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Acoustics — Measurement of sound absorption properties of road surfaces in situ —

Part 1:
Extended surface method

Acoustique — Mesurage in situ des propriétés d'absorption acoustique des revêtements de chaussées —

Partie 1: Méthode de la surface étendue

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

This second edition cancels and replaces the first edition (ISO 13472-1:2002), which has been technically revised.

The main changes compared to the previous edition are as follows:

— Reference to IEC 60651 has been replaced with reference to IEC 61672-1;

— Reference to ISO 18233 has been added, in order to have a standardized description of MLS and ESS signals. Two references on ESS have been added to the Bibliography;

— Requirements of a precision ±0,005 m on the source-microphone distance has been released to ±0,01 m due to the correcting capability offered by the accurate alignment procedure in the new Annex F;

— A procedure, taken from ISO 11819-2, to check the road surface dryness has been specified in 8.1;

— Specifications of the time window have been improved;

— Former Annex D on MLS signals has been deleted (replaced by a reference to ISO 18233);

— Former Annex G on correction of small time shifts has been replaced with the new Annex F, specifying an accurate alignment procedure; Annex F is now normative.

A list of all parts in the ISO 13472 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document describes a test method for measuring, in situ, the sound absorption coefficient of road surfaces as a function of frequency under normal incidence.

This method provides a means of evaluating the sound absorption characteristics of a road surface without damaging the surface. It is intended to be used during road construction, road maintenance and other traffic noise studies. It may also be used to qualify the absorption characteristics of road surfaces used for vehicle and tyre testing. However, the standard uncertainty is limited to 0,05.

This method is based on free-field propagation of the test signal from the source to the road surface and back to the receiver, and covers an area of approximately 3 m^2 and a frequency range, in one-third-octave bands, from 250 Hz to 4 kHz (see IEC 61260).

To complement this method, a spot method (see ISO 13472-2) is available. This method is based on the transmission of the test signal from the source to the road surface and back to the receiver inside a tube and covers an area of approximately 0,1 m^2 and a frequency range, in one-third-octave bands, from 315 Hz to 2 kHz.

Both methods should give the same results in the frequency range from 315 Hz to 2 kHz.

They are both applicable also to acoustic materials other than road surfaces.

The measurement results of this method are comparable with the results of impedance tube methods, performed on bore cores taken from the surface (e.g. ISO 10534-1 and ISO 10534-2).

The measurement results of this method are in general not comparable with the results of the reverberation room method (see ISO 354), because the method described in this document uses a directional sound field, while the reverberation room method assumes a diffuse sound field.

See Annex E for information about sound absorption coefficient under non-normal incidence.

Acoustics — Measurement of sound absorption properties of road surfaces in situ —

Part 1: Extended surface method

1 Scope

This document describes a test method for measuring in situ the sound absorption coefficient of road surfaces as a function of frequency in the range from 250 Hz to 4 kHz.

Normal incidence is assumed. However, the test method can be applied at oblique incidence although with some limitations (see Annex F). The test method is intended for the following applications:

— determination of the sound absorption properties of road surfaces in actual use;

— comparison of sound absorption design specifications of road surfaces with actual performance data of the surface after completion of the construction work.

The complex reflection factor can also be determined by this method.

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.

ISO 10534-1, *Acoustics — Determination of sound absorption coefficient and impedance in impedance tubes — Part 1: Method using standing wave ratio*

ISO 10534-2, *Acoustics — Determination of sound absorption coefficient and impedance in impedance tubes — Part 2: Transfer-function method*

IEC 61672-1, *Electroacoustics – Sound level meters – Part 1: Specifications*

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

3 Terms and definitions

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

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

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

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

3.1
angle of incidence
angle between the normal to the surface under test and the direction of the sound wave impinging on the test surface

3.2
sound power reflection factor
Q_W
fraction of the impinging sound power which is reflected from the surface material of the road (see 3.4)

Note 1 to entry: A spherical sound wave incident on the sample surface is assumed.

