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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by the European Committee for Standardization (CEN) Technical Committee CEN/TC 126, *Acoustic properties of building elements and of buildings*, in collaboration with ISO Technical Committee TC 43, *Acoustics*, SC 2, *Building acoustics*, in accordance with the agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This first edition cancels and replaces ISO 15712-3:2005, which has been technically revised.

A list of all the parts in the ISO 12354 series can be found on the ISO website.

## Introduction

This document is part of a series specifying calculation models in building acoustics.

Although this document covers the main types of building construction it cannot as yet cover all variations in the construction of buildings. It sets out an approach for gaining experience for future improvements and developments.

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 meantime, 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 organization, 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.

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

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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

### 1 Scope

This document 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 in accordance with ISO 16283-3. Calculations can be carried out for frequency bands or for single number ratings.

The calculation results can also be used for calculating the indoor sound pressure level due to for instance road traffic (see [Annex E](#)).

This document describes the principles of the calculation model, lists the relevant quantities and defines its applications and restrictions.

### 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 717-1, *Acoustics — Rating of sound insulation in buildings and of building elements — Part 1: Airborne sound insulation*

ISO 10140-1:2016, *Acoustics — Laboratory measurement of sound insulation of building elements — Part 1: Application rules for specific products*

ISO 12354-1:2017, *Building acoustics — Estimation of acoustic performance of buildings from the performance of elements — Part: Airborne sound insulation between rooms (in revision)*

### 3 Terms and definitions

For the purposes of this document, the following terms and definitions, and the symbols and units listed in [Annex A](#), apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

#### 3.1 Quantities to express building performance

NOTE The sound insulation of façades in accordance with ISO 16283-3 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 ISO 717-1, for instance  $R'_{w}$ ,  $D_{1s,2m,nT,w}$  or  $(R'_{w} + C_{tr})$ .

**3.1.1**

**apparent sound reduction index**

$R'_{45^\circ}$

<loudspeaker> airborne sound insulation of a building element when the sound source is a loudspeaker and the angle of incidence is 45°, which is evaluated from

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

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**

$R'_{tr,s}$

<traffic noise> airborne sound insulation of a building element when the sound source is traffic noise, which is evaluated from

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

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**

$D_{2m,nT}$

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, which is evaluated from

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

where

$L_{1,2m}$  is the average sound pressure level at 2 m in front of the façade including the reflecting effects from 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.

Note 1 to entry: 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

$D_{2m,n}$

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, which is evaluated from

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

where  $A_0$  is the reference equivalent sound absorption area, in square metres for dwellings given as 10 m<sup>2</sup>.

Note 1 to entry: 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  $D_{ls,2m,n}$ .

## 3.2 Quantities to express element performance

NOTE 1 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 ISO 717-1, for instance  $R_w(C;C_{tr})$  and  $D_{n,e,w}(C;C_{tr})$ .

NOTE 2 For the calculations, additional information on constructions could be necessary; for example, the shape of the façade (see [Annex C](#)), the total façade area (see 4.3.1), etc.

### 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, which is evaluated from

$$R = \left( 10 \lg \frac{W_1}{W_2} \right) \text{dB}$$

Note 1 to entry: This quantity shall be determined in accordance with ISO 10140-1:2016, Annexes A, B, C and D.

### 3.2.2

#### element normalized level difference

$D_{n,e}$

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 technical element (e.g. transfer air devices, electrical cable ducts, transit sealing systems), which is evaluated from

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

where  $A$  is the equivalent sound absorption area in the receiving room, in square metres.

Note 1 to entry:  $D_{n,e}$  is normalized to the reference equivalent sound absorption area ( $A_0$ ) in the receiving room;  $A_0 = 10 \text{ m}^2$ .

Note 2 to entry: This quantity shall be determined in accordance with ISO 10140-1:2016, Annex E.

