



BSI Standards Publication

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

Part 1: Airborne sound insulation between rooms

National foreword

This British Standard is the UK implementation of EN ISO 12354-1:2017. It is identical to ISO 12354-1:2017. It supersedes BS EN 12354-1:2000, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EH/1/6, Building acoustics.

A list of organizations represented on this committee can be obtained on request to its secretary.

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English Version

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

Acoustique du bâtiment - Calcul de la performance
acoustique des bâtiments à partir de la performance
des éléments - Partie 1: Isolement acoustique aux
bruits aériens entre des locaux (ISO 12354-1:2017)

Bauakustik - Berechnung der akustischen
Eigenschaften von Gebäuden aus den
Bauteileigenschaften - Teil 1: Luftschalldämmung
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European foreword

This document (EN ISO 12354-1:2017) has been prepared by Technical Committee ISO/TC 43 “Acoustics” in collaboration with Technical Committee CEN/TC 126 “Acoustic properties of building elements and of buildings” the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by February 2018, and conflicting national standards shall be withdrawn at the latest by February 2018.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 12354-1:2000.

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Endorsement notice

The text of ISO 12354-1:2017 has been approved by CEN as EN ISO 12354-1:2017 without any modification.

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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).

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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.

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 15712-1:2005, 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 document 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 and an estimation procedure has been presented in [Annex K](#). 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.

This document 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 calculation models described use the most general approach for engineering purposes, with a clear link to measurable quantities that specify the performance of building elements. The known limitations of these calculation models are described in this document. Other calculation models also exist, each with their own applicability and restrictions.

The models are based on experience with predictions for dwellings; they could also be used for other types of buildings provided the construction systems and dimensions of elements are not too different from those in dwellings.

The document also provides details for application to lightweight constructions (typically steel or wood framed lightweight elements as opposed to heavier masonry or concrete elements).

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

Part 1: Airborne sound insulation between rooms

1 Scope

This document specifies calculation models designed to estimate the airborne sound insulation between adjacent rooms in buildings, primarily using measured data which characterize direct or indirect flanking transmission by the participating building elements, and theoretically-derived methods of sound propagation in structural elements.

A detailed model is described for calculation in frequency bands, in the frequency range 1/3 octave 100 Hz to 3 150 Hz in accordance with ISO 717-1, possibly extended down to 1/3 octave 50 Hz if element data and junction data are available (see [Annex I](#)); the single number rating can be determined from the calculation results. A simplified model with a restricted field of application is deduced from this, calculating directly the single number rating, using the single number ratings of the elements; a method to determine uncertainty is proposed for the simplified model (see [Annex K](#)).

This document describes the principles of the calculation scheme, 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 (all parts), *Acoustics — Laboratory measurement of sound insulation of building elements*

ISO 10848-1, *Acoustics — Laboratory measurement of the flanking transmission of airborne and impact sound between adjoining rooms — Part 1: Frame document*

ISO 10848-2, *Acoustics — Laboratory measurement of the flanking transmission of airborne and impact sound between adjoining rooms — Part 2: Application to light elements when the junction has a small influence*

ISO 10848-3, *Acoustics — Laboratory measurement of the flanking transmission of airborne and impact sound between adjoining rooms — Part 3: Application to light elements when the junction has a substantial influence*

ISO 10848-4, *Acoustics — Laboratory measurement of the flanking transmission of airborne and impact sound between adjoining rooms — Part 4: Application to junctions with at least one heavy element*

ISO 15186-3, *Acoustics — Measurement of sound insulation in buildings and of building elements using sound intensity — Part 3: Laboratory measurements at low frequencies*

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 between rooms in accordance with ISO 16283-1 can be expressed in terms of several related 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 , $D_{nT,w}$ or $(D_{nT,w} + C)$.

3.1.1

apparent sound reduction index

R'

minus 10 times the common logarithm of the ratio of the total sound power W_{tot} transmitted into the receiving room to the sound power W_1 which is incident on a separating element, evaluated from

$$R' = -10 \lg \tau' \text{ dB}$$

Note 1 to entry: This ratio is denoted by τ' , where

$$\tau' = W_{\text{tot}} / W_1$$

Note 2 to entry: In general, the total sound power transmitted into the receiving room consists of the power radiated by the separating element, the flanking elements and other components.

The index R' is normally determined from measurements according to

$$R' = L_1 - L_2 + \left(10 \lg \frac{S_s}{A} \right) \text{ dB}$$

where

L_1 is the average sound pressure level in the source room, in decibels;

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

A is the equivalent sound absorption area in the receiving room, in square metres;

S_s is the area of the separating element, in square metres.

3.1.2

standardized level difference

D_{nT}

difference in the space and time average sound pressure levels produced in two rooms by one or more sound sources in one of them, corresponding to a reference value of the reverberation time in the receiving room, which is evaluated from

$$D_{nT} = L_1 - L_2 + \left(10 \lg \frac{T}{T_o} \right) \text{ dB}$$

where

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

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

3.1.3

normalized level difference

D_n

difference in the space and time average sound pressure levels produced in two rooms by one or more sound sources in one of them, corresponding to the reference equivalent sound absorption area in the receiving room, which is evaluated from

$$D_n = L_1 - L_2 - \left(10 \lg \frac{A}{A_0} \right) \text{dB}$$

where A_0 is the reference absorption area given as 10 m².

3.2 Quantities to express element performance

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

NOTE 2 For the calculations, additional information on the element can be necessary; for example, mass per unit area m' in kg/m², type of element, material, type of junction, 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 (all parts) or ISO 15186-3 (use of acoustical intensity).

3.2.2

sound reduction improvement index

ΔR

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: This quantity shall be determined in accordance with ISO 10140-1:2016, Annex G.

3.2.3

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

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

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.

3.2.4

normalized level difference for indirect airborne transmission

$D_{n,s}$

difference in the space and time average sound pressure level produced in two rooms by a source in one of them, which is evaluated from

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

Note 1 to entry: Transmission is only considered to occur through a specified path between the rooms (e.g. ventilation systems, corridors). $D_{n,s}$ 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: The subscript s indicates the type of transmission system considered.

Note 3 to entry: This quantity shall be determined with a measurement method which is comparable to ISO 10140-1:2016, Annex G.

3.2.5

flanking normalized level difference

$D_{n,f}$

difference in the space and time average sound pressure level produced in two rooms by a source in one of them, which is evaluated from

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

Note 1 to entry: Transmission is only considered to occur through a specified flanking path between the rooms (e.g. suspended ceiling, access floor, façade). $D_{n,f}$ 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 10848-1, ISO 10848-2 and ISO 10848-3.

Note 3 to entry: For clarity, the term $D_{n,f}$ is used when only one flanking path determines the sound transmission (such as with suspended ceiling) and the term $D_{n,f,ij}$ is used when only one specified transmission path ij out of several paths is considered (such as structure-borne transmission on junctions of three or four connected elements).

3.2.6

vibration reduction index

K_{ij}

quantity related to the vibrational power transmission over a junction between structural elements, normalized in order to make it an invariant quantity, which is determined by normalizing the direction-averaged velocity level difference over the junction, to the junction length and the equivalent sound absorption length, if relevant, of both elements in accordance with

$$K_{ij} = \frac{D_{v,ij} + D_{v,ji}}{2} + \left(10 \lg \frac{l_{ij}}{\sqrt{a_i a_j}} \right) \text{dB}$$

where

- $D_{v,ij}$ is the velocity level difference between element i and j, when element i is excited, in decibels;
 $D_{v,ji}$ is the velocity level difference between element j and i, when element j is excited, in decibels;
 l_{ij} is the common length of the junction between element i and j, in metres;
 a_i is the equivalent absorption length of element i, in metres;
 a_j is the equivalent absorption length of element j, in metres.

