strength*

— *Part 6: Sampling, preparing and testing concrete cores*

— *Part 7: Non-destructive tests on hardened concrete*

Testing of concrete —

Part 7:
Non-destructive tests on hardened concrete

1 Scope

This part of ISO 1920 specifies non-destructive test methods for use on hardened concrete.

The methods included are

a) determination of rebound number,

b) determination of ultrasonic pulse velocity, and

c) determination of pull-out force.

NOTE These test methods are not intended to be an alternative for the determination of compressive strength of concrete, but with suitable correlations they can provide an estimate of *in-situ* strength.

2 Terms and definitions

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

NOTE Additional terms are defined in other parts of ISO 1920.

2.1
rebound number
⟨rebound number test⟩ reading on a rebound hammer, which is related to the proportion of the energy returned to the hammer after striking the surface of the concrete

2.2
test area
⟨rebound number test⟩ region of concrete that is being assessed and which, for practical purposes, is assumed to be of uniform quality

2.3
median
⟨rebound number test⟩ middle value of a set of numbers when arranged in size order

NOTE If the set has an even number of items, the median is taken as the mean of the middle two.

2.4
transit time
⟨ultrasonic pulse velocity test⟩ time taken for an ultrasonic pulse to travel from the transmitting transducer to the receiving transducer, passing through the interposed concrete

2.5
onset
⟨ultrasonic pulse velocity test⟩ leading edge of the pulse detected by the measuring apparatus

2.6
rise time
⟨ultrasonic pulse velocity test⟩ time for the leading edge of the first pulse to rise from 10 % to 90 % of its maximum amplitude

3 Determination of rebound number

3.1 Principle

A mass propelled by a spring strikes a plunger in contact with the surface. The test result is expressed in terms of the rebound distance of the mass.

NOTE Annex A describes a method of obtaining a correlation between strength and rebound number.

3.2 Apparatus

3.2.1 Rebound hammer, hammer comprising a spring-loaded steel hammer that, when released, strikes a steel plunger in contact with the concrete surface.

The spring-loaded hammer shall travel with a fixed and repeatable velocity. The rebound distance of the steel hammer from the steel plunger shall be measured on a linear scale attached to the frame of the instrument.

The rebound hammer shall be calibrated twice a year to validate the calibration curve. It shall also be calibrated whenever there is a reason to question its proper operation.

NOTE Several types and sizes of rebound hammers are commercially available for testing various strengths and types of concrete. Each type and size of hammer should be used only with the strength and type of concrete for which it is intended. For testing concretes with a low surface hardness, such as lightweight concrete, a pendulum-type rebound hammer of low impact energy is suitable.

3.2.2 Steel reference anvil, for verification of the hammer, defined with a hardness of minimum 52 HRC and a mass of 16 kg ± 1 kg and a diameter of approximately 150 mm, except where the annex in a national standard defines a different mass.

NOTE Verification on an anvil will not guarantee that different hammers will yield the same results at other points on the rebound scale.

3.2.3 Abrasive stone, medium-grain texture silicon carbide stone or equivalent material.

3.3 Test area

3.3.1 Selection

If the concrete elements to be tested are not at least 100 mm thick and fixed within a structure, they shall be rigidly supported during testing. Areas exhibiting honeycombing, scaling, rough texture, or high porosity should be avoided.

In selecting an area to be tested, the factors described in Annex B should be taken into account.

A test area shall be approximately 300 mm × 300 mm.

NOTE It is normally better to confine the readings to a limited test area, rather than take random readings over the whole structure or element.

3.3.2 Preparation

Heavily textured or soft surfaces and surfaces with loose mortar shall be ground smooth using the abrasive stone (3.2.3).

Smooth-formed or trowelled surfaces may be tested without grinding.

Remove any water present on the surface of the concrete.

3.4 Procedure

3.4.1 Preliminaries

Use the rebound hammer (3.2.1) in accordance with the manufacturer's instructions for its operation. Activate it at least three times before taking any readings, to ensure that it is working correctly.

Before a sequence of tests on a concrete surface, take and record readings using the steel reference anvil (3.2.2) and ensure that they are within the range recommended by the manufacturer. If they are not, then clean and/or adjust the hammer.

The hammer should normally be operated at a temperature within the range of 10 °C to 35 °C.

3.4.2 Determination

Hold the hammer firmly in a position that allows the plunger to impact perpendicularly to the surface being tested. Gradually increase the pressure on the plunger until the hammer impacts.

After impact, record the rebound number.

NOTE There are hammers with automatic writing equipment and, in these cases, the rebound number is recorded automatically.

Use a minimum of nine readings to obtain a reliable estimate of the rebound number for a test area.

