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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

Reference number
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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 3.

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 part of ISO 13472 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 13472-1 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

ISO 13472 consists of the following parts, under the general title *Acoustics — Measurement of sound absorption properties of road surfaces* in situ:

— *Part 1: Extended surface method*

Other parts are in preparation.

Annexes A and B form a normative part of this part of ISO 13472. Annexes C, D, E, F and G are for information only.

Introduction

This part of ISO 13472 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 in this part of ISO 13472 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.

To complement this method, a spot method (will be part 2) is under development. 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 (ISO 354), because the method described in this part of ISO 13472 uses a directional sound field, while the reverberation room method assumes a diffuse sound field.

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

Part 1:
Extended surface method

1 Scope

This part of ISO 13472 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 test tracks according to ISO 10844, with limitations, and other similar standards;

— 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 normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 13472. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 13472 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

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 60651, *Electroacoustics — Sound level meters*

IEC 61260, *Electroacoustics — Octave and fractional-octave-band filters*

GUM:1993, *Guide to the expression of uncertainty in measurement*. BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML

3 Terms and definitions

For the purposes of this part of ISO 13472, the following terms and definitions apply.

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)

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 This quantity is necessary in order to understand the correction procedure described in annex B. 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 must remain free of reflecting objects causing parasitic reflections (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, in decibels, between the level of the nominal useful signal and the level of the background noise at the moment of detection of the useful event

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

NOTE 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

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 $H_\text{i}(f)$ and of the reflected path $H_\text{r}(f)$ are obtained. The ratio of the squared modulus of these transfer functions gives the sound power reflection factor $Q_W(f)$ from which the sound absorption coefficient can be calculated (see clause 3), apart from a factor K_r due to geometrical spreading.

Taking into account also this factor K_r due to geometrical spreading, the sound absorption coefficient is computed as:

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

where

$$K_\text{r} = \frac{d_\text{s} - d_\text{m}}{d_\text{s} + d_\text{m}}$$

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.

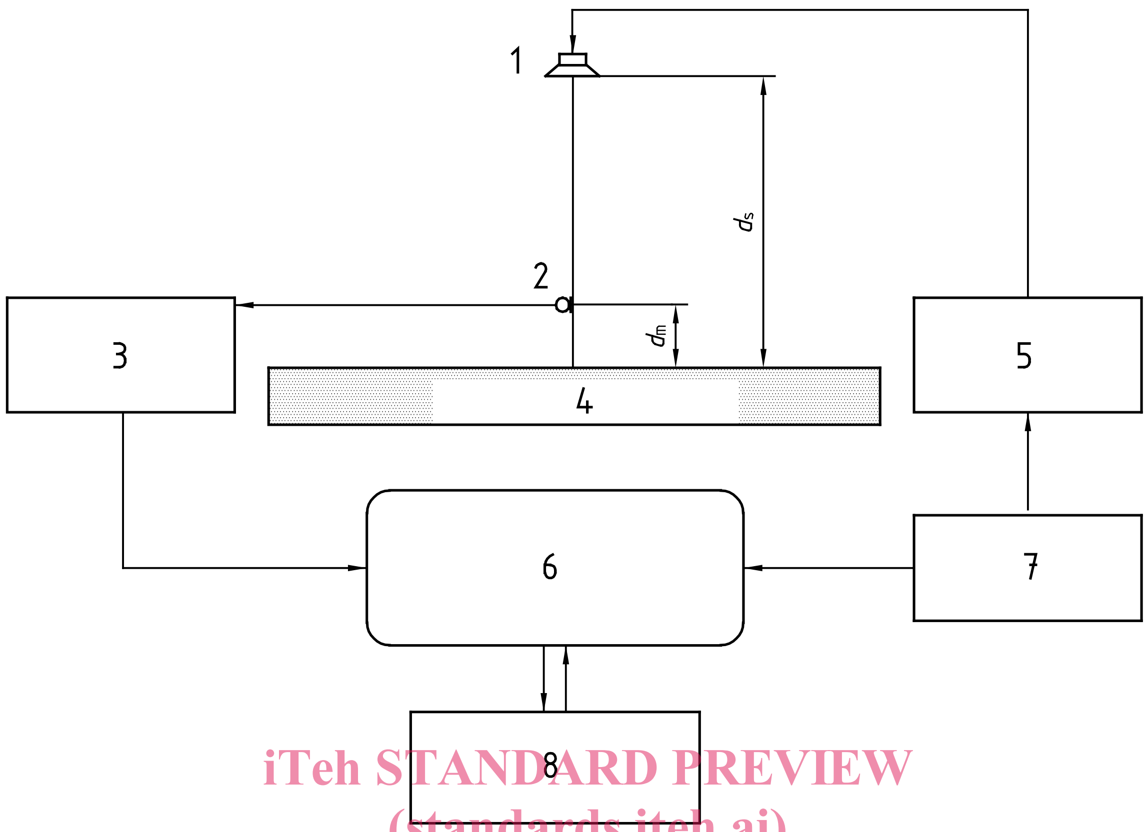
NOTE The complex reflection factor, necessary for propagation calculations or comparison of measurement results with theoretical calculations can be found as follows:

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

with $\Delta\tau$ the time difference between arrival of the direct and the reflected impulses.

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 as being absorbed. Thus, the sound absorption coefficient may be slightly overestimated.



Key

1 Sound source
2 Microphone
3 Microphone amplifier
4 Surface under test
5 Loudspeaker amplifier
6 Impulse response time windows and Fourier transform
7 Signal generation
8 Analyser or computer

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

4.2 Signal separation techniques

This part of ISO 13472 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 impulse response consists of a direct path component, a reflected path component coming from the surface under test and other parasitic components [see Figure 3 a)]. The separation of those different components can be achieved in two different ways.

a) Temporal separation: if geometry is arranged such that a sufficient time delay exists between the arrival of the direct and reflected time signals, the relevant components can be extracted from the overall impulse response by application of time windows. Figure 2 shows a simple time separation technique for the case where the geometry is arranged such that the reflected component occurs after the direct one has decayed to zero.

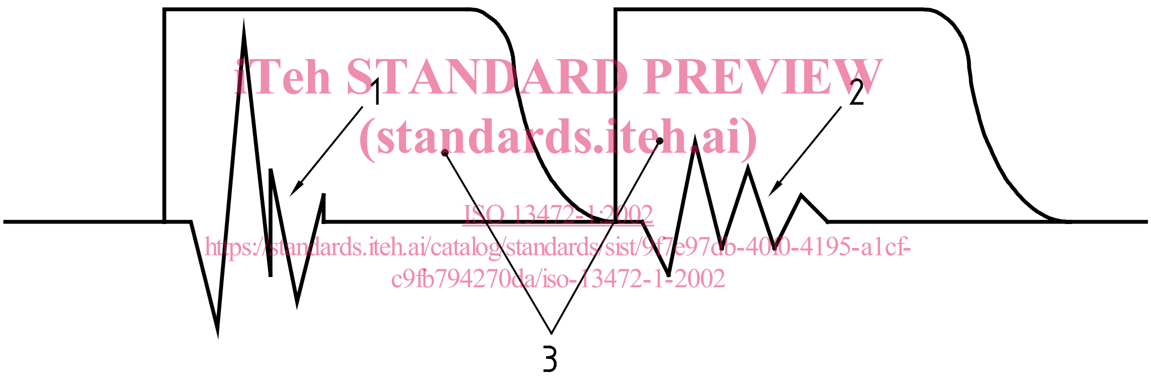
b) Signal subtraction technique: the impulse response of the direct path is not extracted from the overall impulse response; instead, it is removed from the overall impulse response by subtraction of an identical signal (see Figure 3).

The subtraction technique is preferred over temporal separation because it allows a longer sampling interval (necessary for low-frequency measurements) within a certain geometrical size of the system. 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. Therefore in this part of ISO 13472 the subtraction technique is required.

The distance d_{m} between the microphone and the plane of reference for the surface under test can be relatively small. For source and microphone distances from the plane of reference for the road surface, this part of ISO 13472 requires the following values: $d_{\mathrm{s}} = 1{,}25$ m and $d_{\mathrm{m}} = 0{,}25$ m (see Figure 1). These distances shall be kept constant during the averaging process ($\pm$ 0,005 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 for (see annex G).

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 (less than 10 min).



