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Building acoustics — Estimation of acoustic performance of buildings from the performance of elements —

Part 3:
Airborne sound insulation against outdoor sound

Acoustique du bâtiment — Calcul de la performance acoustique des bâtiments à partir de la performance des éléments —

Partie 3: Isolement aux bruits aériens venus de l'extérieur

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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 2.

The main task of technical committees is to prepare International Standards. 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 document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15712-3 was prepared by CEN/TC 126, *Acoustic properties of building products and of buildings* (as EN 12354-3:2000), and was adopted without modification by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 2, *Building acoustics*.

Throughout the text of this document, read "...this European Standard..." to mean "...this International Standard...".

Building acoustics — Estimation of acoustic performance of buildings from the performance of elements —

Part 3:
Airborne sound insulation against outdoor sound

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 :

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

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 :

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

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 :

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

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 :

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

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 :

$$D_{2m,n} = D_{2m,nT} - 10 \lg \left(0{,}16 \frac{V}{T_0 A_0}\right) = D_{2m,nT} - 10 \lg 0{,}32\, V \text{ dB} \quad (5)$$

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 :

$$D_{tr,2m,nT} \approx D_{ls,2m,nT} \text{ dB} \quad (6)$$

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 :

$$R = 10 \lg \frac{W_1}{W_2} \text{ dB} \qquad (7)$$

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.

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

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 :

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

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 el 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.

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

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 τ_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 :

$$R'_{45^\circ} = R' + 1 \text{dB} \tag{11}$$

$$R'_{tr,s} = R' \text{ dB} \tag{12}$$

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 :

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

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

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

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

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

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

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 ;

— for lightweight double elements, such as panels, the actual sound reduction index can be smaller than in accordance with laboratory measurements on full size elements, due to differences in area and often a larger number of connections ;

— the sound transmission through small elements, such as air inlets, can be influenced by their position relative to reflecting walls and/or ceilings. This is either accounted for by the mounting position in the laboratory in accordance with EN 20140-10 or the effect can be estimated ; see annex D. The effect of mounting position for small elements is also influenced by outside walls and ceilings. This shall be taken into account when calculating R' ; see annex D ;

— if the façade is not plane, the area is to be taken as the total area of all parts as seen from the inside, as long as the sound incident on all parts of the façade is the same. If this is not the case, each part of the façade with homogeneous incident sound shall be treated separately. If the different parts of the total façade can have different incident sound levels, as with large bay or bow windows, a corner room or room under a roof, it is possible either to consider these parts separately or combined as the total envelope of the receiving room, depending on requirements and the prescribed measurement situation (kind of source, source position, outside microphone position). In the latter case the results of calculations for each part shall be combined, taking into account the outside sound levels for each part, relative to a reference (microphone) position as defined for the field measurements.

4.5 Limitations

— the differences in sound field between the various situations in the field and the assumption of a diffuse field for the prediction as in the laboratory situation, causes some systematic differences. The average of these differences is taken into account, thus reducing the systematic error, leaving some increase in the inaccuracy of the prediction due to the random error.

— it is assumed that with the distance of 2 m for the outside microphone the effect of possible interference caused by the façade is sufficiently reduced, since effect is not taken into account in the calculation model. This will generally be the case for octave band levels, but for one-third octave band levels the interference effect might not be negligible.

5 Accuracy

The calculation model predicts the performance of buildings as it can be measured, assuming state-of-the-art workmanship and high measurement accuracy.

The accuracy of the prediction by the presented model depend on many factors: the accuracy of the input data, the fitting of the situation into the model, the type of elements involved, the geometry of the situation and the type of quantity to be predicted. It is therefore not possible to specify the accuracy in general for all types of situations and applications. Data on the accuracy will have to be gathered in the future by comparing the results of the model with a variety of field situations. However, some indications can be given.

The estimation of the normalized level difference from the composing parts of the façade is on average correct; the single number rating ($D_{\text{ls,2m,nT, w}} + C_{\text{tr}}$) shows a standard deviation of about 1,5 dB, while for individual octave bands the standard deviations will be larger, up to 3 dB.

