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

Part 2: Impact sound insulation between rooms

Acoustique du bâtiment — Calcul de la performance acoustique des bâtiments à partir de la performance des éléments —

Partie 2: Isolement acoustique au bruit de choc entre des locaux

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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 15712-2 was prepared by CEN/TC 126, *Acoustic properties of building products and of buildings* (as EN 12354-2:2000), and was adopted without modification by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 2, *Building acoustics*.

Throughout the text of this document, read "...this European Standard..." to mean "...this International Standard...".

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

Part 2:
Impact sound insulation between rooms

1 Scope

This European Standard specifies calculation models designed to estimate the impact sound insulation between rooms in buildings, primarily on the bases of measured data which characterizes direct or indirect flanking transmission by the participating building elements and theoretically derived methods of sound propagation in structural elements.

A detailed model is described for calculation in frequency bands ; the single number rating of buildings can be determined from the calculation results. A simplified model with a restricted field of application is deduced from this, calculating directly the single number rating, using the single number ratings of the elements.

This European Standard describes the principles of the calculation scheme, lists the relevant quantities and defines its applications and restrictions. It is intended for acoustical experts and provides the framework for the development of application documents and tools for other users in the field of building construction, taking into account local circumstances.

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

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

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 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 140-1 : 1997).

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

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

EN ISO 140-7, *Acoustics - Measurement of sound insulation in buildings and of building elements - Part 7 : Field measurements of impact sound insulation of floors.* (ISO 140-7 : 1998).

EN ISO 140-8, *Acoustics - Measurement of sound insulation in buildings and of building elements - Part 8 : Laboratory measurements of the reduction of transmitted impact noise by floor coverings on a heavyweight standard floor.* (ISO 140-8 : 1997).

EN ISO 140-12, *Acoustics - Measurement of sound insulation in buildings and of building elements – Part 12 : Laboratory measurement of room-to-room airborne and impact sound insulation of an access floor.* (ISO 140-12 : 2000).

EN ISO 717-1, *Acoustics – Rating of sound insulation in buildings and of building elements – Part 1 : Airborne sound insulation* (ISO 717-1 : 1996).

EN ISO 717-2 : 1996, *Acoustics - Rating of sound insulation in buildings and of building elements – Part 2 : Impact sound insulation.* (ISO 717-2 : 1996).

EN 12354-1 : 2000, *Building Acoustics - Estimation of acoustic performance of buildings from the performance of elements - Part 1 : Airborne sound insulation between rooms.*

prEN ISO 10848-1, *Acoustics - Laboratory measurement of flanking transmission of airborne and impact sound between adjoining rooms - Part 1 : Frame document.* (ISO/DIS 10848-1 : 1999).

3 Relevant quantities

3.1 Quantities to express building performance

The impact sound insulation between rooms in accordance with EN ISO 140-7 can be expressed in two related quantities. These quantities are determined in frequency bands (one-third octave bands or octave bands) from which the single number rating for the building performance can be obtained in accordance with EN ISO 717-2 : 1996, for instance $L'_{n,w}$, $L'_{nT,w}$ or ($L'_{nT,w} + C_I$).

3.1.1 Normalized impact sound pressure level L'_n : The impact sound pressure level corresponding to the reference equivalent absorption area in the receiving room.

$$L'_n = L_i + 10 \lg \frac{A}{A_o} \text{ dB} \tag{1}$$

where

L_i is the impact sound pressure level measured in the receiving room, in decibels ;

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

A_o is the reference equivalent absorption area ; for dwellings A_o = 10 m^2.

This quantity is to be determined in accordance with EN ISO 140-7.

3.1.2 Standardized impact sound pressure level L'_{nT} : The impact sound pressure level corresponding to a reference value of the reverberation time in the receiving room.

$$L'_{nT} = L_i - 10 \lg \frac{T}{T_o} \text{ dB} \tag{2}$$

where

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

T_o is the reference reverberation time (for dwellings : T_o = 0,5 s).

This quantity is to be determined in accordance with EN ISO 140-7.

3.1.1.1 Relation between quantities

The relation between the quantities L'_{nT} and L'_n is given by :

$$L'_{nT} = L'_n - 10 \lg \frac{0{,}16\, V}{A_o T_o} = L'_n - 10 \lg 0{,}032\, V \text{ dB} \tag{3}$$

where

V is the volume of the receiving room, in cubic metres.

It is sufficient to estimate one of these quantities to deduce the other one. In this document the normalized impact sound pressure level L'_n is chosen as the prime quantity to be estimated.

