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Acoustics — Laboratory measurement of the flanking transmission of airborne and impact sound between adjoining rooms —

Part 1: Frame document

Acoustique — Mesurage en laboratoire des transmissions latérales du bruit aérien et des bruits de choc entre des pièces adjacentes —

Partie 1: Document cadre

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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.

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 10848-1 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 Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 2, *Building acoustics*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

ISO 10848 consists of the following parts, under the general title *Acoustics — Laboratory measurement of the flanking transmission of airborne and impact sound between adjoining rooms*:

— *Part 1: Frame document*

— *Part 2: Application to light elements when the junction has a small influence*

— *Part 3: Application to light elements when the junction has a substantial influence*

The following part is under preparation:

— *Part 4: Application to all other cases*

Acoustics — Laboratory measurement of the flanking transmission of airborne and impact sound between adjoining rooms —

Part 1:
Frame document

1 Scope

ISO 10848 specifies measurement methods to be performed in a laboratory test facility in order to characterize the flanking transmission of one or several building components. The performance of the building components is expressed either as an overall quantity for the combination of elements and junction (such as $D_{\mathrm{n,f}}$ and/or $L_{\mathrm{n,f}}$) or as the vibration reduction index K_{ij} of a junction.

This part of ISO 10848 contains definitions, general requirements for test specimens 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 EN 12354-1 and EN 12354-2.

2 Normative references

The following referenced documents are indispensable for the application 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 140-1, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 1: Requirements for laboratory test facilities with suppressed flanking transmission*

ISO 140-3:1995, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 3: Laboratory measurements of airborne sound insulation of building elements*

ISO 140-6:1998, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 6: Laboratory measurements of impact sound insulation of floors*

ISO 354, *Acoustics — Measurement of sound absorption in a reverberation room*

ISO 3382, *Acoustics — Measurement of the reverberation time of rooms with reference to other acoustical parameters*

ISO 7626-1, *Vibration and shock — Experimental determination of mechanical mobility — Part 1: Basic definitions and transducers*

ISO 10848-2:2006, *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 10848-3:2006, *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*

IEC 61260, *Electroacoustics — Octave-band and fractional-octave-band filters*

IEC 60651, *Sound level meters*

IEC 60804, *Integrating-averaging sound level meters*

IEC 60942, *Sound calibrators*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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 This quantity is expressed in decibels.

NOTE 2 If a continuously moving microphone is used, L is determined by

$$L = 10 \lg \frac{\frac{1}{T_m} \int_0^{T_m} p^2(t)\mathrm{d}t}{p_0^2} \text{ dB} \tag{1}$$

where

p is the sound pressure, in pascals;

p_0 is the reference sound pressure, in pascals; p_0 = 20 μPa;

T_m is the integration time, in seconds.

NOTE 3 If fixed microphone positions are used, L is determined by

$$L = 10 \lg \frac{p_1^2 + p_2^2 + ... + p_n^2}{n \cdot p_0^2} \text{ dB} \tag{2}$$

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

NOTE 4 In practice usually the sound pressure levels L_i are measured. In this case L is determined by

$$L = 10 \lg \frac{1}{n} \sum_{i=1}^{n} 10^{L_i/10} \text{ dB} \tag{3}$$

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

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

NOTE $D_{n,f}$ is normalized to an equivalent sound absorption area (A_0) in the receiving room and is expressed in decibels:

$$D_{n,f} = L_1 - L_2 - 10 \lg \frac{A}{A_0} \text{ dB} \quad (4)$$

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;

A_0 is the reference equivalent sound absorption area, in square metres; A_0 = 10 m^2.

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 standard tapping machine operating at different positions on a tested floor in the source room, when the transmission only occurs through a specified flanking path

NOTE $L_{n,f}$ is normalized to an equivalent sound absorption area (A_0) in the receiving room and is expressed in decibels

$$L_{n,f} = L_2 + 10 \lg \frac{A}{A_0} \text{ dB} \quad (5)$$

where

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;

A_0 is the reference equivalent sound absorption area, in square metres; A_0 = 10 m^2.

3.4
average velocity level
L_v
ten times the common logarithm of the ratio of the time and space averaged mean squared normal velocity of an element to the squared reference velocity v_0 (v_0 = 1 × 10^{-9} m/s)

$$L_v = 10 \lg \frac{\frac{1}{T_m} \int_0^{T_m} v^2(t) \mathrm{d}t}{v_0^2} \text{ dB} \quad (6)$$

NOTE 1 It should be stressed that 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 × 10^{-8} m/s.

NOTE 2 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/s^2.

NOTE 3 If airborne or stationary structure-borne excitation is used, the spatial averaging is calculated with

$$L_v = 10 \ \lg \frac{v_1^2 + v_2^2 + \cdots + v_n^2}{n \cdot v_0^2} \ \mathrm{dB} \tag{7}$$

where v_1, v_2, v_n are r.m.s. (root mean square) velocities at n different positions on the element, in metres per second.

NOTE 4 For transient structure-borne excitation, use Equations (9) and (10).

3.5
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 The quantity is expressed in seconds.

NOTE 2 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.

3.6
velocity level difference

$D_{v,ij}$

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

$$D_{v,ij} = L_{v,i} - L_{v,j} \tag{8}$$

NOTE 1 If a transient structure-borne excitation is used, then the normal velocity should be measured simultaneously on both elements and the velocity level difference determined by:

$$D_{v,ij} = \frac{1}{M\ N} \sum_{m=1}^{M} \sum_{n=1}^{N} (D_{v,ij})_{mn} \ \mathrm{dB} \tag{9}$$

where

M is the number of excitation points on element i;

N is the number of transducer positions on each element for each excitation point;

$(D_{v,ij})_{mn}$ is the velocity level difference as given by Equation (10) for one excitation point and one pair of transducer positions only, in decibels:

$$(D_{v,ij})_{mn} = 10 \ \lg \frac{\int_0^{T_\mathrm{m}} v_i^2(t) \ \mathrm{d}t}{\int_0^{T_\mathrm{m}} v_j^2(t) \ \mathrm{d}t} \ \mathrm{dB} \tag{10}$$

and

v_i, v_j are the normal velocities at points on elements i and j respectively, in metres per second;

T_m is the integration time, in seconds.