The estimation of the apparent sound reduction index of a façade from the composing elements is expected to be at least as accurate.

NOTE This is based on comparison of the normalized level difference in over 70 situations, covering a large variety of façade designs ; the acoustic data used for the composing parts were on the safe side, that is around 1 dB lower than laboratory measurement results.

In applying the predictions it is advisable to vary the input data, especially in complicated situations and with rare elements with questionable input data. The resulting variation in the results gives an impression of the expected accuracy, assuming state-of-the-art workmanship.

Annex A
(normative)

List of symbols

Table A.1 – List of symbols

Symbol	Physical quantity	Unit
A	equivalent sound absorption area in the receiving room	[m²]
A_o	reference equivalent sound absorption area; for dwellings given as 10 m²	[m²]
c_o	speed of sound in air	[m/s]
C	spectrum adaptation term 1 in accordance with EN ISO 717-1	[dB]
C_{tr}	spectrum adaptation term 2 in accordance with EN ISO 717-1	[dB]
$D_{2m,nT}$	standardized sound level difference of a façade (additional index 'tr' if measured with traffic noise or 'l_s' if measured with loudspeaker sound)	[dB]
$D_{2m,n}$	normalized sound level difference of a façade (additional index 'tr' if measured with traffic noise or 'l_s' if measured with loudspeaker sound)	[dB]
$D_{2m,nT,w}$	weighted standardized sound level difference of a façade in accordance with EN ISO 717-1	[dB]
$D_{2m,n,w}$	weighted normalized sound level difference of a façade in accordance with EN ISO 717-1	[dB]
$D_{n,e}$	element normalized sound level difference for a small building element	[dB]
$D_{n,e,lab}$	element normalized sound level difference for a small building element, as determined in the laboratory	[dB]
$D_{n,e,situ}$	element normalized sound level difference for a small building element, as in the actual field situation	[dB]
f	frequency	[Hz]
i	index for an element of a façade	[-]
j	index for a composing part of an element of a façade	[-]
k	index for sealed gaps and joints	[-]
k_o	wave number (= $2\pi f/c_o$)	[m^{-1}]
$l_{s,k}$	length of sealed gap or joint k	[m]
l_o	reference length; given as 1 m	[m]
l_{lab}	length of a small building element for the laboratory measurement of $D_{n,e,lab}$	[m]
l_{situ}	length of a small building element in the field situation	[m]
L_1	average sound pressure level in the source room	[dB re 20 µPa]
$L_{1,s}$	average sound pressure level on the outside surface of a façade	[dB re 20 µPa]
$L_{1,in}$	average sound pressure level of the incident sound field	[dB re 20 µPa]
$L_{1,2m}$	average sound pressure level at 2 m in front of a façade	[dB re 20 µPa]
$L_{eq,1,s}$	average equivalent sound pressure level on the outside surface of a façade	[dB re 20 µPa]
L_2	average sound pressure level in the receiving room	[dB re 20 µPa]

(to be continued)

Table A.1 (*concluded*)