3.2 Quantities to express element performance

The quantities expressing the element performance are used as part of the input data to estimate building performance. These quantities are determined in one-third octave bands and can also be expressed in octave bands. In relevant cases a single number rating for the element performance can be obtained from this, in accordance with EN ISO 717-2 : 1996, for instance $L_{nw}(C_I)$, ΔL_w $(C_{I\Delta})$ or ΔL_{lin} and $R_w(C; C_{tr})$.

3.2.1 Normalized impact sound pressure level L_n : The impact sound pressure level corresponding to the reference equivalent sound absorption area in the receiving room.

$$L_n = L_i + 10 \lg \frac{A}{A_o} \text{ dB} \tag{4}$$

where

L_i is the impact sound pressure level measured in the receiving room by using the standard tapping machine in accordance with EN ISO 140-7, in decibels ;

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

A_o is the reference equivalent absorption area with A_o = 10 m^2.

This quantity is to be determined in accordance with EN ISO 140-6.

3.2.2 Reduction of impact sound pressure level ΔL (improvement of impact sound insulation) : The reduction in normalized impact sound pressure level resulting from installation of the test floor covering.

$$\Delta L = L_{no} - L_n \text{ dB} \tag{5}$$

where

L_{no} is the normalized impact sound pressure level in the absence of floor covering, in decibels ;

L_n is the normalized impact sound pressure level when the floor covering is in place, in decibels.

This quantity is to be determined in accordance with EN ISO 140-8.

3.2.3 Reduction of impact sound pressure level ΔL_d : The reduction of impact sound pressure level by an additional layer on the receiving side of the separating element (floor). This quantity has to be determined in accordance with EN ISO 140-8.

3.2.4 Normalized flanking impact sound pressure level $L_{n,f}$: The space and time average sound pressure level in the receiving room produced by a standardized tapping machine operating at different positions on the element in the source room, normalized to the reference equivalent sound absorption area (A_o) in the receiving room ; A_o = 10 m^2. Transmission is only considered to occur through a specified flanking element, e.g. access floor.

$$L_{n,f} = L_i + 10 \lg \frac{A}{A_o} \text{ dB} \tag{6}$$

This quantity is to be determined in accordance with prEN ISO 10848-1.

NOTE For access floors see EN ISO 140-12.

3.2.5 Airborne sound reduction index R : Ten times the common logarithm of the ratio of the sound power W_1 incident on a test specimen to the sound power W_2 transmitted through the specimen.

$$R = 10 \lg \frac{W_1}{W_2} \text{ dB} \tag{7}$$

This quantity is to be determined in accordance with EN ISO 140-3.

3.2.6 Sound reduction improvement index ΔR : The difference in sound reduction index between a basic structural element with an additional layer (e.g. a suspended ceiling) and the basic structural element without this layer for direct transmission.

Annex D of EN 12354-1 : 2000 gives information on the determination and the use of this quantity.

3.2.7 Vibration reduction index K_{ij} : This quantity is related to the vibrational power transmission over a junction between structural elements, normalized in order to make it an invariant quantity. It is determined by normalizing the direction-averaged velocity level difference over the junction, to the junction length and the equivalent absorption length, if relevant, of both elements in accordance with the following equation :

$$K_{ij} = \frac{D_{v,ij} + D_{v,ji}}{2} + 10 \lg \frac{l_{ij}}{\sqrt{a_i \, a_j}} \text{ dB} \tag{8}$$

where

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

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

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

a_i is the equivalent absorption length of element i, in metres ;

a_j is the equivalent absorption length of element j, in metres.

The equivalent absorption length is given by :

$$a = \frac{2{,}2\,\pi^2 S}{c_o \, T_s} \sqrt{\frac{f_{ref}}{f}} \tag{9}$$

where :

T_s is the structural reverberation time of the element i or j, in seconds ;

S is the area of element i or j, in square metres ;

f is the centre band frequency, in Hertz ;

f_{ref} is the reference frequency ; f_{ref} = 1000 Hz ;

c_o is the speed of sound in air, in metres per second.

NOTE 1 The equivalent absorption length is the length of a fictional totally absorbing edge of an element if its critical frequency is assumed to be 1000 Hz, giving the same loss as the total losses of the element in a given situation.

The quantity K_{ij} is to be determined in accordance with prEN ISO 10848-1.

NOTE 2 For the time being values for this quantity can be taken from annex E of EN 12354-1 : 2000 or be deduced from available data on the junction velocity level difference according to that annex.

3.2.8 Other element data

For the calculation additional information on the elements can be necessary, e.g. :

— mass per unit area m', in kilograms per square metre ;

— type of element ;

— material ;

— type of junction.

3.3 Other terms and quantities

Direct transmission : Transmission due to impact excitation and sound radiation from a separating element.

