
**Acoustics — Laboratory and field
measurement of flanking transmission
for airborne, impact and building
service equipment sound between
adjoining rooms —**

**Part 1:
Frame document**

Acoustique — Mesurage en laboratoire et sur site des transmissions latérales du bruit aérien, des bruits de choc et du bruit d'équipement technique de bâtiment entre des pièces adjacentes —

Partie 1: Document cadre



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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

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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).

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 voluntary nature of standards, 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 ISO/TC 43, *Acoustics*, Subcommittee SC 2, *Building acoustics*.

This second edition cancels and replaces the first edition (ISO 10848-1:2006), which has been technically revised with the following changes:

- a) extension to field measurements;
- b) extension to building service equipment;
- c) normalized direction-averaged vibration level difference for junctions between lightweight elements has been introduced;
- d) an assessment method for the decrease in vibration level with distance has been introduced;
- e) transmission function measurements with a calibrated structure-borne sound source has been introduced;
- f) definitions of element types A and B to avoid issues with the terms “heavy” and “light” have been added.

A list of all the parts in the ISO 10848 series can be found on the ISO website.

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Acoustics — Laboratory and field measurement of flanking transmission for airborne, impact and building service equipment sound between adjoining rooms —

Part 1: Frame document

1 Scope

ISO 10848 (all parts) specifies measurement methods to characterize the flanking transmission of one or several building components. These measurements are performed in a laboratory test facility or in the field.

The performance of the building components is expressed either as an overall quantity for the combination of elements and junction (such as the normalized flanking level difference and/or normalized flanking impact sound pressure level) or as the vibration reduction index of a junction or the normalized direction-average vibration level difference of a junction.

Two approaches are used for structure-borne sound sources in buildings, a normalized flanking equipment sound pressure level and a transmission function that can be used to estimate sound pressure levels in a receiving room due to structure-borne excitation by service equipment in a source room. The former approach assumes that flanking transmission is limited to one junction (or no junction if the element supporting the equipment is the separating element), and the latter considers the combination of direct (if any) and all flanking transmission paths.

This document contains definitions, general requirements for test elements and test rooms, and measurement methods. Guidelines are given for the selection of the quantity to be measured, depending on the junction and the types of building elements involved. Other parts of ISO 10848 specify the application for different types of junction and building elements.

The quantities characterizing the flanking transmission can be used to compare different products, or to express a requirement, or as input data for prediction methods, such as ISO 12354-1 and ISO 12354-2.

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 717-2, *Acoustics — Rating of sound insulation in buildings and of building elements — Part 2: Impact sound insulation*

ISO 3382-2, *Acoustics — Measurement of room acoustic parameters — Part 2: Reverberation time in ordinary rooms*

ISO 7626-1, *Mechanical vibration and shock — Experimental determination of mechanical mobility — Part 1: Basic terms and definitions, and transducer specifications*

ISO 7626-5, *Vibration and shock — Experimental determination of mechanical mobility — Part 5: Measurements using impact excitation with an exciter which is not attached to the structure*

ISO 10140-4:2010, *Acoustics — Laboratory measurement of sound insulation of building elements — Part 4: Measurement procedures and requirements*

ISO 10140-5:2010, *Acoustics — Laboratory measurement of sound insulation of building elements — Part 5: Requirements for test facilities and equipment*

IEC 61183, *Electroacoustics—Random-incidence and diffuse-field calibration of sound level meters*

IEC 61260 (all parts), *Electroacoustics — Octave-band and fractional-octave-band filters*

IEC 61672-1, *Electroacoustics — Sound level meters elements — Part 1: Specifications*

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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 average sound pressure level in a room

L

ten times the common logarithm of the ratio of the space and time average of the sound pressure squared to the square of the reference sound pressure, the space average being taken over the entire room with the exception of those parts where the direct radiation of a sound source or the near field of the boundaries (walls, etc.) is of significant influence

Note 1 to entry: This quantity is expressed in decibels.

Note 2 to entry: If a continuously moving microphone is used, L is determined as follows:

$$L = 10 \lg \left(\frac{\frac{1}{T_m} \int_0^{T_m} p^2(t) dt}{p_0^2} \right)$$

3.2 normalized flanking level difference

$D_{n,f}$

difference in the space and time averaged sound pressure level produced in two rooms by one or more sound sources in one of them, when the transmission only occurs through a specified flanking path and the result is normalized to an equivalent sound absorption area in the receiving room as follows:

$$D_{n,f} = L_1 - L_2 - 10 \lg \frac{A}{A_0}$$

where

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

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

A is the equivalent sound absorption area in the receiving room, in m²;

A_0 is the reference equivalent sound absorption area, in m²; $A_0 = 10 \text{ m}^2$

Note 1 to entry: This quantity is expressed in decibels.

Note 2 to entry: For clarity, the term $D_{n,f}$ is used when only one flanking path determines the sound transmission (such as with suspended ceilings) and the term $D_{n,f,ij}$ is used when only one specified transmission path ij out of several paths is considered (such as with structure-borne sound transmission on junctions of three or four connected elements).

3.3

normalized flanking impact sound pressure level

$L_{n,f}$

space and time averaged sound pressure level in the receiving room produced by a tapping machine operating at different positions on a tested element (floor) in the source room, when the transmission only occurs through a specified flanking path and the result is normalized to an equivalent sound absorption area, in the receiving room and is expressed as follows:

$$L_{n,f} = L_2 + 10 \lg \frac{A}{A_0}$$

where

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

A is the equivalent sound absorption area in the receiving room, in m²;

A_0 is the reference equivalent sound absorption area, in m²; $A_0 = 10 \text{ m}^2$

Note 1 to entry: This quantity is expressed in decibels.

Note 2 to entry: For clarity, the term $L_{n,f}$ is used when only one flanking path determines the sound transmission (such as with access floors) and the term $L_{n,f,ij}$ is used when only one specified transmission path ij out of several paths is considered (such as with structure-borne sound transmission on junctions of three or four connected elements).

3.4

normalized flanking equipment sound pressure level

$L_{ne0,f}$

space and time averaged sound pressure level in the receiving room produced by a structure-borne sound source injecting a unit power (1 W) at different positions on a tested element in the source room, when the transmission only occurs through a specified flanking path and the result is normalized to an equivalent sound absorption area in the receiving room and is expressed as follows:

$$L_{ne0,f} = L_{2e} + 10 \lg \frac{A}{A_0}$$

where

L_{2e} is the average sound pressure level in the receiving room with a structure-borne sound source injecting 1 W into the tested element, in dB;

A is the equivalent sound absorption area in the receiving room, in m²;

A_0 is the reference equivalent sound absorption area, in m²; $A_0 = 10 \text{ m}^2$

Note 1 to entry: This quantity is expressed in decibels.

Note 2 to entry: For clarity, the term $L_{ne0,f}$ is used when only one flanking path determines the sound transmission (such as with equipment installed on access floors or light façades) and the term $L_{ne0,f,ij}$ is used when only one specified transmission path ij out of several paths is considered (such as with structure-borne sound transmission on junctions of three or four connected elements).

Note 3 to entry: The sound pressure level generated by any equipment, $L_{ne,f,equip}$, can be approximated when the equipment has been characterized using EN 15657 and its averaged installed power $L_{W,equip}$ has been determined from the spatial average single equivalent mobility of the supporting element as described in EN 15657:2009, C.3 and using EN 15657 to give the installed power from the equipment and receiver characteristics.

3.5 transmission function for excitation position k

$D_{TF,k}$

difference between the space and time averaged sound pressure level in the receiving room and the structure-borne sound power level for a source at excitation position k on the source element as follows:

$$D_{TF,k} = L_{av,k} - L_{W,k}$$

where

$L_{av,k}$ is the average sound pressure level in the receiving room, in dB, referenced to 2×10^{-5} Pa;

$L_{W,k}$ is the structure-borne sound power level, in dB, referenced to 10^{-12} W.

Note 1 to entry: This quantity is expressed in decibels.

Note 2 to entry: The transmission function [25] is specific to the building in which it is measured and quantifies the combination of all the transmission paths from the power injected at a source position on an element to a spatial average sound pressure level in a receiving room in a building. In some cases, the transmission function will only correspond to the combination of all the flanking paths, but in some situations, it will be a combination of the direct transmission path and all the flanking paths. The building could either be a laboratory set-up (such as a flanking laboratory with wall and/or floor junctions) or an actual building.