**3.2.3**

**sound reduction improvement index**

$\Delta R$   
 difference in sound reduction index between a basic structural element with an additional layer (e.g. a resilient wall skin, a suspended ceiling, a floating floor) and the basic structural element without this layer

Note 1 to entry: For direct transmission, this quantity shall be determined in accordance with ISO 10140-1:2016, Annex G.

Note 2 to entry: ISO 12354-1:2017, Annex D gives information on the determination and the use of this quantity.

**3.2.4**

**sound reduction index of joints or slits**

$R_s$   
 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 through the joint or the slit, which is evaluated from

$$R_s = L_1 - L_2 + \left( 10 \lg \left( \frac{S_o \cdot l}{A \cdot l_o} \right) \right)$$

Note 1 to entry:  $R_s$  is normalized to the length  $l$  of the joint or slit and the equivalent sound absorption area  $A$  in the receiving room, with  $S_o = 1 \text{ m}^2$  and  $l_o = 1 \text{ m}$ .

Note 2 to entry: This quantity shall be determined in accordance with ISO 10140-1:2016, Annex J.

**3.3 Other terms and quantities**

**3.3.1**

**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

Note 1 to entry: This quantity is used as a common calculation quantity from which the various quantities for the building performance can be obtained.

Note 2 to entry: In some countries the building performance is not expressed in one of the measurable quantities, but in this quantity  $R'$ .

**3.3.2**

**façade shape level difference**

$\Delta L_{fs}$   
 difference between 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, which can be determined according to

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

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 1 to entry: 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

“Façade” is understood to mean 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. As shown by [Formula \(1\)](#):

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

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;

$\tau_f$  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  $\tau_e$  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, [Formulae \(7\)](#) and [\(8\)](#) could be integrated in [Formula \(1\)](#), resulting in the often used expression for the sound reduction index of composed elements.

For direct transmission the sound power ratio  $\tau_e$  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. Guidelines for the practical use of the model are given in [Annex F](#).

For flanking transmission the sound power ratio  $\tau_f$  can be determined according to [4.3](#).

The apparent sound reduction index of the façade is determined from [Formulae \(2\)](#) and [\(3\)](#):

$$R'_{45^\circ} = R' + 1 \text{ dB} \quad (2)$$

$$R'_{\text{tr,s}} = R' \text{ dB} \quad (3)$$

NOTE 3 These equations represent the average relation between the quantities. For the single number rating the variation around the average is typically  $\pm 1$  dB. For frequency bands the spread is typically  $\pm 2$  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 [Formula \(4\)](#):

$$D_{2m,nT} = R' + \Delta L_{fs} + \left( 10 \lg \left( C_{sab} \frac{V}{T_0 S} \right) \right) \text{dB} \quad (4)$$

where

$C_{sab}$  is the Sabine constant, in seconds per metre with  $C_{sab} = 0,16 \text{ s/m}$ .

$V$  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;

$\Delta L_{fs}$  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 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 ISO 717-1. The calculations can be extended to higher or lower frequencies if acoustic data are available for such a larger frequency range. Information of airborne sound insulation in the low frequency range down to 50 Hz can be found in ISO 12354-1:2017, Annex I. The issues of field measurement of façade sound insulation in the low frequency range are specifically considered in ISO 16283-3.

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 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  $R'_{45^\circ,w}$  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 3 150 Hz. If a larger frequency range is considered the appropriate spectrum adaptation term for such a larger frequency range should be used.

NOTE 5 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 6 The energetic summation involved in the model is exact for  $(R_w + C_{tr})$  and a reasonable approximation for  $R_w$ .

The two sound level differences,  $D_{2m,nT}$  and  $D_{2m,n}$ , are directly related to each other, as shown by [Formula \(5\)](#):

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

where

$C_{sab}$  is the Sabine constant, in seconds per metre with  $C_{sab} = 0,16 \text{ s/m}$ .

$V$  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, as shown by [Formula \(6\)](#):

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

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.

A calculation example is given in [Annex G](#).