Note 1 to entry: The equivalent absorption length is given by

$$a = \frac{2, 2\pi^2 S}{c_o T_s} \sqrt{\frac{f_{\text{ref}}}{f}}$$

where

- T_s is the structural reverberation time of the element i or j, in seconds;
 S is the area of element i or j, in square metres;
 f is the centre band frequency, in Hertz
 f_{ref} is the reference frequency; $f_{\text{ref}} = 1\,000$ Hz;
 c_o is the speed of sound in air, in metres per second.

Note 2 to entry: The equivalent absorption length is the length of a fictional totally-absorbing edge of an element if its critical frequency is assumed to be 1 000 Hz, giving the same loss as the total losses of the element in a given situation.

Note 3 to entry: The quantity K_{ij} shall be determined in accordance with ISO 10848-1 and ISO 10848-4.

3.2.7

normalized direction-averaged vibration level difference

$\overline{D_{v,ij,n}}$

difference in velocity level between elements i and j, averaged over the excitation from i and excitation from j, and normalized to the junction length and the measurement areas on both elements in accordance with

$$\overline{D_{v,ij,n}} = \frac{D_{v,ij} + D_{v,ji}}{2} + \left(10 \lg \frac{l_{ij} l_0}{\sqrt{S_{m,i} S_{m,j}}} \right) \text{dB}$$

where

- $D_{v,ij}$ is the velocity level difference between element i and j, when element i is excited, in decibels;
 $D_{v,ji}$ is the velocity level difference between element j and i, when element j is excited, in decibels;
 l_{ij} is the common length of the junction between element i and j, in metres;
 $S_{m,i}$ is area of element i over which the velocity is averaged, in square metres;
 $S_{m,j}$ is area of element j over which the velocity is averaged, in square metres;
 l_0 is the reference length, in metres; $l_0 = 1$ m.

Note 1 to entry: The quantity $\overline{D_{v,ij,n}}$ shall be determined in accordance with ISO 10848-1 and ISO 10848-4.

Note 2 to entry: In case of lightweight, often highly-damped junction elements, the use of K_{ij} (3.2.6) is no longer valid (non-uniform vibration field); however, the notion of vibration level difference is still appropriate^[30] and this quantity can be normalized as defined in 3.2.7.

3.2.8 direction-averaged junction velocity level difference

$D_{v,ij}$

average of the junction velocity level difference from element i to j and element j to I, evaluated from

$$D_{v,ij} = \frac{D_{v,ij} + D_{v,ji}}{2} \text{ dB}$$

3.2.9 flanking sound reduction index

R_{ij}

minus 10 times the common logarithm of the flanking transmission factor τ_{ij} , which is evaluated from

$$R_{ij} = -\left(10 \lg \tau_{ij}\right) \text{ dB}$$

where

$$\tau_{ij} = W_{ij} / W_1$$

and where

τ_{ij} is the ratio of the sound power W_{ij} radiated from a flanking element j in the receiving room due to incident sound on element i in the source room to the sound power W_1 ;

W_1 is the incident sound power on a reference area in the source room.

Note 1 to entry: The area of the separating element is chosen as the reference area.

Note 2 to entry: The area of the separating element is chosen as the reference since then the contribution of each transmission path to the total transmission is directly indicated, which is not the case with other choices.

3.3 Other terms and quantities

3.3.1 airborne direct transmission

transmission due only to sound incident on a separating element that is then directly radiated by the element or transmitted through parts of it (airborne) such as slits, air moving devices or louvres

3.3.2 indirect transmission

transmission of sound from a source room to a receiving room, through transmission paths other than the direct transmission path

Note 1 to entry: It can be divided into airborne transmission and flanking transmission.

3.3.3 indirect airborne transmission

indirect transmission of sound energy via an airborne transmission path, e.g. ventilation systems, corridors, double facades

3.3.4**flanking transmission****indirect structure-borne transmission**

transmission of sound energy from an excited element in the source room to a receiving room via structural (vibrational) paths in the building construction, e.g. walls, floors, ceilings

Note 1 to entry: In cases of cavity walls and suspended ceilings airborne transmission can contribute to or even dominate the transmission.

3.3.5**Type A element**

element with a structural reverberation time that is primarily determined by the connected elements (up to at least the 1 000 Hz one-third-octave band), and a decrease in vibration level of less than 6 dB across the element in the direction perpendicular to the junction line (up to at least the 1000 Hz one-third-octave band)

Note 1 to entry: Examples include cast in situ concrete, solid wood (including cross laminated timber panels), glass, plastic, metal, bricks/blocks/slabs with a finish/topping (e.g. plaster, parge coat, screed, concrete) that mechanically connects them together.

Note 2 to entry: An element may only be defined as Type A over part, or parts of the frequency range. For example, some masonry walls can be Type A elements in the low- and mid-frequency ranges and a Type B element in the high-frequency range.

3.3.6**Type B element**

any element that is not a Type A element

Note 1 to entry: Examples typically include plasterboard/timber cladding on timber or metal frames.

Note 2 to entry: An element may only be defined as Type B over part or parts of the frequency range. For example, some masonry walls can be Type A elements in the low- and mid-frequency ranges and a Type B element in the high-frequency range.

4 Calculation models**4.1 General principles**

The sound power in the receiving room is due to sound radiated by the separating structural elements and the flanking structural elements in that room and by the relevant direct and indirect airborne sound transmission. The total transmission factor can be divided into transmission factors, related to each element in the receiving room and the elements and systems involved in the direct and indirect airborne transmission, as shown by [Formula \(1\)](#):

$$R' = -(10 \lg \tau') \text{ dB} \quad (1)$$

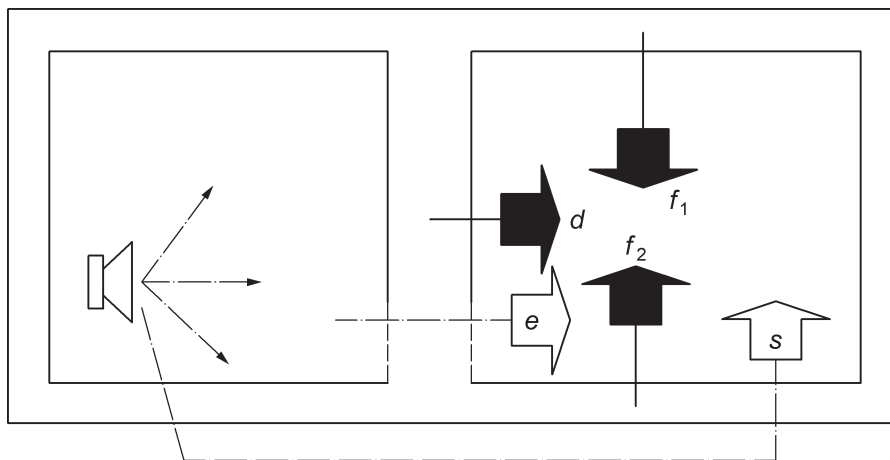
where

$$\tau' = \tau_d + \sum_{f=1}^n \tau_f + \sum_{e=1}^m \tau_e + \sum_{s=1}^k \tau_s$$

