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Preskušanje betona v konstrukcijah - 4. del: Določanje hitrosti prehoda ultrazvoka

Testing concrete in structures - Part 4: Determination of ultrasonic pulse velocity

Prüfung von Beton in Bauwerken - Teil 4: Bestimmung der Ultraschall-Impulsgeschwindigkeit

Essais pour béton dans les structures - Partie 4 : Détermination de la vitesse de propagation des ultrasons

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European foreword

This document (EN 12504-4:2021) has been prepared by Technical Committee CEN/TC 104 “Concrete and related products”, the secretariat of which is held by SN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2022, and conflicting national standards shall be withdrawn at the latest by January 2022.

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

This document supersedes EN 12504-4:2004.

In comparison with the previous edition, the following changes have been made:

— option to use equipment utilizing transverse waves.

This document is one of a series on testing concrete.

EN 12504, *Testing concrete in structures*, consists of the following parts:

— *Part 1: Cored specimens — Taking, examining and testing in compression;*

— *Part 2: Non-destructive testing — Determination of rebound number;*

— *Part 3: Determination of pull-out force;*

— *Part 4: Determination of ultrasonic pulse velocity.*

This document is based on the International Standard ISO 1920-7, *Testing of concrete — Part 7: Non-destructive tests on hardened concrete*. It is recognized that the ultrasonic pulse velocity determined using this document is a convention in as much that the path length over which the pulse travels is not always strictly known.

The measurement of pulse velocity can be used for the determination of the uniformity of concrete, the presence of cracks or voids, changes in properties with time and in the determination of dynamic physical properties. These subjects were considered to be outside the scope of this document, but some information is given in Annex B and more information can be found in the technical literature. The measurement can also be used to estimate the strength of *in situ* concrete elements or specimens given in EN 13791, *Assessment of in situ compressive strength in structures and precast concrete components*. However, it is not intended as an alternative to the direct measurement of the compressive strength of concrete.

Any feedback and questions on this document should be directed to the users’ national standards body. A complete listing of these bodies can be found on the CEN website

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

1 Scope

This document specifies a method for the determination of the velocity of propagation of pulses of ultrasonic longitudinal waves or ultrasonic transverse waves in hardened concrete, which is used for a number of applications.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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, *Concrete - Specification, performance, production and conformity*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 206 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at https://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1
transit time
time taken for an ultrasonic pulse to travel from the transmitting transducer to the receiving transducer, passing through the interposed concrete

Note 1 to entry: Transit time is referred to as time of flight in EN ISO 5577.

3.2
onset
leading edge of the pulse detected by the measuring apparatus

3.3
rise time
time for the leading edge of the first pulse to rise from 10 % to 90 % of its maximum amplitude

4 Principle

A pulse of longitudinal or transverse vibrations is produced by an ultrasonic 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 ultrasonic transducer and an electronic timing device enables the transit time of the pulse to be measured.

5 Apparatus

5.1 General

The ultrasonic test equipment consists of an electrical pulse generator, a pair of transducers, an amplifier and an 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. A reference bar or prism is used to zero the instrument or to provide a datum for the velocity measurement.

NOTE 1 This is typically necessary when the user changes the length of the cables being used.

Three forms of the electronic timing devices are available:

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

b) an interval timer with a direct reading digital display;

c) an A-scan display built directly into the instrument.

NOTE 2 An oscilloscope or integrated A-scan display provides the facility for monitoring the wave form of the pulse, which can be advantageous in complex testing situations or in automatic system measurements.

5.2 Performance requirements

The ultrasonic test equipment shall conform to the following performance requirements:

— It shall be capable of measuring transit times in the reference bar or prism to a limit deviation of ± 0,1 µs.

— 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.

— The pulse repetition frequency shall be low enough to ensure that the onset of the received signal is free from interference by reverberations.

The ultrasonic test equipment shall be capable of determining the transit time of the first front of the pulse with the lowest possible threshold, even though this may be of small amplitude compared with that of the first half wave of the pulse.

The ultrasonic test equipment shall be used within the operating conditions stated by the manufacturer.

5.3 Transducers

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

NOTE For longitudinal waves, 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. For ultrasonic pulse-echo measurements using transverse waves the transducer with a frequency of 40 kHz to 60 kHz is also typical, but in this case the path length is limited to a maximum of approximately 2,5 m.

6 Procedures

6.1 Determination of pulse velocity

6.1.1 Factors influencing pulse velocity determination

In order to provide a determination of pulse velocity, which is reproducible, it is necessary to take into account various factors which can influence the measurements. These are set out in Annex B.