NOTE 2 For practical purposes, Equation (8) is preferable to Equation (9).

3.7
direction-averaged velocity level difference
$\overline{D_{v,ij}}$
arithmetic average of $D_{v,ij}$ and $D_{v,ji}$ as defined by the following equation:

$$\overline{D_{v,ij}} = \frac{1}{2}(D_{v,ij} + D_{v,ji}) \text{ dB} \tag{11}$$

where

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

$D_{v,ji}$ 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 decibels.

3.8
equivalent absorption length a_j of an element j
length of a fictional totally absorbing junction of the 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

NOTE 1 a_j is expressed in metres.

NOTE 2 It is given by the following equation:

$$a_j = \frac{2{,}2\ \pi^2\ S_j}{T_{s,j}\ c_0 \sqrt{\frac{f}{f_{ref}}}} \tag{12}$$

where

$T_{s,j}$ is the structural reverberation time of the element j, in seconds;

S_j is the surface area of the element j, in square metres;

c_0 is the speed of sound in air, in metres per second;

f is the current frequency, in hertz;

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

NOTE 3 For lightweight, well-damped types of elements where the actual situation has no real influence on the sound reduction index and damping of the elements, a_j is taken as numerically equal to the surface area S_j of the element: $a_j = S_j / l_0$, where the reference length l_0 = 1 m.

3.9
vibration reduction index
K_{ij}
value given by the following equation and expressed in decibels:

$$K_{ij} = \overline{D_{v,ij}} + 10\ \lg \frac{l_{ij}}{\sqrt{a_i a_j}} \text{ dB} \tag{13}$$

where

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

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

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

NOTE It follows from Equations (11) to (13) that K_{ij} can be obtained from measurements of the velocity level difference in both directions across the junction as well as the structural reverberation time of the two elements.

3.10
light element
element for which the boundary conditions, when mounted in the test facility, have no influence on the test result, for example because the element is much lighter than the surrounding test facility (see 8.2) or highly damped

NOTE 1 A test element may be regarded as highly damped in case of a strong decrease in vibration across the element as specified in 4.3.4.

NOTE 2 Timber or metal-framed stud walls or wooden floors on beams often fulfil this definition of a light element.

4 Quantities to characterize flanking transmission

4.1 General

In this part of ISO 10848, the flanking transmission by coupled elements and junctions is characterized in two ways:

— by an overall transmission quantity for a specified flanking path ($D_{n,f}$ or $L_{n,f}$);

— by the vibration transmission over a junction (K_{ij}).

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

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

$D_{n,f}$ and $L_{n,f}$ 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. $D_{n,f}$ and $L_{n,f}$ depend on the dimensions of the elements involved.

$D_{n,f}$ is measured with airborne excitation. For measurements of $L_{n,f}$, a standard tapping machine is used.

4.3 Vibration reduction index, K_{ij}

4.3.1 General

The vibration reduction index K_{ij} is defined in EN 12354-1 as a situation invariant quantity to characterize a junction between elements. K_{ij} is determined according to Equation (13). It is based on power transmission considerations as a simplification of statistical energy analysis (SEA) theory. This implies in principle that the basic assumptions of SEA are strictly met.

The main assumptions are that:

— the coupling between i and j is weak;

— the vibration fields in the elements are diffuse.

K_{ij} might not be relevant 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 with distance across the element, for example due to high internal losses or periodic structure (see 4.3.4);

c) low modal overlap factors or low mode counts.

The limitations are important for the frequency range where reliable measurements are expected, and/or for the accuracy of the measurement results.

K_{ij} is measured with structure-borne or airborne excitation.

NOTE 1 With airborne excitation the vibrations of the source element are both forced and resonant. Since forced vibrations do not always contribute to the vibration transmission through a junction, K_{ij} measured with airborne excitation tends to be greater than when measured with structure-borne excitation. This is mainly the case below the critical frequency, and the mentioned difference is therefore most important for lightweight elements.

NOTE 2 If values for R_i and R_j measured for elements i and j according to ISO 140-3 or ISO 15186-1 [4] are available, K_{ij} can be determined indirectly from $D_{\text{n,f}}$ by

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

In theory, this equation is only correct when R_i and R_j are associated with resonant transmission only. However, measured values obtained with ISO 140-3 or ISO 15186-1 also include forced transmission. In this part of ISO 10848, K_{ij} is always measured directly as given by Equation (13) or (14).

4.3.2 K_{ij} for lightweight well-damped elements

For lightweight, well-damped types of elements (for example, timber or metal-framed stud walls or wooden floors on beams) where the actual situation has no real influence on the sound reduction index and damping of the elements, Equation (13) can be simplified as:

$$K_{ij} = \overline{D_{v,ij}} + 10 \ \lg \frac{l_{ij}}{\sqrt{S_i S_j}} \ \text{dB} \qquad (14)$$

However, K_{ij} is often not relevant for such elements because the vibration fields are not reverberant, and the application of K_{ij} for light elements in prediction models such as EN 12354-1 and EN 12354-2 has in several cases been shown to be inaccurate. Therefore, the validity and practical use of K_{ij} shall be evaluated for each specific case. An example of a useful application of K_{ij} as given by Equation (14) is the comparison of different junctions between the same elements.