and where the indices d, f, e and s refer to the different contributions to the sound transmission illustrated in [Figure 1](#),

and where

- τ' is the sound power ratio of total radiated sound power in the receiving room relative to incident sound power on the common part of the separating element;
- τ_d is the sound power ratio of radiated sound power by the common part of the separating element relative to incident sound power on the common part of the separating element. It includes the paths Dd and Fd shown in [Figure 2](#);
- τ_f is the sound power ratio of radiated sound power by a flanking element f in the receiving room relative to incident sound power on the common part of the separating element. It includes paths Ff and Df shown in [Figure 2](#);
- τ_e is the sound power ratio of radiated sound power in the receiving room by an element in the separating element due to direct airborne transmission of incident sound on this element, relative to incident sound power on the common part of the separating element;
- τ_s is the sound power ratio of radiated sound power in the receiving room by a system s due to indirect airborne transmission of incident sound on this transmission system, relative to incident sound power on the common part of the separating element;
- n is the number of flanking elements; normally $n = 4$, but it can be smaller or larger;
- m is the number of elements with direct airborne transmission;
- k is the number of systems with indirect airborne transmission.

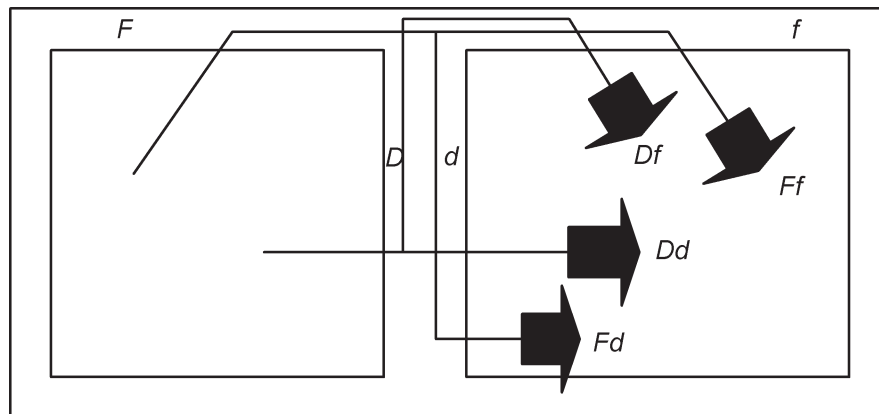


Key

- d radiated directly from the separating element
- f_1 and f_2 radiated from flanking elements
- e radiated from components mounted in the separating element
- s indirect transmission

Figure 1 — Illustration of the different contributions to the total sound transmission to a room

The sound radiated by a structural element can be considered to be the sum of structure-borne sound transmission through several paths. Each path can be identified by the element i on which the sound is incident in the source room and the radiating element j in the receiving room. The paths for a flanking element and the separating element are shown in [Figure 2](#), where in the source room the elements i are designated by F for the flanking element and D for the separating element and in the receiving room the elements j are designated by f for a flanking element and d for the separating element.

**Key***Dd* direct direct path*Df* direct flanking path*Fd* flanking direct path*Ff* flanking flanking path**Figure 2 — Definition of sound transmission paths *ij* between two rooms**

The main assumptions with this approach are that the transmission paths described can be considered to be independent and that the sound and vibrational fields behave statistically. Within these restrictions this approach is quite general, in principle allowing for various types of structural elements, i.e. monolithic elements, cavity walls, lightweight double leaf walls, and different positioning of the two rooms. However, the available possibilities to describe the transmission by each path impose restrictions in this respect. The model presented is therefore restricted to adjacent rooms, while the type of elements is mainly restricted by the available information on the vibration reduction index, the normalized direction-averaged vibration level difference or the normalized flanking level difference. Some indications are given in [Annex J](#) for the application to other double elements such as cavity walls.

The transmission factor for the separating element consists of contributions from the airborne direct transmission and *n* flanking transmission paths, as shown by [Formula \(2\)](#):

$$\tau_d = \tau_{Dd} + \sum_{F=1}^n \tau_{Fd} \quad (2)$$

The transmission factor for each of the flanking elements *f* in the receiving room consists of contributions from two flanking transmission paths, as shown by [Formula \(3\)](#):

$$\tau_f = \tau_{Df} + \tau_{Ff} \quad (3)$$

The transmission factors for these structure-borne transmission paths are related to the sound reduction index for direct transmission R_{Dd} and the flanking sound reduction index R_{ij} as shown by [Formula \(4\)](#):

$$\begin{aligned} \tau_{Dd} &= 10^{-R_{Dd}/10} \\ \tau_{ij} &= 10^{-R_{ij}/10} \end{aligned} \quad (4)$$

The transmission factors for the direct and indirect airborne transmission are related to the element normalized level difference $D_{n,e}$ and the normalized level difference for indirect airborne transmission $D_{n,s}$ as shown by [Formula \(5\)](#):

$$\tau_e = \frac{A_o}{S_s} 10^{-D_{n,e}/10}$$

$$\tau_s = \frac{A_o}{S_s} 10^{-D_{n,s}/10}$$
(5)

where

S_s is the area of the separating element, in square metres;

A_o is the reference equivalent sound absorption area, in square metres.

In order to calculate a single number rating for the building performance in accordance with ISO 717-1, the calculation shall be carried out for octave bands from 125 Hz to 2 000 Hz or for one-third-octave bands from 100 Hz to 3 150 Hz.

NOTE The calculations can be extended to higher or lower frequencies if element data and junction data are available for these frequencies. However, especially for the lower frequencies, no information is available at this time on the accuracy of calculations for these extended frequency regions; see [Annex I](#).

The detailed model deals with both direct and flanking transmission as well as direct and indirect airborne transmission. Since these transmission paths can be considered as independent they are treated separately. The calculation of the direct and flanking transmission is described in [4.2](#). The direct and indirect airborne transmission is described in [4.3](#).

The simplified model calculates the building performance as a single number rating, based on the single number ratings of the performance of the elements involved. The simplified model is described in [4.4](#).

In this document the apparent sound reduction index R' is chosen as the prime quantity to be estimated.

The level differences are related to the apparent sound reduction index as shown by [Formulae \(6\)](#) and [\(7\)](#):

$$D_n = R' + \left(10 \lg \frac{A_o}{S_s} \right) = R' + \left(10 \lg \frac{10}{S_s} \right) \text{dB}$$
(6)

$$D_{nT} = R' + \left(10 \lg \frac{C_{sab} V}{T_o S_s} \right) = R' + \left(10 \lg \frac{0,32 V}{S_s} \right) \text{dB}$$
(7)

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.

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

4.2 Detailed model for structure-borne transmission

4.2.1 Input data

The transmission for each of the paths can be determined from the following:

- sound reduction index of separating element: R_s ;
- sound reduction index for element i in source room: R_i ;

- sound reduction index for element j in receiving room: R_j ;
- sound reduction index improvement by additional layers added to the separating element in the source room and/or in the receiving room: $\Delta R_D, \Delta R_d$;
- sound reduction index improvement by additional layers added to the element i in the source room and/or element j in the receiving room: $\Delta R_i, \Delta R_j$;
- structural reverberation time for an element in the laboratory: $T_{s,lab}$;
- vibration reduction index for each transmission path from element i to element j : K_{ij} ;
- normalized direction-averaged velocity level difference between element i to element j : $\overline{D_{v,ij,n}}$;
- flanking normalized level difference $D_{n,f}$;

NOTE 1 Normally this concerns only transmission path Ff for a given flanking element, but the quantity could also be applied to other transmission paths like Fd or Df.