## 4.2 Determination of direct transmission from acoustic data on elements

### 4.2.1 General

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 technical and other elements is in accordance with ISO 10140-1.

### 4.2.2 Small technical elements

Small technical elements are calculated using [Formula \(7\)](#):

$$\tau_{e,i} = \frac{A_0}{S} 10^{-D_{n,e,i}/10} \quad (7)$$

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

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.

### 4.2.3 Other elements

Other elements are calculated using [Formula \(8\)](#):

$$\tau_{e,i} = \frac{S_i}{S} 10^{-R_i/10} \quad (8)$$

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 separate "element", see [Annex B](#).

In case an element consists of a basic element and a lining, the sound reduction index can either be the index for the complete element or the combinations of the indices for the basic element and the improvement by the lining following [Formula \(9\)](#):

$$R_i = R_{\text{basic},i} + \Delta R_{\text{lining},i} \quad (9)$$

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  $\tau_f$  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 ISO 12354-1, with the area  $S_s$  taken as the total area  $S$  of the façade. For all flanking elements this concerns  $\tau_{Ff}$  and  $\tau_{Df}$  in the notation of ISO 12354-1, 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  $\tau_{Fd}$  in the notation of ISO 12354-1, 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** However, in most case it is not necessary to calculate the contribution of flanking transmission. In the cases with rigid elements, flanking transmission can be incorporated in a global way by reducing the sound reduction index for this type of rigid, heavy façade elements; subtracting 2 dB is normally acceptable.

### 4.4 Limitations

The following phenomena, not taking into account in prediction, might affect the results.

- 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 model presented depends 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 ( $D_{ls,2m,nT,w} + C_{tr}$ ) 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 for these situations, assuming similar workmanship.

When the model is used to directly calculate the single number rating for the building performance, based on the single number ratings of the elements involved, the uncertainty can be calculated using the method proposed in ISO 12354-1:2017, Annex K; however, the formulae used for airborne sound insulation against outdoor sound ([Clause 4](#)) are different from the ones used for airborne sound insulation between rooms and the partial derivatives required for the determination of uncertainty should be modified consequently.

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## 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	$m^2$
$A_0$	reference equivalent sound absorption area; for dwellings given as $10 m^2$	$m^2$
$c_0$	speed of sound in air	$m/s$
$C$	spectrum adaptation term 1 in accordance with ISO 717-1	$dB$
$C_{tr}$	spectrum adaptation term 2 in accordance with 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 ISO 717-1	$dB$
$D_{2m,n,w}$	weighted normalized sound level difference of a façade in accordance with 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	-
$k_0$	wave number ( $= 2 \pi f / c_0$ )	$m^{-1}$
$l_{s,k}$	length of sealed gap or joint $k$	$m$
$l_0$	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	$dB \text{ re } 20 \mu Pa$
$L_{1,s}$	average sound pressure level on the outside surface of a façade	$dB \text{ re } 20 \mu Pa$
$L_{1,in}$	average sound pressure level of the incident sound field	$dB \text{ re } 20 \mu Pa$
$L_{1,2m}$	average sound pressure level at $2 m$ in front of a façade	$dB \text{ re } 20 \mu Pa$
$L_{eq,1,s}$	average equivalent sound pressure level on the outside surface of a façade	$dB \text{ re } 20 \mu Pa$
$L_2$	average sound pressure level in the receiving room	$dB \text{ re } 20 \mu Pa$
$L_{eq,2}$	average equivalent sound pressure level in the receiving room	$dB \text{ re } 20 \mu Pa$
$L_{2,n}$	average sound pressure level in the receiving room, normalized to $A_0$	$dB \text{ re } 20 \mu Pa$
$L_{2,nT}$	average sound pressure level in the receiving room, normalized to $T_0$	$dB \text{ re } 20 \mu Pa$
$m$	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	-

Table A.1 (continued)