Record the position and orientation of the hammer for each set of readings.

No two impact points shall be closer together than 25 mm and none shall be within 50 mm from an edge.

NOTE It is preferable to draw a regular grid of lines 25 mm to 50 mm apart and take the intersections of the lines as the test points.

Examine each impression made on the surface after impact. If the impact has crushed or broken through a near-to-surface void, the result shall be discounted.

3.4.3 Reference checking

After testing the concrete, take readings using the steel anvil (3.2.2). Record and compare these with those taken prior to the test (see 3.4.1). If the results differ, clean and/or adjust the hammer and repeat the test.

3.5 Test results

The result for the test area shall be taken as the mean of all the readings, adjusted if necessary to take into account the orientation of the hammer in accordance with the manufacturer's instructions, and expressed as a whole number.

If more than one hammer is to be used, a sufficient number of tests should be made on similar concrete surfaces so as to determine the magnitude of the differences to be expected.

NOTE 1 A method for obtaining a correlation between strength and rebound number is given in Annex A.

NOTE 2 For factors influencing the rebound number, see Annex B.

If more than 20 % of all the readings differ from the mean value by more than 6 units, the entire set of readings shall be discarded.

3.6 Test report

An example of a test report is given in Annex C.

In addition to the details required by Clause 6, the report shall include the following:

a) identification of the rebound hammer;

b) reference anvil readings, before and after tests;

c) test result (mean value) and hammer orientation for each test area;

d) individual rebound hammer readings (when specified);

e) test result adjusted for hammer orientation (if appropriate).

4 Determination of ultrasonic pulse velocity

4.1 Principle

A pulse of longitudinal vibrations is produced by an electro-acoustical transducer held in contact with one surface of the concrete under test. After traversing a known path length in the concrete, the pulse of vibrations is converted into an electrical signal by a second transducer and electronic timing circuits enable the transit time of the pulse to be measured.

4.2 Apparatus

The apparatus comprises the following.

4.2.1 Electrical pulse generator

The pulse velocity of the apparatus should be calibrated against a standard calibration bar, generally supplied by the manufacturer of the apparatus.

4.2.2 Pair of transducers

The natural frequency of the transducers should normally be within the range 20 kHz to 150 kHz.

NOTE Frequencies as low as 10 kHz and as high as 200 kHz can sometimes be used. High-frequency pulses have a well-defined onset but, as they pass through the concrete, they become attenuated more rapidly than pulses of lower frequency. It is therefore preferable to use high-frequency transducers (60 kHz to 200 kHz) for short path lengths (down to 50 mm) and low frequency transducers (10 kHz to 40 kHz) for long path lengths (up to a maximum of 15 m). Transducers with a frequency of 40 kHz to 60 kHz are found to be useful for most applications.

4.2.3 Amplifier

4.2.4 Electronic timing device, for measuring the time interval elapsing between the onset of a pulse generated at the transmitting transducer and the onset of its arrival at the receiving transducer.

Two forms of the electronic timing apparatus are available:

— an oscilloscope on which the first front of the pulse is displayed in relation to a suitable time scale;

— an interval timer with a direct reading digital display.

NOTE An oscilloscope provides the facility for examining the wave form, which can be advantageous in complex situations.

4.2.5 Apparatus for determination of arrival time of the pulse

The apparatus shall be capable of determining, in microseconds, the time of arrival of the first front of the pulse, even though this may be of small amplitude compared with that of the first half wave of the pulse.

4.3 Performance requirements of apparatus

The apparatus shall conform to the following performance requirements:

a) it shall be capable of measuring transit times in the calibration bar to an accuracy of ± 0,1 μs;

b) the electronic excitation pulse applied to the transmitting transducer shall have a rise time of not greater than one-quarter of its natural period; this is to ensure a sharp pulse onset;

c) the pulse repetition frequency shall be low enough to ensure that the onset of the received signal is free from interference by reverberations;

d) the apparatus shall be used within the operating conditions stated by the manufacturer;

e) the apparatus shall be in calibration at the time of the test.

4.4 Procedure

4.4.1 Factors influencing pulse velocity measurements

In order to provide a measurement of pulse velocity that is repeatable, it is necessary to take into account the various factors that influence the measurements. These are set out in Annex E.

4.4.2 Transducer arrangement

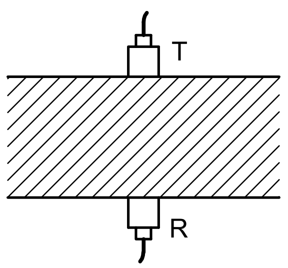
Place the two transducers on opposite faces (direct transmission), or on adjacent faces (semi-direct transmission), or on the same face (indirect or surface transmission) (see Figure 1). Although the direction in which the maximum energy is propagated is at right angles to the face of the transmitting transducer, it is possible to detect pulses that have travelled through the concrete in some other direction.

