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

Part 2:
Spot method for reflective surfaces

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

Partie 2: Méthode ponctuelle pour les surfaces réfléchissantes

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Foreword

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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 13472-2:2010), which has been technically revised.

The main changes are as follows:

— mandatory choice of the transfer function formulation and quality requirements for the coherence function;

— an alternative microphone arrangement and application of alternating transfer functions are presented to cancel the distortion due to destructive interference at the microphone positions.

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 method provides a means to evaluate the sound absorption characteristics of a road surface without damaging the surface. The field of application is limited to low absorption surfaces such as those in accordance with ISO 10844 and similar surfaces. Due to air leakage the method is not reliable if the measured sound absorption coefficient exceeds 0,15. Surfaces with a sound absorption coefficient of 0,10 or below are considered reflective.

The method in this document is based on propagation of the test signal from the source to the road surface and back to the receiver through an impedance tube with a diameter of 80 mm to 100 mm. The tube covers an area of approximately 0,005 m^2 to 0,008 m^2 and a frequency range, in one-third octave bands, from 250 Hz to 1 600 Hz for a 100 mm diameter, or from 250 Hz to 2 000 Hz, for an 80 mm diameter tube. It uses the test procedure and signal processing described in ISO 10534-2, but because of the defined frequency range of application, the dimensions of the system are not freely adjustable.

The essential part in the ISO 10534-2 procedure is the determination of the transfer function between two microphones at different distances from the sample at the end of the tube. In this case of a reflecting sample at specific frequencies destructive interferences (nodes) will occur at the microphone positions jeopardizing the correct determination of the transfer function between the microphone pair.

Therefore in this document the ISO 10534-2 procedure is extended with a preference for transfer function H calculated as the ratio of the auto spectrum S_{22} at the lowest microphone position and the cross spectrum S_{21} and requirements on the resolution, the sample frequency and the block length in the FFT analysis added with a requirement on the average narrow band coherence within a one-third octave band. Recommendations for improvement of the accuracy by alternative microphone arrangement, variation in transfer function and type of random noise are presented in Annex C.

This method is complementary to the extended surface method (ISO 13472-1[3]) that covers an area of approximately 3 m^2 and a frequency range, in one-third octave bands, from 250 Hz to 4 000 Hz.

Both methods should give similar results in the valid frequency range, but their fields of application and therefore their accuracy will differ strongly. The method described in ISO 13472-1 has limited accuracy at small sound absorption values and is therefore unfit to check compliance of surfaces with the requirements in ISO 10844 or similar regulations, while the method described in this standard fails at higher sound absorption values.

Within their ranges of applicability the methods are applicable also to acoustic materials other than road surfaces.

The measurement results by this method are comparable with the results of the impedance tube method, performed on bore cores taken from the surface such as ISO 10534-1, ISO 10534-2 and ASTM E 1050-19.

The measurement results obtained with this method are in general not comparable with the results of the reverberation room method (ISO 354[1]), because the method described in this International Standard uses a plane progressive wave at normal incidence, while the reverberation room method uses a diffuse sound field.

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

Part 2:
Spot method for reflective surfaces

1 Scope

This document specifies a test method for measuring in situ the sound absorption coefficient of road surfaces for the one-third octave band frequencies ranging from 250 Hz to 1 600 Hz under normal incidence conditions. If necessary for practical applications the diameter of the tube can be reduced to 80 mm. This will increase the upper boundary of the frequency range to 2 000 Hz one-third octave band (see 5.4) but reduces the area under test.

The test method is intended for the following applications:

— determination of the sound absorption coefficient (and, if of interest, also the complex acoustical impedance) of semi-dense to dense road surfaces;

— determination of the sound absorption properties of test tracks according to ISO 10844[2] or other similar standards and test surfaces defined in national and international type approval regulations for road vehicles and their tyres;

— verification of the compliance of the sound absorption coefficient of a road surface with design-specifications or other requirements.

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 10534-2:2023, *Acoustics — Determination of acoustic properties in impedance tubes — Part 2: Two-microphone technique for normal sound absorption coefficient and normal surface impedance*

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

3 Terms and definitions

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

ISO and IEC maintain terminology 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
frequency range
frequency interval in which measurements are valid, specified in one-third octave bands

Note 1 to entry: See IEC 61260 (all parts).

Note 2 to entry: The frequency range is specified in one-third octave bands. This means that its lowest frequency is the lower limit of the lower one-third octave band specified and its highest frequency is the upper limit of the highest one-third octave band specified. A frequency range specified in one-third octave bands of 250 Hz to 1 600 Hz centre frequency implies a frequency range specified in narrow bands of 224 Hz to 1 778 Hz.