3.6 spatial average transmission function

$D_{TF,av}$

average transmission function from K excitation positions on the source element as follows:

$$D_{TF,av} = 10 \lg \left(\frac{\sum_{k=1}^K 10^{D_{TF,k}/10}}{K} \right)$$

3.7 normalized spatial average transmission function

$D_{TF,av,n}$

spatial average transmission function (3.6) which is normalized to an equivalent sound absorption area in the receiving room that is calculated as follows:

$$D_{TF,av,n} = D_{TF,av} + 10 \lg \frac{A}{A_0}$$

Note 1 to entry: This quantity is expressed in decibels.

Note 2 to entry: Normalized transmission functions can be used in the following ways:

- to assess the accuracy of prediction models such as ISO 12354-1 or ISO 12354-2 which consider a limited number of flanking transmission paths that are either measured according to ISO 10848 (all parts), or estimated according to ISO 12354-1 or ISO 12354-2;
- to create databases of average transmission functions as a simplified prediction tool for different building types;
- to determine the optimum position for service equipment in an existing building.

3.8 structural reverberation time

T_s

time that would be required for the velocity or acceleration level in a structure to decrease by 60 dB after the structure-borne sound source has stopped

Note 1 to entry: This quantity is expressed in seconds.

Note 2 to entry: The definition of T_s with a decrease by 60 dB of the velocity or acceleration level in a structure can be fulfilled by linear extrapolation of shorter evaluation ranges.

3.9

average velocity level

L_v

ten times the common logarithm of the ratio of the time and space averaged mean-square normal velocity of an element to the squared reference velocity as follows:

$$L_v = 10 \lg \left(\frac{\frac{1}{T_m} \int_0^{T_m} v^2(t) dt}{v_0^2} \right)$$

where v_0 is the reference velocity, in m/s; $v_0 = 1 \times 10^{-9}$ m/s

Note 1 to entry: This quantity is expressed in decibels.

Note 2 to entry: The reference velocity preferred in ISO 1683 is 1×10^{-9} m/s, although a common reference value in some countries is still $v_0 = 5 \times 10^{-8}$ m/s.

Note 3 to entry: Instead of the average velocity level, the average acceleration level L_a can be measured. The reference acceleration preferred in ISO 1683 is 1×10^{-6} m/s².

3.10

velocity level difference

$D_{v,ij}$

difference between the *average velocity level* (3.9) of an element i and that of an element j , when only the element i is excited (airborne or structure-borne)

Note 1 to entry: This quantity is expressed in decibels.

3.11

direction-averaged velocity level difference

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

arithmetic average of $D_{v,ij}$ and $D_{v,ji}$ as defined as follows:

$$\overline{D_{v,ij}} = \frac{1}{2} (D_{v,ij} + D_{v,ji})$$

where

$D_{v,ij}$ is the difference between the *average velocity level* (3.9) of an element i and that of an element j , when only the element i is excited, in dB;

$D_{v,ji}$ is the difference between the average velocity level of an element j and that of an element i , when only the element j is excited, in dB.

Note 1 to entry: This quantity is expressed in decibels.

3.12

equivalent absorption length of an element

a_j

length of a fictional totally-absorbing junction of an element j when the critical frequency is assumed to be 1 000 Hz, giving the same losses as the total losses of the element j in a given situation as follows:

$$a_j = \frac{2,2\pi^2 S_j}{T_{s,j} c_0 \sqrt{\frac{f}{f_{\text{ref}}}}}$$

where

$T_{s,j}$ is the *structural reverberation time* (3.8) of the element j , in s;

S_j is the surface area of the element j , in m²;

c_0 is the speed of sound in air, in m/s;

f is the frequency, in Hz;

f_{ref} is the reference frequency, in Hz ($f_{\text{ref}} = 1\,000$ Hz).

Note 1 to entry: This quantity is expressed in metres.

3.13

vibration reduction index

K_{ij}
direction-averaged velocity level difference (3.11) between two elements across a junction that is normalised to the junction length and the equivalent sound absorption length of both elements as follows:

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

where

$\overline{D_{v,ij}}$ is the direction-averaged velocity level difference between elements i and j , in dB;

l_{ij} is the junction length between elements i and j , in m;

a_i, a_j are the equivalent absorption lengths of elements i and j , in m.

Note 1 to entry: This quantity is expressed in decibels.

Note 2 to entry: K_{ij} can be obtained from measurements of the *velocity level difference* (3.10) in both directions across the junction and the *structural reverberation time* (3.8) of the two elements i and j .

3.14

normalized direction-average 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 as follows:

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

where

l_0 is the reference length, in m; $l_0 = 1$ m;

$S_{m,i}$ is the area of element i over which the velocity is measured, in m²;

$S_{m,j}$ is the area of element j over which the velocity is measured, in m².

Note 1 to entry: This quantity is expressed in decibels.

3.15

Type A element

element with a *structural reverberation time* (3.8) 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 6dB across the element in the direction perpendicular to the junction line (up to at least the 1 000 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-frequency and mid-frequency ranges and a *Type B element* (3.16) in the high-frequency range[15].

3.16

Type B element

element that is not a *Type A element* (3.15)

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-frequency and mid-frequency ranges and a Type B element in the high-frequency range[15].

4 Quantities to characterize flanking transmission

4.1 General

Flanking transmission by coupled elements and junctions is characterized in the following ways:

- by vibration transmission across a junction using K_{ij} for Type A elements or combinations of Type A and B elements;
- by vibration transmission across a junction using $\overline{D_{v,ij,n}}$ for Type B elements;
- by an overall transmission quantity for a specified flanking path ($D_{n,f}$, $L_{n,f}$ or $L_{ne0,f}$) for Type B elements.

Each of these quantities has its own restrictions and field of application.

The vibration reduction index is related to the normalized flanking level difference using [Formula \(1\)](#):

$$K_{ij} = D_{n,f} - \frac{R_i + R_j}{2} - 10 \lg \left(\frac{\sqrt{a_i a_j}}{l_{ij}} \right) + 10 \lg \left(\frac{\sqrt{S_i S_j}}{A_0} \right) \quad (1)$$

where R_i and R_j only correspond to resonant transmission for elements i and j , hence R_i and R_j measured according to ISO 10140-2 or ISO 15186-1 shall be corrected before they can be inserted in [Formula \(1\)](#) because they include forced transmission. ISO 12354-1 indicates how to correct the measured sound reduction index to remove the forced transmission.

The normalized flanking level difference can be calculated from the acoustic performance of the elements using [Formula \(2\)](#):

$$D_{n,f} = \frac{R_i + R_j}{2} + \Delta R_i + \Delta R_j + \overline{D_{v,ij,n}} + 10 \lg \left(\frac{A_0}{l_0 l_{ij}} \right) \quad (2)$$

NOTE This relationship can be used to check the consistency of $D_{n,f}$ and $\overline{D_{v,ij,n}}$ measurements from ISO 10848-3 for Type B elements where the junction has a substantial influence.

4.2 Normalized flanking level difference, $D_{n,f}$, normalized flanking impact sound pressure level, $L_{n,f}$, and normalized flanking equipment sound pressure level, $L_{ne0,f}$

4.2.1 General

$D_{n,f}$, $L_{n,f}$ and $L_{ne0,f}$ characterize the flanking transmission over an element in the source room and an element in the receiving room, including the sound radiation in the receiving room. $D_{n,f}$, $L_{n,f}$ and $L_{ne0,f}$ depend upon the dimensions of the elements involved. $D_{n,f}$ is measured with airborne excitation, $L_{n,f}$ is measured with a standard tapping machine and $L_{ne0,f}$ is measured according to [7.1.1.3](#).

4.2.2 $\overline{D_{v,ij,n}}$ estimated from measurements of $D_{n,f}$

When $D_{n,f}$ is measured for junctions of only Type B elements, $\overline{D_{v,ij,n}}$ can be estimated from $D_{n,f}$ using [Formula \(3\)](#):

$$D_{n,f} = \frac{R_i + R_j}{2} + \Delta R_i + \Delta R_j + \overline{D_{v,ij,n}} + 10 \lg \left(\frac{A_0}{l_0 l_{ij}} \right) \quad (3)$$

4.3 Vibration reduction index, K_{ij}

4.3.1 General

The vibration reduction index K_{ij} is defined in ISO 12354-1 and ISO 12354-2 as a situation invariant quantity to characterize a junction between elements. K_{ij} is measured with structure-borne excitation and is determined according to [Formula \(14\)](#) which is based on power transmission considerations as a simplification of Statistical Energy Analysis (SEA). This implies that the following assumptions of classical SEA are met:

- the coupling between i and j is weak;
- the vibration fields in the elements are diffuse.