Symbol	Physical quantity	Unit
$R$	sound reduction index of an element in accordance with ISO 10140 (all parts).	dB
$R'$	apparent sound reduction index of a façade for diffuse incident sound	dB
$R'_{45^\circ}$	apparent sound reduction index of a façade for sound incident from an angle of $45^\circ$	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 joint or slit $k$ between parts of a façade, per unit length	dB
$R'_{45^\circ,w}$	weighted apparent sound reduction index of a façade for sound incident from an angle of $45^\circ$ in accordance with ISO 717-1	dB
$R'_{tr,w}$	weighted apparent sound reduction index of a façade for traffic noise in accordance with ISO 717-1	dB
$S$	total area of the façade as seen from the inside	$m^2$
$S_i$	area of an element $i$ of the façade	$m^2$
$S_j$	area of a part $j$ of an element $i$	$m^2$
$S_{open}$	area of the opening in an air inlet	$m^2$
$T$	reverberation time in the receiving room	s
$T_0$	reference reverberation time; for dwellings given as 0,5 s	s
$V$	volume of the receiving room	$m^3$
$W_1$	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 ISO 717-1	-
$x,y,r$	distances of a small element to reflecting planes	m
$\Delta L_{fs}$	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	-
$\tau_f$	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 estimated in accordance with [Formula \(B.1\)](#):

$$\tau_e = \sum_{j=1}^n \frac{S_j}{S} 10^{-R_j/10} + \frac{l_0}{S} \sum_{k=1}^m l_{s,k} 10^{-R_{s,k}/10} \quad (\text{B.1})$$

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;

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

$l_{s,k}$  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](#) information is given about the sound reduction index of typical parts of façade elements.

In [B.3](#) information is given about the sound reduction index of (sealed) joints and slits.

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

### B.2.1 General

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.2.2 Glazing

The sound reduction index of glazing is determined in accordance with ISO 10140-1:2016, Annex D. The measurement results presented in [Table B.1](#) take 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 ISO 717-1. The data represent the average result minus a standard deviation of approximately 1 dB to 2 dB.

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 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.2.3 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 taken into account.

The sound reduction index of doors is determined in accordance with ISO 10140-1:2016, Annex B.

### B.2.4 Window frames

The sound reduction index of window frames is 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 joints and slits between elements and parts can be expressed in the sound reduction index  $R_s$  per unit length of the joint as measured in accordance with ISO 10140-1:2016, Annex J.

**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
<b>Single panes (mm)</b>							
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)
<b>Laminated panes (mm) + plastic laminate (0,5 to 1) (mm)</b>							
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)
<b>Double pane units with single or laminated panes (mm); air filled cavity from (6 to 16) (mm)</b>							
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 EN 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.							

## 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).

$\Delta L_{fs}$  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 [Formula \(C.1\)](#):

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

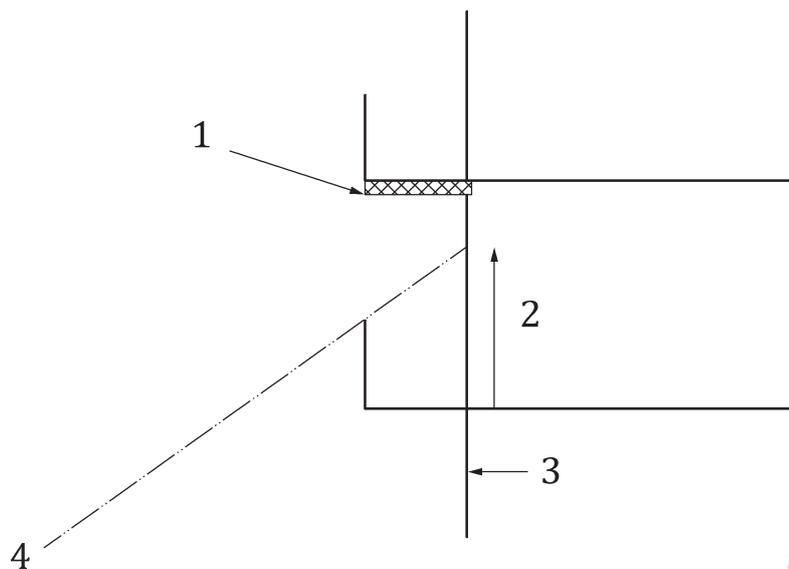
where

$L_{1,2m}$  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,  $\Delta L_{fs}$ , 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  $\alpha_w$  in accordance with 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 characterized 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