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

Direction-averaged junction velocity level difference $\overline{D_{v,ij}}$: The average of the junction level difference from element i to j and from element j to i :

$$\overline{D_{v,ij}} = \frac{D_{v,ij} + D_{v,ji}}{2} \tag{10}$$

Flanking normalized impact sound pressure level $L_{n,ij}$: Average sound pressure level in the receiving room due to impact excitation of element i (floor) in the source room and sound radiation only by element j in the receiving room, normalized to the reference equivalent absorption area of A_0 = 10 m^2.

Further symbols used in this standard appear in annex A.

4 Calculation models

4.1 General principles

The sound power radiated into the receiving room is due to sound radiated by each structural element in that room. The sound radiated by each of the structural elements is caused by sound transmitted to that element due to impact on a structural element in the source room. It is assumed that the transmission via each of these paths can be considered to be independent and that the sound and vibrational fields behave statistically, so that the impact sound pressure level L'_n can be obtained by addition of the energy transmitted via each path. The transmission paths considered are defined in Figure 1, where d indicates the direct impact sound transmission and f flanking impact sound transmission.

For rooms above each other the total impact sound pressure level L'_n in the receiving room is determined by :

$$L'_n = 10 \lg \left(10^{L_{n,d}/10} + \sum_{j=1}^{n} 10^{L_{n,ij}/10} \right) \text{dB} \tag{11}$$

where

$L_{n,d}$ is the normalized impact sound pressure level due to direct transmission, in decibels ;

$L_{n,ij}$ is the normalized impact sound pressure level due to flanking transmission, in decibels ;

n is the number of elements.

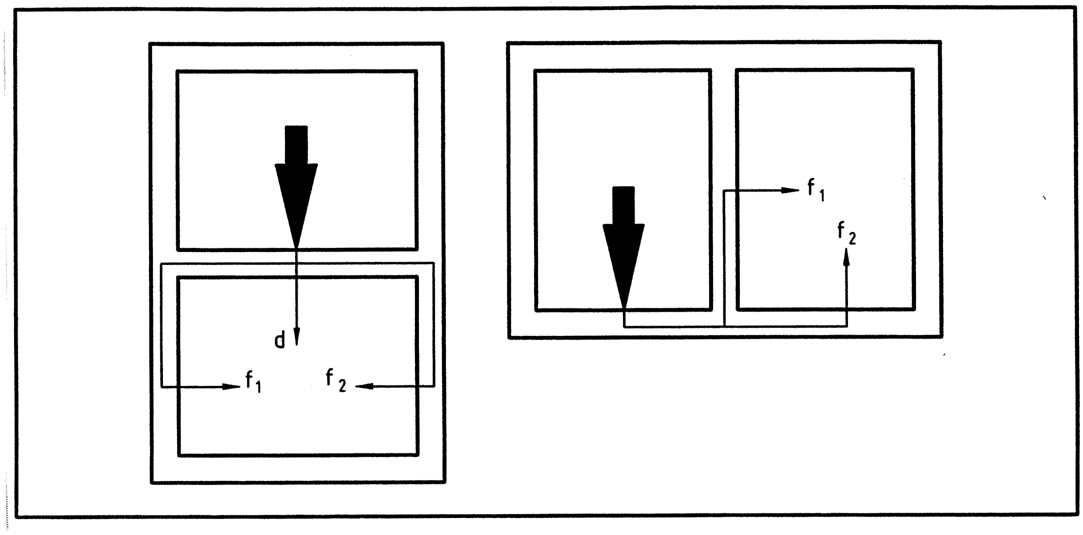

Figure 1 — Definition of sound transmission paths between two rooms, above each other and next to each other respectively

For rooms next to each other the total impact sound pressure level L'_{n} in the receiving room is determined by :

$$L'_{\mathrm{n}} = 10 \lg \sum_{j=1}^{n} 10^{L_{\mathrm{n,ij}}/10} \ \mathrm{dB} \qquad (12)$$

NOTE 1 For common situations the number of flanking elements to consider is n = 4 for rooms above each other and n = 2 for rooms next to each other.

The detailed model calculates the building performance in frequency bands, based on acoustic data for the building elements in frequency bands (one-third octave bands or octave bands). As a minimum the calculation has to be performed for octave bands from 125 Hz to 2000 Hz or for one-third octave bands from 100 Hz to 3150 Hz. From this the single number rating for the building performance can be obtained in accordance with EN ISO 717-2 : 1996.

NOTE 2 The calculations can be extended to higher or lower frequencies if element data are available for these frequencies. However, no information is available at this time on the accuracy of calculations for the extended lower frequency regions.

The detailed model is described in 4.2.

The simplified model calculates the building performance directly as a single number rating, based on the single number ratings of the performance of the elements involved.

The simplified model is described in 4.3.