- area of separating element: S_s ;
- area of element i in source room: S_i ;
- area of element j in receiving room: S_j ;
- common coupling length between element i and element j as measured from surface to surface: l_{ij} .

NOTE 2 If D_{nT} or D_n is calculated, the area of the separating element serves as an arbitrary reference and could be taken as 10 m² throughout the calculations.

Information on sound reduction index is given in [Annex B](#).

Information on structural reverberation time for homogeneous elements is given in [Annex C](#).

Information on sound reduction index improvement and flanking sound reduction index improvement is given in [Annex D](#).

Information on vibration reduction index and on flanking normalized level difference for common junctions is given in [Annex E](#).

The acoustic data on the elements involved should be taken primarily from standardized laboratory measurements. However, they may also be deduced in other ways: using theoretical calculations, empirical estimations or field measurements. Further information is given in [Annexes B](#) to [E](#). The sources of data used shall be clearly stated.

For each flanking transmission path, the sound reduction index R of the involved elements (including the separating element) should relate to the resonant transmission only. If laboratory measurement results are used as input data, this is therefore correct above the critical frequency; a correction shall be applied below that frequency, see [Annex B](#). If the values of the sound reduction index are based on calculations from material properties, it is best to consider only resonant transmission over the whole frequency range of interest.

For airborne direct transmission, R shall include forced transmission as included in laboratory measurements. However, transferring these laboratory data to the *in situ* situation requires the use of the structural reverberation which applies to resonant transmission only (see [4.2.2](#)).

4.2.2 Transfer of input data to *in situ* values

4.2.2.1 General

Acoustic data for the elements (structural elements, additional layers and junctions) shall be converted into *in situ* values before the actual determination of the sound transmission.

For the additional layers, the laboratory value can be used as an approximation for the *in situ* value of the improvement ΔR_{situ} , as shown by [Formula \(8\)](#):

$$\Delta R_{\text{situ}} = \Delta R \text{ dB} \quad (8)$$

For each flanking transmission path, the sound reduction index improvement ΔR of the involved elements (including the separating element) should relate to the resonant transmission only. However, measurement methods to determine this are not readily available. There is some evidence to indicate that the improvement for airborne direct transmission is also a reasonable estimate for the improvement for flanking transmission. An exception is lightweight basic elements, for which there are indications that using the same value for flanking transmission as for airborne direct transmission can no longer be assumed. See [Annex D](#).

NOTE With lightweight elements, the additional reduction of sound transmission for flanking transmission (for each frequency band) can then be approximated as $\Delta R_f = \Delta R_d / 2$.

For structural elements and junctions, two cases shall be considered: Type A elements ([4.2.2.2](#)) and Type B elements ([4.2.2.3](#)).

4.2.2.2 Type A elements

For Type A elements, the *in situ* value of the sound reduction index R_{situ} for the separating element and each of the flanking elements follows from [Formula \(9\)](#):

$$R_{\text{situ}} = R - \left(10 \lg \frac{T_{\text{s},\text{situ}}}{T_{\text{s},\text{lab}}} \right) \text{ dB} \quad (9)$$

where

$T_{\text{s},\text{situ}}$ is the *in situ* structural reverberation time of the element, in seconds;

$T_{\text{s},\text{lab}}$ is the structural reverberation time of the element in the laboratory, in seconds.

The structural reverberation time, both for the laboratory and *in situ*, is therefore to be taken into account; see [Annex C](#).

NOTE As a first approximation it can be assumed that $R_{\text{situ}} = R$.

For the junctions, the *in situ* transmission is characterized by the direction-averaged junction velocity level difference $D_{\text{v},\text{ij},\text{situ}}$. This follows from the vibration reduction index, as shown by [Formula \(10\)](#):

$$D_{\text{v},\text{ij},\text{situ}} = K_{\text{ij}} - \left(10 \lg \frac{l_{\text{ij}}}{\sqrt{a_{\text{i},\text{situ}} a_{\text{j},\text{situ}}}} \right) \text{ dB} ; \overline{D_{\text{v},\text{ij},\text{situ}}} \geq 0 \text{ dB} \quad (10)$$

with [Formula \(11\)](#):

$$a_{\text{i},\text{situ}} = \frac{2,2 \pi^2 S_{\text{i}}}{c_o T_{\text{s},\text{i},\text{situ}}} \sqrt{\frac{f_{\text{ref}}}{f}} \quad (11)$$

$$a_{\text{j},\text{situ}} = \frac{2,2 \pi^2 S_{\text{j}}}{c_o T_{\text{s},\text{j},\text{situ}}} \sqrt{\frac{f_{\text{ref}}}{f}}$$

where

- $a_{i,situ}$ is the *in situ* equivalent absorption length of element i, in metres;
 $a_{j,situ}$ is the *in situ* equivalent absorption length of element j, in metres;
 f is the band centre frequency, in Hertz;
 f_{ref} is the reference frequency; $f_{ref} = 1\,000$ Hz;
 c_o is the speed of sound in air, in metres per second;
 l_{ij} is the coupling length of the common junction between elements i and j, in metres;
 S_i is the area of element i, in square metres;
 S_j is the area of element j, in square metres;
 $T_{s,i,situ}$ is the *in situ* structural reverberation time of element i, in seconds;
 $T_{s,j,situ}$ is the *in situ* structural reverberation time of element j, in seconds.

In this case, the *in situ* structural reverberation time shall be taken into account; see [Annex C](#).

4.2.2.3 Type B elements

For Type B elements, the structural reverberation time $T_{s,situ}$ shall be taken as being equal to $T_{s,lab}$ which leads to a correction term of 0 dB ($R_{situ} = R$).

For the Type B elements, the *in situ* direction-averaged junction velocity level difference follows from the normalized direction-averaged junction velocity level difference (with l_0 a reference length of 1 m), as shown by [Formula \(12\)](#):

$$\overline{D}_{v,ij,situ} = \overline{D}_{v,ij,n} - \left(10 \lg \frac{l_o l_{ij}}{\sqrt{S_{i,situ} S_{j,situ}}} \right) \text{ dB} \quad (12)$$

In the case of a junction composed of elements of both categories (for example Type B wall on Type A floor), [Formula \(10\)](#) can still be used as an approximation, the equivalent absorption length of the Type B element being taken equal to the element area [[Formula \(13\)](#)] and K_{ij} being estimated as per [3.2.6](#).

$$a_{i,situ} = S_{i,situ} / l_0 \quad (13)$$

4.2.3 Determination of direct and flanking transmission *in situ*

4.2.3.1 General

The sound reduction index for airborne direct transmission is determined from the adjusted input value for the separating element according to [Formula \(14\)](#):

$$R_{Dd} = R_{s,situ} + \Delta R_{D,situ} + \Delta R_{d,situ} \text{ dB} \quad (14)$$

For flanking transmission, two cases shall be considered: Type A elements ([4.2.3.2](#)) and Type B elements ([4.2.3.3](#)).