6.1.2 Transducer arrangement

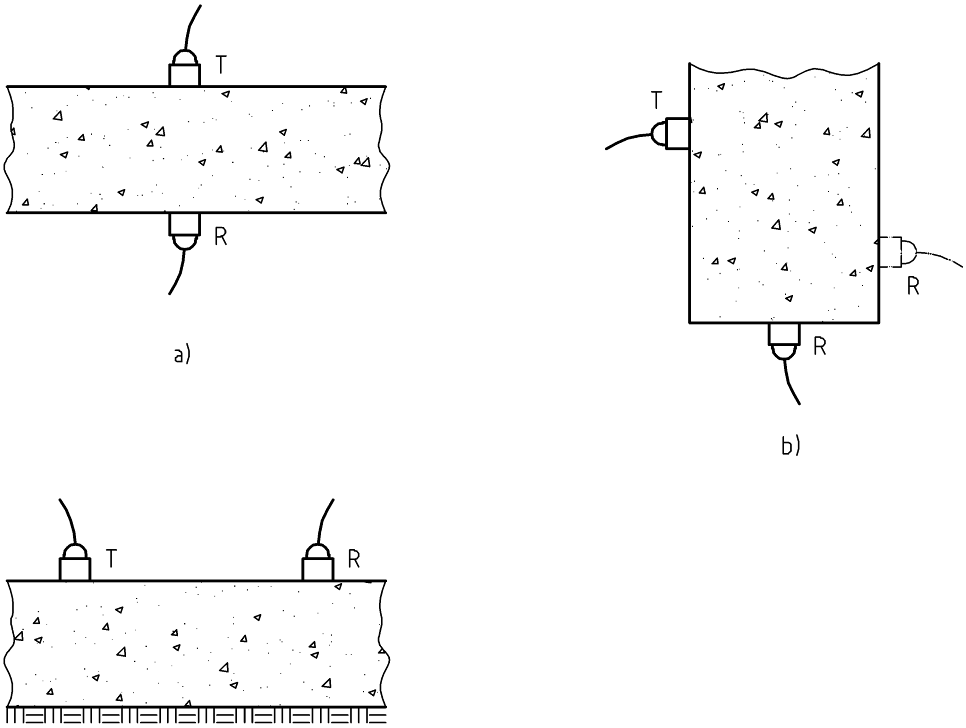
Although the direction in which the maximum energy is propagated is at right angles to the face of the transmitting transducer, it is possible to detect pulses which have travelled through the concrete in some other direction. It is therefore possible to make measurements of pulse velocity by placing the two transducers on opposite faces (direct transmission), or on adjacent faces (semi-direct transmission), or the same face (indirect or surface transmission; pulse-echo transmission) (see Figure 1) of a concrete structure or specimen. In the case of pulse-echo transmission, the receiver detects pulses which have travelled through the concrete to the opposite surface and have been reflected back to the first surface.

Where it is necessary to place the transducers on opposite surfaces but not directly opposite each other such arrangement shall be regarded as a semi-direct transmission (see Figure 1 b).

NOTE 1 The indirect transmission arrangement is the least sensitive and is 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.

NOTE 2 The semi-direct transmission arrangement is used when the direct arrangement cannot be used, for example at the corners of structures.

NOTE 3 Pulse-echo transmission is an alternative to indirect transmission when only one face of the concrete is accessible. The sensitivity is comparable with direct transmission.



a) Direct transmission **b)Semi-direct transmission** **c) Pulse-echo transmission**

Key

R is the receiver transducer

T is the transmitter transducer

Figure 1 — Transducer positioning

6.1.3 Path length measurement

For direct transmission, the path length is the shortest distance between the transducers. The measurement of the path length shall be recorded to the nearest 1 % of the measured distance.

For semi-direct transmission, it is generally found to be sufficiently accurate to take the path length as the distance measured from centre to centre of the transducer faces. The accuracy of path length is dependent upon the size of the transducer compared with the centre to centre distance.

With indirect transmission, the path length is not measured, but a series of measurements is made with the transducers at different distances apart (see Annex A).

For pulse-echo transmission, the path length is two times the distance from the surface where the transducer is placed and the opposite surface. The path length shall be recorded as for direct transmission.

6.1.4 Coupling the transducers onto the concrete

There shall be adequate acoustical coupling between the concrete and the face of each transducer. For many concrete surfaces, the finish is sufficiently smooth to ensure good acoustical contact by the use of a coupling medium such as petroleum jelly, grease, soft soap and kaolin/glycerol paste and by pressing the transducer against the concrete surface.

Repeated readings of the transit time should be made until a minimum value is obtained, indicating that the thickness of the couplant has been reduced to a minimum.

When the concrete surface is very rough and uneven, the area of the surface should be smoothed and levelled by grinding, or by the use of a quick-setting epoxy resin.

NOTE 1 Special transducers are available for use on very rough surfaces.

NOTE 2 Pulse-echo transducers can utilize dry point contact elements which do not require a couplant. In this case, it is typical for several transducer elements to be connected in parallel to provide sufficient signal strength.

6.1.5 Measurement of transit time

Using the ultrasonic test equipment the transit time shall be determined in accordance with the manufacturer's instruction (see 5.2).

7 Expression of result

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

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

where

V is the pulse velocity, in km/s;

L is the path length, in mm;

T is the transit time, in µs.

For the velocity by indirect transmission, see Annex A.

The resultant determination of the pulse velocity shall be expressed to the nearest 10 m/s.