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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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Contents

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.

$$R = 10 \lg \frac{W_1}{W_2} \text{ dB} \quad (7)$$

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 :

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

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 :

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

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 excitated 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 :

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

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 :

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

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.

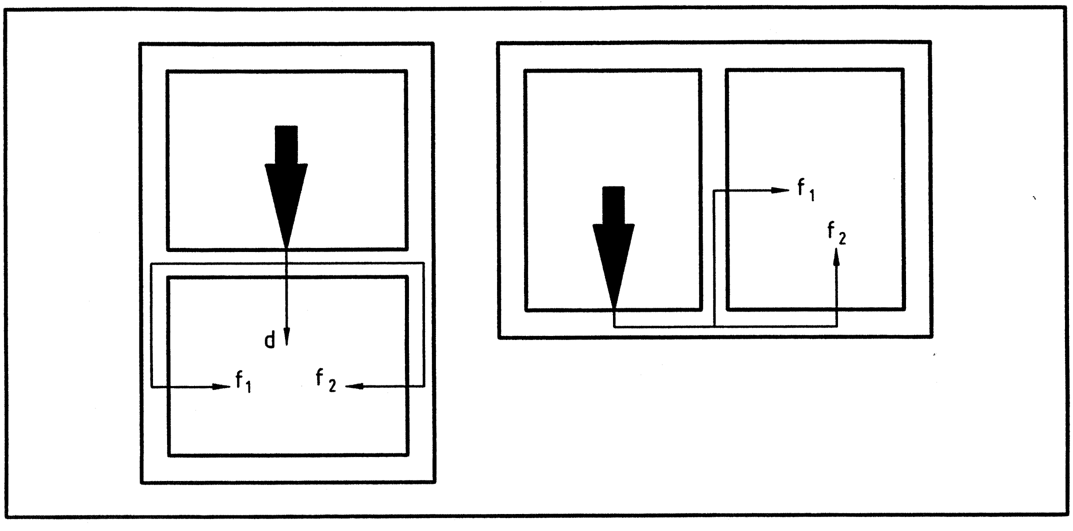


Figure 1 — Definition of sound transmission paths between two rooms, above each other and next to each other respectively

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

$$L'_n = 10 \lg \sum_{j=1}^{n} 10^{L_{n,ij}/10} \text{ dB} \tag{12}$$

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 :

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

Sound reduction index :

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

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 $T_{\text{s,situ}}$ shall be taken equal to $T_{\text{s,lab}}$ 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 :

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

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 $\overline{D_{\text{v,ij,situ}}}$. This follows from the vibration reduction index :

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

with

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

(17)

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

where

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

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

f is the centre band frequency, in Hertz ;

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

c_o is the sound speed in air, in metres per second ;

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

S_i is the area of the excited element i (floor), in square metres ;

S_j is the area of the radiating element j in the receiving room, in square metres ;

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

$T_{s,\,j,situ}$ is the structural reverberation time of element j in the actual field situation, in seconds.

For the following building elements the equivalent absorption length a_{situ} is taken numerically equal to the area of the element, so $a_{i,situ} = S_i / l_o$ and/or $a_{j,situ} = S_j / l_o$, where the reference length l_o = 1 m :

— 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 for the actual field situation has to be taken into account in accordance with annex C of EN 12354-1 : 2000.

NOTE 2 As a first approximation the equivalent absorption length can be taken as $a_{i,situ} = S_i / l_o$ and $a_{j,situ} = S_j / l_o$ for all types of elements, with l_o = 1 m. If in that case the vibration reduction index has a lower value than a minimum value $K_{ij,min}$, that minimum value is used. The minimum value is given by (ij = Ff, Fd or Df).

$$K_{ij,min} = 10 \lg \left[l_{ij} l_o \left(\frac{1}{S_i} + \frac{1}{S_j} \right) \right] \text{ dB} \qquad (18)$$

4.2.3 Determination of direct and flanking transmission

The normalized impact sound pressure level for direct transmission is determined from adjusted input values as follows :

$$L_{n,d} = L_{n,situ} - \Delta L_{situ} - \Delta L_{d,situ} \text{ dB} \qquad (19)$$

The normalized impact sound pressure level for flanking transmission from the separating element i (floor) to the flanking element j is determined from adjusted input values as follows :

$$L_{n,ij} = L_{n,situ} - \Delta L_{situ} + \frac{R_{i,situ} - R_{j,situ}}{2} - \Delta R_{j,situ} - \overline{D_{v,ij,situ}} - 10 \lg \sqrt{\frac{S_i}{S_j}} \text{ dB} \qquad (20)$$

where :

S_i is the area of the excitated element (floor), in square metres ;

S_j is the area of the radiating element in the receiving room, in square metres.