4.2.3.2 Type A elements

For Type A elements, the flanking sound reduction index is determined from the adjusted input values according to [Formula \(15\)](#), with $ij = Ff, Fd$ and Df :

$$R_{ij} = \frac{R_{i,situ}}{2} + \Delta R_{i,situ} + \frac{R_{j,situ}}{2} + \Delta R_{j,situ} + \overline{D_{v,ij,situ}} + \left(10 \lg \frac{S_s}{\sqrt{S_i S_j}} \right) \text{dB} \quad (15)$$

In the case of diagonal transmission, a separating element of area $S_s = 10 \text{ m}^2$ shall be used.

NOTE For certain suspended ceilings and light uninterrupted façade, the flanking transmission is dominated by path Ff (the junction having a small influence, the contribution of path Df can be neglected). In that case, it is possible to characterize the flanking transmission for this construction as a whole by laboratory measurements (see [Annex G](#)).

4.2.3.3 Type B elements

For buildings made of Type B elements, the flanking transmission can be characterized adequately either by the normalized flanking sound level difference $D_{n,f}$, or by using the normalized direction-averaged junction velocity level.

The flanking sound reduction index can be deduced from the flanking sound level difference as shown by [Formula \(16\)](#) (see also [Annex G](#)):

$$R_{ij} = D_{n,f,ij,situ} + \left(10 \lg \frac{S_s I_{lab}}{A_o I_{ij}} \right) \text{dB} \quad (16)$$

In case of dominant structure-borne sound transmission, $D_{n,f,ij,situ}$ can be taken as identical to the laboratory situation. In case of important indirect airborne transmission path, the measured or estimated $D_{n,f,lab}$ for the laboratory situation shall be transferred to *in situ*, as indicated in [G.2.2](#). See [Annex G](#) for further guidance.

The flanking sound reduction index can also be deduced from the performance of the elements by combining [Formulae \(15\)](#) and [\(12\)](#), as shown by [Formula \(17\)](#):

$$R_{ij} = \frac{R_{i,situ}}{2} + \Delta R_{i,situ} + \frac{R_{j,situ}}{2} + \Delta R_{j,situ} + \overline{D_{v,ij,n}} + \left(10 \lg \frac{S_s}{I_o I_{ij}} \right) \text{dB} \quad (17)$$

The sound reduction indices, R_i and R_j , refer to either the double element as a whole or the inner leaf element, that are also distinguished in the normalized direction-averaged vibration level difference

$D_{v,ij,n}$ (see [Annex F](#)) and should relate to resonant transmission only.

The sound transmission by the separating element and by the flanking elements can be calculated in accordance with [Formulae \(2\)](#) and [\(3\)](#), applying [Formulae \(4\)](#), [\(8\)](#) to [\(17\)](#) inclusive. The total sound transmission (apparent sound reduction index) can be calculated with [Formula \(1\)](#), using the results of [4.3](#) if applicable.

4.2.4 Limitations

The limitations are as follows.

- The model can be used only for combinations of elements for which the vibration reduction index or the normalized vibration level difference is known or can be estimated from known values.
- The model is only applicable for bare structural elements which have approximately the same radiation characteristics for both sides.

- c) With very large floors, floors with columns and lightweight internal walls, the floor of a room can no longer be considered as an independent element; see proposed solution in [Annex J](#).
- d) The contribution of secondary transmission paths involving more than one junction is neglected. This is partly compensated by the values for the vibration reduction index or the normalized vibration level difference as far as these are based on field measurements, but could cause an underestimation of flanking transmission with homogeneous elements in other cases. These secondary transmission paths may become important when additional layers are applied to several elements.
- e) The model only describes the transmission between adjacent rooms.

4.3 Detailed model for airborne transmission

4.3.1 Determination from measured airborne direct transmission for small technical elements

The contribution can be directly determined from the element normalized level difference of the elements considered, $D_{n,e}$, through [Formulae \(5\)](#) and [\(1\)](#). In principle the element as applied should be identical to the element for which data are available, so $D_{n,e,situ} = D_{n,e}$.

NOTE However, for some types of elements, like slits or transfer air devices, it is feasible to extrapolate the acoustic behaviour of an element as applied *in situ* from the element data on an equivalent element with for instance a different length. In that case, $D_{n,e,situ}$ could be deduced from $D_{n,e}$ by taking into account the different dimensions in an appropriate way.

4.3.2 Determination from measured total indirect transmission

No standardized methods of measurement are currently available to characterize the indirect airborne transmission $D_{n,s}$ for transmission systems as a whole. While it is desirable to develop such methods for certain transmission systems such as domestic ventilation systems, for many other indirect transmission systems it may be preferable to base predictions on data for the separate elements of such systems (see [4.3.3](#)).

4.3.3 Determination from the performance of the separate elements of a system

No calculation scheme is currently available to determine the normalized level difference $D_{n,s}$ from knowledge and acoustical data on the elements involved in the transmission, i.e. ventilation ducts, silencers, suspended ceilings, corridor/hall, doors and door-gaps. Some proposals do, however, exist, which could form the basis for further development of such schemes. Information is given for some situations in [Annex H](#).

4.4 Simplified model

4.4.1 General

The application of the simplified model is restricted over a frequency range 100 Hz to 3150 Hz; its application to lightweight constructions is restricted to the use of $D_{n,f}$ [see [Formula \(21\)](#)].

4.4.2 Calculation procedure

The simplified version of the calculation model predicts the weighted apparent sound reduction index on the bases of the weighted sound reduction indices of the elements involved. It concerns the weighting in accordance with ISO 717-1. The model is given for the weighted sound reduction index, R_w , but can also be applied to the single number rating with the spectrum adaptation term, i.e. $R_w + C$. 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. R'_w or $(R'_w + C)$.

NOTE 1 For convenience, the sums with the spectrum adaptation term can be denoted by one symbol, for instance $R'_w + C = R'_A$ and $D_{nT,w} + C = D_{nT,A}$.

NOTE 2 The energetic summation involved in the model is exact for R'_A and a reasonable approximation for R'_w .

The influence of the structural damping of elements is taken into account in an average way, neglecting the specifics of the situation. Each flanking element should be essentially the same on the source and receiving side. Additionally, the airborne transmission through technical elements and other transmission systems can be incorporated.

For the simplified model, the prediction [Formulae \(1\)](#), [\(2\)](#), [\(3\)](#), [\(4\)](#), and [\(5\)](#) are re-written and the weighted apparent sound reduction index between two rooms is determined from Formula (18):

$$R'_w = - \left(10 \lg \left(10^{-R_{Dd,w}/10} + \sum_{F=f=1}^n 10^{-R_{Ff,w}/10} + \sum_{f=1}^n 10^{-R_{Df,w}/10} + \sum_{F=1}^n 10^{-R_{Fd,w}/10} + \frac{A_o}{S_s} \sum_{j=1}^m 10^{-D_{n,j,w}/10} \right) \right) \text{ dB} \quad (18)$$

where

$R_{Dd,w}$ is the weighted sound reduction index for airborne direct transmission, in decibels;

$R_{Ff,w}$ is the weighted flanking sound reduction index for the transmission path Ff, in decibels;

$R_{Df,w}$ is the weighted flanking sound reduction index for the transmission path Df, in decibels;

$R_{Fd,w}$ is the weighted flanking sound reduction index for the transmission path Fd, in decibels;

$D_{n,j,w}$ is the weighted normalized sound level difference for the transmission through a small technical element j ($D_{n,e}$) or an airborne transmission system j ($D_{n,s}$), in decibels;

n is the number of flanking elements in a room; normally $n = 4$, but it can be smaller or larger depending on the design and construction of the considered situation (see [Annex J](#));

m is the number of airborne transmission elements or systems j;

S_s is the area of the separating element, in square metres;

A_o is the reference equivalent absorption area, in square metres; $A_o = 10 \text{ m}^2$.

