SLOVENSKI STANDARD
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Akustika v stavbah - Ocenjevanje akustiļ nih lastnosti stavb iz lastnosti sestavnih delov - 3. del: Izolirnost pred zvokom v zraku iz zunanjosti

Building acoustics - Estimation of acoustic performance of buildings from the performance of elements - Part 3: Airborne sound insulation against outdoor sound

Bauakustik - Berechnung der akustischen Eigenschaften von Gebäuden aus den Bauteileigenschaften - Teil 3: Luftschalldämmung von Außenbauteilen gegen Außenlärm

Acoustique du bâtiment - Calcul de la performance acoustique des bâtiments a partir de la performance des éléments - Partie 3: Isolement aux bruits aériens venus de l'extérieur

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This European Standard was approved by CEN on 22 January 2000.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
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Foreword

This European Standard 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of an identical text or by endorsement, at the latest by September 2000, and conflicting national standards shall be withdrawn at the latest by September 2000.

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

- Part 1: *Building acoustics – Estimation of acoustic performance of buildings from the performance of elements – Part 1 : Airborne sound insulation between rooms.*

- Part 2: *Building acoustics – Estimation of acoustic performance of buildings from the performance of elements – Part 2 : Impact sound insulation between rooms.*

- Part 3: *Building acoustics – Estimation of acoustic performance of buildings from the performance of elements – Part 3 : Airborne sound insulation against outdoor sound.*

- Part 4: *Building acoustics – Estimation of acoustic performance of buildings from the performance of elements – Part 4 : Transmission of indoor sound to the outside.*

- Part 5: *Building acoustics – Estimation of acoustic performance of buildings from the performance of elements – Part 5 : Noise from technical installations and equipment.*

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

The accuracy of this standard can only be specified in detail after widespread comparisons with field data, which can only be gathered over a period of time after establishing the prediction model. To help the user in the mean time, indications of the accuracy have been given, based on earlier comparisons with comparable prediction models. It is the responsibility of the user (i.e. a person, an organisation, the authorities) to address the consequences of the accuracy, inherent for all measurement and prediction methods, by specifying requirements for the input data and/or applying a safety margin to the results or applying some other correction.

Annex A (normative) forms an integral part of this part of EN 12354, Annexes B, C, D, E and F 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, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This European Standard specifies a calculation model to estimate the sound insulation or the sound pressure level difference of a façade or other external surface of a building. The calculation is based on the sound reduction index of the different elements from which the façade is constructed and it includes direct and flanking transmission. The calculation gives results which correspond approximately to the results from field measurements according to EN ISO 140-5. Calculations can be carried out for frequency bands or for single number ratings.

The calculation results can be used also for calculating the indoor sound pressure level due to for instance road traffic ; this use is treated in the informative annex D.

This document 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 dwellings ; it can also be used for other types of buildings provided the dimensions of constructions are not too different from those in dwellings.

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).

prEN 12354-1:1999, *Building acoustics - Estimation of acoustic performance of buildings from the performance of elements - Part 1 : Airborne sound insulation between rooms.*

EN 20140-10, *Acoustics - Measurement of sound insulation in buildings and of building elements - Part 10 : Laboratory measurement of airborne sound insulation of small building elements (ISO 140-10:1991).*

EN ISO 140-1, *Acoustics - Measurement of sound insulation in buildings and of building elements - Part 1 : Requirements for laboratory test facilities with suppressed flanking transmission (ISO 140-1:1997).*

EN ISO 140-3, *Acoustics - Measurement of sound insulation in buildings and of building elements - Part 3 : Laboratory measurements of airborne sound insulation of building elements (ISO 140-3:1995).*

EN ISO 140-5, *Acoustics - Measurement of sound insulation in buildings and of building elements - Part 5 : Field measurements of airborne sound insulation of façade elements and façades (ISO 140-5:1998).*

EN ISO 717-1, *Acoustics - Rating of sound insulation in buildings and of building elements - Part 1 : Airborne sound insulation (ISO 717-1:1996).*

EN ISO 11654, *Acoustics – Sound absorbers for use in buildings - Rating of sound absorption* (ISO 11654:1997).