NOTE For certain floors as flanking construction, such as access floors, the transmission is dominated by path Ff (the contribution of path Fd being negligible). In that case it is possible to characterize the flanking transmission for this construction as a whole by laboratory measurements (see annex D).

4.2.4 Interpretation for several types of elements

Information on the interpretation for several types of elements is given in EN 12354-1 : 2000.

4.2.5 Limitations

— the model is only applicable to combinations of elements for which the junction transmission index is known or can be estimated from known values ;

— the elements should have approximately the same radiation characteristics to both sides ;

— the contribution of secondary transmission paths, involving more than one junction, is neglected ;

— the reduction of impact sound pressure level ΔL measured on a massive floor in accordance with EN ISO 140-8 cannot be used in combination with timber floors or other lightweight composite floor constructions.

4.3 Simplified model

4.3.1 Calculation procedure

The simplified version of the calculation model predicts the weighted normalized impact sound pressure level on the basis of weighted values of the elements involved, determined in accordance with the weighting procedure of EN ISO 717-2 : 1996. Its application is restricted to rooms above each other and a homogeneous basic floor construction. The influence of structural damping is taken into account in an average way, neglecting the specifics of the situation and the flanking transmission is accounted for in a global way, based on calculations with the detailed model.

The weighted normalized impact sound pressure level $L'_{n,w}$ is given by :

$$L'_{n,w} = L_{n,w,eq} - \Delta L_w + K \text{ dB} \quad (21)$$

where

K is the correction for impact sound transmission over the homogeneous flanking constructions in decibels, as given in Table 1.

Table 1 - Correction *K* for flanking transmission in decibels

Mass per unit area of the separating element (floor) in kg/m²	Mean mass per unit area of the homogeneous flanking elements not covered with additional layers in kg/m²								
	100	150	200	250	300	350	400	450	500
100	1	0	0	0	0	0	0	0	0
150	1	1	0	0	0	0	0	0	0
200	2	1	1	0	0	0	0	0	0
250	2	1	1	1	0	0	0	0	0
300	3	2	1	1	1	0	0	0	0
350	3	2	1	1	1	1	0	0	0
400	4	2	2	1	1	1	1	0	0
450	4	3	2	2	1	1	1	1	1
500	4	3	2	2	1	1	1	1	1
600	5	4	3	2	2	1	1	1	1
700	5	4	3	3	2	2	1	1	1
800	6	4	4	3	2	2	2	1	1
900	6	5	4	3	3	2	2	2	2

If one or more massive flanking constructions are covered by additional layers (wall lining) with a resonant frequency f_0 < 125 Hz according to D.2 of EN 12354-1 : 2000 the surface masses of the covered elements are not considered in the calculation of the mean mass value.

NOTE In principle a correction term K to express the contribution of flanking transmission could also be derived for other room configurations than rooms above each other.

4.3.2 Input data

Acoustic data on the elements involved should be taken primarily from standardized laboratory measurements. However, they may also be deduced in other ways, using theoretical calculations, empirical estimations or measurement results from field situations. Information on this is given in some annexes. The sources of data used shall be clearly stated.

The input data consist of the following :

— equivalent weighted normalized impact sound pressure level of the floor base : $L_{n,w,eq}$.

The single number rating to express element performance of heavy floor bases is obtained by rating the frequency depending normalized impact sound pressure level following the procedure described in annex B of EN ISO 717-2 : 1996 :

— weighted reduction of impact sound pressure level of the floor covering : ΔL_w.

The single number rating to express element performance of floor coverings (floating floors or soft floor coverings) is obtained by applying the procedure described in clause 5 of EN ISO 717-2 : 1996.

Information on the equivalent weighted normalized impact sound pressure level $L_{n,w,eq}$ for common homogeneous floor constructions is given in B.2.

Information on the weighted normalized impact sound improvement index ΔL_w of floating floors is given in C.2.

4.3.3 Limitations

- the model is only applicable to homogeneous building constructions (masonry and/or concrete) with floating floors or soft coverings on a homogeneous floor construction ;
- it is only applicable for rooms above each other and for rooms of conventional size in dwellings.

5 Accuracy

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

The main experience in the application of similar models, as far as the detailed model is concerned, is based on buildings with homogeneous building elements, e.g. brick walls, concrete floors and walls, gypsum blocks etc. For vertical impact sound transmission the prediction of the single number value is correct with a standard deviation of 2 dB. For horizontal transmission the calculated single number values have a varying bias error of 0 dB to 5 dB with a standard deviation of around 3 dB. The bias is expected to be caused largely by neglecting the structural reverberation time.