Symbol	Physical quantity	Unit
$L_{eq,2}$	average equivalent sound pressure level in the receiving room	[dB re 20 μPa]
$L_{2,n}$	average sound pressure level in the receiving room, normalized to A_0	[dB re 20 μPa]
$L_{2,nT}$	average sound pressure level in the receiving room, normalized to T_0	[dB re 20 μPa]
m	number of flanking elements or number of sealed gaps or joints between parts	[-]
n	number of elements in a façade or parts of an element	[-]
n_e	number of small building elements	[-]
R	sound reduction index of an element in accordance with EN ISO 140-3	[dB]
R'	apparent sound reduction index of a façade for diffuse incident sound	[dB]
$R'_{45°}$	apparent sound reduction index of a façade for sound incident from an angle of 45°	[dB]
$R'_{tr,s}$	apparent sound reduction index of a façade for traffic noise	[dB]
R_i	sound reduction index for element i of the façade	[dB]
R_j	sound reduction index for composing part j of an element of a façade	[dB]
$R_{s,k}$	sound reduction index of sealed gap or joint k between parts of a façade, per unit length	[dB]
$R'_{45°,w}$	weighted apparent sound reduction index of a façade for sound incident from an angle of 45° in accordance with EN ISO 717-1	[dB]
$R'_{tr,w}$	weighted apparent sound reduction index of a façade for traffic noise in accordance with EN ISO 717-1	[dB]
S	total area of the façade as seen from the inside	[m²]
S_i	area of an element i of the façade	[m²]
S_j	area of a part j of an element i	[m²]
S_{open}	area of the opening in an air inlet	[m²]
T	reverberation time in the receiving room	[s]
T_o	reference reverberation time; for dwellings given as 0,5 s	[s]
V	volume of the receiving room	[m³]
W_1	sound power incident on a test specimen in the source room	[W]
W_2	sound power radiated from a test specimen into the receiving room due to incident sound on that specimen in the source room	[W]
w	index to indicate weighted sound reduction indices in accordance with EN ISO 717-1	[-]
x,y,r	distances of a small element to reflecting planes	[m]
ΔL_{fs}	façade shape level difference	[dB]
$\Delta D_{n,e}$	reduction of the element normalized level difference due to the vicinity of reflecting planes	[dB]
$\tau_{e,i}$	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	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	[-]

Annex B
(informative)

Determination of transmission by elements from composing parts

B.1 Sound power ratio for composed element

If no data are available on the acoustic performance of an element as applied, the sound power ratio for that element may be estimated globally from acoustic data on parts of that element.

For typical elements, like a specific type of window, this could be done by applying adjustments to the sound reduction index of the main part, i.e. the glazing, to take into account the influence of window frame and sealing. Such adjustments should be based on the results of general research of the considered effects.

Another approach is to use the sound reduction index of each part that forms the element, taking into account the relative area of the parts. In this respect the sealing of joints and gaps between parts forms a special type of part which often has to be taken into account. For this part the acoustic performance can best be expressed as the sound reduction index per unit length, taking into account the actual length.

Neglecting the interaction which can be present in the sound transmission with combined small elements, the sound power ratio for an element composed of several parts j and sealings k between the parts is then to be estimated in accordance with :

$$\tau_e = \sum_{\mathrm{j}=1}^{\mathrm{n}} \frac{S_{\mathrm{j}}}{S} 10^{-R_{\mathrm{j}}/10} + \frac{l_0}{S} \sum_{\mathrm{k}=1}^{\mathrm{m}} l_{\mathrm{s,k}} 10^{-R_{\mathrm{s,k}}/10} \tag{B.1}$$

where

R_{j} is the sound reduction index of part j of the element, in decibels ;

S_{j} is the area of a part j of the element, in square metres ;

$R_{\mathrm{s,k}}$ is the sound reduction index of sealed gap or joint k per unit length, in decibels ;

$l_{\mathrm{s,k}}$ is the length of sealed gap or joint k, in metres, with l_0 = 1 m as reference ;

n is the number of parts composing the element ;

m is the number of sealed gaps or joints between parts.

NOTE This is not to be used to state the acoustic performance of elements composed of several parts. It can however be used to estimate the influence of a different quality of the sealings than applied for the laboratory measurement of the sound reduction index of an element.

In B.2 some information is given about the sound reduction index of typical parts of façade elements.

In B.3 some information is given about the sound reduction index of (sealed) gaps and joints.

B.2 Sound reduction index of composing parts of façade elements

In this clause information is given on the sound reduction index of some typical parts as applied in façade elements, such as windows and doors composed of glazing, door leaves, frames and sealings.

B.2.1 Glazing

The sound reduction index of glazing presented here is deduced from measurement results taking into account the spread in results for nominally identical elements and can thus be considered as being on the safe side. These values can be used in cases when no other information is available and serve as an indication of what is typical for some types of products.

The sound reduction index is given in octave bands with the single number rating calculated in accordance with EN ISO 717-1. The data represent the average result minus a standard deviation of approximately 1 dB to 2 dB.