3 Relevant quantities

3.1 Quantities to express building performance

The sound insulation of façades in accordance with EN ISO 140-5 can be expressed in several quantities. These quantities are determined in frequency bands (one-third octave bands or octave bands) from which the single number rating for the building performance can be obtained in accordance with EN ISO 717-1, for instance R'_w, $D_{ls,2m,nT,w}$ or ($R'_w + C_{tr}$).

3.1.1 Apparent sound reduction index $R'_{45°}$

Airborne sound insulation of a building element when the sound source is a loudspeaker and the angle of incidence is 45°. This apparent sound reduction index is evaluated from :

$$R'_{45°} = L_{1,s} - L_2 + 10 \lg \frac{S}{A} - 1{,}5 \text{ dB} \tag{1}$$

where

- $L_{1,s}$ is the average sound pressure level on the outside surface of the building element including the reflecting effects from the façade, in decibels ;
- L_2 is the average sound pressure level in the receiving room, in decibels ;
- S is the area of the building element, in square metres ;
- A is the equivalent sound absorption area in the receiving room, in square metres.

3.1.2 Apparent sound reduction index $R'_{tr,s}$

Airborne sound insulation of a building element when the sound source is traffic noise. This apparent sound reduction index is evaluated from :

$$R'_{tr,s} = L_{eq,1,s} - L_{eq,2} + 10 \lg \frac{S}{A} - 3 \text{ dB} \tag{2}$$

where

- $L_{eq,1,s}$ is the average equivalent sound pressure level on the outside surface of the building element including the reflecting effects from the façade, in decibels ;
- $L_{eq,2}$ is the average equivalent sound pressure level in the receiving room, in decibels.

3.1.3 Standardized level difference $D_{2m,nT}$

The difference between the outdoor sound pressure level at 2 m in front of the façade and the sound pressure level in the receiving room, corresponding to a reference value of the reverberation time. The standardized level difference is evaluated from :

$$D_{2m,nT} = L_{1,2m} - L_2 + 10 \lg \frac{T}{T_0} \text{ dB} \tag{3}$$

where

- $L_{1,2m}$ is the average sound pressure level at 2 m in front of the façade, in decibels ;

T is the reverberation time in the receiving room, in seconds ;

L_2 is the average sound pressure level in the receiving room, in decibels ;

T_0 is the reference reverberation time, in seconds; for dwellings given as 0,5 s.

The standardized level difference can be determined either with the prevailing traffic noise or with noise from a loudspeaker. This is indicated by adding the subscript tr' and ls' respectively, i.e. $D_{tr,2m,nT}$ or $D_{ls,2m,nT}$.

3.1.4 Normalized level difference $D_{2m,n}$

The difference between the outdoor sound pressure level at 2 m in front of the façade and the sound pressure level in the receiving room, corresponding to a reference value of absorption area. The normalized level difference is evaluated from :

$$D_{2m,n} = L_{1,2m} - L_2 - 10 \lg \frac{A}{A_0} \text{ dB} \tag{4}$$

where

A_0 is the reference equivalent sound absorption area, in square metres ; for dwellings given as 10 m².

The normalized level difference can be determined either with the prevailing traffic noise or with noise from a loudspeaker. This is indicated by adding the subscript 'tr' and 'ls' respectively, i.e $D_{tr,2m,n}$ or $D_{ls,2m,n}$.

3.1.5 Relations between quantities

The two **sound reduction indices**, $R'_{45°}$ and $R'_{tr,s}$, tend to give results with a systematic difference over a large frequency range. The apparent sound reduction index $R'_{45°}$, both for the single number rating and for the lower frequencies, gives results which are 0 dB to 2 dB higher than the results for $R'_{tr,s}$. $R'_{tr,s}$ gives values which are comparable to those measured under laboratory conditions. These differences will be taken into account in the calculation model.