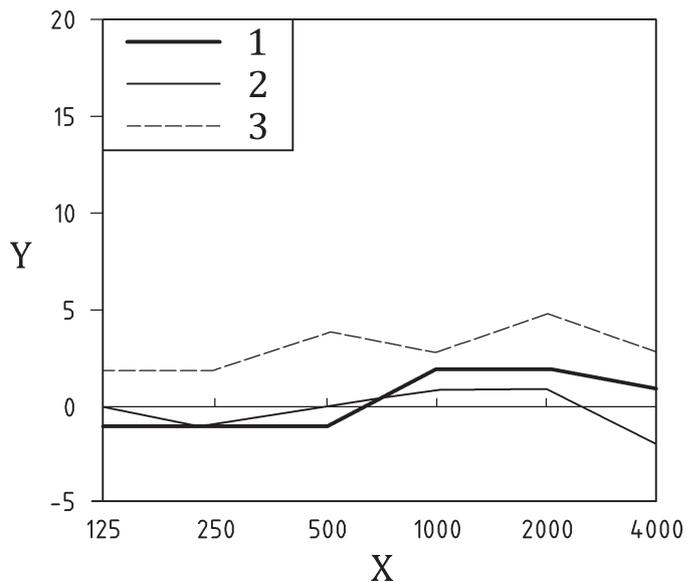
**Figure C.1 — Illustration of relevant parameters for the façade shape level difference**

The data in [Table C.1](#) 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 [Figures C.2](#) and [C.3](#).

**Table C.1 — Façade shape level difference for different façade shapes and sound source orientations**

$\Delta L_{fs}$ dB	1 plane	2 gallery			3 gallery			4 gallery			5 gallery				
absorption roof ( $\alpha_w$ ) $\Rightarrow$	does not apply	$\leq 0,3$	0,6	$\geq 0,9$	$\leq 0,3$	0,6	$\geq 0,9$	$\leq 0,3$	0,6	$\geq 0,9$	$\leq 0,3$	0,6	$\geq 0,9$		
line-of-sight on façade: <1,5 m	0	-1	-1	0	-1	-1	0	0	0	1	does not apply				
(1,5 to 2,5) m	0	does not apply			-1	0	2	0	1	3					
>2,5 m	0				1	1	2	2	2	3	3	4	6		
	6 balcony	7 balcony			8 balcony			9 terrace							
								open fence			closed fence				
absorption roof ( $\alpha_w$ ) $\Rightarrow$	$\leq 0,3$	0,6	$\geq 0,9$	$\leq 0,3$	0,6	$\geq 0,9$	$\leq 0,3$	0,6	$\geq 0,9$	$\leq 0,3$	0,6	$\geq 0,9$	$\leq 0,3$	0,6	$\geq 0,9$
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 to 2,5) m	-1	1	3	0	2	4	1	1	2	3	4	5	5	6	7
>2,5 m	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](#).