NOTE 3 If D_{nT} or D_n is calculated, the area of the separating element serves as an arbitrary reference and could be taken as 10 m^2 throughout the calculations.

NOTE 4 For certain building situations with combination of lightweight elements and massive elements, e.g. with suspended ceilings or lightweight facades, the flanking transmission is dominated by path Ff and the third and fourth terms in Formula (18) can be neglected for that flanking element.

NOTE 5 The contribution by one flanking element to the total flanking transmission can be evaluated by adding the corresponding transmission via the paths Ff and Df; the contribution of flanking transmission to the radiation by the separating element can be evaluated by adding the transmission via the paths Fd for all flanking elements.

For each transmission path the weighted sound reduction index is predicted from the input data on the elements and junctions (see [4.4.2](#)).

The weighted sound reduction index for airborne direct transmission is determined from the input value for the separating element according to [Formula \(19\)](#):

$$R_{Dd,w} = R_{s,w} + \Delta R_{Dd,w} \text{ dB} \quad (19)$$

where

$R_{s,w}$ is the weighted sound reduction index of the separating element, in decibels;

$\Delta R_{Dd,w}$ is the total weighted sound reduction index improvement by additional lining on the source and/or receiving side of the separating element, in decibels.

The weighted flanking sound reduction indices are determined from the input values according to [Formula \(20\)](#):

$$\begin{aligned} R_{Ff,w} &= \frac{R_{F,w} + R_{f,w}}{2} + \Delta R_{Ff,w} + K_{Ff} + \left(10 \lg \frac{S_s}{l_o l_f} \right) \text{ dB} \\ R_{Fd,w} &= \frac{R_{F,w} + R_{s,w}}{2} + \Delta R_{Fd,w} + K_{Fd} + \left(10 \lg \frac{S_s}{l_o l_f} \right) \text{ dB} \\ R_{Df,w} &= \frac{R_{s,w} + R_{f,w}}{2} + \Delta R_{Df,w} + K_{Df} + \left(10 \lg \frac{S_s}{l_o l_f} \right) \text{ dB} \end{aligned} \quad (20)$$

where

$R_{F,w}$ is the weighted sound reduction index of the flanking element F in the source room, in decibels;

$R_{f,w}$ is the weighted sound reduction index of the flanking element f in the receiving room, in decibels;

$\Delta R_{Ff,w}$ is the total weighted sound reduction index improvement by additional lining on the source and/or receiving side of the flanking element, in decibels;

$\Delta R_{Fd,w}$ is the total weighted sound reduction index improvement by additional lining on the flanking element at the source side and/or separating element at the receiving side, in decibels;

$\Delta R_{Df,w}$ is the total weighted sound reduction index improvement by additional lining on the separating element at the source side and/or flanking element at the receiving side, in decibels;

K_{Ff} is the vibration reduction index for transmission path Ff, in decibels;

K_{Fd} is the vibration reduction index for transmission path Fd, in decibels;

K_{Df} is the vibration reduction index for transmission path Df, in decibels;

S_s is the area of the separating element, in square metres;

l_f is the common coupling length of the junction between separating element and the flanking elements F and f, in metres;

l_o is the reference coupling length; $l_o = 1 \text{ m}$.

NOTE 5 In [Formula \(20\)](#), it is assumed that the element absorption length a is equal to the element area S .

For lightweight constructions, the weighted flanking sound reduction index $R_{ij,w}$ for any path Ff, Df or Fd shall be determined from the corresponding weighted flanking normalized level difference $D_{n,f,ij,w}$ using [Formula \(21\)](#):

$$R_{ij,w} = D_{n,f,ij,w} + \left(10 \lg \frac{l_{lab}}{l_{ij}} \frac{S_s}{A_o} \right) \text{ dB} \quad (21)$$

For certain flanking constructions, like suspended ceilings and lightweight facades, the transmission is normally dominated by path Ff, as characterized by the weighted flanking normalized level difference $D_{n,f,w}$, so the contributions of path Df and Fd can be neglected. $D_{n,f,w}$ can be either measured or determined from the performance of elements (see [Annex G](#)). For horizontal flanking elements like ceilings l_{lab} is usually of 4,5 m and for vertical flanking elements like facades l_{lab} is usually 2,5 m.

4.4.3 Input data

Acoustic data on the elements involved should be taken primarily from standardized laboratory measurements. However, they may also be deduced in other ways, using theoretical calculations, empirical estimations or field measurements. Information on this is given in [Annexes B, D, E and J](#). The sources of data used shall be clearly stated.

The input data consist of the following.

- a) The weighted sound reduction index of the elements: $R_{s,w}$, $R_{F,w}$, $R_{f,w}$.

Information for homogeneous elements is given in [Annex B](#).

- b) The vibration reduction index for each junction and path: K_{FF} , K_{Fd} , K_{Df} .

Information for common junctions is given in [Annex E](#). If the values for the vibration reduction index depend on frequency, the mean value averaged over the frequency range 1/3 octave 250 Hz to 1 000 Hz should be taken as an approximation in accordance with ISO 10848 (all parts), but then the result can be less accurate.

If a flanking element has insignificant or no structural contact with the separating element, only K_{FF} is relevant (see [Annex J](#)), while the transmission paths Fd and Df are neglected (i.e. by setting the K_{ij} values very high).

- c) The weighted normalized flanking sound level difference for transmission path Ff: $D_{n,f,Ff,w}$.

- d) The total weighted sound reduction index improvement for the separating element: $\Delta R_{Dd,w}$.

This value follows either directly from available results for the appropriate combination or is deduced from results for each of the layers involved separately, as shown by [Formula \(22\)](#):

$$\begin{aligned} \text{one layer : } \Delta R_{Dd,w} &= \Delta R_{D,w} \quad \text{or} \quad \Delta R_{d,w} \quad \text{dB} \\ \text{two layers : } \Delta R_{Dd,w} &= \Delta R_{D,w} + \frac{\Delta R_{d,w}}{2} \quad \text{or} \quad = \Delta R_{d,w} + \frac{\Delta R_{D,w}}{2} \quad \text{dB} \end{aligned} \quad (22)$$

In the case of two linings, half the value is taken for the lining with the lower value; however, if both linings have a negative value, then half the value is taken for the lining with the higher value.

- e) The total weighted sound reduction index improvement for each flanking path: $\Delta R_{Ff,w}$, $\Delta R_{Fd,w}$, $\Delta R_{Df,w}$.

These values follow either directly from available results for the appropriate combination or are deduced from results for each of the layers involved separately ($ij = Ff, Fd$ or Df), as shown by [Formula \(23\)](#):

one layer : $\Delta R_{ij,w} = \Delta R_{i,w}$ or $\Delta R_{j,w}$ dB

two layers: $\Delta R_{ij,w} = \Delta R_{i,w} + \frac{\Delta R_{j,w}}{2}$ or $= \Delta R_{j,w} + \frac{\Delta R_{i,w}}{2}$ dB (23)

In the case of two linings, half the value is taken for the lining with the lower value; however, if both linings have a negative value, then half the value is taken for the lining with the higher value.