Table B.1 - Examples of the sound reduction index of glazing

Glazing type	**Sound reduction index (dB)**						
	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 k Hz	R_W $(C;C_{tr})$ dB
Single panes (mm)							
3	14	19	25	29	33	25	28 (-1;-4)
4	17	20	26	32	33	26	29 (-2;-3)
5	19	22	29	33	29	31	30 (-1;-2)
6	18	23	30	35	27	32	31 (-2;-3)
8	20	24	29	34	29	37	32 (-2;-3)
10	23	26	32	31	32	39	33 (-2;-3)
12	27	29	31	32	38	47	34 (0;-2)
Laminated panes (mm) + plastic laminate (0,5-1) mm							
6+	20	23	29	34	32	38	32 (-1;-3)
8+	20	25	32	35	34	42	33 (-1;-3)
10+	24	26	33	33	35	44	34 (-1;-3)
Double pane units with single or laminated panes (mm) ; air filled cavity from (6-16) mm							
4-(6-16)-4	21	17	25	35	37	31	29 (-1;-4)
6-(6-16)-4	21	20	26	38	37	39	32 (-2;-4)
6-(6-16)-6	20	18	28	38	34	38	31 (-1;-4)
8-(6-16)-4	22	21	28	38	40	47	33 (-1;-4)
8-(6-16)-6	20	21	33	40	36	48	35 (-2;-6)
10-(6-16)-4	24	21	32	37	42	43	35 (-2;-5)
10-(6-16)-6	24	24	32	37	37	44	35 (-1;-3)
6-(6-16)-6+	20	19	30	39	37	46	33 (-2;-5)
6-(6-16)-10+	24	25	33	39	40	49	37 (-1;-5)

NOTE 1 This selection and the values are in accordance with prEN 12758-1. The single number ratings are deduced from results in 1/3-octave bands and therefore single number ratings deduced from the given octave band data might result in values which differ 1 dB at the most.

NOTE 2 Though it is known that for a given double pane unit the sound reduction increases with increasing cavity width, this effect has been found to be too small to take into account here for air filled cavities in the light of the inherent spread in results for nominally identical units.

To determine the sound reduction index for a glazed window with these data, the sound transmission through the window frame and through the sealing is to be taken into account.

For a large group of glazing, say R_W less than 37 dB, the sound transmission through the window frame can be ignored, if the area of the element is taken as that of the glazing plus frame.

B.2.2 Doors

To determine the sound reduction index for a door, the sound transmission through the door leaves, the glazing - if present - , the door frame and through the sealing is to be taken into account.

The sound reduction index of door leaves or door leaves with frame is to be related to the area of the considered construction. The most practical method to determine it, is from measurements on complete doors with perfect sealing of the gaps and joints between parts. It will often be sufficient to deduce in this way values for some common types of doors, since for specific situations and constructions the predictions should be based on measurement results for the complete element.

B.2.3 Window frames

The sound reduction index of window frames is to be related to the area of the frame. The most practical method to determine it, is from measurements on complete windows with perfect sealing of the gaps and joints between parts, where the transmission by the glazing is either subtracted by calculation or blocked during the measurements. It will often be sufficient to deduce in this way values for some common types of window frames, since for specific situations and constructions the predictions should be based on measurement results for the complete element.

B.3 Quality of sealing of gaps and joints

The quality of the sealing of gaps and joints between elements and parts can be expressed in the sound reduction index R_s per unit length of the gap. A standardized measurement method to determine this quantity is not yet available. It can be developed on the basis of sound insulation measurements in accordance with EN ISO 140-3 or EN 20140-10, specifying the mounting method and evaluation of the results. The most practical way is to deduce this sound reduction index from measurements on a typical element with gaps and/or joints, with and without additional sealing of the considered gaps and joints.

Annex C
(informative)

Influence of façade shape

The effect of the exterior shape of façades can be both positive (less sound transmission) and negative (more sound transmission). The positive effect is due to shielding or partial shielding of the façade plane by balconies or other objects. The negative effect is due to extra reflections and a sound field that could be considered to be reverberant when a balcony forms a partial enclosure around the façade plane. Calculation of these effects on the basis of the given geometry shows reasonable accordance with measured effects (field tests, scale-model tests).