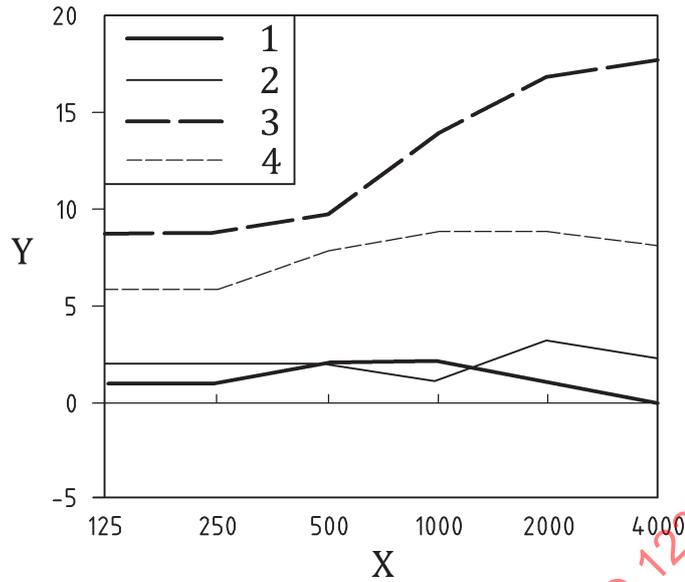
**Key**

- 1 open gallery low
- 2 open balcony high
- 3 open terrace high

X frequency in Hz

Y  $L_{fs}$  in dB

**Figure C.2 — Illustrations of the frequency dependence of the façade shape level difference in octave bands — “low” cases**



**Key**

- 1 closed gallery high
- 2 closed balcony high
- 3 closed terrace high
- 4 open terrace high

X frequency in Hz  
 Y  $\Delta L_{fs}$  in dB

NOTE The legends refer to [Table C.1](#): “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 <1,5 m and “high” means the line-of-sight >2,5 m.

**Figure C.3 — Illustrations of the frequency dependence of the façade shape level difference in octave bands — “high” cases**

## Annex D (informative)

### Sound reduction index of elements

#### D.1 General

The sound reduction index of façade elements is determined by measurements in accordance with ISO 10140-2. In this annex some indication is given about the application of data from such measurements or other sources.

#### D.2 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 ISO 12354-1. 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.3 Small technical 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 shown by [Formula \(D.1\)](#):

$$D_{n,e} = -10 \lg \left( \frac{S_{\text{open}}}{A_0} \right) \quad (\text{D.1})$$

where

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

$A_0$  is the reference equivalent sound absorption area, in square metres for dwellings given as 10 m<sup>2</sup>.

**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 formula.

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  $l_{\text{situ}}$ , as shown by [Formula \(D.2\)](#):

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

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 [Formula \(D.3\)](#):

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

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,  $k_0 = 2 \pi f / c_0$ .

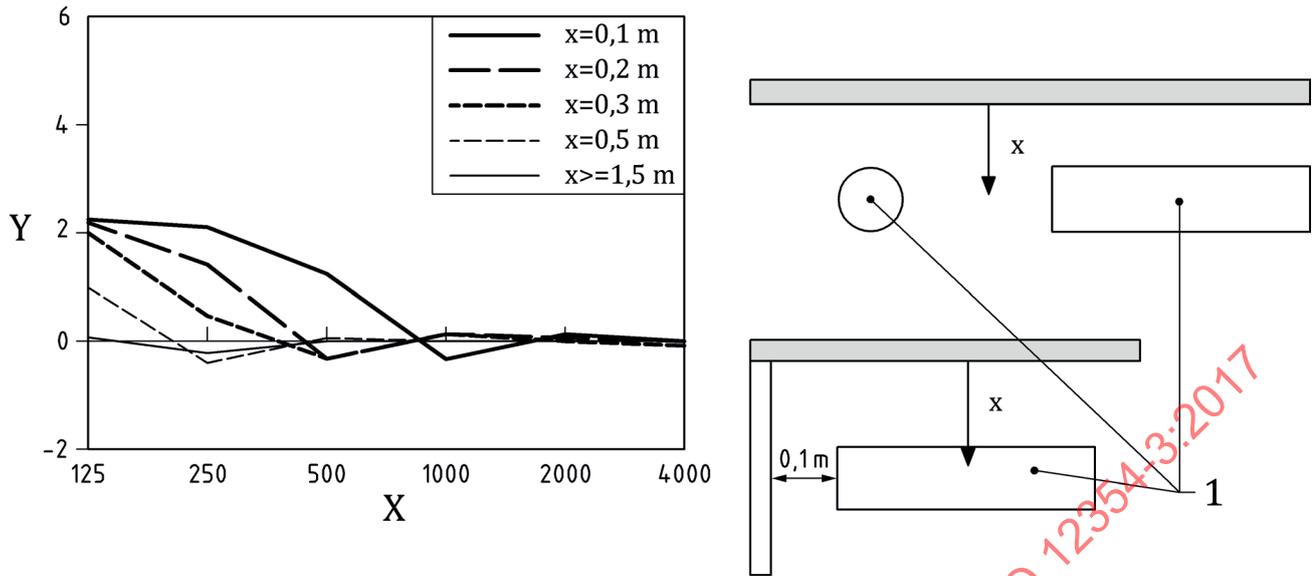
For an element, the results according to this formula shall be averaged over frequency within the considered band width and over the open area of the element.