K_{ij} might not be relevant and might not be situation-invariant in the following cases:

- a) elements that are strongly coupled, such that the individual elements cannot be considered as SEA subsystems (see [4.3.3](#));
- b) elements where the vibration field cannot be considered as reverberant due to a significant decrease in vibration level with distance across the element, for example, due to high internal losses or periodicity in the structure. This shall be assessed using [Annex A](#);
- c) low modal overlap factors or low mode counts (see ISO 10848-4:2017, 6.3.1 for Type A elements).

The above limitations can be used to identify the frequency range where measurements are applicable to ISO 12354 and indicate potential issues with the accuracy of the measurement results.

4.3.2 K_{ij} for combinations of Type A and B elements

The formula in 3.13 can be used for combinations of Type A and B elements by replacing the absorption length of the Type B element(s) with its surface area.

4.3.3 Strong coupling between Type A elements

The measured value of K_{ij} may not be relevant due to strong coupling, if the condition in Formula (4) is not satisfied:

$$D_{v,ij} \geq 3\text{dB} - 10 \lg \left(\frac{m_i f_{cj}}{m_j f_{ci}} \right) \quad (4)$$

where

m_i, m_j are the masses per unit area of the elements, in kg/m²;

f_{ci}, f_{cj} are the critical frequencies of the elements, in Hz.

If Formula (4) is not satisfied in the laboratory situation, it might be possible to increase the total damping by adding damping material to the edges of the elements or by connecting the elements to other structural elements.

NOTE Connecting test elements to other structural elements increases the likelihood of unwanted flanking transmission via structure-borne paths affecting the measurement [16] and therefore the measurement will not be situation invariant because it will include many additional flanking paths. This is a particular issue with *in situ* measurements.

For homogeneous and isotropic elements, f_c can be calculated by Formula (5):

$$f_c = \frac{c_0^2}{1,8 h c_L} \quad (5)$$

where

c_0 is the speed of sound in air, in m/s;

c_L is the longitudinal wave speed, in m/s;

h is the thickness, in m.

For some elements, f_c can be estimated by identifying the dip in the sound reduction index curve.

For orthotropic plates, there are two critical frequencies, $f_{c,x}$ and $f_{c,y}$, in the x-directions and y-directions respectively; hence, an effective critical frequency of the element can be calculated using Formula (6):

$$f_c = \sqrt{f_{c,x} f_{c,y}} \quad (6)$$

4.4 Normalized direction-average vibration level difference, $\overline{D_{v,ij,n}}$

4.4.1 General

For Type B elements, the use of K_{ij} is no longer valid due to the existence of non-uniform vibration fields; however, the use of vibration level difference as a descriptor is still appropriate. [17,18] Compared to Type A elements which are rigidly connected, Type B elements often have significantly higher vibration level differences that are frequency-dependent.

The existence of unwanted airborne and structure-borne flanking paths will limit the possibility to quantify this transmission path in both the laboratory and the field.

4.5 Selection of the measurement method

The different possibilities mentioned below are summarized in [Table 1](#) according to the types of junction and elements.

Table 1 — Different measurement methods according to the types of junction and test elements

Type of junction	$D_{n,f}$ and/or $L_{n,f}$ and/or $L_{ne0,f}$ ^a	K_{ij}	$\overline{D_{v,ij,n}}$
Type A elements Laboratory and field (see ISO 10848-4)	Not applicable	Applicable if flanking transmission along paths other than ij is suppressed or insignificant ^b	Not applicable
Type B elements where the junction has a small influence Laboratory only (see ISO 10848-2)	Applicable after verification (see 8.3)	Not applicable	Not applicable
Type B elements where the junction has a substantial influence Laboratory and field (see ISO 10848-3)	Applicable after shielding and possible indirect determination of $\overline{D_{v,ij,n}}$	Not applicable	Applicable if transmission path other than ij is suppressed or insignificant ^b
Combination of Type A and Type B elements Laboratory and field (see ISO 10848-4)	Not applicable	Applicable if flanking transmission along paths other than ij is suppressed or insignificant ^b	Not applicable
^a Shielding is not necessary in the source room for measurement of $L_{n,f}$ and $L_{ne0,f}$.			
^b Field measurements are allowed.			

5 Instrumentation

5.1 General

The loudspeaker shall fulfil the requirements on directivity given in ISO 10140-5:2010, Annex D.

The standard tapping machine shall meet the requirements given in ISO 10140-5:2010, Annex E.

If used, the instruments for measuring sound pressure levels, including microphone(s), as well as cable(s), windscreen(s), recording devices and other accessories, shall meet the requirements for a class 1 instrument according to IEC 61672-1 for random incidence application.

Specifications and calibration of the vibration transducers shall comply with ISO 7626-1.

The filters shall meet the requirements for a class 1 instrument according to IEC 61260 (all parts).

The reverberation time equipment shall comply with the requirements defined in ISO 3382-2.

All other equipment shall meet the requirements for measurement in [Clause 7](#).

5.2 Verification

Compliance of the sound pressure level measuring instrument, the filters and the sound calibrator with the relevant requirements shall be verified by the existence of a valid certificate of compliance. If applicable, random incidence response of the microphone shall be verified by a procedure from IEC 61183. All compliance testing shall be conducted by a laboratory being accredited or otherwise nationally authorized to perform the relevant tests and calibrations and ensuring metrological traceability to the appropriate measurement standards.

Unless national regulations dictate otherwise, it is recommended that the sound calibrator should be calibrated at intervals not exceeding one year, the compliance of the instrumentation system with the requirements of IEC 61672-1 should be verified at intervals not exceeding two years, and the compliance of the filter set with the requirements of IEC 61260 (all parts) should be verified at intervals not exceeding two years.

6 General requirements for test facility and test elements

6.1 Laboratory

For laboratory measurements of $D_{n,f}$, $L_{n,f}$ and $L_{ne0,f}$, the test facility shall comply with the following requirements, corresponding to the general requirements of rooms for laboratory tests with suppressed flanking transmission specified in ISO 10140-5 unless there are specific requirements on dimensions in a product standard.

NOTE For example, with unitized products such as curtain walling, EN 13830 gives dimensions for the test elements.

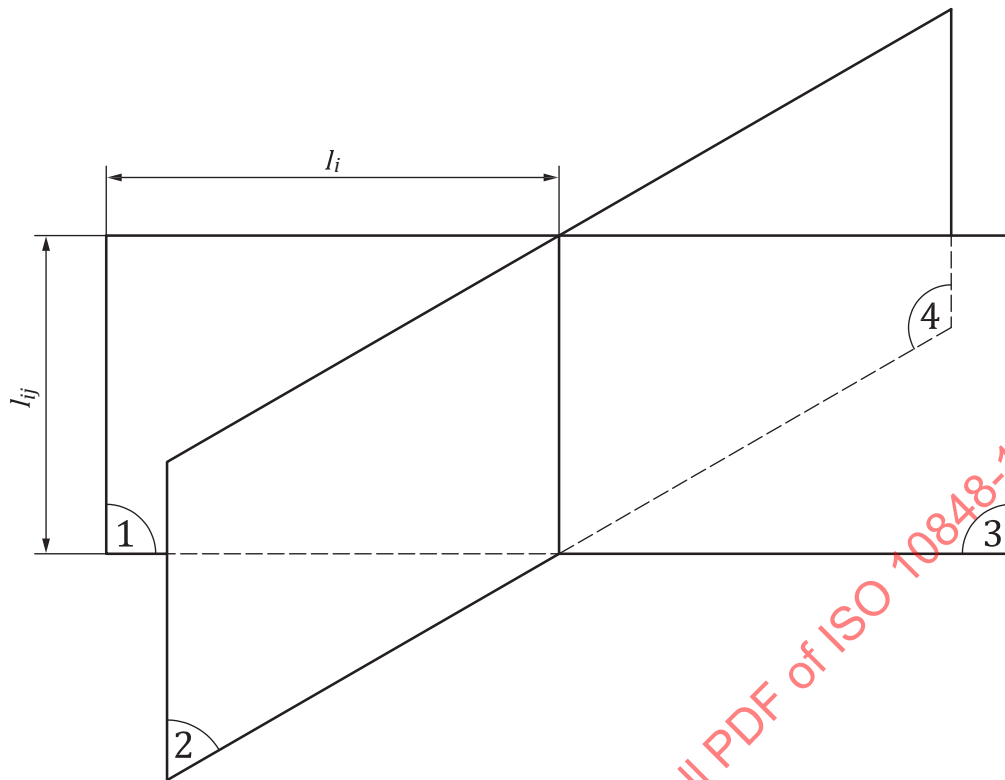
The volumes and corresponding dimensions of the laboratory test rooms should not be exactly the same. A difference in room volumes and/or in the linear dimensions of at least 10 % is recommended. The room volumes shall be at least 50 m³. The ratios of the room dimensions should be chosen so that the modal frequencies in the low-frequency bands are spaced as uniformly as possible. Large variations of the sound pressure level in the room indicate the presence of strong standing waves. In this case, it is necessary to install diffusing elements in the rooms. The positions and the necessary number of diffusing elements shall be evaluated by experiments with the goal that the measured quantity (for example, $D_{n,f}$) is not influenced when further diffusing elements are installed (see ISO 10140-5).

