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Akustika v stavbah - Ocenjevanje akustiļ nih lastnosti stavb iz lastnosti sestavnih delov - 6. del: Absorpcija zvoka v zaprtih prostorih

Building acoustics - Estimation of acoustic performance of buildings from the performance of elements - Part 6: Sound absorption in enclosed spaces

Bauakustik - Berechnung der akustischen Eigenschaften von Gebäuden aus den Bauteileigenschaften - Teil 6: Schallabsorption in Räumen

Acoustique du bâtiment - Calcul de la performance acoustique des bâtiments a partir de la performance des éléments - Partie 6: Absorption acoustique des pieces et espaces fermés

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Foreword

This document (EN 12354-6:2003) has been prepared by Technical Committee CEN/TC 126 “Acoustic properties of building products and of buildings”, the secretariat of which is held by AFNOR.

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of an identical text or by endorsement, at the latest by June 2004, and conflicting national standards shall be withdrawn at the latest by June 2004.

This document is the first version of a standard which forms a part of a series of standards specifying calculation models in building acoustics:

— *Part 1: Airborne sound insulation between rooms*

— *Part 2: Impact sound insulation between rooms*

— *Part 3: Airborne sound insulation against outdoor sound*

— *Part 4: Transmission of indoor sound to the outside*

— *Part 5: Sound levels due to service equipment*

— *Part 6: Sound absorption in enclosed spaces*

Although this part covers the most common types of enclosed spaces in buildings it cannot yet cover all variations of such spaces. It sets out an approach for gaining experience for future improvements and developments of the standard.

The accuracy of this standard cannot be specified in detail until wide ranging comparisons with field data have been made, which can, in turn, only be gathered over a period of use of the prediction model. To help the user in the meantime, indications of the accuracy have been given, based on earlier comparable prediction models. It is the responsibility of the user (i.e. a person, an organisation, the authorities) to consider the consequences of the accuracy, inherent in all measurement and prediction methods, to specify requirements for input data and/or apply a safety margin to the results or to apply some other correction.

Annex A is normative, annexes B, C, D and E are informative.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This European Standard describes a calculation model to estimate the total equivalent sound absorption area or reverberation time of enclosed spaces in buildings. The calculation is primarily based on measured data that characterise the sound absorption of materials and objects. Calculations can only be carried out for frequency bands.

This European Standard describes the principles of the calculation model, lists the relevant quantities and defines its applications and restrictions. It is intended for acoustical experts and provides the framework for the development of application documents and tools for other users in the field of building construction, taking into account local circumstances.

The model is based on experience with predictions for rooms, such as rooms in dwellings and offices, and common spaces in buildings, such as stairwells, corridors and rooms containing machinery and technical equipment. It is not intended to be used for very large or irregularly-shaped spaces, such as concert halls, theatres and factories.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN ISO 354, *Acoustics - Measurement of sound absorption in a reverberation room (ISO 354:2003).*

ISO 9613-1, *Acoustics - Attenuation of sound during propagation outdoors - Part 1: Calculation of the absorption of sound by the atmosphere.*

3 Relevant quantities

3.1 Building performance

3.1.1
quantities to express building performance
sound absorption in enclosed spaces can be expressed in terms of the equivalent absorption area or the reverberation time in accordance with prEN ISO 3382-2. These quantities are determined in frequency bands (one-third octave bands or octave bands)

3.1.2
equivalent sound absorption area of a room A
hypothetical area of a totally absorbing surface without diffraction effects which, if it were the only absorbing element in the room, would give the same reverberation time as the room under consideration

NOTE Equivalent sound absorption area of a room is expressed in m^2.

3.1.3
reverberation time T
time required for the sound pressure level to decrease by 60 dB after the sound source has stopped

NOTE 1 Reverberation time is expressed in s.

NOTE 2 The definition of T with a decrease by 60 dB of the sound pressure level may be fulfilled by linear extrapolation of a shorter evaluation range.

NOTE 3 Where a decay curve is not monotonic the reverberation time is defined by the times at which the decay curve first reaches 5 dB and 25 dB below the initial level, respectively. In the case of uncertainty this reverberation time should be labelled T_{20}.

3.2 Element performance

3.2.1
quantities to express element performance
sound absorption of elements in accordance with EN ISO 354 can be expressed as the equivalent sound absorption area or the sound absorption coefficient. These quantities are determined in one-third octave bands and can also be expressed in octave bands

NOTE Also a single number rating for the element performance can be obtained from the frequency band data in accordance with EN ISO 11654 [7], for instance α_w(M). Such single number ratings may be used for comparing or specifying the required performance of products, but they cannot be used directly to calculate the performance in situ.