The resulting element normalized level difference for a corner position follows from [Formula \(D.4\)](#):

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

For octave bands and two types of elements, the resulting effects are illustrated in [Figure D.1](#) (two-plane corner) and [Figure 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.

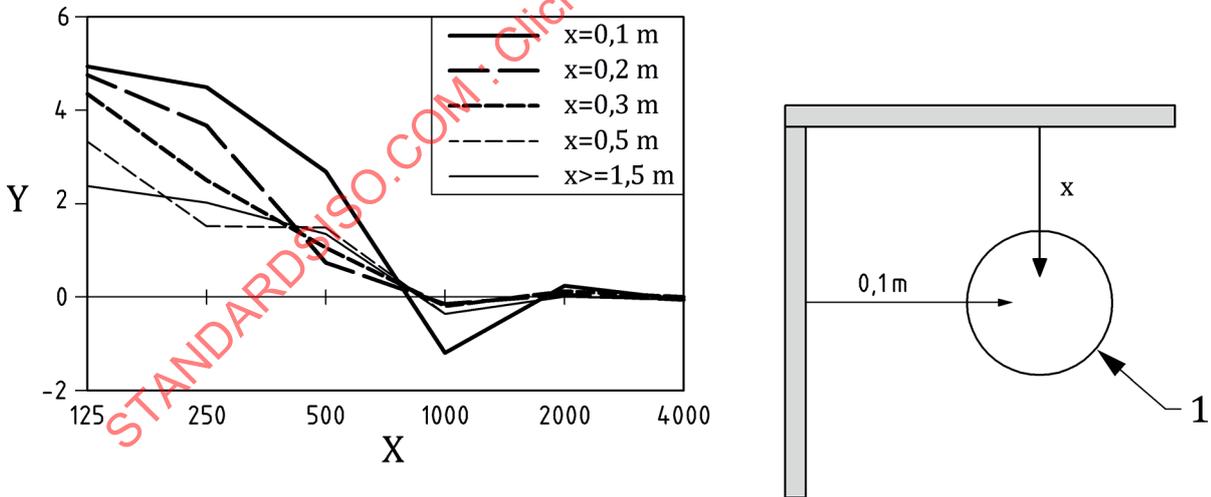
The element normalized level difference *in situ* can be affected by the direction of the incident sound in a more specific way than the other type of façade elements. Especially with ventilation openings there has shown to be a tendency of lower values at angle were the sound is directed into the opening.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



a) Effect on  $D_{ne}$  of nearness of reflecting side walls or ceilings (interior or exterior), relative to position without reflecting side walls      b) Geometric configurations: small element near two-plane corner, gap element near two- or three-plane corner

**Key**  
 1 element  
 X frequency in Hz  
 Y  $\Delta D_{ne}$  in dB

Figure D.1 — Resulting effects (two-plane corner)



a) Effect on  $D_{ne}$       b) Geometric configuration: small element near three-plane corner

**Key**  
 1 element  
 X frequency in Hz  
 Y  $D_{ne}$  in dB

Figure D.2 — Resulting effects (three-plane corner)