Information on the weighted sound reduction index improvement is given in [Annex D](#).

- f) The weighted normalized sound level difference for technical elements: $D_{n,e,w}$.
- g) The weighted normalized sound level difference for indirect airborne sound transmission through a system: $D_{n,s,w}$.

4.4.4 Limitations

The following comments apply concerning the limitation of the prediction by the models presented.

- a) The limitations for the detailed model also apply for the simplified model.
- b) The simplified model applies mainly to dwellings where the dimensions of the elements are similar to those in the test facility. Deviations from this may result in less accurate results.
- c) The simplified model assumes elements for which the sound reduction index has a similar frequency dependence; with elements which have a clearly deviating frequency behaviour, as for instance double, lightweight elements, the accuracy may be less.

5 Accuracy

The calculation models predict the measured performance of buildings, assuming good workmanship and high measurement accuracy. The accuracy of the prediction by the models presented depends on many factors: the accuracy of the input data, the fitting of the situation to the model, the type of elements and junctions involved, the geometry of the situation and the workmanship. It is therefore not possible to specify the accuracy of the predictions in general for all types of situations and applications. Data on the accuracy have to be gathered in the future by comparing the results of the model with field measurements from a variety of different buildings. However, some indications can be given.

The main experience in the application of similar models has been so far with buildings where the basic structural elements are homogeneous, i.e. brick walls, concrete, gypsum blocks, etc. In those situations, the prediction of the single number rating by the detailed model is on average correct (no bias error) with a standard deviation of 1,5 dB to 2,5 dB (the lower value if all aspects are taken into account, the larger to complex situations and when neglecting the structural reverberation time).

Predictions with the simplified model show a standard deviation of about 2 dB. Uncertainty for the simplified model can be estimated using the method proposed in [Annex K](#).

In applying the predictions it is advisable to vary the input data, especially in complicated situations and with atypical elements with questionable input data. The resulting variation in the results gives an impression of the expected accuracy for these situations, assuming similar workmanship. A possibility to do this in a more systematic way by estimating overall accuracy from the accuracy of all acoustic input data is described in [Annex K](#).

Annex A (normative)

Symbols

Table A.1 — List of symbols

Symbol	Physical quantity	Unit
a	equivalent absorption length of a structural element	m
a_{situ}	equivalent absorption length of a structural element <i>in situ</i>	m
A	equivalent sound absorption area in the receiving room	m ²
A_o	reference equivalent sound absorption area; for dwellings given as 10 m ²	m ²
A_h	equivalent sound absorption area of a hall	m ²
B_i	bending stiffness per unit width of element i	Nm
c_B	bending wave speed	m/s
c_L	quasi-longitudinal wave speed	m/s
C_α	correction term for absorption above suspended ceiling	dB
$C_{\text{doorpos.}}$	correction term to take into account the relative position of the doors in a hall	dB
C_c	coefficient used in presence of elastic interlayers in junction	-
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
c_o	speed of sound in air (= 340 m/s)	m/s
C_{sab}	Sabine constant (= 0,16 s/m)	s/m
C_w	Waterhouse correction	dB
D_{nT}	standardized sound level difference	dB
$D_{\text{nT,w}}$	weighted standardized sound level difference	dB
$D_{\text{n,e}}$	element normalized level difference of small building elements	dB
$D_{\text{n,e,situ}}$	element normalized level difference of small building elements <i>in situ</i>	dB
$D_{\text{n,s}}$	normalized sound level difference for indirect transmission through a system s	dB
$D_{\text{n,f}}$	flanking normalized level difference	dB
$D_{\text{n,f,lab}}$	flanking normalized level difference in laboratory	dB
$D_{\text{n,f,situ}}$	flanking normalized level difference <i>in situ</i>	dB
$D_{\text{n,f,ij}}$	flanking normalized level difference between excited element i and receiving element j	dB
$D_{\text{n,f,ij,situ}}$	flanking normalized level difference between excited element i and receiving element j <i>in situ</i>	dB
$D_{\text{n,f,ij,w}}$	weighted flanking normalized level difference between excited element i and receiving element j	dB
$D_{\text{n,f,Ff,w}}$	weighted flanking normalized level difference for the transmission path Ff	dB
$D_{\text{n,j,w}}$	weighted normalized sound level difference for transmission through an small technical element or system	dB
$D_{\text{n,f,w}}$	weighted flanking normalized level difference	dB
$D_{\text{v,ij}}$	junction velocity level difference between excited element i and receiving element j	dB
$D_{\text{v,ij,situ}}$	direction-averaged junction velocity level difference between elements i and j <i>in situ</i>	dB

Table A.1 (continued)

Symbol	Physical quantity	Unit
$D_{v,ij,n}$	normalized direction-averaged velocity level difference between elements i and j	dB
d	depth of cavity of additional linings	m
E_l	Young's modulus of a flexible interlayer	N/m ²
f	frequency	Hz
f_c	critical frequency	Hz
$f_{c,eff}$	effective critical frequency, taking into account longitudinal and shear waves	Hz
f_{ref}	reference frequency (= 1 000 Hz)	Hz
f_l	characteristic frequency for the effect of flexible inter layers at junctions	Hz
f_p	plateau frequency for the sound reduction index	Hz
f_K	frequency to express the frequency dependence of the vibration reduction index (= 500 Hz)	Hz
f_o	mass-spring resonance frequency	Hz
h_{pl}	free height of the plenum above the ceiling	m
h_{lab}	laboratory value, as reference, for h_{pl} (= 0,7 m)	m
i, j	indices for an element; for a transmission path ij, i indicates an element in the source room (= F, D) and j an element in the receiving room (= f, d)	-
k	index for a border of an element	-
k_o	wave number in air ($k_o = 2 \pi f / c_o$)	rad/m
K_{ij}	vibration reduction index for each transmission path ij over a junction	dB
K_{Ff}	vibration reduction index for each transmission path Ff	dB
K_{Fd}	vibration reduction index for each transmission path Fd	dB
K_{Df}	vibration reduction index for each transmission path Df	dB
$K_{ij,min}$	minimum value for K_{ij} <i>in situ</i>	dB
L_1	average sound pressure level in the source room	dB re 20 µPa
L_2	average sound pressure level in the receiving room	dB re 20 µPa
L_k	length of border k of a total floor plate between load-bearing walls	m
l_{ij}	common coupling length between element i and element j	m
l_f	common coupling length between flanking element f and separating element	m
l_{lab}	laboratory value, as reference, for l_{ij}	m
l_k	length of border k of an element	m
l_o	reference length (= 1 m)	m
m'	mass per unit area of an element	kg/m ²
m'_o	reference mass per unit area (= 1 kg/m ²)	kg/m ²
M	$\lg \left(m'_{\perp i} / m'_i \right)$	-
n	number of flanking elements in a room	-
R	sound reduction index of an element	dB
R^*	sound reduction index of an element for the resonant transmission only	dB
R_{meas}	measured sound reduction index of an element	dB
R_{situ}	sound reduction index of an element in the actual field situation	dB
R'	apparent sound reduction index	dB

Table A.1 (continued)