ΔL_{fs} is defined as the difference in sound pressure level of the incoming sound field and the sound on the surface of the façade plus 6 dB, thus being 0 dB for a reflecting, plane façade. It can be measured with reasonable accuracy according to :

$$\Delta L_{fs} = L_{1,2m} - L_{1,s} + 3 \text{ dB} \qquad \text{(C.1)}$$

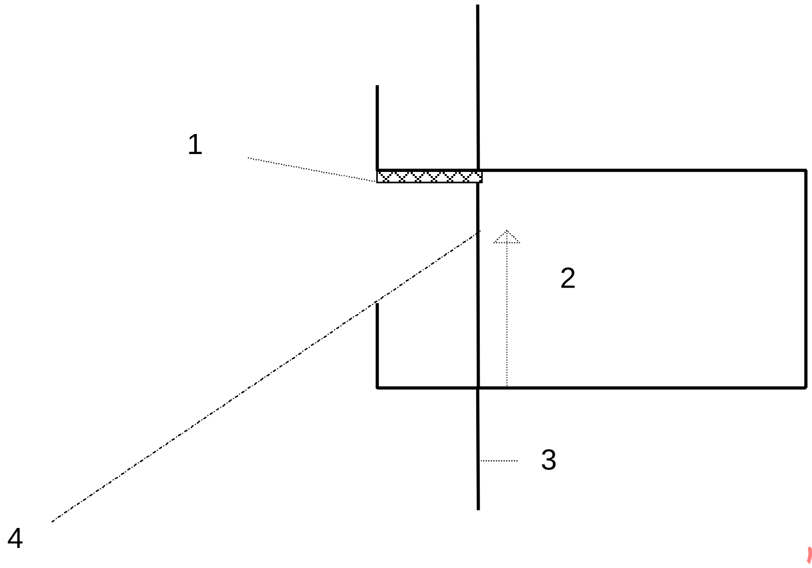
where

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

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

Examples of the level difference due to the façade shape, ΔL_{fs}, are presented in Figure C.2. The value depends on the shape of the façade, the absorption of the underside of any balcony and on the general direction of the incoming sound.

The shape of the façade is indicated by a vertical cross-section through the gallery, balcony or terrace. If these have closed fences, i.e no substantial opening in the fence, the fence is indicated on the cross-section otherwise not. The absorption is indicated by the weighted sound absorption coefficient α_w in accordance with EN ISO 11654 as $\leq 0,3$; 0,6 or $\geq 0,9$. The effect for intermediate values can be deduced by interpolation ; $\alpha_w \geq 0,9$ applies also if a reflecting surface above the considered façade is absent. The direction of the incoming sound is characterised by the height of the line of sight from the source at the façade plane; the relevant source position is the one which results in the lowest height (see Figure C.1).

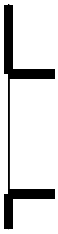
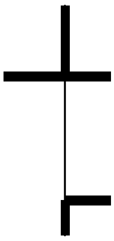
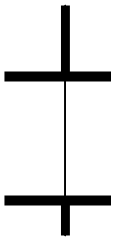
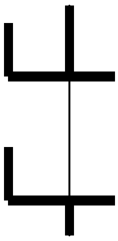
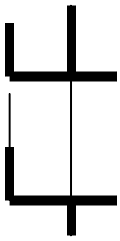


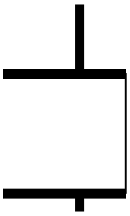
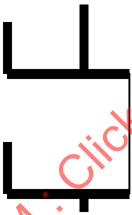
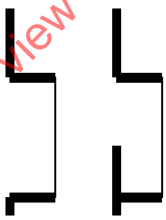
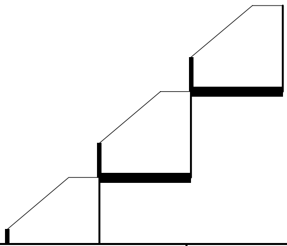
Key