4.3.3 Strong coupling between elements

The measured value of K_{ij} may not be relevant due to strong coupling, if the following condition is not satisfied:

$$D_{v,ij} \geqslant 3 - 10 \ \lg \left(\frac{m_i \ f_{\text{c}j}}{m_j \ f_{\text{c}i}} \right) \text{dB} \qquad (15)$$

where

m_i, m_j are the masses per unit area of the elements, in kilograms per square metre;

f_{ci}, f_{cj} are the critical frequencies of the elements, in hertz, for example determined by Equation (20).

Inequality (15) is mainly of importance for heavy elements. If inequality (15) is not satisfied, try for example to increase the energy loss by providing the edges of the elements with damping material or connecting them to other structures.

4.3.4 Strong decrease in vibration across an element

If the measured velocity level decreases by more than 6 dB over the allowed measurement area for any element of the tested junction when the accelerometer is moved away from a stationary vibration source (keeping the minimum distance given in 7.2.4), then the measured value of K_{ij} may not be relevant.

NOTE A velocity level decrease of more than 6 dB can occur in, for example, lightweight elements such as timber or metal-framed stud walls or wooden floors on beams. In some types of masonry walls, it can occur at high frequencies.

4.4 Selection of the principle of measurement

The different possibilities mentioned below are summarized in Table 1 according to the types of junction and elements.

In certain cases, the tested specimen is placed in such a way in the test facility that only one path is dominant. This is generally the case for suspended ceilings, or access floors, or lightweight façades laterally mounted in the test facility. The separating element is only built to separate the two volumes and has no substantial effect on the flanking transmission. Typically, the separating element is not rigidly connected to the flanking element, and the gap between separating and flanking element is sealed with a flexible material.

In these cases, verifications shall be carried out to make sure that only the path considered is dominant, then the measurements may be done without any further action to separate path ij.

ISO 10848-2 deals with this type of element. $D_{n,f}$ and $L_{n,f}$ are the relevant quantities to be measured.

In certain other cases, the tested junction is formed by three or four light elements (light compared to the walls of the test facility), which are connected by a solid junction or coupling elements or mortars. This is the case, for example, for T or X junctions of plasterboard or chipboard on studs. In these cases, 3 or 6 different paths ij exist.

Verifications shall be made to make sure that no flanking path occurs through the test facility. Then, depending on the measured quantity, it may be necessary to separate each of path ij by shielding other paths ij both on the source and receiving sides.

ISO 10848-3 deals with these types of junction. For lightweight, well-damped elements where the actual situation (dimensions and boundary conditions) has no real influence on the sound reduction index and damping of the elements, $D_{n,f}$ and $L_{n,f}$ are the relevant quantities to measure. If the acoustical properties of the elements are substantially influenced by the actual situation, K_{ij} as specified by Equation (13) is the relevant quantity to measure. For special applications such as, for example, comparison of different junctions between the same elements, K_{ij} can also be measured between well-damped elements. The validity of measured values of K_{ij} is checked according to 4.3.4.

For all other cases, typically combinations of heavy or heavy and light masonry constructions, it may be necessary to provide a structural break between the tested elements and the test facility and, if the airborne method is selected, to separate each path ij by appropriate shielding both in source and receiving sides.

ISO 10848-4 deals with these types of junction. For junctions between heavy elements, it is recommended to measure K_{ij}. Structure-borne excitation is most appropriate.

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

Type of junction	$D_{n,f}$ and/or $L_{n,f}$ [a]	K_{ij}	
		Structure-borne excitation	**Airborne excitation**
Light flanking elements where the junction has a small influence (see ISO 10848-2)	Applicable after verification (see 8.3)	Not applicable	Not applicable
Light elements structurally connected (see ISO 10848-3)	Applicable primarily for light, well-damped elements after shielding elements other than I-, -	Applicable primarily for elements with reverberant vibration fields	Applicable primarily for elements with reverberant vibration fields after shielding elements other than i, j (slow and inefficient)
Combination of heavy or heavy and light elements structurally connected (see ISO 10848-4[b])	Applicable between light, well-damped elements if transmission along paths other than i, j is insignificant or suppressed by adequate measures, for example shielding	Applicable if transmission along paths other than i, j is insignificant or suppressed by adequate measures, for example structural isolation	Applicable if transmission along paths other than i, j is insignificant or suppressed by adequate measures, for example structural isolation and shielding (slow and inefficient)

[a] Shielding is not necessary in the source room for measurement of $L_{n,f}$ only.

[b] Under preparation.

5 Measuring equipment

The equipment shall be suitable for meeting the requirements of Clause 7.

The loudspeaker shall fulfil the requirements given in Annex C of ISO 140-3:1995.

The standard tapping machine shall meet the requirements given in Annex A of ISO 140-6:1998.

The accuracy of the sound level measurement equipment shall comply with the requirements of accuracy class 0 or 1 defined in IEC 60651 and IEC 60804. If not otherwise stated by the equipment manufacturer, the complete measuring system, including the microphone, shall be adjusted before each measurement using a sound calibrator which complies with the requirements of accuracy class 1 defined in IEC 60942. For sound level meters calibrated for measurements in sound fields of progressive plane waves, corrections for the diffuse sound field shall be applied.

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

The one-third-octave-band filters shall meet the requirements specified in IEC 61260.

The reverberation time equipment shall comply with the requirements specified in ISO 354.

NOTE For pattern evaluation (type testing) and regular verification tests, recommended procedures for sound level meters are given in OIML R 58 [8] and OIML R 88 [9].

6 General requirements for test specimens and test rooms

The dimensions of the test junction shall be as given in Figures 1 and 2. The test facility shall make it possible to install the junction in the test facility and, in addition, it shall comply with the following requirements, corresponding to the general requirements of rooms for laboratory tests with suppressed flanking transmission specified in ISO 140-1.

The volumes and corresponding dimensions of the 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 volumes of the test rooms shall be at least 50 m^3.

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 140-1).