Under normal test conditions, the reverberation time in rooms with a test element installed shall not exceed 2 s and shall not be less than 1 s. Where the reverberation time at low frequencies (50 Hz to 200 Hz) exceeds 2 s, a check shall be made to determine whether the measured quantity (for example, $D_{n,f}$) depends on the reverberation time. When such a dependence is found, even with diffusors in the rooms, the room shall be modified to adjust the reverberation time to values between 1 s and not higher than 2 (V/50)^{2/3} s at low frequencies (V is the value of the room volume in m³).

The background noise level in the receiving room shall be sufficiently low to permit measurements of the sound transmitted from the source room, considering the power output in the source room and the sound insulation of the test elements for which the laboratory is intended.

The dimensions of the test elements that form the junction shall be as given in [Figures 1](#) and [2](#). The test element may be of a dimension smaller than the dimension of the test facility. In these cases, the gap shall be filled with an element with sufficient sound insulation.

Examples of test facilities for different kinds of junctions are shown on [Figure 3](#). To assess the possible influence of sound transmission through the envelope of the facility or through a filler element, shielding of these surfaces in the test rooms shall be applied according to the procedures specified in [Clause 9](#).



NOTE All dimensions are considered from the surface of the elements

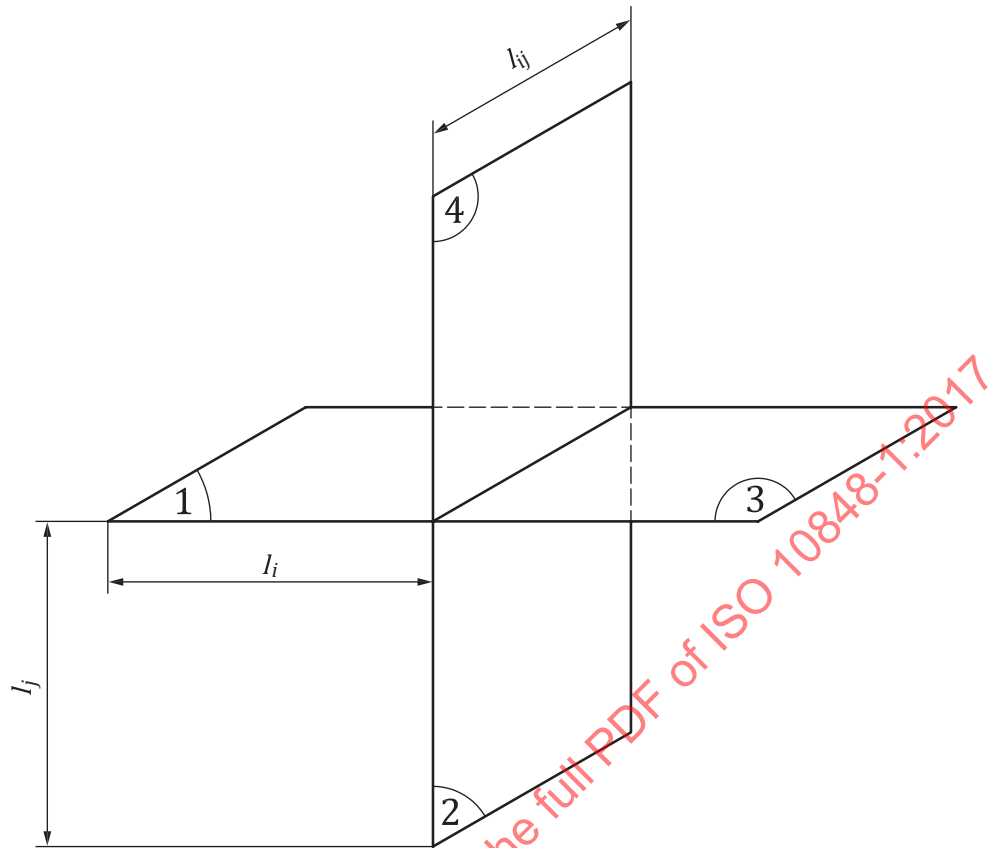
$$l_{ij} \geq 2,3 \text{ m}$$

$$3,0 \text{ m} \leq l_i < 6,0 \text{ m for all elements } i$$

$$\left| \frac{l_{ij} - l_i}{l_i} \right| \geq 0,1 \text{ when the junction only contains Type A elements}$$

$$\left| \frac{l_i - l_j}{l_i} \right| \geq 0,1 \text{ when the junction only contains Type A elements}$$

Figure 1 — Vertical junction



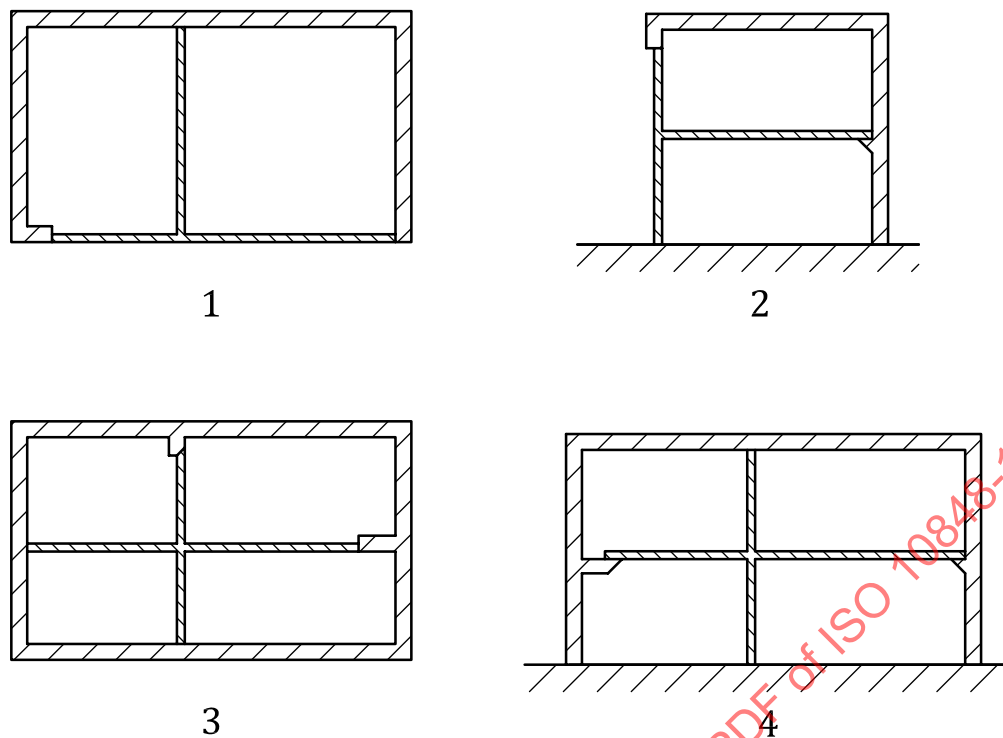
NOTE All dimensions are considered from the surface of the elements
 $l_{ij} \geq 2,3 \text{ m}$

$3,0 \text{ m} \leq l_i < 6,0 \text{ m}$ for all elements i

$\left| \frac{l_{ij} - l_i}{l_i} \right| \geq 0,1$ when the junction only contains Type A elements

$l_1 > l_2, \left| \frac{l_1 - l_2}{l_1} \right| \geq 0,1$ when the junction only contains Type A elements

Figure 2 — Horizontal junction

**Key**

- 1 horizontal section of T-junction – horizontal transmission
- 2 vertical section of T-junction – vertical transmission
- 3 horizontal section of cross-junction – horizontal transmission
- 4 vertical section of cross-junction – vertical transmission

Figure 3 — Examples of test facilities for different kinds of junctions

6.2 Field

The requirements on the test facility and test elements for laboratory measurements in 6.1 can be used as a guide for field measurements. However, it will not usually be possible to satisfy them in the field; hence, the connected building structure shall be described in the test report.