It may be necessary to place the transducers on opposite faces but not directly opposite each other. Such arrangements shall be regarded as a semi-direct transmission [see Figure 1 b)].

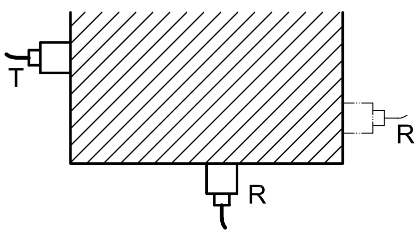
The indirect transmission arrangement is the least sensitive and should be used when only one face of the concrete is accessible, or when the quality of the surface concrete relative to the overall quality is of interest.

See Annex D for the method of determining the ultrasonic pulse velocity by indirect transmission.

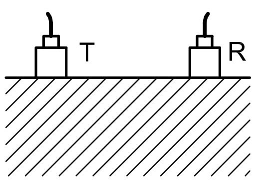
The semi-direct transmission arrangement has a sensitivity intermediate between the other two arrangements and should only be used when the direct arrangement cannot be used.



a) **Direct transmission**



b) **Semi-direct transmission**



c) **Indirect transmission**

Key

T is the transmitter

R is the receiver

Figure 1 — Positioning of transducers

4.5 Expression of results

For direct and semi-direct transmissions the pulse velocity shall be calculated from the formula:

$$V = \frac{L}{T}$$

where

V is the pulse velocity, in kilometres per second;

L is the path length, in millimetres;

T is the time taken by the pulse to traverse the length, in microseconds.

For indirect transmission, the pulse velocity shall be calculated in accordance with Annex D.

The resultant determination of the pulse velocity shall be expressed to the nearest 0,01 km/s or to three significant figures.

NOTE For a method of determining a correlation between pulse velocity and strength, see Annex F.

4.6 Test report

An example of a test report is given in Annex G.

In addition to the details required by Clause 6, the report shall include the following:

a) type and make of apparatus used, including: dimensions of contact area transducers, natural pulse frequency of transducers, and any special characteristics;

b) arrangements of transducers and transmission method (including a sketch, where appropriate);

c) details of reinforcing steel or ducts in the vicinity of the test areas (if known);

d) surface conditions and preparation at test points;

e) measured values of path length (for direct and semi-direct transmission), including method of measurement and accuracy of measurement;

f) pulse velocity.

5 Determination of pull-out force

5.1 Principle

The force required to pull out a disc installed a fixed distance below the surface of the concrete is measured.

5.2 Apparatus

The apparatus shall be as follows [see Figure 2 c)].

5.2.1 Insert, made of metal not readily attacked by fresh concrete, of sufficient thickness and strength to avoid deformation during the test.

The diameter of the head of the pull-out insert shall be 25 mm ± 0,1 mm. The sides of the insert shall be smooth.

The shaft, which may be removable, should have a diameter not more than 0,6 of the diameter of the head and a length such that the outer surface of the head is the same depth below the concrete surface as its diameter.

The insert may be cast into the concrete or positioned in hardened concrete in an under-reamed groove from a drilled hole. Inserts for casting-in should have a circular head and tapered shaft to minimize side friction during subsequent testing [see Figure 2 a) and b)].

The inserts may be coated with a release agent to prevent bonding to the concrete and may be notched to prevent their rotation in the concrete if the shafts are to be unscrewed.

Inserts for use in drilled holes should have means for expanding to 25 mm ± 0,1 mm.

5.2.2 Drilling and under-reaming equipment

Specialized equipment shall be used for drilling and then enlarging the base of the hole, when the insert is not cast into the concrete.

5.2.3 Bearing ring, that can be placed on the concrete surface symmetrically around the insert axis, having an inside diameter of 55 mm ± 0,1 mm and an outside diameter of 70 mm ± 1 mm.

The width of the bearing ring shall not be less than 0,4 of the diameter of the head of the pull-out insert.

5.2.4 Loading system, capable of applying a tensile force to the insert with the reaction being transmitted to the concrete surface through the bearing ring.

The loading system should ensure that the bearing ring is concentric with the insert shaft and that the load is applied perpendicular to the plane of the insert.

The loading system should include a means of indicating the maximum applied force to an accuracy of 2 % in the anticipated working range. The dial, scale or display shall have a resettable device that records the maximum applied force.

The loading system shall be calibrated twice a year and whenever there is a reason to question its proper operation.