Calculation examples with the simplified model show that about 60 % of the predicted values are in a range of ± 2 dB compared to the measured values and 100 % are in a range of ± 4 dB. There is at present no experience with the correction of flanking transmission of impact sound. It is expected that this correction will improve the accuracy of the model for common field situations.

In applying the predictions it is advisable to vary the input data, especially in complicated situations and with atypical elements with questionable input data. The resulting variation in the results gives an impression of the expected accuracy for these situations, assuming similar workmanship.

Annex A
(normative)

Symbols

Symbol	Physical quantity	unit
a	equivalent absorption length of a structural element	[m]
a_{situ}	equivalent absorption length of a structural element in the actual field situation	[m]
A	equivalent sound absorption area in the receiving room	[m²]
A_o	reference equivalent sound absorption area ; for dwellings given as 10 m²	[m²]
c_o	speed of sound in air (= 340 m/s)	[m/s]
c_L	longitudinal wave speed	[m/s]
C_l	spectrum adaptation term for impact sound according to EN ISO 717-2 : 1996	[dB]
$C_{l\Delta}$	spectrum adaptation term for impact sound reduction by floor coverings according to annex A of EN ISO 717-2 : 1996	[dB]
$D_{v,ij}$	junction velocity level difference between excited element i and receiving element j	[dB]
$\overline{D_{v,ij,situ}}$	direction-averaged junction velocity level difference between elements i and j in the actual field situation	[dB]
f	Frequency	[Hz]
f_{ref}	reference frequency (= 1000 Hz)	[Hz]
i	indices for an element in the source room (= D,F)	[-]
j	indices for an element in the receiving room (= d,f)	[-]
K	correction term for flanking transmission	[dB]
K_{ij}	vibration reduction index for each transmission path ij over a junction	[dB]
$K_{ij,min}$	minimum value for K_{ij} in the actual field situation	[dB]
L_i	average impact sound pressure level in the receiving room	[dB re 20 μPa]
L_n	normalized impact sound pressure level	[dB re 20 μPa]
$L_{n,f}$	normalized flanking impact sound pressure level	[dB re 20 μPa]
$L_{n,situ}$	normalized impact sound pressure level in the actual field situation	[dB re 20 μPa]
$L_{n,w,eq}$	equivalent weighted normalized impact sound pressure level	[dB re 20 μPa]

L'_n	normalized impact sound pressure level in the field	[dB re 20 μPa]
$L'_{n,w}$	weighted normalized impact sound pressure level in the field (EN ISO 717-2 : 1996)	[dB re 20 μPa]
L'_{nT}	standardized impact sound pressure level in the field	[dB re 20 μPa]
$L_{n,d}$	normalized impact sound pressure level by direct transmission	[dB re 20 μPa]
$L_{n,ij}$	normalized impact sound pressure level by flanking transmission	[dB re 20 μPa]
L_2	average impact sound pressure level in the receiving room due only to sound transmission via path Ff (for certain flanking elements)	[dB re 20 μPa]
ΔL	reduction of impact sound pressure level by a floor covering	[dB]
ΔL_{situ}	reduction of impact sound pressure level by a floor covering in the actual field situation	[dB]
ΔL_d	reduction of impact sound pressure level by an additional layer on the receiving side of the separating element	[dB]
$\Delta L_{d,situ}$	reduction of impact sound pressure level by an additional layer on the receiving side of the separating element in the actual field situation	[dB]
ΔL_w	weighted reduction of impact sound pressure level by a floor covering (EN ISO 717-2 : 1996)	[dB]
ΔL_{lin}	unweighted linear reduction of impact sound pressure level by a floor covering (annex A of EN ISO 717-2 : 1996)	[dB]
l_{ij}	common coupling length between element i and element j	[m]
l_{Ff}	common coupling length between flanking elements F, f and the separating element	[m]
l_{lab}	laboratory value, as reference, for l_{ij}	[m]
l_o	reference length (= 1 m)	[m]
m'	mass per unit area of an element	[kg/m^2]
m'_o	reference mass per unit area (= 1 kg/m^2	^{2}]
n	number of flanking elements in a room	[-]
R	sound reduction index of an element	[dB]
R_{situ}	sound reduction index of an element in the actual field situation	[dB]
R_i	sound reduction index of the excited element i in source room	[dB]
$R_{i,situ}$	sound reduction index of the excited element i in the actual field situation	[dB]
R_j	sound reduction index for element j in receiving room	[dB]
$R_{j,situ}$	sound reduction index of element j in the actual field situation	[dB]