For measurements requiring sound pressure levels in rooms, the room volumes shall be at least 25 m³.

7 Measurement methods

7.1 Measurement of $D_{n,f}$, $L_{n,f}$ and $L_{ne0,f}$

7.1.1 Generation of sound field in the source room

7.1.1.1 Airborne sound

The sound generated in the source room shall be steady and shall have a continuous spectrum in the frequency range considered. Pink noise or white noise as the source signal is recommended. If the sound is filtered, the filters shall have a bandwidth of at least one-third octave. When using broad-band noise, the spectrum of the noise source may be modified to ensure an adequate signal-to-noise ratio in the receiving room; however, the sound spectrum in the source room shall not have level differences larger than 6 dB between adjacent one-third octave bands.

The sound power should be sufficiently high for the sound pressure level in the receiving room to be at least 15 dB higher than the background level in any frequency band. If this is not fulfilled, corrections shall be applied as described in ISO 10140-4. The correction value shall not exceed 1,3 dB.

If the sound source enclosure contains more than one loudspeaker operating simultaneously, the loudspeakers shall be driven in phase. Multiple sound sources may be used simultaneously, provided that they are of the same type and are driven at the same level by similar but uncorrelated signals. Continuously moving loudspeakers may be used. When using a single sound source, it shall be operated in at least two positions. They shall be in the same room or the measurement shall be repeated in the opposite direction by changing source and receiving room with one or more source positions in each room.

Place the loudspeaker enclosure so as to give a sound field as diffused as possible and at such a distance from the test specimen that the direct radiation upon it is not dominant. The sound fields in the rooms depend strongly on the type and on the position of the sound source. Qualification of the loudspeakers, loudspeaker positions and continuously moving loudspeakers shall be performed using the procedures in ISO 10140-5:2010, Annex D.

For measurements in the low-frequency range, guidance on loudspeaker positions is given in ISO 10140-4:2010, Annex A.

7.1.1.2 Impact sound

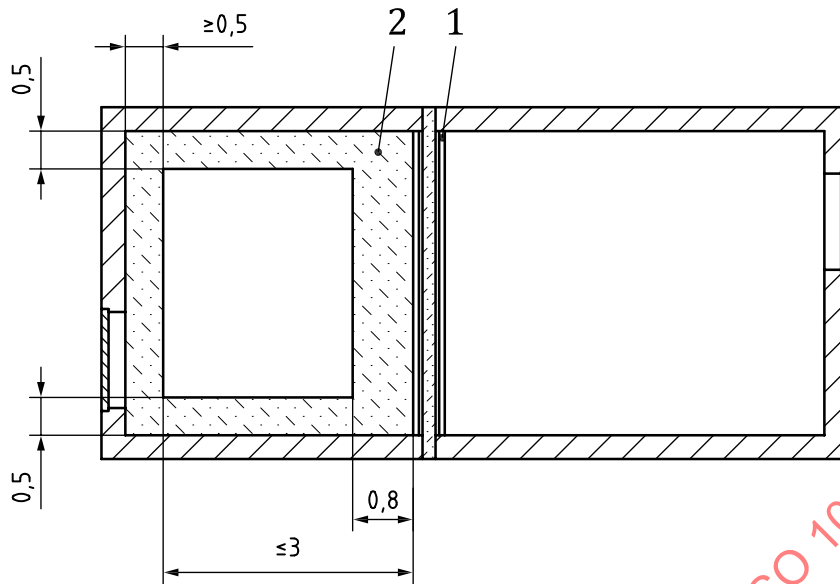
The impact sound shall be generated by the standard tapping machine (see ISO 10140-5:2010, Annex E). The distance of the tapping machine from the edges of the floor shall be at least 0,5 m and at least 0,8 m from the separating wall, but not more than 3 m (see [Figure 4](#)).

A minimum of four tapping machine positions shall be used for Type A elements and a minimum of six positions shall be used for Type B elements. These shall be evenly distributed in the permitted area. In the case of anisotropic Type A floor constructions (with ribs, beams, etc.) or Type B floors, more excitation positions may be necessary. The hammer connecting line shall be orientated at 45° to the direction of the beams or ribs.

The impact sound pressure levels may reveal a time dependency after the tapping is started. In such a case, the measurements should not begin until after the sound level has become steady. If stable conditions are not reached after 5 min, then the measurements should be carried out over a well-defined measurement period. The measurement period shall be reported.

When floors with soft coverings are under test, the standard tapping machine shall fulfil the requirements given in ISO 10140-5:2010, Annex E. Advice regarding the mounting of the standard tapping machine on soft floor coverings is also given in ISO 10140-5:2010, Annex E.

Corrections for background noise shall be applied as described in ISO 10140-4. The correction value shall not exceed 1,3 dB.



Key

- 1 dividing wall
- 2 area where tapping machine shall *not* be placed

Figure 4 — Floor surface where the tapping machine shall not be placed for measurements of normalized flanking impact sound pressure level $L_{n,f}$

7.1.1.3 Equipment sound

A calibrated structure-borne sound source shall be used as described in [Annex B](#) to excite the source element to determine $L_{ne0,f}$ using a known power level, L_{Wcal} . On the source element, a minimum of four excitation positions shall be used for Type A elements and a minimum of six excitation positions shall be used for Type B elements. For the N excitation positions, sound pressure levels in the receiving room are measured according to [7.1.2](#) to determine $D_{TF,av,n}$ and the results normalized to unit power (1 W) according to [Formula \(7\)](#):

$$L_{ne0,f} = D_{TF,av,n} + L_{W0} \quad (7)$$

where $L_{W0} = 10\lg(1/10^{-12}) = 120$ dB.

7.1.2 Measurement of the average sound pressure level

7.1.2.1 General

Obtain the average sound pressure level by using a single microphone moved from position to position, or by an array of fixed microphones, or by a continuously moving microphone. The sound pressure levels at the different microphone positions shall be averaged on an energy basis for all sound source positions, see [Formulae \(6\) to \(8\)](#).

NOTE 1 If a continuously moving microphone is used, L is determined according to [Formula \(8\)](#):

$$L = 10\lg \left(\frac{\frac{1}{T_m} \int_0^{T_m} p^2(t) dt}{p_0^2} \right) \quad (8)$$

where

p is the sound pressure, in Pa;

p_0 is the reference sound pressure, in Pa; $p_0 = 2 \times 10^{-5}$ Pa;

T_{int} is the integration time, in s.

NOTE 2 If fixed microphone positions are used, L is determined according to [Formula \(9\)](#):

$$L = 10 \lg \left(\frac{p_1^2 + p_2^2 + \dots + p_n^2}{n \cdot p_0^2} \right) \quad (9)$$

where $p_1, p_2, \dots, p_n$ are root mean square (r.m.s.) sound pressures at n different positions in the room, in Pa.

NOTE 3 In practice, usually the sound pressure levels L_i are measured. In this case, L is determined according to [Formula \(10\)](#):

$$L = 10 \lg \left(\frac{1}{n} \sum_{i=1}^n 10^{L_i / 10} \right) \quad (10)$$

where L_i are the sound pressure levels L_1 to L_n at n different positions in the room, in dB.

7.1.2.2 Microphone positions

As a minimum, five microphone positions shall be used in each room. These shall be distributed within the maximum permitted space throughout each room. When using a moving microphone, the sweep radius shall be at least 1 m. The plane of the traverse shall be inclined in order to cover a large proportion of the permitted room space and shall not lie in any plane within 10° of a room surface.

The duration of a traverse period shall be not less than 15 s. The following separating distances are minimum values and shall be exceeded where possible:

- 0,7 m between microphone positions;
- 0,7 m between any microphone position and room boundaries or diffusers;
- 1,0 m between any microphone position and the sound source;
- 1,0 m between any microphone position and the test specimen.

For measurements in the low-frequency range, additional guidance on the number of microphone positions and minimum distances is given in ISO 10140-4:2010, Annex A.

7.1.2.3 Averaging time

At each individual microphone position, the averaging time shall be at least 6 s at each frequency band with centre frequencies below 400 Hz. For bands of higher centre frequencies, the time may be decreased to not less than 4 s. Using a moving microphone, the averaging time shall cover a whole number of traverses and shall be not less than 30 s.