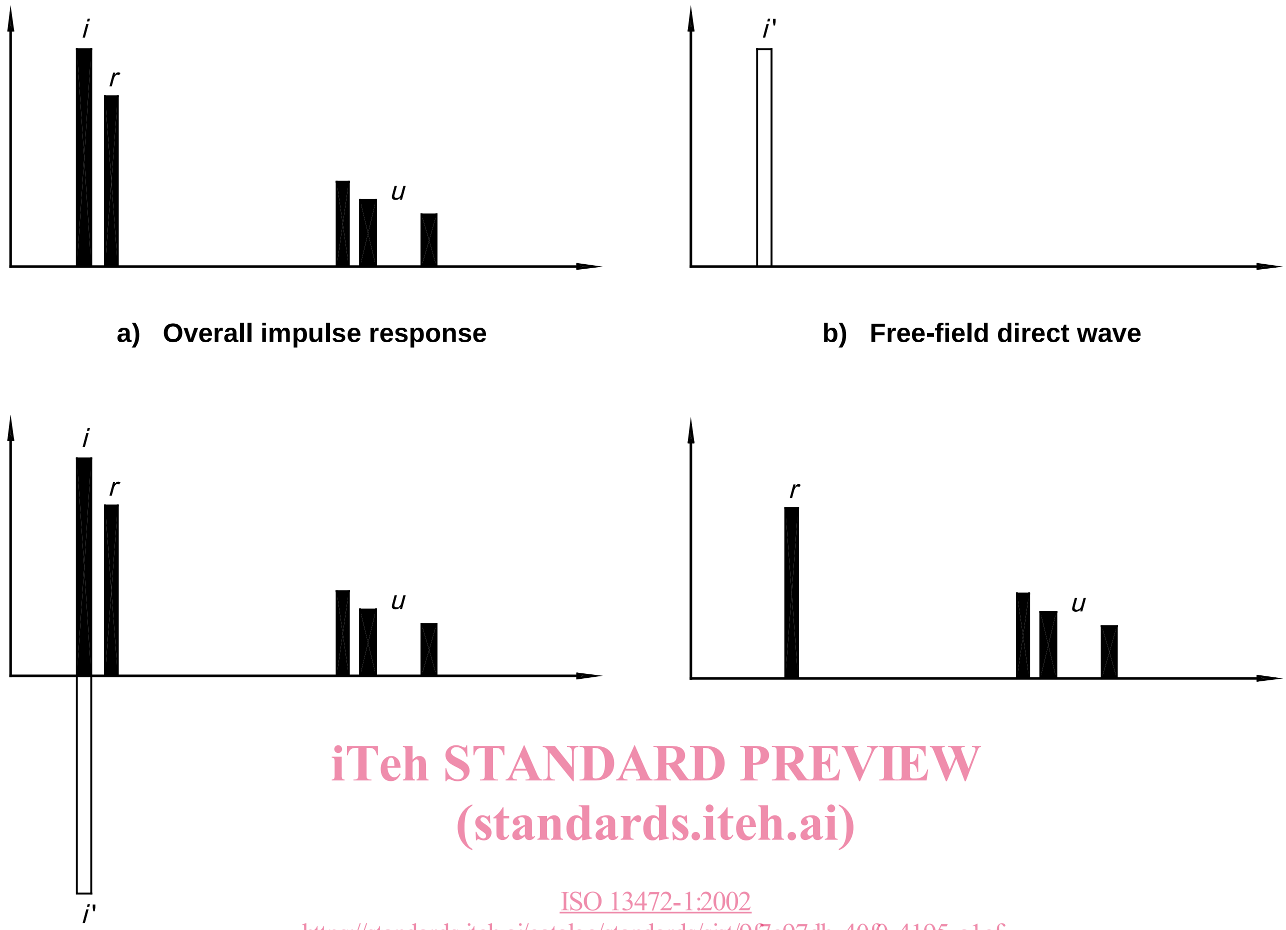
Key

1 Direct component

2 Reflected component

3 Time window ($T_{\mathrm{w,direct}} = T_{\mathrm{w,reflected}}$)

Figure 2 — Example of separation of the impulse response of the direct and the reflected path using time windows



a) Overall impulse response

b) Free-field direct wave

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

d) Result

i is the direct incident wave

r is the reflected wave

u is unwanted parasitic reflections

i' is the free-field direct wave

Figure 3 — Principle of the signal subtraction technique

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, it is recommended that at least 50 impulse responses be acquired and averaged.

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).