3.2
sound absorption coefficient at normal incidence
α
fraction of the sound power of a plane wave at normal incidence on the test object that is absorbed within the test object

3.3
sound pressure reflection factor at normal incidence
r
complex ratio of the pressure of the reflected wave to the pressure of the incident wave at the surface of the test object for a plane wave at normal incidence

3.4
plane of reference
hypothetical plane defined by the underside of the sealing device at which the sound pressure reflection factor and the normal surface impedance is calculated

3.5
cross spectrum
S_{12}
product $p_2 \cdot p_1^*$ determined by the complex sound pressure p_1 and p_2 at two microphone positions 1 and 2

Note 1 to entry: * means the complex conjugate.

3.6
auto spectrum
S_{11}
product $p_1 \cdot p_1^*$ determined by the complex sound pressure p_1 at a microphone position 1

3.7
transfer function
H_{12}
transfer function from microphone position 1 to 2, defined by the complex ratio $p_2/p_1 = (S_{22}/S_{21})$

Note 1 to entry: The transfer function can also be defined as (S_{12}/S_{11}) but applying that definition will lead a slightly higher error when averaged over one-third octave bands (see Reference [7]).

3.8
coherence function
$\gamma^2{}_{12}$
coherence between the signals at positions 1 and 2 defined by $\gamma^2{}_{12} = |S_{12}|^2/(S_{11} \cdot S_{22})$

3.9
normal surface impedance
Z
ratio of the complex sound pressure to the normal component of the complex sound particle velocity in the reference plane

4 Principle of the method

4.1 Measurement principle

The measurement principle is based on a standard impedance tube utilizing a two microphones arrangement (see ISO 10534-2 or ASTM E 1050-19). A sound signal from a loudspeaker located at one end propagates through the tube. The open end of the tube is placed on the surface to be measured without distortion of the surface. The complex acoustic transfer function between two microphone positions at different heights is determined and used to compute the normal-incidence sound absorption coefficient and related quantities.

The procedure enables a single skilled operator to perform such measurements.

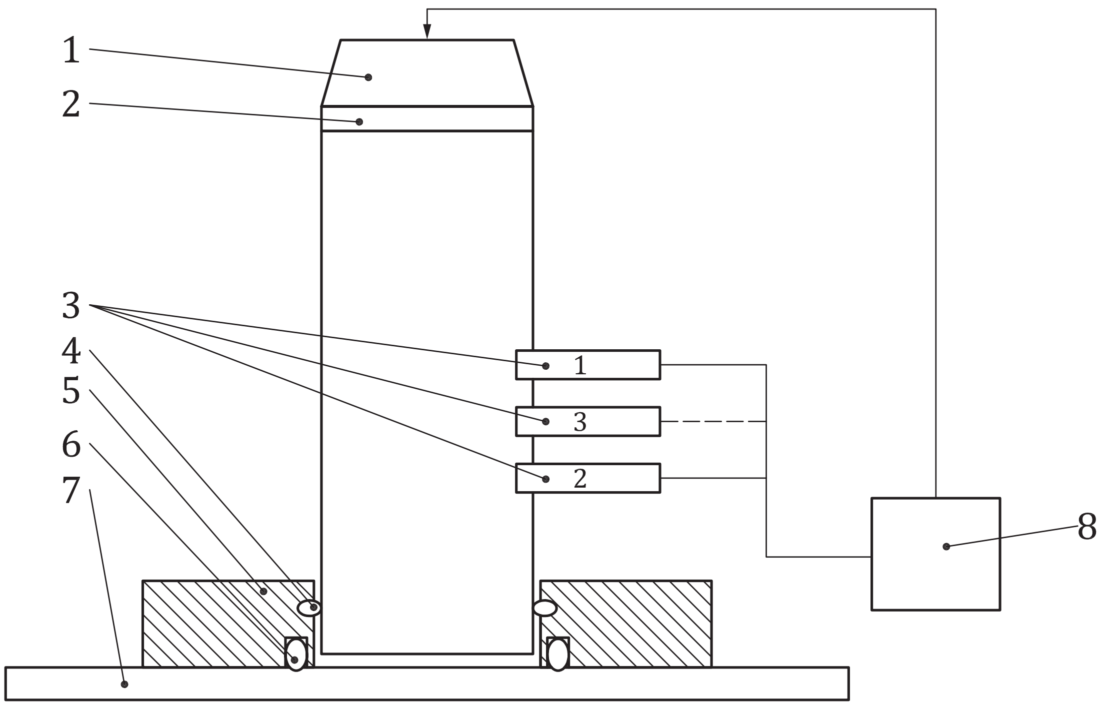
The application of this procedure on reflective surfaces exhibits destructive interferences at the microphone positions at specific frequencies. The occurrence of such destructive interferences jeopardizes the accurate calculation of the transfer function signalled by the loss of coherence between the signals at both microphone positions. The quality loss due to interference is addressed in this document by defining a minimal resolution in the FFT analysis and a minimal number of averages over the auto spectra and cross spectra that are used to calculate the transfer function. The coherence in narrow bands over a one-third octave band is used as a quality criterium.