The reverberation time in the rooms under normal test conditions (with negligible absorption by the test object) shall not be excessively long or short. Where the reverberation time at low frequencies exceeds 2 s or is less than 1 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 test frequencies (V is the value of the room volume in cubic metres). These requirements refer to the test rooms with a heavy, reflective test object.

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 specimens for which the laboratory is intended.

Examples of test facilities for different kinds of junctions are shown on Figure 3.

The test facility can be constructed in various ways varying from heavy masonry to lightweight, multiple leaf partitions.

If a lightweight test object is to be rigidly connected to the facility, a heavy envelope should preferably comply with 8.2. If this is not the case, the envelope shall have a high sound insulation, but weak structural connections with the test junction, or the envelope of the source and receiving room respectively shall be separated by vibration breaks.

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 (light or heavy) with sufficient sound insulation.

In case of any doubt about a possible influence on the test result from 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 check procedures specified in Clause 9.

NOTE The requirements and recommendations, as stated in this Clause 6, are intended to improve reproducibility between measurements made by different organizations on similar materials.

7 Measurement methods

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

7.1.1 Generation of sound field in the source room

7.1.1.1 Airborne noise

The sound generated in the source room shall be steady and shall have a continuous spectrum in the frequency range considered. Use filters with a bandwidth of at least one-third octave. Pink noise or white noise as the source signal is recommended. When using broad-band noise, the spectrum of the noise source may be modified to ensure an adequate signal-to-noise ratio at high frequencies in the receiving room. 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 shown in ISO 140-3. 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 diffuse 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 and of the loudspeaker positions shall be performed using the procedures in Annex C of ISO 140-3:1995. Guidance on the use of continuously moving loudspeakers is given in Annex C of ISO 140-3:1995.

7.1.1.2 Impact sound pressure level

The impact sound shall be generated by the standard tapping machine (see Annex A of ISO 140-6:1998). 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). As a minimum, four tapping machine positions evenly distributed in the permitted area shall be used; in the case of anisotropic floor constructions (with ribs, beams, etc.), more 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 Annex A of ISO 140-6:1998. Advice regarding the mounting of the standard tapping machine on soft floor coverings is given also in Annex A of ISO 140-6:1998.

Corrections for background noise shall be applied as shown in ISO 140-6. The correction value shall not exceed 1,3 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 [see Equations (1) to (3)] for all sound source positions.

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 taking in the room space uniformly. 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.

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.

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

The correction term of Equations (4) and (5) containing the equivalent sound absorption area is evaluated from the reverberation time measured with the same procedure as specified in ISO 140-3 and determined using Sabine's formula:

$$A = \frac{0{,}16\ V}{T}\ \text{m}^2 \tag{16}$$

where

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

V is the receiving room volume, in cubic metres;

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

7.2 Measurement of the vibration reduction index with structure-borne excitation

7.2.1 General

The principle of measurement for the vibration reduction index K_{ij} is based on Equation (13) or (14). The transmission 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 transmissions occur between the tested elements through constructions of the test facility (see also Clauses 6 and 8).

The required quantities are the direction averaged level difference $\overline{D_{v,ij}}$ and, in the case of using Equation (13), the equivalent absorption lengths a_i and a_j. All these quantities can be obtained by vibration measurements with structure-borne excitation. $\overline{D_{v,ij}}$ is obtained from the mean value of the velocity level differences $D_{v,ij}$ and $D_{v,ji}$, and each velocity level difference is obtained by exciting one structure at several points, and by measuring the surface average velocity level of both elements i and j.

The values of a_i and a_j are determined according to Equation (11) after measurement of the structural reverberation times $T_{s,i}$ and $T_{s,j}$ or taken as constant values, for example for lightweight elements.

NOTE As a supplement to the following specifications, see for example NT ACOU 090 [10].

7.2.2 Vibration transducer

The vibration transducer shall be mounted on 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 attachment of the transducer to the test element should be stiff in the direction normal to the surface of the element. The mass of the transducer should be small enough to minimize structural loading of the structure under test.

NOTE For further details, see ISO 7626-1.

7.2.3 Generation of vibration on the "source" element

To generate a vibrational field, the excitation may be stationary or transient.

A stationary excitation on a horizontal surface can be provided by, for example, a tapping machine as specified in 7.1.1.2. A modified tapping machine may be used on vertical elements. Instead of a tapping machine, an electrodynamic exciter (vibrator) may be used.

A transient excitation can be provided by an impact of a hammer or a dropping mass. In the case of using a transient excitation, $D_{v,ij}$ shall be measured for each pair of transducers separately. Both single and multiple impacts are allowed.

Multiple hammer hits with approximately the same strength may be given over an area of 1 m^2 to 2 m^2 over a time period of 20 s to 30 s. The frequency of hits around 1 Hz to 2 Hz is recommended but should be higher in the case of background noise problems. The number of transducer positions and the procedure for determination of the velocity level difference using transducer pairs is the same as for transient excitation at single positions (see 7.2.4).

For both stationary 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 (stationary or transient), the specifications in 7.2.5 or 7.2.6 shall be followed.

7.2.4 Performance of the measurement

On each element (source and receiving plate) a minimum of three excitation positions and a minimum of nine transducer positions shall be used. For each excitation position three different pairs of transducer positions shall be used. All positions shall be randomly distributed over the surface of the element, but not symmetrical. The transducers shall be mounted on the not excited side of the source plate ("outside") and the radiating side of the receiving plate ("inside"). For substantially homogeneous constructions the side of the construction is irrelevant, but not so for double leaf constructions.

In case of inhomogeneous elements (e.g. masonry walls with hollow bricks), the velocity level varies over the surface of the single bricks. Therefore, the positions shall also be randomly distributed over the sub-elements.

NOTE Above 2 500 Hz, a dependence between the velocity level and distance from the excitation position can occur on masonry walls. Hence, the measured vibrational level difference $D_{v,ij}$ is strongly dependent on the size of the element or the excitation and transducer positions. A check of the decrease in vibration across an element is specified in 4.3.4.