For measurements in the low-frequency range, additional guidance is given on the averaging time in ISO 10140-4:2010, Annex A.

7.1.3 Measurement of reverberation time and evaluation of the equivalent sound absorption area

The equivalent sound absorption area is evaluated from the reverberation time measured using the same procedure as described in ISO 10140-4 and determined according to [Formula \(11\)](#):

$$A = \frac{0,16V}{T} \quad (11)$$

where

- A is the equivalent sound absorption area, in m^2 ;
- V is the receiving room volume, in m^3 ;
- T is the reverberation time in the receiving room, in s.

7.2 Measurement of K_{ij} and $\overline{D_{v,ij,n}}$

7.2.1 General aspects for K_{ij}

The vibration reduction index K_{ij} shall be measured using structure-borne excitation and calculated according to [Formula \(13\)](#). The required quantities are the direction-averaged level difference $\overline{D_{v,ij}}$ and the equivalent absorption lengths a_i and a_j . $\overline{D_{v,ij}}$ shall be obtained from the mean value of the velocity level differences $D_{v,ij}$ and $D_{v,ji}$, and each velocity level difference obtained by exciting one structure at several points, and by measuring the surface average velocity level of both elements i and j .

For Type A elements, the values of a_i and a_j shall be determined according to [Formula \(16\)](#) using measurements of the structural reverberation times $T_{s,i}$ and $T_{s,j}$.

7.2.2 General aspects for $\overline{D_{v,ij,n}}$

For measurement with structure-borne excitation, the normalized direction-average vibration level difference shall be determined as described in [3.14](#). If airborne or steady-state structure-borne excitation is used, the spatial averaging is calculated using [Formula \(12\)](#):

$$L_v = 10 \lg \left(\frac{v_1^2 + v_2^2 + \dots + v_n^2}{n \cdot v_0^2} \right) \quad (12)$$

where v_1, v_2, v_n are r.m.s. velocities at n different positions on the element, in m/s.

For steady-state excitation, the velocity level difference between element i and that of an element j , is calculated using [Formula \(13\)](#):

$$D_{v,ij} = L_{v,i} - L_{v,j} \quad (13)$$

If transient structure-borne excitation is used, then the normal velocity should be measured simultaneously on both elements and the velocity level difference determined using [Formulae \(14\)](#) and [\(15\)](#):

$$D_{v,ij} = \frac{1}{MN} \sum_{m=1}^M \sum_{n=1}^N (D_{v,ij})_{mn} \quad (14)$$

where

M is the number of excitation positions on element i ;

N is the number of measurement positions on each element for each excitation position;

$(D_{v,ij})_{mn}$ is the velocity level difference as given by [Formula \(15\)](#) for one excitation position and one pair of measurement positions only, in dB:

$$(D_{v,ij})_{mn} = 10 \lg \left(\frac{\int_0^{T_{\text{int}}} v_{i,mn}^2(t) dt}{\int_0^{T_{\text{int}}} v_{j,mn}^2(t) dt} \right) \quad (15)$$

where

v_i, v_j are the normal velocities at points on elements i and j respectively, in m/s;

T_{int} is the integration time, in s.

7.2.3 Vibration measurement

Vibration measurements shall be carried out using accelerometers mounted directly onto the surface of the test element. It shall have a sufficient sensitivity and low noise in order to obtain a signal-to-noise ratio of the measurement chain that is adequate to cover the dynamic range of the response of the structure.

The fixing of the accelerometer to the test element should be stiff in the direction normal to the surface of the element. Bees wax or petroleum wax is convenient but weak fixing can cause measurement errors in the high-frequency range. If the surface texture prevents use of wax, then small metal washers can be glued/cemented to the surface to allow wax fixing or fixing via a stud on the washer (see ISO 5348).

The mass of any accelerometer in contact with the test element shall be small enough to minimize the effects of mass loading on the measured vibration. Mass loading can be avoided when the inequality in [Formula \(16\)](#) is satisfied^[15].

$$m_{\text{acc}} < \frac{1}{2\pi f Y_{\text{dp}}} \quad (16)$$

where

m_{acc} is the mass of the accelerometer, in kg;

Y_{dp} is the driving-point mobility, in N·s/m;

f is the centre frequency of the one-third octave band, in Hz.

For materials such as concrete, masonry, solid bricks, timber, plasterboard and glass, the driving-point impedance in the central region of a plate can be estimated by assuming a thin, isotropic plate as shown in [Formula \(17\)](#):

$$Y_{\text{dp}} = \frac{1}{8\sqrt{B\rho_s}} = \frac{1}{2,3\rho_s c_L h} \quad (17)$$

where

B is the bending stiffness, in N·m;

ρ_s is the mass per unit area of the plate, in kg/m²;

c_L is the longitudinal wavespeed, in m/s;

h is the plate thickness, in m.

For orthotropic plates with bending stiffnesses B_x and B_y in the x-directions and y-directions, respectively, an effective bending stiffness can be calculated according to [Formula \(18\)](#):

$$B = \sqrt{B_x B_y} \quad (18)$$

7.2.4 Generation of vibration on the source element

To generate a vibrational field, the excitation may be steady-state or transient. In each frequency band, the measured velocity level on the receiving element shall be at least 10 dB higher than the background noise level in any frequency band. If this is not fulfilled, corrections shall be applied as described in ISO 10140-4. The correction value shall not exceed 1,3 dB.

Steady-state excitation on a horizontal surface can be provided by an electrodynamic shaker with a noise signal or a tapping machine specified in [7.1.1.2](#) for floors or a tapping machine adapted for walls where the multiple impacts are mechanically controlled to be repeatable.

Transient excitation can be provided by single or manually-applied multiple impacts of a hammer or a dropped mass and $D_{v,ij}$ shall be simultaneously measured on the source and receiving elements. Multiple hammer hits should be manually applied with approximately the same strength over an area of 1 m² to 2 m² over a time period of 20 s to 30 s. The frequency of hits should be 1 Hz to 2 Hz but may need to be higher when there is high background noise.

For both steady-state and transient excitation, care shall be taken to avoid self-noise of the source or the radiation from the excited element excites other elements.

Depending on the type of excitation (steady-state or transient), the specifications in [7.2.6](#) or [7.2.7](#) shall be followed.

7.2.5 Procedure for Type A and B elements

On the source element, a minimum of four excitation positions shall be used for Type A elements and a minimum of six excitation positions shall be used for Type B elements. On each plate, a minimum of three measurement positions per excitation position shall be used for Type A and B elements.

All measurement positions shall be randomly distributed over the surface of each test element such that some of them may be on top of the frame. The measurement and excitation positions shall be arranged using the following minimum distances:

- 0,5 m between excitation positions and the test element boundaries;
- 1,0 m between different excitation positions (Type A);
- 0,7 m between different excitation positions (Type B);
- 1,0 m between excitation positions and the junction under test;
- 1,0 m between excitation positions and the associated measurement positions;
- 0,25 m between measurement positions and the test element boundaries;
- 0,5 m between the individual measurement positions for each associated excitation position.

For elements that can be considered as homogeneous, either side of the construction can be used to measure the vibration.

For inhomogeneous elements formed from sub-elements (e.g. masonry walls formed from hollow bricks, beam and block floors), the velocity level can vary over the surface of each bricks. Therefore, the positions shall also be randomly distributed over the sub-elements. For framed floors (e.g. beam and block floors), the axis of the tapping machine shall have an angle of 45° to the direction of any beams/joists.

For framed elements, the positions shall be randomly distributed over the area (therefore, some of the positions may be on top of the frame). For framed floors (e.g. timber joist floor), the axis of the tapping machine shall have an angle of 45° to the direction of any beams/joists/studs.

For double-leaf elements, it is necessary to identify which element is to be considered in the source room and the receiving room. Two kinds of elements are considered: single-frame elements where the layer(s) on both sides of the wall/floor are directly connected to the same frame and double-frame elements where there are two isolated frames that support the layer(s) on each side of the wall/floor. In the prediction model for both single-frame and double-frame walls/floors, it is possible to consider either the whole element or only the inner leaf [i.e. layer(s) and frame] that faces into the source and receiving rooms. Note that the appropriate $D_{v,ij,n}$ index will be measured differently as shown in Figure 5.

For junctions of lightweight walls and floors, it is advisable for the operator not to stand on the floor unless it can be shown that the weight of the operator (and any damping that they provide to the structure) will not affect the transmission of vibration across the junction.