Annex C describes various methods to improve the coherence.

There is no need for a calibration for microphones as required in typical acoustic measurements, but it does require a specific verification of the microphone pair(s) for amplitude and phase relationship between microphones and the determination of the internal energy loss of the system.

The absorption coefficient covers the one-third octave band frequency range from 250 Hz to 1 600 Hz in case of a 100 mm tube diameter and 250 Hz to 2 000 Hz in case of an 80 mm tube diameter.

The set-up of the system is given in Figure 1.



Key

1 loudspeaker

2 vibration isolation

3 microphone 1
microphone 2
optional microphone 3

4 sealing between tube and in situ device

5 in situ test fixture

6 sealing between fixture and surface under test (see Annex D)

7 surface under test

8 sound source and signal analyser

Figure 1 — Configuration of the measuring device and related equipment

4.2 Signal analysis

The signal processing is described in ISO 10534-2 and ASTM E1050-19[5]. It consists of the measurement of the complex transfer function H_{12} between the pair(s) of microphones 1 and 2 in the presence of the sample under test. The transfer function is used to calculate the complex pressure reflection factor from which the acoustic absorption is derived. The procedure described in ISO 10534-2 and ASTM E1050-19 includes a sub-procedure to calibrate amplitude and phase response of the microphones.

In order to control the error in the test result, primarily caused by the nodes, it is also necessary to determine the coherence between the pair(s) of microphones.

The narrowband coherence values are used as quality criterium. At least 80 % of all narrowband frequencies within a one-third octave band shall have a coherence value of 80 % or higher.

NOTE This criterium is comparable to that stipulated in EN 15461.

In case of application of three microphones (see C.1) the coherence is also used to select the optimal microphone pair

The sound reflection factor, sound absorption coefficient and acoustic impedance is determined according to the procedure defined in ISO 10534-2:2023, 8.7 to 8.10.

For this document preference is given to a transfer function H calculated as the ratio of the auto spectrum S_{22} at the lowest microphone position and the cross spectrum S_{21}; $H = S_{22}/S_{21}$. Although the narrow band error is similar to a calculation based on the conventional $H = S_{12}/S_{11}$ the one-third octave result is averaged over more narrow band results, thus reducing the effect of the narrow band error on the overall one-third octave result.

4.3 In situ fixture

In the present method the test sample holder described in ISO 10534-2 is replaced by an in situ test fixture that enables an airtight connection between the inside of the test tube and the surface of the road under test. The test tube and the fixture can be either integrated into a single piece or it can be connected by a fixing device and an airtight seal such as a rubber O-ring.

At the underside of the in situ test fixture, sealing to the road surface is obtained by a ring of plastic deformable material that creates an airtight sealing of the fixture to the surface texture of the road. Sealing is improved with a small groove made in the fixture (see Annex D).

5 Test equipment

5.1 Components of the test system

The test equipment comprises a signal generator, a sound source, a tube, two or three microphones mounted flush with the inside wall of the tube at the specified positions, an in situ test fixture device to maintain an airtight fit to the surface and a signal processing unit capable of doing complex Fourier transforms (FFT) in two channels simultaneously.

5.2 Sound source

The sound source shall meet the requirements defined in ISO 10534-2. It exhibits the following characteristics:

— be sealed to and vibration-isolated from the tube to minimize structure born sound excitation of the tube;

— have a uniform power response over the frequency range of interest.

5.3 Test signal

The test signal shall be broad band with a uniform spectral density over the frequency range of interest.

A signal generator capable of producing a compatible test signal is often incorporated in a frequency analysis system. When employing alternative signals it is recommended that the time blocks in the frequency analysis be synchronized with repetitions in the test signal pattern.

NOTE A source that generates a periodic random noise signal prevents loss of coherence due to FFT leakage.

5.4 Impedance tube

5.4.1 Tube diameter

The diameter of the tube shall be between 80 mm and 100 mm. A larger diameter than 100 mm jeopardizes measurements at the upper boundary of the highest required one-third octave-band of 1 600 Hz.

In cases of uneven surfaces such that can exist at proving grounds for heavy vehicles, an 80 mm diameter is preferred to obtain satisfactorily sealing between the in situ fixture and the road surface.

NOTE 1 Not meeting the maximal diameter requirement affects the frequency range. The upper frequency f_u at a given diameter is given by Formula (1). See also ISO 10534-2:

$$f_u = 0{,}58 \frac{c_o}{d} \quad (1)$$