In the case of composite elements, the number of positions may be increased, and the positions shall be distributed over all different types of sub-elements. The following procedure shall be used for checking the necessary number of transducer positions.

a) Make measurements for at least nine transducer positions on each element i, j.

b) For each pair of transducer positions m,n on elements i and j, measure the velocity level difference $(D_{v,ij})_{mn}$ as defined in Equation (10).

c) For each one-third-octave-band, determine the difference Δ_{mn} between the minimum and maximum values of $(D_{v,ij})_{mn}$.

d) The necessary number of transducer positions on each element is at least $0{,}7 \times \Delta_{mn,\max}$ where $\Delta_{mn,\max}$ is the maximum value for all one-third-octave-bands.

The source shall be located at three different randomly distributed positions on the element under test. In the case of anisotropic constructions (with beams or bars), a higher number of positions may be necessary at and between these discontinuities. In the case of using a tapping machine, the axis of the tapping machine shall have an angle of 45° to the direction of the beams or bars.

In the case of stationary excitation, the velocity level difference $D_{v,ij}$ can be determined according to Equation (8) as the difference between the average velocity levels $L_{v,i}$ and $L_{v,j}$ of the two elements i and j, when element i is excited, provided that the same force is applied for all positions of excitation.

In the case of transient excitation, the force is not constant, and $D_{v,ij}$ shall be determined with simultaneous measurements on both elements according to Equation (9) as the arithmetic mean for at least $3 \times 3 = 9$ measurements.

With a vibrator, the force can vary and should be verified at least before the vibrator is dismounted and moved to another position. If this is not possible, Equation (9) may be applied to keep the force constant.

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

— 0,5 m between excitation points and the test element boundaries;

— 1,0 m between excitation points and the junction under test;

— 1,0 m between excitation points and the associated transducer positions;

— 0,25 m between transducer positions and the test element boundaries;

— 0,5 m between the individual transducer positions.

The maximum distance between transducer positions and the junction under test shall be 3,5 m.

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

In each frequency band, the measured velocity level 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 shown in ISO 140-3. The correction value shall not exceed 1,3 dB.

7.2.5 Specifications for stationary excitation

A stationary source is, for example, a tapping machine or an electrodynamic exciter (vibrator).

Detailed instructions concerning fixation and usage of vibration exciters should be taken from ISO 7626-2 [5].

With a vibrator, it is possible to use, for example, the MLS-technique to improve the signal-to-noise ratio (see ISO 18233 for details).

NOTE The use of the maximum length sequence technique requires that the system by linear. Non-linearity 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, it can happen that the velocity level has 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 transducer position, the integration time T_m (measurement period) shall be selected in such a way that no significant change in the average level can occur. The integration time T_m (measurement period) shall be a minimum of 10 s.

In case of measurement of the average velocity level with stationary excitation, it has to 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.

7.2.6 Specifications for transient excitation

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 transducer position, the integration time T_m shall not be shorter than the longest structural reverberation time of the two elements. On the other hand, the integration time shall be so short that the background noise level is at least 10 dB lower than the signal level.

NOTE The longest structural reverberation time of the elements occurs at low frequencies.

7.3 Measurement of the structural reverberation time

7.3.1 General

The structural reverberation time of an element is determined with point excitations and measurements of the velocity or acceleration at different transducer positions. The integrated impulse response method as defined in ISO 3382 is used with backward integration of the squared impulse response.

The specifications for the vibration transducer given in 7.2.2 shall be followed.

NOTE The relation between the total loss factor η_{total} and the structural reverberation time T_s of the element is given by

$$\eta_{total} = \frac{2{,}2}{f \ T_s}$$

The total loss factor includes the internal losses, the edge losses and the radiation losses.

7.3.2 Excitation of the element under test

Two methods of excitation may be used: vibrator excitation or hammer excitation. With a vibrator, the impulse response is measured with the MLS (Maximum Length Sequence) technique or another method that can yield the correct impulse response.

For laboratory measurements, the preferred method uses a vibrator with an MLS signal. Hammer excitation may be used if it can be shown that the reverberation time measurements on the test element are not affected because the hammer blow is too strong. This verification is 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. The recorded decay curves shall start at least 35 dB above the background level.

Detailed instructions concerning fixing and usage of vibration exciters should be taken from ISO 7626-2 [5]. If an impact hammer is used, the limitations given in ISO 7626-5 [6] regarding non-linearity, high damping and frequency range should be taken into account.

NOTE The use of the maximum length sequence technique requires that the system is linear. Non-linearity 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.

7.3.3 Measurement and excitation points

At least three excitation points shall be used on the test element. At least three transducer positions shall be used for each excitation point.

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

— 0,5 m between transducer positions and the test element boundaries;

— 1 m between the excitation point and the associated transducer positions;

— 0,5 m between the individual transducer 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. 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 evaluation range shall be between 5 dB and 20 dB, or 25 dB below the maximum level. If multi-sloped decay curves occur during the measurements, the evaluation range shall predominantly account for the upper sections of the curves.

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 following requirements:

$$T_\mathrm{s} > 35/f \qquad (17)$$

and

$$T_\mathrm{s} > T_\mathrm{det} \qquad (18)$$

where T_det is the reverberation time of the averaging detector.

If inequality (17) 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 inequality (17).

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 analog tape recorder and reverse replay.

If inequality (18) 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 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 Measurement of the vibration reduction index with airborne excitation

The vibration reduction index K_{ij} may also be measured with airborne excitation, but it can be a slow and inefficient method compared to structure-borne excitation, since both directions have to be tested, and shielding has to be done.

The specifications for the positions and type of sound source are the same as given in 7.1.1.1. The velocity level difference is determined according to Equation (8) or (9). At least 9 transducer positions on each element shall be used, distributed as specified in 7.2.4. For each transducer position, the integration time T_m (measurement period) shall be at least 10 s.