3.2.2
equivalent sound absorption area of an object A_{obj}
difference between the equivalent sound absorption area with and without the object (test specimen) in the test room

NOTE Equivalent sound absorption area of an object is expressed in m^2.

3.2.3
sound absorption coefficient α_s
equivalent sound absorption area of a test specimen divided by the area of the test specimen

NOTE 1 For plane absorbers with both sides exposed, this relates to each side as an average value over both sides.

NOTE 2 This quantity applies only to a flat absorber or a specified array of objects, and not to single objects.

3.2.4
other relevant data
for calculations additional information may be necessary, e.g.:

- area of the room boundary elements;
- volume and shape of the enclosed space;
- amount and nature of objects and fittings in the enclosed space;
- number of people assumed to be present in the room

3.3 Other terms and quantities

3.3.1
absorption by air A_{air}
equivalent absorption area of the sound attenuation by air

3.3.2
empty room volume V
volume of the enclosed space without the objects and fittings present

3.3.3
object volume V_{obj}
volume of the smallest regular shaped envelope for an object, ignoring small elements that protrude through that envelope

NOTE An example of small protruding elements which can be ignored, are the legs of a table.

3.3.4
object fraction Ψ
ratio of the sum of the volumes of all objects to the volume of the empty space

3.3.5
object array
specific array of objects for which the absorption is expressed by a sound absorption coefficient α_s related to the surface area covered by the array.

4 Calculation models

4.1 General principles

For the calculation of the equivalent sound absorption area and reverberation time in enclosed spaces it is assumed that the sound field is diffused. This means that the dimensions of the enclosed space are similar (see 4.6) and the absorption is distributed over the space; the presence of sound scattering objects relaxes these restrictions. The effect of absorption by surfaces, by objects - including persons -, by object arrays and by air is taken into account.

NOTE 1 For other situations, such as irregularly shaped spaces and irregular absorption distribution, guidance for improved calculation models is given in annex D. In irregularly shaped spaces, such as stairwells or rooms filled with machinery, it is assumed that the sound pressure level and hence absorption better characterises the performance than reverberation time.

The model can be used to calculate the building performance in frequency bands, based on acoustic data for the elements in frequency bands. The calculation is normally performed in octave bands in the frequency range from 125 Hz to 4 000 Hz.

NOTE 2 The calculations can be extended to higher or lower frequencies. However, particularly for the lower frequencies no information is available at present on the accuracy of calculations for these extended frequency regions.

A list of symbols used in the models is given in annex A.

4.2 Input data

The equivalent absorption area and the reverberation time can be determined from:

— absorption coefficient of surface i: $\alpha_{s,i}$;

— area of surface i: S_i;

— equivalent absorption area of object j: $A_{obj,j}$;

— absorption coefficient of object array k: $\alpha_{s,k}$;

— area of surface covered by the object array k: S_k;

— volume of empty enclosed space: V;

— volume of object j or object array k: $V_{obj,j}$, $V_{obj,k}$.

The acoustic data on the materials, objects and object configurations involved should be taken primarily from standardized laboratory measurements in accordance with EN ISO 354. However, they may also be deduced in other ways, using theoretical calculations, empirical estimations or field measurement results. Data sources used shall be clearly stated.

The input data for calculations in octave bands can be taken as the arithmetic mean value of the corresponding one-third octave band values.

NOTE Using the arithmetic mean value of one-third octave band values as input for calculations in octave bands can be inaccurate for absorbers other than broad band absorbers.

Information on the sound absorption by some materials and surface treatments is given in annex B.

Information on the sound absorption by some typical objects is given in annex C.

4.3 Determination of the total equivalent absorption area

The total equivalent sound absorption area for an enclosed space follows from:

$$A = \sum_{i=1}^{n} \alpha_{s,i} \, S_i + \sum_{j=1}^{o} A_{obj,j} + \sum_{k=1}^{p} \alpha_{s,k} \, S_k + A_{air} \tag{1}$$

where

n is the number of surfaces i;

o is the number of objects j;

p is the number of object arrays k.

The equivalent absorption area for air absorption follows from:

$$A_{air} = 4 \, m \, V \, (1 - \Psi) \tag{2}$$

where

m is the power attenuation coefficient in air, in Neper per metre;

V is the volume of the empty enclosed space, in cubic metres;

Ψ is the object fraction.

