INTERNATIONAL STANDARD

ISO 12354-1

First edition
2017-07

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

Part 1:
Airborne sound insulation between rooms

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

Reference number
ISO 12354-1:2017(E)

ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

Contents

Page

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).

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).

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.

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

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

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

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

where A_0 is the reference absorption area given as 10 m^2.

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/m^2, 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

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

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_o) in the receiving room; $A_o = 10\ \text{m}^2$

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

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

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_o) in the receiving room; $A_o = 10\ \text{m}^2$.

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

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

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_o) in the receiving room; $A_o = 10\ \text{m}^2$.

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

$D_{\mathrm{v,ij}}$	is the velocity level difference between element i and j, when element i is excited, in decibels;
$D_{\mathrm{v,ji}}$	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

$$a = \frac{2{,}2\pi^2 \, S}{c_{\mathrm{o}} \, T_{\mathrm{s}}} \sqrt{\frac{f_{\mathrm{ref}}}{f}}$$

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; $f_{\mathrm{ref}} = 1\,000$ 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

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

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

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

where

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

Note 1 to entry: The quantity $\overline{D_{\mathrm{v,ij,n}}}$ 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

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

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

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

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):

$$R' = -\left(10\,\lg \tau'\right)\ \mathrm{dB} \qquad (1)$$

where

$$\tau' = \tau_{\mathrm{d}} + \sum_{\mathrm{f}=1}^{\mathrm{n}} \tau_{\mathrm{f}} + \sum_{\mathrm{e}=1}^{\mathrm{m}} \tau_{\mathrm{e}} + \sum_{\mathrm{s}=1}^{\mathrm{k}} \tau_{\mathrm{s}}$$

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;

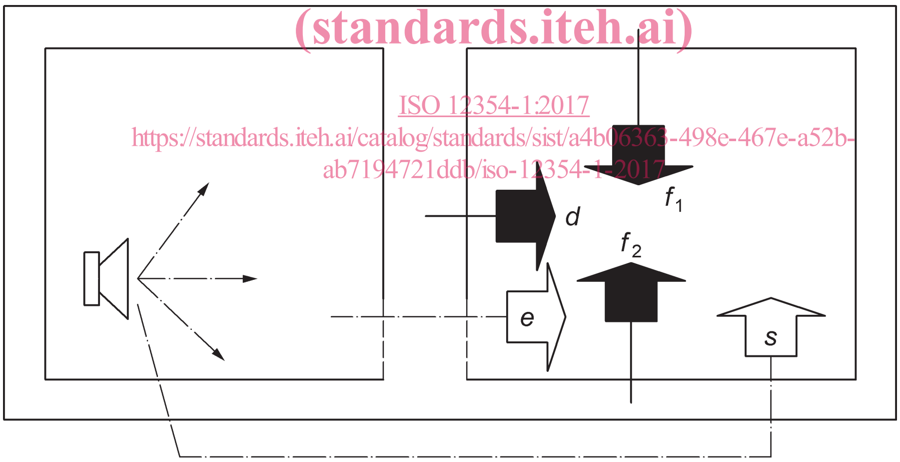
τ_e is the sound power ratio of radiated sound power in the receiving room by an element in the separating element due to direct airborne transmission of incident sound on this element, relative to incident sound power on the common part of the separating element;

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.

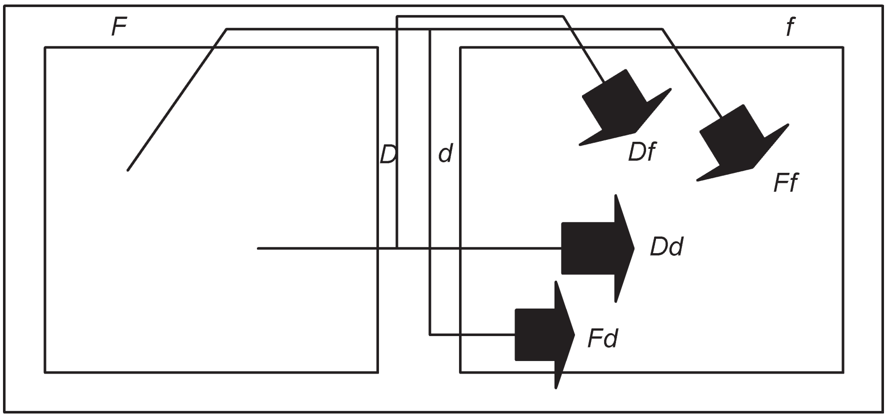


Key

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):

$$\tau_{\mathrm{d}} = \tau_{\mathrm{Dd}} + \sum_{\mathrm{F}=1}^{\mathrm{n}} \tau_{\mathrm{Fd}} \tag{2}$$

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):

$$\tau_{\mathrm{f}} = \tau_{\mathrm{Df}} + \tau_{\mathrm{Ff}} \tag{3}$$

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):

$$\begin{aligned} \tau_{\mathrm{Dd}} &= 10^{-R_{\mathrm{Dd}}/10} \\ \tau_{\mathrm{ij}} &= 10^{-R_{\mathrm{ij}}/10} \end{aligned} \tag{4}$$