7.5 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	4 000	5 000

8 Influences from the structures of the test facility

8.1 Criterion to verify flanking transmissions through constructions of the test facility

8.1.1 General

The general requirement is that the transmissions 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 vibrational energy is always positive from any tested element j to any room element k.

This requirement is fulfilled if, in each frequency band when element i is excited,

$$10 \ \lg \left(\frac{m_j \cdot f_{ck}}{m_k \cdot f_{cj}} \right) + D_{v,jk} \geqslant 0 \ \ \text{dB} \qquad (19)$$

where

m_j, m_k are the mass per unit area of elements j, k, in kilograms per square metre;

f_{cj}, f_{ck} are the critical frequencies, in hertz;

$D_{v,jk}$ is the velocity level difference during the test, in decibels.

For homogeneous and isotropic elements, f_c can be calculated by

$$f_c = \frac{c_0^2}{1{,}8\, c_L \cdot h \cdot \pi} \qquad (20)$$

where

c_0 is the speed of sound in air, in metres per second;

c_L is the longitudinal wave speed, in metres per second;

h is the thickness, in metres;

For other types of elements, f_c can be estimated by observing the dip in the sound reduction index curve.

8.1.2 Practical considerations

Inequality (19) indicates that the velocity level difference $D_{v,jk}$ should be as large as possible.

This can be obtained by using the following different solutions:

a) by using constructions in the test facility which are much heavier than the tested constructions;

b) by using 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).

8.2 Conventional limit for light elements compared with the surrounding elements of the test facility

Referring to Table 1, an element is considered to be a light element without any further verification if its surface mass is less than or equal to 0,16 times the surface mass of the lightest element of the test facility rigidly connected to this element.

If this condition is fulfilled, the light junction may be constructed with rigid connections with the test rooms, and ISO 10848-2 and ISO 10848-3 should be used.

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

Referring to Table 1, a light flanking element (ceiling, floor, facade, etc.) is considered as structurally independent from the separating element if the following test conditions are fulfilled:

a) install the flanking element without connection to the separating element;

b) use the structure-borne method to determine $(D_{v,ij})_0$ between the source and receiving element;

c) connect the separating element;

d) use the structure-borne method to determine $(D_{v,ij})_1$ between source and receiving element;

e) 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.

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 airborne excitation shielding, the other element in the room with the sound source 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 technique, the requirement for shielding in the receiving room is not applicable.

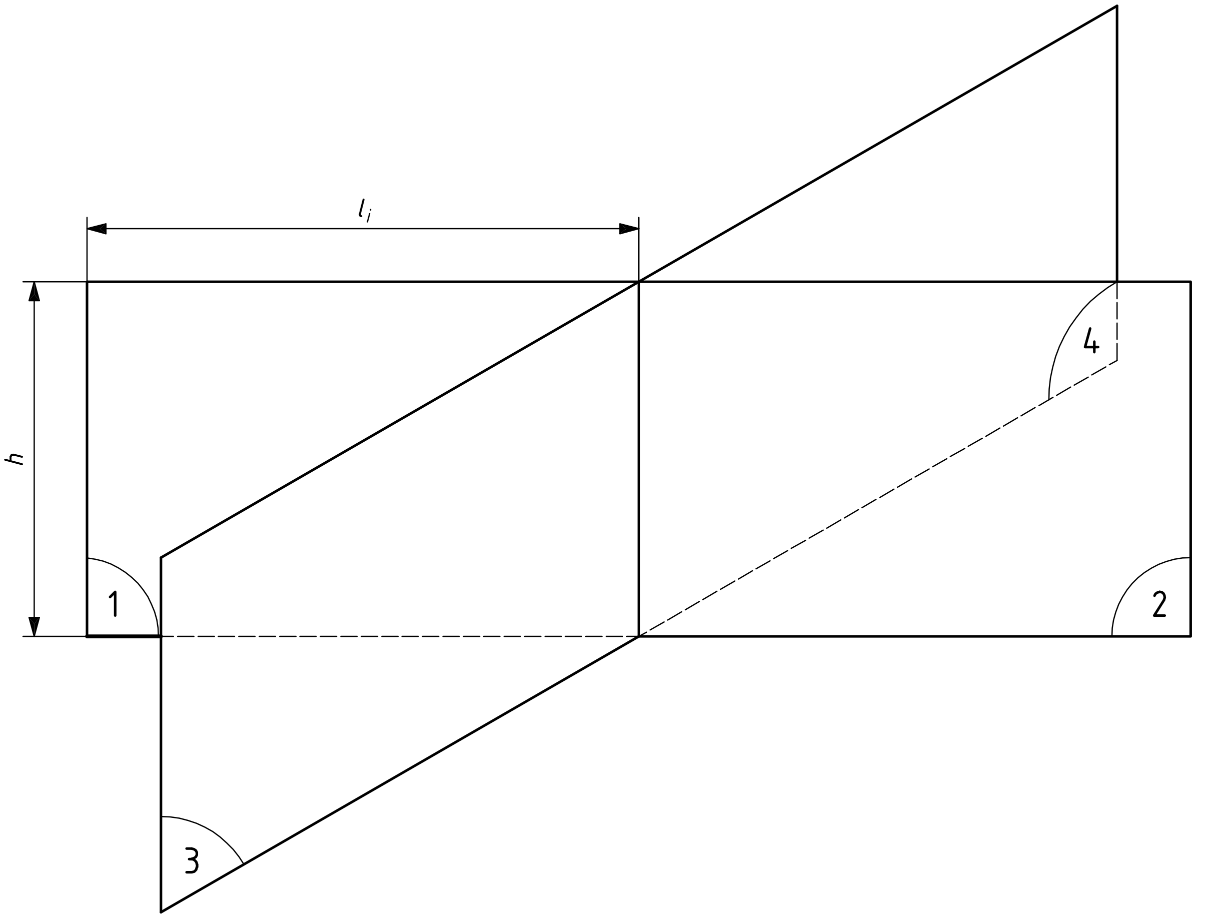
The determination of the minimum shield efficiency for test elements expressed as the sound reduction index improvement ΔR depends on the type of junction. If, for example, the 3 or 4 elements of the junction are identical, a ΔR of 10 dB in all frequency bands is sufficient for the test elements.