3.3
sound absorption coefficient
α
ratio of the sound power entering the surface of the test object (without return) to the incident sound power:

$$\alpha = 1 - Q_W$$

3.4
sound pressure reflection factor
Q_p
complex ratio of the pressure amplitude of the reflected wave to the pressure amplitude of the incident wave at the surface of the road

Note 1 to entry: A spherical sound wave incident on the sample surface is assumed.

Note 2 to entry: This quantity is necessary in order to understand the correction procedure described in Annex B and Formula (C.4). The sound power reflection factor is equal to the squared modulus of the sound pressure reflection factor: $Q_W(f) = |Q_p(f)|^2$.

3.5
geometrical spreading factor
attenuation of the magnitude of a sound pressure wave travelling from one point to another due to the spherical spreading

3.6
plane of reference for the road surface
hypothetical plane tangential to the majority of the elements of the surface under test

3.7
maximum sampled area
surface area, contained within the plane of reflection, which shall remain free of reflecting objects causing parasitic reflections

Note 1 to entry: See Annex A.

3.8
background noise
noise coming from sources other than the test signal

3.9
signal-to-noise ratio
S/N
difference between the level of the nominal useful signal and the level of the background noise at the moment of detection of the useful event

Note 1 to entry: The signal-to-noise ratio is given in decibels.

3.10
impulse response
time signal at the output of a system when a Dirac function is applied to the input

Note 1 to entry: The Dirac function, also called δ function, is the mathematical idealization of a signal infinitely short in time which carries a unit amount of energy.

3.11
transfer function
Fourier transform of the *impulse response* (3.10)

4 Summary of the method

4.1 General principle

A sound source driven by a signal generator is positioned above the surface to be tested and a microphone is located between the source and the surface. The measurement method is based on the assessment of the transfer function between the output of the signal generator and the output of the microphone. This transfer function is composed of two factors, one coming from the direct path (from the signal generator through the amplifier and loudspeaker to the microphone) and a second coming from the reflected path (from the signal generator through the amplifier, loudspeaker and surface under test to the microphone) (see Figure 1).

The overall impulse response containing the direct and reflected sound is measured in the time domain. This overall impulse response consists of the impulse response of the direct path and, after some delay due to the longer travelling distance, the impulse response of the reflected path.

With suitable time domain processing (e.g. signal subtraction and temporal separation, see 4.2), these responses can be separated. After a Fourier transform, the transfer functions of the direct path $H_{\mathrm{i}}(f)$ and of the reflected path $H_{\mathrm{r}}(f)$ are obtained. The ratio of the squared modulus of these transfer functions gives the sound power reflection factor $Q_W(f)$; in order to account for the path length difference between the direct and reflected component, the above ratio is also multiplicated by a factor K_{r} intended to compensate for the greater geometrical spreading of the reflected path, see Formula (2). Then, the sound absorption coefficient can be calculated from the sound power reflection factor $Q_W(f)$ (see 3.3).

Taking into account also the factor K_{r} due to geometrical spreading, the sound absorption coefficient is computed as given by Formula (1):

$$\alpha(f)=1-Q_W(f)=1-\frac{1}{K_{\mathrm{r}}^2}\left|\frac{H_{\mathrm{r}}(f)}{H_{\mathrm{i}}(f)}\right|^2 \tag{1}$$

$$K_{\mathrm{r}}=\frac{d_{\mathrm{s}}-d_{\mathrm{m}}}{d_{\mathrm{s}}+d_{\mathrm{m}}} \tag{2}$$

where

d_{s} is the distance between the sound source and the reference plane for the surface under test;

d_{m} is the distance between the microphone and the reference plane for the surface under test.