4.2 Detailed Model

4.2.1 Input data

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

— normalized impact sound pressure level of the floor : L_{n} ;

— reduction of the impact sound pressure level of the floor covering : ΔL ;

— reduction of the impact sound pressure level of additional layers on the receiving room side of the separating element i (floor) : ΔL_{d} ;

— sound reduction index of the excitated element (floor) : R_i ;

— sound reduction index for direct transmission of flanking element j in the receiving room : R_j ;

— sound reduction index improvement by internal layers of flanking element j in the receiving room : ΔR_j ;

— structural reverberation time for an element in the laboratory : $T_{s,lab}$;

— vibration reduction index for each transmission path between element i (floor) and element j : K_{ij} ;

— area of the separating element (floor) : S_i ;

— area of the flanking element j in the receiving room : S_j ;

— common coupling length between element i (floor) and flanking element j : l_{ij}.

Information on the normalized impact sound pressure level for common homogeneous floors is given in B.1.

Information on the impact sound improvement index for common floor coverings is given in C.1.

Information on the sound reduction index of common homogeneous elements is given in annex B of EN 12354-1 : 2000.

Information on the sound reduction index improvement is given in annex D of EN 12354-1 : 2000.

Information on the vibration reduction index for common junctions is given in annex E of EN 12354-1 : 2000.

4.2.2 Transfer of input data to in-situ values

Acoustic data for elements (separating and flanking structural elements, additional layers and coverings, junctions) have to be converted into in-situ values before the actual determination of the sound transmission.

For elements the in-situ values for the normalized impact sound pressure level $L_{n,situ}$ and the sound reduction index R_{situ} follow from :

Impact sound pressure level :

$$L_{n,situ} = L_n + 10 \lg \frac{T_{s,situ}}{T_{s,lab}} \text{ dB} \tag{13}$$

Sound reduction index :

$$R_{situ} = R - 10 \lg \frac{T_{s,situ}}{T_{s,lab}} \text{ dB} \tag{14}$$

where

$T_{s,\,situ}$ is the structural reverberation time for the element in the actual field situation, in seconds ;

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

For each flanking transmission path the sound reduction index, R, of the elements involved (including the separating element) should relate to the resonant transmission only. It is correct to apply the laboratory sound reduction index above the critical frequency. Below the critical frequency this can be considered a reasonable estimation which errs on the low side, due to non-resonant transmission. If the values of the sound reduction index are based on calculations from material properties, it is best to consider only resonant transmission over the frequency range of interest.

For the following building elements the structural reverberation time $T_{s,situ}$ shall be taken equal to $T_{s,lab}$ which leads to a correction term of 0 dB :

— lightweight, double leaf elements, such as timber framed or metal framed stud walls ;

— elements with an internal loss factor greater than 0,03 ;

— elements which are much lighter than the surrounding structural elements (by a factor of at least three) ;

— elements which are not firmly connected to the surrounding structural elements.

Otherwise the structural reverberation time, both for the laboratory and for the actual field situation, has to be taken into account in accordance with annex C of EN 12354-1 : 2000.

NOTE 1 As a first approximation the correction terms for all types of elements can be taken as 0 dB.

For additional layers and coverings the in-situ values can be taken as the laboratory value as an approximation :

$$\begin{aligned} \Delta R_{situ} &= \Delta R \quad \text{dB} \\ \Delta L_{situ} &= \Delta L \quad \text{dB} \\ \Delta L_{d,situ} &= \Delta L_d \quad \text{dB} \end{aligned} \qquad (15)$$

If appropriate data for the impact sound improvement index ΔL_d by suspended ceilings on the receiving side of the separating floor is not available, the airborne sound improvement index ΔR can be used as an estimation.

For the **junctions** the in-situ transmission is characterized by the direction-averaged junction velocity level difference $\overline{D_{v,ij,situ}}$. This follows from the vibration reduction index :

$$\overline{D_{v,ij,situ}} = K_{ij} - 10 \lg \frac{l_{ij}}{\sqrt{a_{i,situ}\, a_{j,situ}}} \text{ dB} ; \overline{D_{v,ij,situ}} \geq 0 \text{ dB} \qquad (16)$$

with

$$a_{i,situ} = \frac{2{,}2\, \pi^2 S_i}{c_o T_{s,i,situ}} \sqrt{\frac{f_{ref}}{f}}$$

$$a_{j,situ} = \frac{2{,}2\, \pi^2 S_j}{c_o T_{s,j,situ}} \sqrt{\frac{f_{ref}}{f}} \qquad (17)$$

where

$a_{i, situ}$ is the equivalent absorption length of element i in the actual field situation, in metres ;

$a_{j, situ}$ is the equivalent absorption length of element j in the actual field situation, in metres ;

f is the centre band frequency, in Hertz ;