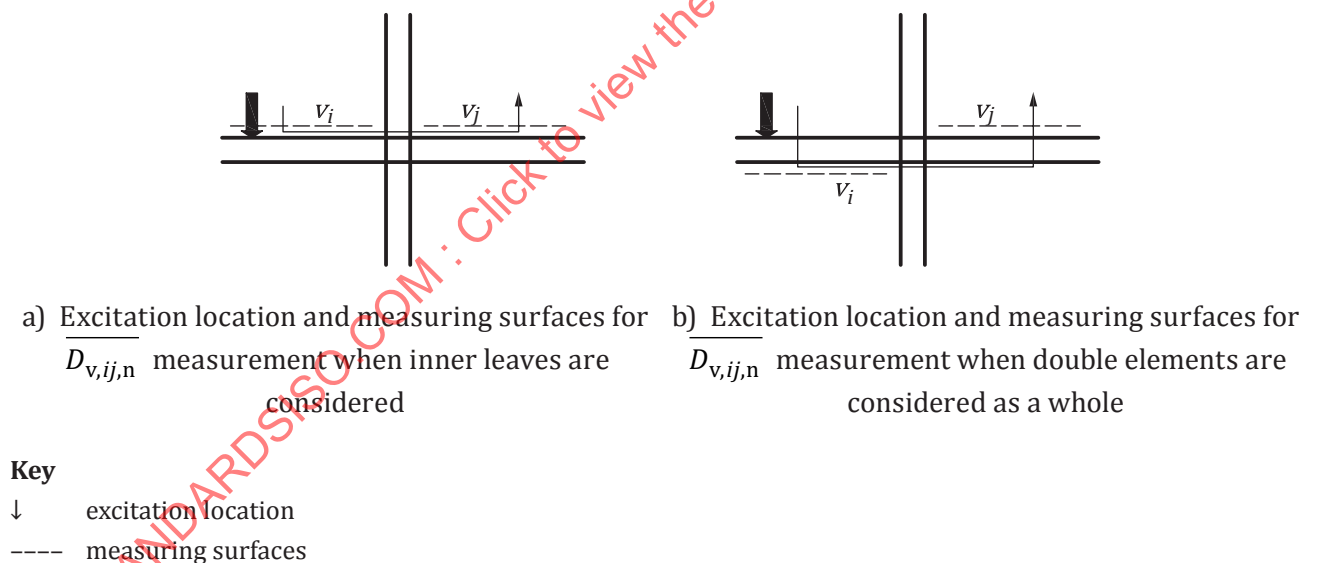


Figure 5 — Possible junction measurement configurations

7.2.6 Steady-state excitation

Steady-state excitation can be applied using, for example, a tapping machine or an electrodynamic shaker.

In the case of stationary excitation, the velocity level difference $D_{v,ij}$ can be determined according to Formulae (12) and (13).

Detailed instructions concerning fixation and usage of electrodynamic shakers are described in ISO 7626-2.

With a shaker, maximum length sequence (MLS) or swept sine signals can be used to improve the signal-to-noise ratio as described in ISO 18233.

NOTE The use of the maximum length sequence technique requires that the system be linear. Nonlinearity can be detected by low signal-to-noise ratios in the calculated impulse response. They can be reduced by decreasing the excitation level and, if necessary, increasing the period of measurement.

With a tapping machine, the velocity level may have a time dependence after starting the excitation. In this case, the measurement should not be started until the velocity level is constant. If no stable condition is reached after 5 min, the measurement procedure with transducer pairs shall be performed as for transient excitation.

For each measurement position, the integration time T_{int} (measurement period) shall be selected in such a way that no significant change in the average level can occur. The integration time T_{int} (measurement period) shall be a minimum of 10 s.

In case of measurement of the average velocity level with stationary excitation, it shall be ensured that the excitation is constant for different positions. If it cannot be validated that the source is constant, use the velocity level difference for transducer pairs.

7.2.7 Transient excitation

In the case of transient excitation, the velocity level difference $D_{v,ij}$ shall be determined using [Formula \(14\)](#).

To ensure a minimum signal-to-noise ratio of 10 dB in each frequency band, it may be advantageous to use different masses and materials for the impact hammer because different materials lead to different excitations in frequency bands.

For each measurement position, the integration time T_{int} shall not be shorter than the longest structural reverberation time of the two elements. On the other hand, the integration time shall be sufficiently short that the background noise level is at least 10 dB lower than the signal level.

7.3 Measurement of the structural reverberation time for Type A elements

7.3.1 General

The structural reverberation time is determined with point excitation and measurements of acceleration at different measurement positions. The integrated impulse response method is used as defined in ISO 3382-2 with backward integration of the squared impulse response.

In general, acceleration rather than velocity should be used in order to avoid any signal processing affecting the decay curve.

The vibration measurement shall meet the requirements described in [7.2.3](#).

NOTE The total loss factor equals the sum of the internal losses, coupling losses and radiation losses. The relation between the total loss factor η_{total} and the structural reverberation time T_s of the element is according to [Formula \(19\)](#):

$$\eta_{\text{total}} = \frac{2,2}{fT_s} \quad (19)$$

7.3.2 Excitation of the test element

Two methods of excitation may be used: electrodynamic shaker or impact hammer. With an electrodynamic shaker, the impulse response can be measured with an MLS signal or swept sine signal that can yield the correct impulse response (see ISO 18233).

For laboratory measurements, the preferred method uses an electrodynamic shaker with an MLS or swept sine signal. Details on fixing and using electrodynamic shakers are described in ISO 7626-2.

NOTE The use of the maximum length sequence technique requires that the system is linear. Nonlinearity can be detected by low signal-to-noise ratios in the calculated impulse response. They can be reduced by decreasing the excitation level and, if necessary, by increasing the period of measurement.

If an impact hammer is used, there may be limitations (e.g. nonlinearity, high damping, frequency range) as described in ISO 7626-5 which shall be taken into account.

Hammer excitation may be used if it can be shown that the reverberation time measurements on the test element are not affected by the strength of the hammer blow. This verification shall be done in one position for each element. It may be necessary to use different masses and materials for an impact hammer, because different material leads to different excitations in frequency bands.

7.3.3 Measurement and excitation positions

At least three excitation positions shall be used on the test element. At least three measurement positions shall be used for each excitation position.

The measurement positions and the excitation positions shall be arranged using the following minimum distances:

- 0,5 m between measurement positions and the test element boundaries;
- 1 m between the excitation position and the measurement positions;
- 0,5 m between the measurement positions.

The measurement points shall be randomly distributed over the test element.

7.3.4 Evaluation of the decay curves

The decay curves shall be formed and evaluated as specified in ISO 3382-2. The structural reverberation time of the test element is determined by arithmetic averaging of the individual reverberation times or by energetic averaging of the individual decay curves.

The recorded decay curves shall start at least 35 dB above the background level.

The evaluation range shall be between 5 dB and 15 dB. If multiple-slope or curved decay curves occur during the measurements, the evaluation range shall predominantly account for the upper part of the decay curve.

NOTE For heavy elements that are coupled to other heavy elements, decay curves for bending waves are characterized by a short, fast, straight decay which is followed by distinct curvature due to energy returning from other parts of the building structure; hence, a 5 dB or 10 dB evaluation range is always preferred for field measurements.^[16] An evaluation start point of 3 dB (rather than 5 dB) below the maximum level is feasible for the low-frequency and mid-frequency ranges based on consideration of the signal processing errors in the early part of the decay and the fact that evaluation of the decay curve can only begin after the first reflected wave from the plate boundary arrives at the measurement position. A procedure to evaluate structural decay curves is given in Reference ^[16].

7.3.5 Lower limits for reliable results caused by filter and detector

With traditional forward analysis of the impulse response, it shall be checked that the measured structural reverberation times for one-third octave bands fulfil the requirements in [Formula \(20\)](#) and [\(21\)](#):

$$T_s > 70/f \quad (20)$$

and

$$T_s > 2T_{\text{det}} \quad (21)$$

where T_{det} is the reverberation time of the averaging detector.

If the inequality in [Formula \(20\)](#) is not fulfilled, the time reversal technique shall be applied to reduce the influence from the filter on the decay curve. With this technique, the limit is approximately four times lower than that given by the inequality in [Formula \(20\)](#).