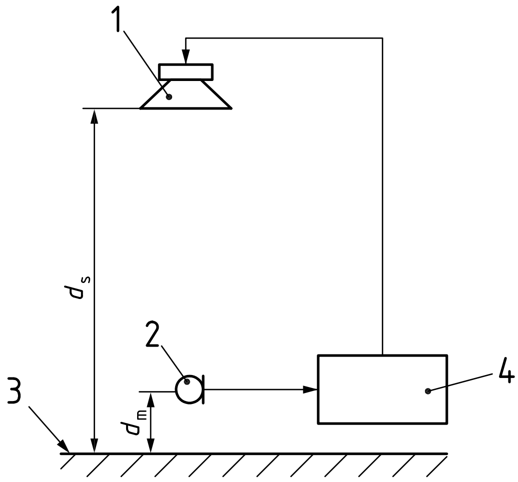
NOTE The complex reflection factor, necessary for propagation calculations or comparison of measurement results with theoretical calculations can be found as follows in Formula (3):

$$Q_p(f)=\frac{1}{K_{\mathrm{f}}}\cdot\frac{H_{\mathrm{r}}(f)}{H_{\mathrm{i}}(f)}\cdot\exp(i2\pi\Delta\tau) \tag{3}$$

where $\Delta\tau$ is the time difference between arrival of the direct and the reflected impulses (see Annex C).

No special requirement is placed upon the signal source as long as it enables determination of the impulse response over the designated frequency interval (see also 5.2).

The method considers the part of the energy that is reflected in a non-specular way and not captured by the microphone as being absorbed. Thus, the sound absorption coefficient may be slightly overestimated.



Key

1 sound source

2 microphone

3 surface under test

4 signal processing unit

d_m is the distance between the microphone and the reference plane for the surface under test

d_s is the distance between the sound source and the reference plane for the surface under test

Figure 1 — Sketch of the essential components of the measurement set-up

4.2 Signal separation technique

This document specifies how the sound source and the microphone shall be positioned over the surface under test and how the overall impulse response shall be measured.

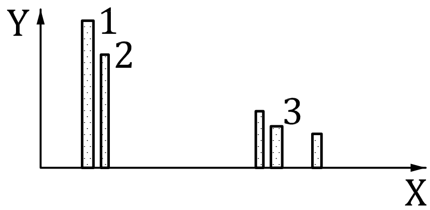
The overall impulse responses consist of a direct component, a component reflected from the surface under test and other parasitic reflections, see Figure 2 a). The direct component and the reflected component from the surface under test shall be separated.

This separation shall be done using the signal subtraction technique (seeFigure 2): the reflected component is extracted from the overall impulse response after having removed the direct component by subtraction of an identical signal [see Figures 2 c) and 2 d)]. This can be obtained by performing a free-field measurement using the same geometrical configuration of the loudspeaker and the microphone. In particular, their relative position shall be kept as constant as possible. The direct component is extracted from the free-field measurement [see Figure 2 b)].

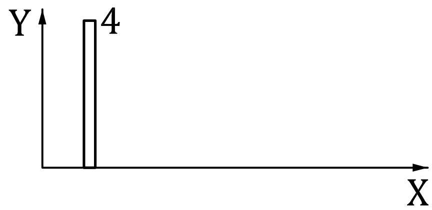
NOTE This technique allows broadening of the time window, leading to a lower frequency limit of the working frequency range, without having very long distances between loudspeaker, microphone and surface under test. Furthermore, the microphone can be placed closer to the road surface so as to improve the S/N ratio and decrease the effect of geometrical spreading.

For source and microphone distances from the plane of reference for the road surface, this document requires the following values: d_s =1,25 m and d_m =0,25 m (see Figure 1). These distances shall be kept constant during the averaging process (±0,01 m).

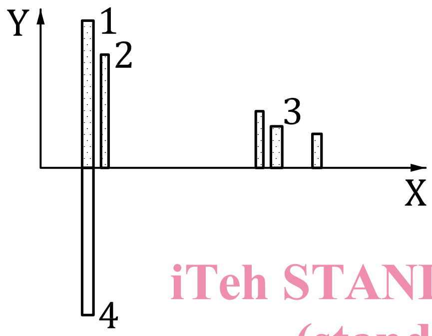
The direct impulse response has to be exactly known in shape, amplitude and time delay. This is obtained by performing a free-field measurement using the same geometrical configuration of the loudspeaker and the microphone. In particular, the distance between them shall be kept strictly constant. This requirement can be met by using a fixed and stable connection between the source and the microphone. If the direct impulse response has been subjected to a small time shift between the free field measurement and the reflection measurement, this shall be corrected (see Annex F).