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 of

$$\Delta R_{min} = 10 - L_{v,1j} + L_{v,2j} \quad \text{if } L_{v,1j} - L_{v,2j} \leqslant 10 \text{ dB} \tag{21}$$

$$\Delta R_{min} = 0 \text{ dB if } L_{v,1j} - L_{v,2j} > 10 \text{ dB} \tag{22}$$



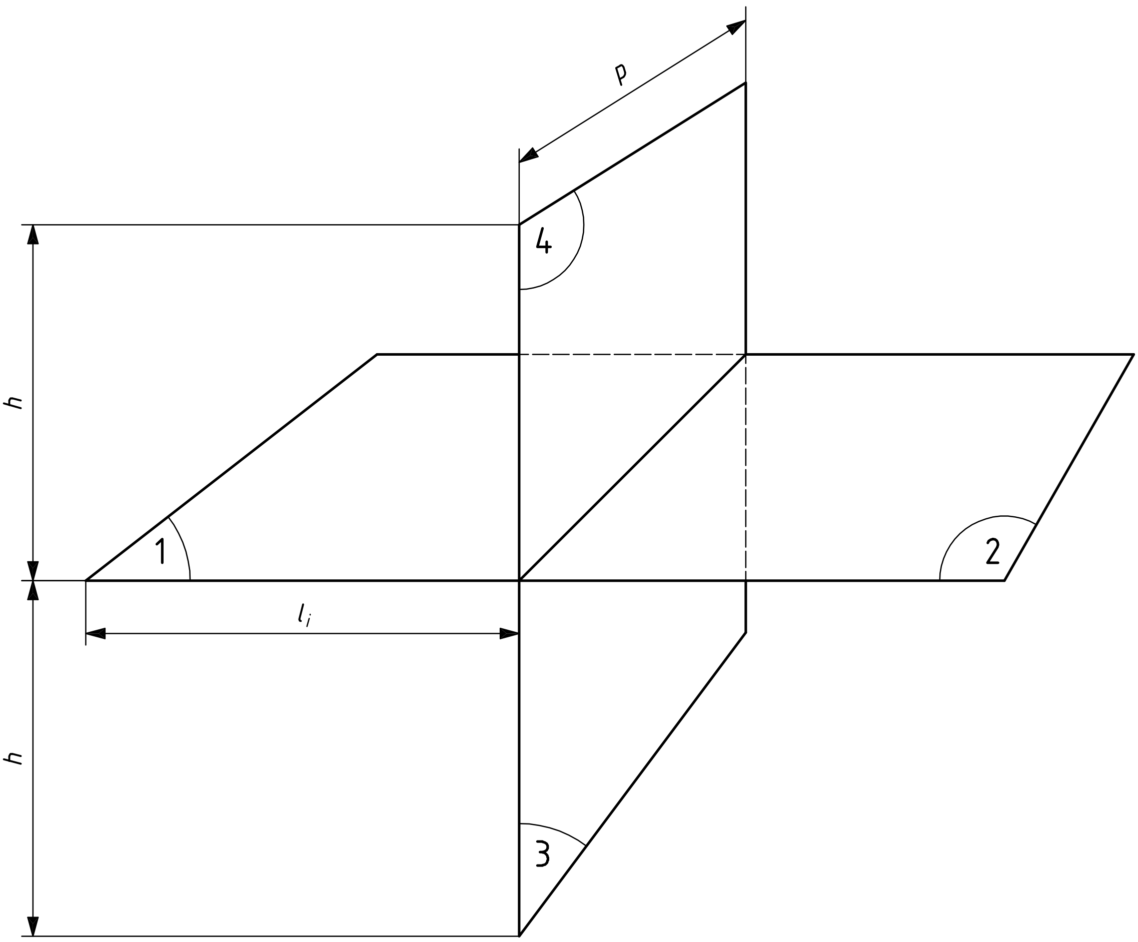
NOTE All dimensions are considered from the surface of the elements.

$h \geqslant 2{,}3$ m

3,5 m $\leqslant l_i <$ 6 m for all elements i

$\left| \frac{l_i - l_j}{l_i} \right| \geqslant 0{,}1$ for all combinations of elements i and j

Figure 1 — Vertical junction



NOTE All dimensions are considered from the surface of the elements.