5.3 Test area

5.3.1 Specimen location

The centres of test positions shall be at least 200 mm apart.

The centres shall be at least 100 mm from the edge of the concrete.

The inserts shall be placed so that all reinforcement is outside the expected conic failure surface by at least one bar diameter, or the maximum aggregate size, whichever is the greater.

The minimum thickness of the concrete to be tested shall be 100 mm.

5.3.2 Number of tests

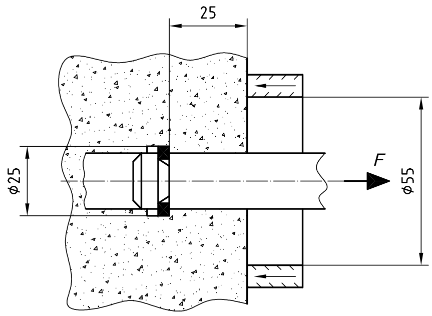
The number of tests required to represent an area or part of a structure shall be specified and will depend upon

a) the variability of the concrete, and

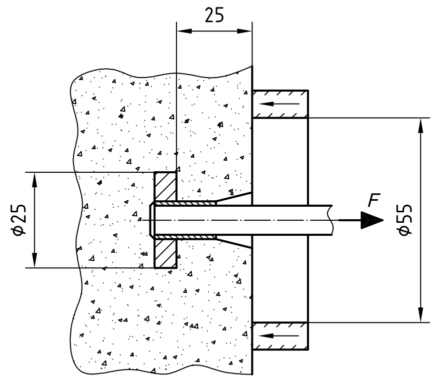
b) the purpose of the test and the accuracy required.

Care should be exercised to avoid averaging individual results if the differences between them reflect real differences in strength due to factors such as variations in curing conditions or batches of concrete.

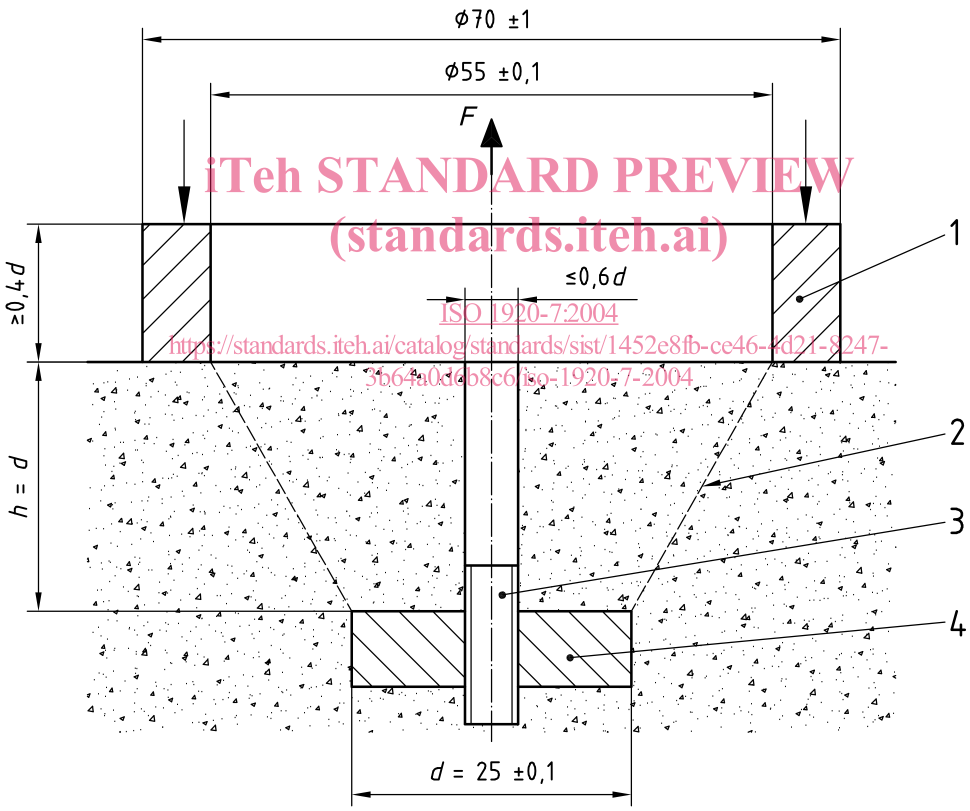
Dimensions in millimetres



a) Insert installed before casting



b) Insert installed after casting



c) Apparatus

Key

1 bearing ring
2 assured conic fracture
3 removable pull-out insert shaft
4 pull-out insert head

F is the pull-out force
d is the diameter of the insert head
h is the distance from the pull-out insert head to the concrete surface

Figure 2 — Schematic representation of pull-out test arrangement