The two **sound level differences**, $D_{2m,nT}$ and $D_{2m,n}$, are directly related to each other :

$$D_{2m,n} = D_{2m,nT} - 10 \lg \; 0{,}16 \frac{V}{T_0 A_0} = D_{2m,nT} - 10 \lg 0{,}32\, V \text{ dB} \tag{5}$$

where

V is the volume of the receiving room, in cubic metres.

It is therefore sufficient to estimate one of these quantities in order to deduce the other. As far as the level differences are concerned the standardized level difference $D_{2m,nT}$ is chosen in this document as the prime quantity to be estimated.

The measurements with traffic noise or a loudspeaker as noise source tend to give results which are equal without a systematic difference. So :

$$D_{tr,2m,nT} \approx D_{ls,2m,nT} \text{ dB} \tag{6}$$

The sound level difference of a façade is related to the sound reduction index. The model for the sound level difference therefore is linked to the model for the sound reduction index.

3.2 Quantities to express element performance

The quantities expressing the performance of elements are used as part of the input data to estimate building performance. These quantities are determined in one-third octave bands and can be expressed in octave bands as well. In relevant cases a single number rating for the element performance can be obtained from this, in accordance with EN ISO 717-1, for instance $R_w(C;C_{tr})$ and $D_{n,e,w}(C;C_{tr})$.

3.2.1 Sound reduction index R

Ten times the common logarithm of the ratio of the sound power W_1, incident on a test specimen to the sound power W_2 transmitted through the specimen :

$$R = 10 \lg \frac{W_1}{W_2} \text{ dB} \tag{7}$$

This quantity is to be determined in accordance with EN ISO 140-3.

3.2.2 Element normalized level difference $D_{n,e}$

The difference in the space and time average sound pressure level produced in two rooms by a source in one room, where sound transmission is only due to a small building element (e.g. transfer air devices). $D_{n,e}$ is normalized to an equivalent sound absorption area (A_o) in the receiving room; A_o=10 m².

$$D_{n,e} = L_1 - L_2 - 10 \lg \frac{A}{A_0} \text{ dB} \tag{8}$$

This quantity is to be determined in accordance with EN 20140-10.

3.2.3 Other relevant data

For the calculations additional information on constructions could be necessary, e.g.:

— the shape of the façade ;

— sealing type and quality for gaps and connections ;

— total façade area.

3.3 Other terms and quantities

Sound reduction index of façade for diffuse incident sound field R'

Sound reduction index of the façade as it hypothetically can be measured with a diffuse incident sound field in the actual field situation. This quantity is used as a common calculation quantity from which the various quantities for the building performance can be obtained.

NOTE In some countries the building performance is not expressed in one of the measurable quantities, but in this quantity R'.

Façade shape level difference ΔL_{fs}

Difference of the sound level of the incident sound, $L_{1,in}$, on a shaped façade and the sound level on the surface of the façade plane, $L_{1,s}$, plus 6 dB. This quantity can be determined according to :

$$\Delta L_{fs} = L_{1,in} - L_{1,s} + 6 \text{ dB} \tag{9}$$

where

$L_{1,in}$ is the average sound pressure level at the position of the façade plane, without the façade being present, in decibels ;

$L_{1,s}$ is the average sound pressure level on the outside surface of the actual façade plane, in decibels.

NOTE Information on the façade shape level difference and the method to determine its values is given in annex C.

4 Calculation models

4.1 General principles

By façade is understood the whole outer surface of a room. The façade can consist of different elements, e.g. window, door, wall, roof, ventilation equipment ; the sound transmission through the façade is due to the sound transmission by each of these elements. It is assumed that the transmission for each element is independent from the transmission of the other elements. The different types of exterior sound fields used in the various measurement situations defined for the determination of the quantities to express the building performance lead to different values. However, it is a reasonably proven assumption that the transmission for a diffuse incident sound field is sufficiently representative for these varying types of exterior sound fields. Therefore the apparent sound reduction index of the façade for diffuse incident sound is calculated, from which all other quantities are deduced.