1 Absorption
2 Height of line of sight
3 Façade plane
4 Sound source

Figure C.1 - Illustration of relevant parameters for the façade shape level difference

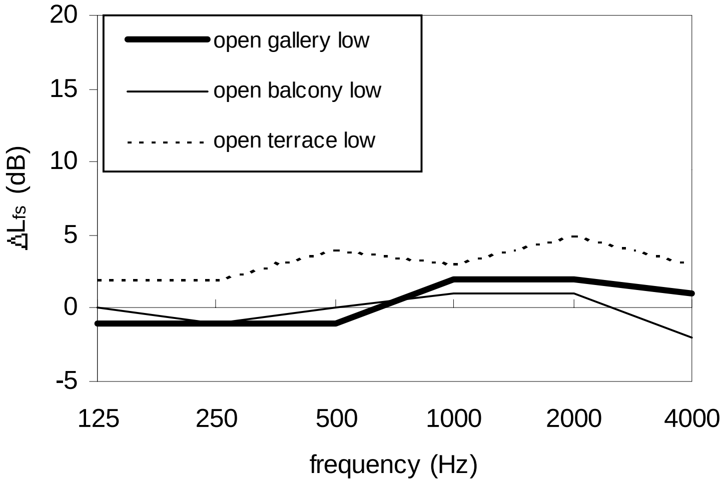
The data in Figure C.2 represent a weighted average over frequency. The values can be used as a first estimate for frequency bands also ; in that case the data under-estimate the effect for higher frequencies for differences larger than 3 dB. Some illustrations of the frequency dependence in octave bands are given in Figure C.3.

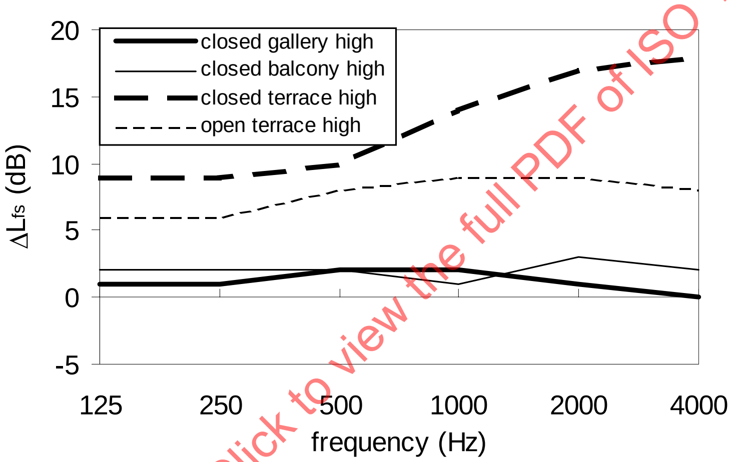
ΔL_{fs} dB	1 plane façade	2 gallery			3 gallery			4 gallery			5 gallery		
													
absorption roof (α_w) ⇒	does not apply	≤0,3	0,6	≥0,9	≤0,3	0,6	≥0,9	≤0,3	0,6	≥0,9	≤0,3	0,6	≥0,9
line-of-sight on façade : <1,5 m	0	-1	-1	0	-1	-1	0	0	0	1	does not apply		
(1,5-2,5) m	0	does not apply			-1	0	2	0	1	3			
>2,5m	0				1	1	2	2	2	3	3	4	6

	6 balcony			7 balcony			8 balcony			9 terrace					
															
										open fence			closed fence		
absorption roof (α_w) ⇒	≤0,3	0,6	≥0,9	≤0,3	0,6	≥0,9	≤0,3	0,6	≥0,9	≤0,3	0,6	≥0,9	≤0,3	0,6	≥0,9
line-of-sight on façade : <1,5 m	-1	-1	0	0	0	1	1	1	2	1	1	1	3	3	3
(1,5-2,5) m	-1	1	3	0	2	4	1	1	2	3	4	5	5	6	7
>2,5m	1	2	3	2	3	4	1	1	2	4	4	5	6	6	7

NOTE The different façade shapes are indicated by a vertical cross-section with the outside to the left and the sound source orientations are indicated by the height of the line of sight on the façade ; see Figure C.1.