NOTE 1 The time reversal technique is achieved by inversion of the impulse response with respect to time before filtering. The technique makes use of the rise time of the filter, which is much shorter than the decay time. It requires a transient memory for the impulse response or an analogue tape recorder and reverse replay.

If the inequality in [Formula \(20\)](#) is not fulfilled, the time reversal technique shall be applied or the impulse responses shall be replayed with slower speed and analysed with transposed filters (see ISO 3382-2 for details concerning limits for reliable results).

NOTE 2 With linear averaging and a very short averaging time, it is often possible to form the decay record without problems related to the averaging detector.

7.4 Frequency range of measurement

The measurements shall be performed using one-third octave band filters having at least the following centre frequencies, in hertz:

100, 125, 160, 200, 250, 315, 400, 500, 630, 800, 1 000, 1 250, 1 600, 2 000, 2 500, 3 150

If additional information in the low-frequency range is required, use one-third octave band filters with the following centre frequencies, in hertz:

50, 63, 80

If additional information in the high-frequency range is required, use one-third octave band filters with the following centre frequencies, in hertz:

4 000, 5 000

8 Influences from other parts of the test facility or the building construction in the field situation

8.1 Laboratory installations of test junctions

In the laboratory, the transmission path between elements i and j shall be dominant compared to all other transmission paths through the test facility. It may be necessary to provide structural breaks where strong transmission occurs between the test elements through the construction of the test facility (see also [Clauses 6](#) and [8](#)).

8.2 Criterion to assess flanking transmission for junctions comprised of Type A elements

8.2.1 General

The general requirement is that the transmission through junctions other than the junction under test shall have no effect on the measured quantities, for example K_{ij} .

This can be achieved if the net flow of modal energy is always positive from any tested element j to any room element k , in each frequency band when element i is excited^[15] according to [Formula \(22\)](#):

$$D_{v,jk} + 10 \lg \left(\frac{m_j f_{c,k}}{m_k f_{c,j}} \right) \geq 0 \text{ dB} \quad (22)$$

where

m_j, m_k are the mass per unit area of elements j and k , in kg/m^2 ;

$f_{c,j}, f_{c,k}$ are the critical frequencies, in Hz;

$D_{v,jk}$ is the velocity level difference between elements j and k with excitation of element i during the test, in dB.

See guidance in [4.3.3](#) to calculate critical frequencies.

8.2.2 Practical considerations

Inequality [\[Formula \(20\)\]](#) indicates that the velocity level difference $D_{v,jk}$ should be as large as possible.

In the laboratory, this can be satisfied with different solutions such as the following:

- using constructions that form the test facility which are much heavier than the tested constructions;
- inserting a vibration break between the tested elements and the constructions of the facility. In order to allow an energy flow and then produce a realistic structural reverberation time, it is, in some cases, recommended that the tested elements be rigidly connected to the constructions of the facility. In these cases, the connection should be made with a part of the test facility which is in contact with only one tested element (back wall, for example).

8.3 Verification procedure for a Type B flanking element that is structurally independent of a separating element

Referring to [Table 1](#), a Type B flanking element (e.g. suspended ceiling, access floor, facade, etc.) is considered as structurally independent from the separating element if the following test conditions are fulfilled:

- install the flanking element without connection to the separating element;
- use structure-borne excitation to determine $(D_{v,ij})_0$ between the source and receiving element;
- connect the separating element;
- use structure-borne excitation to determine $(D_{v,ij})_1$ between the source and receiving element;
- verify that the difference between $(D_{v,ij})_1$ and $(D_{v,ij})_0$ is less than 3 dB in each frequency band.

9 Shielding

The efficiency of a shield or a lining is strongly dependent on the construction behind it. A comparison between the average velocity level before and after shielding can give an indication of the efficiency of the shield. The following specifications are applicable to the shielding of elements of the test specimen, as well as to the shielding of surfaces of the test facility.

Heavy shielding on a test element with a low surface mass may change vibration transmission across the junctions and should be avoided.

NOTE Shielding down to 50 Hz can be achieved using two or three layers of gypsum boards (having a combined mass per unit area of 25 kg/m²) with a 100 mm cavity partly filled (60 % to 80 %) with mineral fibre (<15 kg/m³).

Depending on the test method, it is necessary for junctions of 3 or 4 elements to shield successively each of the elements facing the test rooms. Two elements of the junction will face each room.

When measuring $D_{n,f}$ for transmission through element i and j , shielding shall be carried out of the other element in both rooms.

When measuring $L_{n,f}$ for transmission through element i and j , the other element in the receiving room shall be shielded.

When measuring K_{ij} with structure-borne excitation, shielding is not necessary.

If the radiated sound from element j is measured with intensity according to ISO 15186-1, there is no requirement for shielding in the receiving room.

The determination of the minimum shield efficiency for test elements expressed as the sound reduction index improvement ΔR depends on the type of junction. If for example, the three or four elements of the junction are identical, a ΔR of 10 dB in all frequency bands is sufficient for the test elements.

A general method to determine the required minimum value for ΔR is to measure the average velocity level $L_{v,1j}$ of element j in the receiving room due to excitation of element 1 in the source room, and the average velocity level $L_{v,2j}$ of element j in the receiving room due to the same kind of excitation of element 2 in the source room.

If, for example, the quantity to be tested is $D_{n,f}$, $L_{n,f}$ or K_{ij} for the transmission through element 1 in the source room and element j in the receiving room, and the shielding of element 2 is to be checked, the shielding shall have a minimum level shown by [Formulae \(23\)](#) and [\(24\)](#):

$$\Delta R_{\min} = 10 - L_{v,1j} + L_{v,2j} \text{ if } L_{v,1j} - L_{v,2j} \leq 10 \text{ dB} \quad (23)$$

$$\Delta R_{\min} = 0 \text{ dB if } L_{v,1j} - L_{v,2j} > 10 \text{ dB} \quad (24)$$

10 Expression of results

For the normalized flanking level difference and the normalized flanking impact sound pressure level, the results shall be presented using the single-number quantities, $D_{n,f,w}(C;C_{tr})$ and $L_{n,f,w}(C_I)$, which are determined according to ISO 717-1, and ISO 717-2, respectively. Additional spectrum adaptation terms may be quoted as required.

For the vibration reduction index and the direction-averaged velocity level difference, the results shall be presented using the single-number quantities described in this clause due to fluctuations in the spectrum, particularly in the low-frequency range.

To provide input data relevant to the simplified models described in ISO 12354-1 and ISO 12354-2, the single-number quantity for the vibration reduction index, $\bar{K}_{ij}$, is the arithmetic average of K_{ij} within the frequency range 200 Hz to 1 250 Hz (one-third octave bands). If K_{ij} varies considerably within the

indicated frequency range, care shall be taken in applying $\overline{K_{ij}}$. The single-number quantity for the normalized direction-average vibration level difference, $\overline{D_{v,ij,n}}$, is the arithmetic average of $\overline{D_{v,ij,n}}$ within the frequency range 200 Hz to 1 250 Hz (one-third octave bands). If $\overline{D_{v,ij,n}}$ varies considerably within the indicated frequency range, care shall be taken in applying $\overline{D_{v,ij,n}}$.

To provide input data relevant to the detailed models described in ISO 12354-1 and ISO 12354-2, the one-third octave band results shall be expressed as a single-number quantity for each of the low-frequency, mid-frequency and high-frequency ranges, and these average values shall be used for all one-third octave bands in each of the low-frequency, mid-frequency and high-frequency ranges, respectively.

$\overline{K_{ij,low}}$ and $\overline{D_{v,ij,n,low}}$ are the arithmetic average of the one-third octave band values from 50 Hz to 200 Hz.

$\overline{K_{ij,mid}}$ and $\overline{D_{v,ij,n,mid}}$ are the arithmetic average of the one-third octave band values from 250 Hz to 1 kHz.

$\overline{K_{ij,high}}$ and $\overline{D_{v,ij,n,high}}$ are the arithmetic average of the one-third octave band values from 1,25 kHz to 3,15 kHz.

NOTE 1 The reason for quoting average values is that the boundary conditions, geometry and workmanship in the laboratory or field only represent that specific set of boundary conditions geometry and workmanship; therefore, they are not representative of the ensemble average that is needed for ISO 12354-1 and ISO 12354-2, which is based upon first-order Statistical Energy Analysis (SEA).

NOTE 2 These definitions of low-frequency, mid-frequency and high-frequency ranges^[15] can be used to describe general aspects relating to both direct and flanking transmission.

There is no single-number quantity defined for $L_{ne0,f}$.