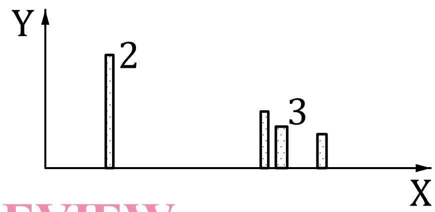
a) Overall impulse response including: direct incident component, reflected component and unwanted parasitic components



b) Free-field direct component



c) Direct component cancellation from the overall impulse response using the free-field direct component



d) Result

Key

X time, expressed in milliseconds

Y impulse response amplitude

1 direct incident component

2 reflected component

3 unwanted parasitic component

4 free-field direct component

Figure 2 — Principle of the signal subtraction technique

In order to avoid temperature differences between the free field measurement and the measurement on the surface under test, it is recommended to perform the two measurements within a short time (<10 min).

4.3 Test method

The measurement shall take place in an essentially free field, i.e. a field free from reflections coming from objects other than the surface under test. However, the use of a time window cancels out reflections arriving after a certain time period, and thus originating from locations further away than a certain distance (see Clause 7).

In order to minimize the effects of the background noise and meteorological variations, a number of impulse responses shall be acquired and averaged to get the minimum S/N ratio as specified in 7.4.

NOTE Experience shows that usually the average of 16 to 32 impulse responses is sufficient.

Often, very small sound absorption values are measured in the low-frequency range. Accurate values in this range are very difficult to obtain. Small variations in the assessment of the sound pressure levels of both the direct signal and the reflected signal can induce high inaccuracies in the sound absorption values. In order to avoid this problem, and in order to improve the accuracy of the method, a reference measurement on a totally reflective surface shall be performed (see Annex B).

5 Test system

5.1 Components of the test system

The test equipment shall comprise an electronic signal generator, a power amplifier and a loudspeaker, a microphone with amplifier and a signal analyser capable of performing cross-correlation and transformations between the time and the frequency domains.

A sketch of the essential components of the measuring system is shown in Figure 1.

The complete measuring system shall meet the requirements of at least a type 2 instrument in accordance with IEC 61672-1. For the purposes of this document, the measurement frequency range is displayed in one-third-octave bands, from 250 Hz to 4 kHz.

5.2 Sound source

The loudspeaker shall

— have a single loudspeaker driver,

— be constructed without any port, e.g. to enhance low frequency response,

— be constructed without any electrically active or passive components (such as crossovers) which can affect the frequency response of the whole system, and

— have a smooth magnitude of the frequency response without sharp irregularities throughout the measurement frequency range, resulting in an impulse response under free-field conditions with a length not greater than 3 ms.

NOTE As the sound power reflection factor is calculated from the ratio of energetic quantities extracted from impulse responses taken using the same loudspeaker and microphone within a short time period, the characteristics of the loudspeaker frequency response are not critical, provided a good quality loudspeaker meeting the above prescriptions is used.

5.3 Test signal

The test signal shall consist of a repeatable short signal with a low peak-to-RMS ratio, typically below 2, and an almost flat spectrum that covers the one-third-octave bands from 250 Hz up to 4 kHz with an acceptable S/N ratio. Several signals may be used, such as maximum-length sequences (MLS) or exponential sine sweep (ESS), see ISO 18233.

6 Data processing

6.1 Calibration

The measurement procedure described in this document is based on the power ratio of two transfer functions extracted from the same electro-acoustical chain. An absolute calibration of the measurement chain with regard to the sound pressure level is, therefore, unnecessary. However, a reference measurement as described in Annex B is required.