Figure C.2 - Façade shape level difference for different façade shapes and sound source orientations





NOTE The legends refer to figure C.2 : 'open gallery' =3, 'closed gallery"=4, 'open balcony'=6, 'closed balcony'=7, 'open terrace'=9 with an open fence ; 'low' means the line-of-sight < 1,5m and 'high' means the line-of-sight >2,5m.

Figure C.3 - Illustrations of the frequency dependence of the façade shape level difference in octave bands

Annex D
(informative)

Sound reduction index of elements

The sound reduction index of façade elements is determined by measurements in accordance with EN ISO 140-1, EN ISO 140-3 and EN 20140-10. In this annex some indication is given about the application of data from such measurements or other sources.

D.1 Building elements

For windows the sound reduction index is determined by the glazing, the frame, the mounting method of the glazing and the sealing of joints and gaps. Especially with openable windows care should be taken that the applied sealing for the laboratory measurements is representative for the field application. Otherwise the effect of a different sealing should be taken into account; see annex B.

For doors the sound reduction index is determined by the construction of the door panel, the frame and the sealing of the gaps. Care should be taken that the applied sealing for the laboratory measurements is representative for the field application. Otherwise the effect of a different sealing should be taken into account; see annex B.

For homogeneous structures some information on the sound reduction index is given in prEN 12354-1:1999. Lightweight panels, roofs and hollow brick walls can show a large variety in construction details, which make it normally necessary to rely on specific data.

D.2 Small elements

These façade elements like air inlets show a large variety in construction details, which make it impossible to present generalized data.

For unsilenced air inlets, like openings or louvres, a global indication is given by treating the element as an opening with negligible sound reduction. This results in an element normalized level difference of :

$$D_{n,e} = -10 \lg \frac{S_{open}}{10} \quad \text{(D.1)}$$

where

S_{open} is the area of the opening, in square metres.

NOTE With small openings resonances can occur, determined by the effective depth of the element, which results in a lower element normalized level difference in certain frequency bands than according to this equation.

Often there will be a larger number of identical small elements or a small element with a larger length, for instance slit-type air inlets, than the actually tested specimen. The element sound level difference to be applied in the calculations can then be estimated from data on the tested element by taking into account the number of elements n_e or the length of the element l_{situ} :

$$D_{n,e,situ} = D_{n,e,lab} - 10 \lg n_e \text{ or } D_{n,e,situ} = D_{n,e,lab} - 10 \lg \frac{l_{situ}}{l_{lab}} \quad \text{(D.2)}$$

This is only allowable when it has been established for similar elements that this extrapolation is correct.

The element normalized level difference will be influenced by the position of the element in the façade with respect to side walls and ceilings, both inside and outside. If this position is fixed in normal use the laboratory mounting will be fixed accordingly, so the data are directly applicable. If for more general cases the laboratory data are without these influences, they can be estimated from the geometry of the situation.

The effect on the element normalized level difference ($\Delta D_{n,e}$) follows from :

$$\Delta D_{n,e} = 10 \lg \left(1 + 0{,}75 \frac{\sin(2k_0 x)}{2k_0 x} + 0{,}75 \frac{\sin(2k_0 y)}{2k_0 y} + 0{,}75 \frac{\sin(2k_0 r)}{2k_0 r} \right) \quad \text{(D.3)}$$

where

x is the distance to a plane in the x-direction, in metres ;

y is the distance to a plane in the y-direction, in metres ;

r is the distance to the corner $= \sqrt{x^2 + y^2}$, in metres ;

k_0 is the wave number, $k_0 = 2 \pi f / c_0$.