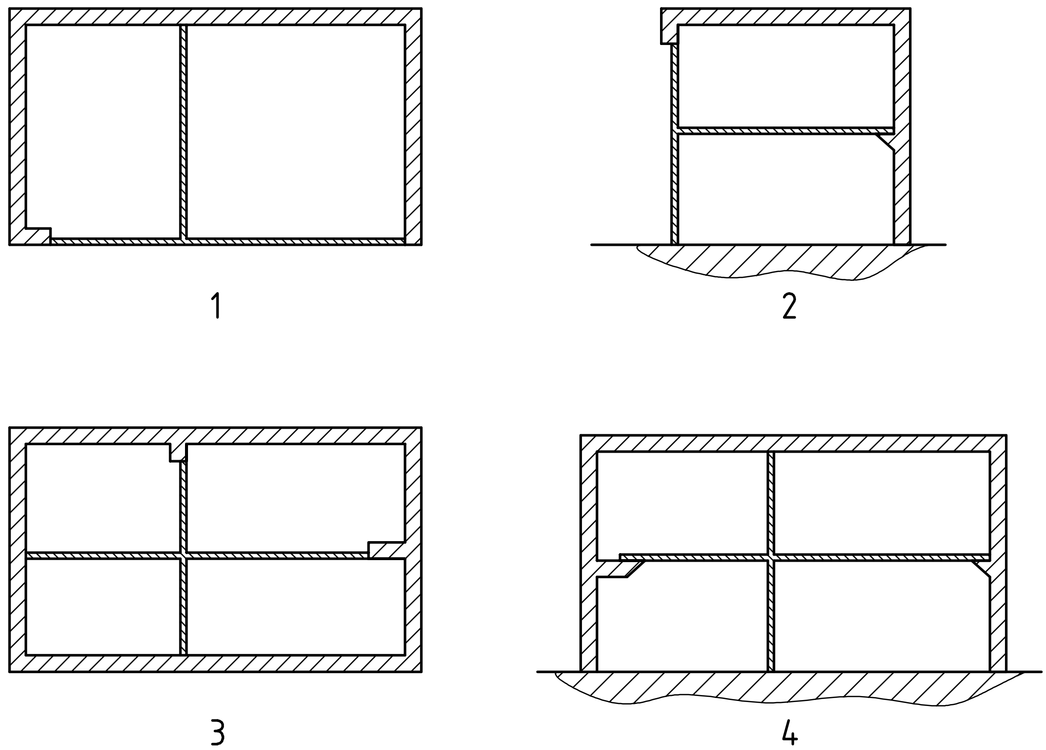
$h \geqslant$ 2,3 m

4 m $\leqslant p$ < 5 m for all elements i

3,5 m $\leqslant l_i$ < 6 m for all elements 1 and 2

$$l_1 > l_2, \left|\frac{l_1 - l_2}{l_1}\right| \geqslant 0,1$$

Figure 2 — Horizontal junction



Key

1 horizontal section of T-junction – horizontal transmission

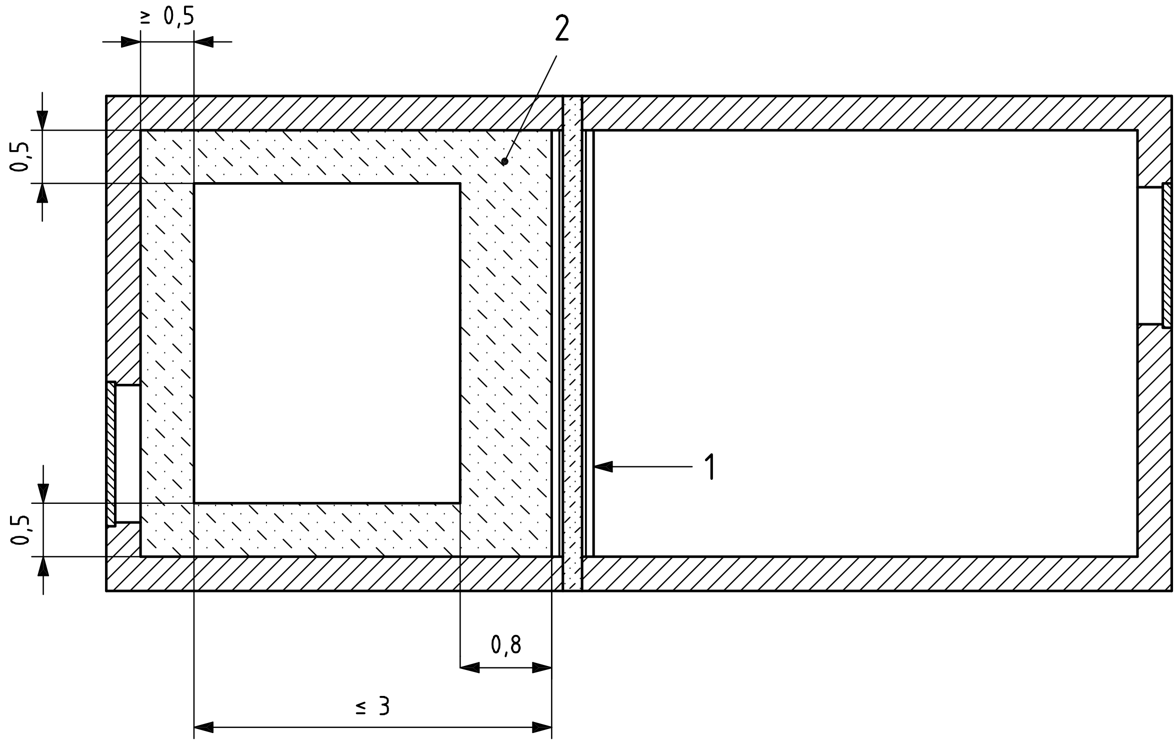
2 vertical section of T-junction – vertical transmission

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

Dimensions in metres



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 $L_{n,f}$

Annex A
(normative)

Single-number rating of the vibration reduction index

To compare results of K_{ij} globally or to use these results as input for the simplified models of EN 12354-1 and EN 12354-2, the one-third-octave-band results can be expressed in a single number. The single number rating of K_{ij}, indicated as the mean vibration reduction index $\overline{K_{ij}}$, is the arithmetic average of K_{ij} within the frequency range 200 Hz to 1 250 Hz (one-third-octave-bands) or 125 Hz to 1 000 Hz (octave-bands).

If K_{ij} varies considerably within the indicated frequency range, care shall be taken in applying $\overline{K_{ij}}$.

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[5] ISO 18233, *Acoustics — Application of new measurement methods in building and room acoustics*

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[11] ISO 10848-4:—[2)], *Acoustics — Laboratory measurement of the flanking transmission of airborne and impact noise between adjoining rooms — Part 4: Application to all other cases*

1) These documents may be obtained from: Organisation internationale de métrologie légale, 11 rue Turgot, 75009 Paris, France.

2) Under preparation.

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