The object fraction follows from:

$$\Psi = \frac{\sum_{j=1}^{o} V_{obj,j} + \sum_{k=1}^{p} V_{obj,k}}{V} \tag{3}$$

The attenuation of sound by transmission through air is specified in ISO 9613-1 as a function of temperature, humidity and frequency. For sound transmission in rooms the relevant values determined in accordance with that standard for common conditions are given in Table 1. If other specific conditions apply, the values for the power attenuation coefficient shall be determined in accordance with ISO 9613-1. If no conditions are specified it is recommended that the values for 20 °C and 50 % - 70 % humidity are used.

If the calculations are restricted to the 1 000 Hz octave band as the highest frequency and to rooms with volumes less than 200 m^3, the absorption by air can be neglected and equation (1) shall be used with $A_{air} = 0\ m^2$.

For hard, irregularly shaped objects such as machinery, storage cupboards or office furniture the equivalent absorption area may be important, but will not normally be available from measurements. For the purpose of this standard the equivalent absorption area of such a hard object can be estimated from its volume by:

$$A_{obj} = V_{obj}^{2/3} \qquad (4)$$

where

V_{obj} is the volume of the hard objects.

NOTE This is an empirical equation used to obtain reliable results for spaces containing a relatively large number of objects as may be found in rooms containing technical equipment.

4.4 Determination of reverberation time

The reverberation time is determined from the total equivalent sound absorption area, as calculated by 4.3, the volume of the empty enclosed space and the object fraction:

$$T = \frac{55{,}3}{c_o} \frac{V(1-\Psi)}{A} \qquad (5)$$

where

c_o is the speed of sound in air, in metres per second.

NOTE For the ratio $55{,}3/c_o$ to be 0,16 as assumed in EN ISO 140-4 [8] the speed of sound has to be taken as 345,6 m/s.

Table 1 — Power attenuation coefficient in air *m* in octave bands, depending on temperature and humidity

	m in 10^{-3} Neper per metre, for octave bands with centre frequency in Hz						
	125	250	500	1k	2k	4k	8k
10 °C, 30 % - 50 % humidity	0,1	0,2	0,5	1,1	2,7	9,4	29,0
10 °C, 50 % - 70 % humidity	0,1	0,2	0,5	0,8	1,8	5,9	21,1
10 °C, 70 % - 90 % humidity	0,1	0,2	0,5	0,7	1,4	4,4	15,8
20 °C, 30 % - 50 % humidity	0,1	0,3	0,6	1,0	1,9	5,8	20,3
20 °C, 50 % - 70 % humidity	0,1	0,3	0,6	1,0	1,7	4,1	13,5
20 °C, 70 % - 90 % humidity	0,1	0,3	0,6	1,1	1,7	3,5	10,6
NOTE These values are deduced from the Tables with the atmospheric-absorption attenuation coefficient in decibels per kilometre in ISO 9613-1 for 1/3 octave bands, by dividing the values in those Tables by 4,343 (=10 lg e). The values for the octave bands are those for the centre 1/3 octave band below 1 kHz and those for the lower 1/3 octave band above 1 kHz. The values are linearly averaged over the humidity within the indicated range.							

4.5 Interpretations

— the model is applicable to regularly shaped rooms in buildings with a reasonable distribution of absorbing material and some scattering of objects, both hard or absorbing, such as would be found in normal rooms in dwellings and offices. In such rooms, the absorption by air can be neglected and the volume fraction will typically be $\Psi < 0{,}05$ for empty rooms and $0{,}05 \leq \Psi \leq 0{,}2$ for furnished rooms;

— in rooms containing technical equipment or machinery, the volume fraction occupied by objects, even hard objects, can be quite important as can the air absorption. However, if the volume fraction is very large the free space can probably not be considered as a single space and thus the model may not be valid; see annex D;

— hard objects or object arrays are only of importance if their dimensions are larger than the wavelength, so objects with dimensions of less than 1 m can normally be neglected;

— in common spaces in buildings such as a stairwell or an entrance hall, the dimensions are such that the estimation of the reverberation time will be less reliable. In such spaces it may be appropriate for any requirements to specify the amount of absorption rather than the reverberation time.

4.6 Limitations

The calculation model for the equivalent absorption area is by definition independent of the type of enclosed space, though the relationship with the resulting sound pressure levels will depend on the type and shape of the enclosed space.

The calculation model for the reverberation time is restricted to enclosed spaces with:

— regular shaped volumes: no dimension should be more than 5 times any other dimension;

— evenly distributed absorption: absorption coefficient should not vary by more than a factor of 3 between pairs of opposite surfaces, unless some sound scattering objects are present;

— not too many objects: the object fraction should be less than 0,2.

If these assumptions are not met, the reverberation time can often be longer than estimated. Indications on how to determine the reverberation time in such situations are given in annex D.