The apparent sound reduction index *R*' of the façade for diffuse incident sound is calculated by adding the sound power directly transmitted by each of the elements and the sound power transmitted by flanking transmission.

$$R' = -10 \lg \left(\sum_{i=1}^{n} \tau_{e,i} + \sum_{f=1}^{m} \tau_f \right) \text{dB} \qquad (10)$$

where

$\tau_{e,i}$ is the sound power ratio of radiated sound power by a façade element i due to direct transmission of incident sound on this element, relative to incident sound power on the total façade ;

τ_f is the sound power ratio of radiated sound power by a façade or flanking element f in the receiving room due to flanking transmission, relative to incident sound power on the total façade ;

n is the number of façade elements for direct transmission ;

m is the number of flanking façade elements.

NOTE 1 The sound power ratio τ_e indicates directly the contribution of the element to the total sound transmission; for this purpose $R_p = -10 \lg \tau_e$ could be designated as the partial sound reduction index.

NOTE 2 For direct transmission only, equation (14) and equation (15) could be integrated in equation (10), resulting in the often used expression for the sound reduction index of composed elements.

For direct transmission the sound power ratio τ_e can be determined for each façade element directly from the acoustic data on that element, including the contribution of each composing part ; see 4.2. Alternatively this sound power ratio for one or more elements could be estimated from acoustic data on each of the composing parts of that element ; see annex B. The choice depends on regulations and the available acoustic data.

For flanking transmission the sound power ratio τ_f can be determined according to 4.3.

The apparent sound reduction index of the façade is determined from :

$$R'_{45°} = R' + 1 \text{ dB} \qquad (11)$$

$$R'_{tr,s} = R' \text{ dB} \qquad (12)$$

NOTE 3 These equations represent the average relation between the quantities. For the single number rating the variation around the average is typically ± 1 dB. For frequency bands the spread is typically ± 2 dB for façades composed from various elements. However, in special cases, e.g. where the transmission is completely dominated by single glass panes, the difference between the two quantities at frequencies around and above the coincidence frequency is less systematic and can be much larger.

The standardized level difference of a façade depends on the sound reduction index of the façade as seen from the inside, the influence of the outside shape of the façade, like balconies, and the room dimensions. It follows from :

$$D_{2m,nT} = R' + \Delta L_{fs} + 10 \lg \frac{V}{6\, T_0 S} \text{ dB} \tag{13}$$

where

V is the volume of the receiving room, in cubic metres ;

S is the total area of the façade as seen from the inside (i.e. the sum of the area of all façade elements), in square metres ;

ΔL_{fs} is the level difference due to façade shape, in decibels.

NOTE 4 The standardized level difference can be used to estimate the sound pressure level inside; see annex E.

Information on the level difference due to the façade shape is given in annex C.

The model can be used to calculate the building performance in frequency bands, based on acoustic data for the building elements in frequency bands (one-third octave bands or octave bands). The calculation is to be performed at least for the octave bands from 125 Hz to 2 000 Hz or for the one-third octave bands from 100 Hz to 3 150 Hz. From these results the single number rating for the building performance can be deduced in accordance with EN ISO 717-1.

NOTE 5 The calculations can be extended to higher or lower frequencies if acoustic data are available for such a larger frequency range. However, especially for the lower frequencies no information is currently available on the accuracy of calculations for these frequency bands.