Symbol	Physical quantity	Unit
R'_w	weighted apparent sound reduction index	dB
R_{ij}	flanking sound reduction index	dB
R_s	sound reduction index of separating element	dB
R_f	sound reduction index of flanking element	dB
$R_{s,situ}$	sound reduction index of separating element <i>in situ</i>	dB
R_{Dd}	sound reduction index for airborne direct transmission	dB
R_{Ff}	sound reduction index for the transmission path Ff	dB
R_{Df}	sound reduction index for the transmission path Df	dB
R_{Fd}	sound reduction index for the transmission path Fd	dB
R_i	sound reduction index for element i in source room	dB
$R_{i,situ}$	sound reduction index of element i <i>in situ</i>	dB
R_j	sound reduction index for element j in receiving room	dB
$R_{j,situ}$	sound reduction index of element j <i>in situ</i>	dB
ΔR	sound reduction index improvement by additional layers	dB
ΔR_{situ}	sound reduction index improvement by additional layers <i>in situ</i>	dB
ΔR_{lab}	measured sound reduction index improvement by additional layers	dB
ΔR_f	sound reduction index improvement by additional layers for flanking transmission	dB
ΔR_s	sound reduction index improvement by additional layers for separating element	dB
ΔR_D	sound reduction index improvement by additional layers for separating element in the source room	dB
ΔR_d	sound reduction index improvement by additional layers for separating element in the receiving room	dB
ΔR_i	sound reduction index improvement by additional layers for element i	dB
ΔR_j	sound reduction index improvement by additional layers for element j	dB
$\Delta R_{D,situ}$	sound reduction index improvement by additional layers for separating element in the source room <i>in situ</i>	dB
$\Delta R_{d,situ}$	sound reduction index improvement by additional layers for separating element in the receiving room <i>in situ</i>	dB
$\Delta R_{i,situ}$	sound reduction index improvement by additional layers for element i <i>in situ</i>	dB
$\Delta R_{j,situ}$	sound reduction index improvement by additional layers for element j <i>in situ</i>	dB
R_{hs}	sound reduction index of the wall between a hall and the source room	dB
R_{hr}	sound reduction index of the wall between the hall and the receiving room	dB
R_w	weighted sound reduction index in accordance with ISO 717-1	dB
$R_{s,w}$	weighted sound reduction index of the separating element	dB
$R_{F,w}$	weighted sound reduction index of the flanking element F in the source room	dB
$R_{f,w}$	weighted sound reduction index of the flanking element f in the receiving room	dB
$R_{Dd,w}$	weighted sound reduction index for airborne direct transmission	dB
$R_{Ff,w}$	weighted sound reduction index for the transmission path Ff	dB
$R_{Df,w}$	weighted sound reduction index for the transmission path Df	dB
$R_{Fd,w}$	weighted sound reduction index for the transmission path Fd	dB
ΔR_w	weighted sound reduction index improvement by additional layers	dB
$\Delta R_{w,situ}$	weighted sound reduction index improvement by additional layers <i>in situ</i>	dB
$\Delta R_{Dd,w}$	total weighted sound reduction index improvement by additional lining on the source and/or receiving side of the separating element	dB

Table A.1 (continued)

Symbol	Physical quantity	Unit
$\Delta R_{Ff,w}$	total weighted sound reduction index improvement by additional lining on the source and/or receiving side of the flanking element	dB
$\Delta R_{Fd,w}$	total weighted sound reduction index improvement by additional lining on the flanking element at the source side and/or separating element at the receiving side	dB
$\Delta R_{Df,w}$	total weighted sound reduction index improvement by additional lining on the separating element at the source side and/or flanking element at the receiving side	dB
Δ_l	correction of the K_{ij} in presence of elastic interlayers in junction	dB
S_{rec}	area of the part of a floor, seen from the receiving room	m ²
S_{tot}	total area of a floor field between load bearing structural elements	m ²
S_{hs}, S_{hr}	area of the wall between the hall and the source room, and receiving room, respectively	m ²
S_{cs}, S_{cr}	the area of the ceiling in the source room and receiving room, respectively	m ²
S_{lab}	laboratory value, as reference, for S_{cs} and S_{cr} (= 20 m ²)	m ²
S_s	area of separating element	m ²
S_i, S_j	area of an element in the source room (i) and receiving room (j), respectively	m ²
$S_{i,situ}, S_{j,situ}$	area of an element in the source room (i) and receiving room (j), respectively <i>in situ</i>	m ²
S_{mi}	area of an element i over which the velocity is averaged	m ²
s'	dynamic stiffness of a layer	MN/m ³
s'_t	apparent dynamic stiffness of a flexible interlayer	MN/m ³
t	thickness of a structural element	m
t_a	thickness of an absorbing lining	m
t_l	thickness of a flexible interlayer	m
T	reverberation time in the receiving room	s
T_0	reference reverberation time; for dwellings given as 0,5 s	s
T_s	structural reverberation time of a (homogeneous) element	s
$T_{s,tot}$	laboratory structural reverberation time for total (homogeneous) element	s
T_{sf}	structural reverberation time of a (homogeneous) flanking element	s
$T_{s,lab}$	laboratory structural reverberation time for each (homogeneous) element	s
$T_{s,situ}$	structural reverberation time <i>in situ</i>	s
V	the volume of the receiving room	m ³
v_i^2	average square velocity over element i (free waves)	(m/s) ²
v_j^2	average square velocity over element j (free waves)	(m/s) ²
W_{tot}	total radiated sound power into receiving room	W
W_{ij}	radiated sound power by element j due to incident sound on element i	W
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	-
α_k	absorption coefficient for bending wave field at border k of an element	-
γ_{ij}	power transmission factor for bending wave field at a junction between element i and j	-
Δ_l	reduction of vibration reduction index by a flexible layer	dB
η_{ij}	coupling loss factor between element i and j	-
η_{tot}	total loss factor	-
$\eta_{tot,lab}$	total loss factor in the laboratory situation	-

Table A.1 (continued)

Symbol	Physical quantity	Unit
$\eta_{\text{tot,situ}}$	total loss factor <i>in situ</i>	-
η_{int}	internal loss factor	-
ρ	density	kg/m ³
ρ_0	density of air	kg/m ³
σ, σ_s	radiation factor for free bending waves (case of structural excitation)	-
σ_f	radiation factor for forced waves	-
σ_a	radiation factor for airborne excitation	-
τ	transmission factor (sound power ratio)	-
τ_{ij}	flanking transmission factor	-
τ'	sound power ratio of total radiated sound power in the receiving room relative to incident sound power on the common part of the separating element	-
τ_d	sound power ratio of radiated sound power by the common part of the separating element relative to incident sound power on the common part of the separating element; it includes the paths Dd and Fd	-
τ_f	sound power ratio of radiated sound power by a flanking construction f in the receiving room relative to incident sound power on the common part of the separating element; it includes paths Ff and Df	-
τ_{Dd}	sound power ratio of radiated sound power for airborne direct transmission	dB
τ_{Ff}	sound power ratio of radiated sound power for the transmission path Ff	dB
τ_{Df}	sound power ratio of radiated sound power for the transmission path Df	dB
τ_{Fd}	sound power ratio of radiated sound power for the transmission path Fd	dB
τ_s	sound power ratio of radiated sound power in receiving room by indirect airborne transmission system s due to incident sound power on this transmission system, relative to incident sound power on the common part of the separating element	-
τ_e	sound power ratio of radiated sound power in the receiving room by an element in the separating element due to direct airborne sound transmission of incident sound on this element, relative to incident sound power on the common part of the separating element	-
$\%S_0$	percentage of the area over which the additional layer is glued to the basic element	%