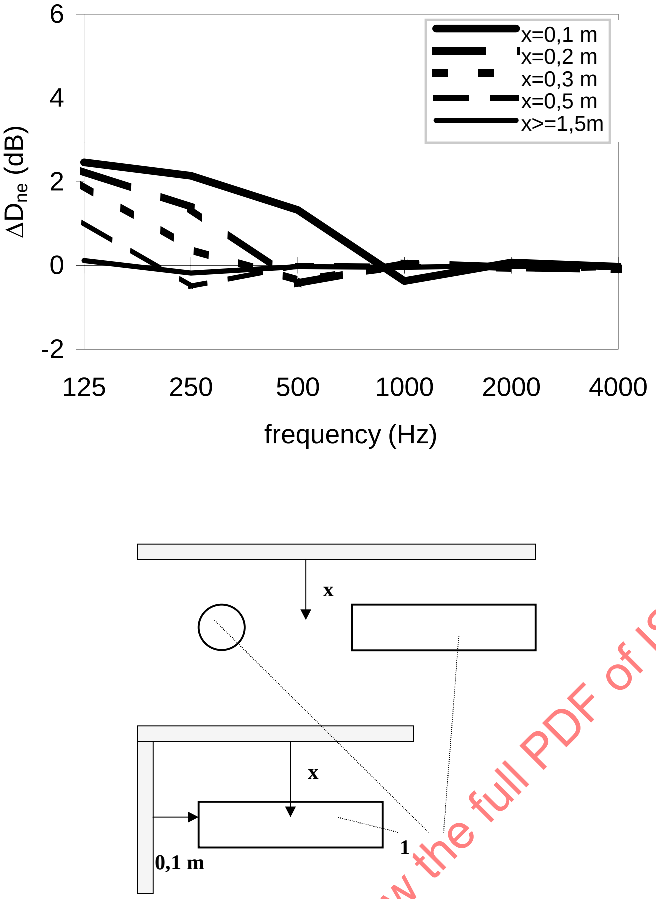
For an element the results according to this equation have to be averaged over frequency within the considered band width and over the open area of the element.

The resulting element normalized level difference for a corner position follows from :

$$D_{n,e,corner} = D_{n,e,free} - \Delta D_{n,e} \quad \text{(D.4)}$$

For octave bands and two types of elements the resulting effects are illustrated in Figure D.1 (two-plane corner) and D.2 (three-plane corner). If a corner position occurs at both sides of the façade (inside and outside), the effects according to these figures shall be added.

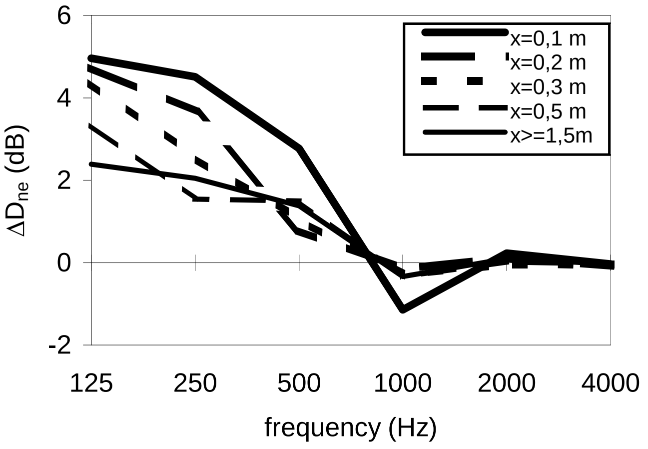
The element normalized level difference in situ can be affected by the direction of the incident sound in a more specific way than the other type of façade elements. Especially with ventilation openings there has shown to be a tendency of lower values at angle were the sound is directed into the opening. This could amount to reduction of 1 dB to 3 dB.

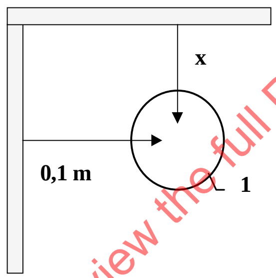


Key

1 element

Figure D.1 - Effect on D_{ne} of nearness of reflecting side walls or ceilings (interior or exterior), relative to position without reflecting side walls; small element near two-plane corner, gap element near two- or three-plane corner





Key

1 element

Figure D.2 - As Figure D.1 for small element near three-plane corner