The model can also be used to calculate directly the single number rating for the building performance, based on the single number ratings of the elements involved. It concerns the weighting in accordance with EN ISO 717-1. The resulting estimate of the building performance is given in the same type of single number rating as is used for the building elements, i.e. using R_w and $D_{n,e,w}$ for elements results in $R'_{45°,w}$ for the façade; using $(R_w + C_{tr})$ and $(D_{n,e,w} + C_{tr})$ for elements results in $(D_{2m,nT,w} + C_{tr})$ for the façade. These spectrum adaptation terms refer to the frequency range covered by the octave bands from 125 Hz to 2 000 Hz or the one-third octave bands from 100 Hz to 3150 Hz. If a larger frequency range is to be considered the appropriate spectrum adaptation term for such a larger frequency range should be used.

NOTE 6 For convenience the sums with the spectrum adaptation term for buildings can be denoted by one symbol, for instance $R'_w + C_{tr} = R'_{Atr}$ and $D_{2m,nT,w} + C_{tr} = D_{2m,nT,Atr}$.

NOTE 7 The energetic summation involved in the model is exact for $(R_w + C_{tr})$ and a reasonable approximation for R_w.

4.2 Determination of direct transmission from acoustic data on elements

All elements of the façade shall be included in the calculation. The sound power ratio is calculated according to the following, where the distinction between small and other elements is in accordance with EN 20140-10.

4.2.1 Small elements

$$\tau_{e,i} = \frac{A_0}{S} 10^{-D_{n,e,i}/10} \tag{14}$$

$A_0 = 10 \text{ m}^2$

where in the input data

$D_{n,e,i}$ is the element normalized sound level difference of small element i, in decibels ;

S is the total area of the façade as seen from the inside (i.e. the sum of the area of all elements), in square metres.

4.2.2 Other elements

$$\tau_{e,i} = \frac{S_i}{S} 10^{-R_i/10} \quad (15)$$

where in the input data

R_i is the sound reduction index of element i, in decibels ;

S_i is the area of element i, in square metres.

The sound transmission through the connections and sealing between elements is considered to be included in the data for one of the connected elements.

NOTE Normally the connection between elements is sufficiently represented by the mounting of the element as applied during the laboratory tests and it is thus included in the acoustic data on the elements. Otherwise it can be added as a seperate 'element', see annex B.

The acoustic data on the elements involved should be taken primarily from standardized laboratory measurements. However, they could also be deduced in other ways, using theoretical calculations, empirical estimations or measurement results from field situations. Some information on this is given in annex D.

The sources of the data used shall be clearly stated.

4.3 Determination of flanking transmission

The sound power ratio τ_f for flanking transmission by element f follows from the summation of the flanking transmission factors for all flanking transmission paths to that element. These flanking transmission factors can be determined in accordance with prEN 12354-1:1999, with the area S_s taken as the total area S of the façade. For all flanking elements this concerns τ_{Ff} and τ_{Df} in the notation of prEN 12354-1:1999, where D designate façade elements and F designates the parts of the façade which are not part of the considered receiving room. For all façade elements this concerns τ_{Fd} in the notation of prEN 12354-1:1999, where d designates the façade elements.

The contribution of flanking transmission is normally negligible. However, if rigid elements, such as concrete or brick, are connected to other rigid elements within the receiving room, such as floors or partition walls, flanking transmission can contribute to the overall sound transmission. This might become important where the requirements are high.

NOTE In most case it is thus not necessary to calculate the contribution of flanking transmission. To be on the safe side, it would be sufficient in the cases with rigid elements to incorporate flanking transmission in a global way by reducing the sound reduction index for this type of rigid, heavy façade elements ; subtracting 2 dB is normally sufficient.

4.4 Interpretations

— for glazing and glazed windows the sound transmission is influenced by area and niches. For areas and niches normally encountered in field situations these effects do not deviate much from the laboratory measurement situation and can be ignored for practical purposes ;

— for several types of elements, especially openable elements, the quality of the sealing is very important for the obtained sound reduction index. It is therefore important to ensure that the quality in the field will indeed be equal to that for the laboratory measurements. In case of doubt the effect of transmission through the gaps and sealing could be estimated as in annex B ;