ΔR_j	sound reduction index improvement by an additional layer on the receiving side of element j	[dB]
$\Delta R_{j,situ}$	sound reduction index improvement by an additional layer on the receiving side of element j in the actual field situation	[dB]
S_i	surface area of the excited element (floor)	[m^2]
S_j	surface area of the radiating element	[m^2]
S_f	surface area of the excited element in the actual field situation	[m^2]
$S_{f,lab}$	surface area of the excited element in the laboratory situation	[m^2]
s'	dynamic stiffness per unit area	[N/m^3]
T	reverberation time in the receiving room	[s]
T_o	reference reverberation time ; for dwellings given as 0,5 s	[s]
T_s	structural reverberation time of a (homogeneous) element	[s]
$T_{s,lab}$	structural reverberation time for each (homogeneous) element in the laboratory situation	[s]
$T_{s,situ}$	structural reverberation time for each (homogeneous) element in the actual field situation	[s]
$T_{s,i,lab}$	structural reverberation time for element i in the laboratory situation	[s]
$T_{s,i,situ}$	structural reverberation time for element i in the actual field situation	[s]
t	Thickness	[m]
V	the volume of the receiving room	[m^3]
v_i^2	average square velocity over element i (free waves)	[$(m/s)^2$]
v_j^2	average square velocity over element j (free waves)	[$(m/s)^2$]
W_1	sound power incident on a test specimen in the source room	[W]
W_2	sound power radiated from a test specimen into the receiving room due to incident sound on that specimen in the source room	[W]
w	index to indicate weighted sound reduction indices according to EN ISO 717-1	[-]
ρ	Density	[kg/m^3]
σ	radiation factor for free bending waves	[-]

Annex B
(informative)

Homogeneous floor constructions

B.1 Normalized impact sound pressure level L_n of homogeneous floor constructions

For homogeneous floor constructions the calculation following 4.2 can be based on the following data if measured values of the normalized impact sound pressure level L_n are not available.

For common monolithic floors the normalized impact sound pressure level can be calculated accurately [5] (see bibliography). The total loss factor as influenced by the laboratory is important and has to be taken into account in accordance with the specifications given in EN ISO 140-1. This is described in annex C of EN 12354-1 : 2000.

The following equations can be used :

$$L_n = L_F + 10 \lg \frac{Re(Y)\sigma}{m'[1\,\mathrm{s\,m^2/kg^2}]} + 10 \lg \frac{T_s}{[1\,\mathrm{s}]} + 10{,}6\ \mathrm{dB} \tag{B.1}$$

With the force level of the standard tapping machine according to EN ISO 140-6 it follows for one-third octave bands [1] (see bibliography) :

$$L_n \approx 155 - 30 \lg \frac{m'}{[1\,\mathrm{kg/m^2}]} + 10 \lg \frac{T_s}{[1\,\mathrm{s}]} + 10 \lg \sigma + 10 \lg \frac{f}{f_{ref}}\ \mathrm{dB} \tag{B.2}$$

where

L_F is the force level of the tapping machine, in decibels (reference 10^{-6} N) ;

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

$Re(Y)$ is the real part of the floor mobility, in second square metres per kilogram ;

σ is the radiation factor for free bending waves ;

T_s is the structural reverberation time, in seconds ;

ρ is the density of the floor, in kilograms per cubic metre ;

c_L is the longitudinal velocity, in metres per second ;

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

The radiation factor for free waves and the structural reverberation time is calculated in accordance with annex B and annex C of EN 12354-1 : 2000.

The forces applied by the tapping machine are reduced at higher frequencies, depending on the dynamic stiffness of the top layer of the floor. This can be taken into account empirically.

Based on calculations according to this model, some examples of the normalized impact sound pressure level in octave bands for monolithic floors are given in Table B.2 for a laboratory situation in accordance with annex C of EN 12354-1 : 2000. The calculations are performed for frequencies at one-third octave distance and results averaged over a band width of an octave. The applied material properties are given in Table B.1, together with the generic material names for which they are indicative.

Table B.1 - Typical material properties

Material	Density ρ (kg/m^3)	Longitudinal velocity c_L (m/s)	Internal loss factor η (-)
Concrete	2300	3500	0,006
Lightweight concrete	1300	1700	0,015

Table B.2 - Calculated normalized impact sound pressure level in octave bands for some monolithic structural elements (examples)

Construction	m' kg/m^2	Normalized impact sound pressure level (dB) in octave bands (Hz)							$L_{n,w}$ (C_I)
		63	125	250	500	1 k	2 k	4 k	
100 mm concrete + 20mm finish	268	65	73	78	78	78	78	76	80 (-11)
180 mm concrete + 50mm finish	509	64	60	65	66	67	68	66	69 (-11)
200 mm lightweight concrete	260	65	72	78	77	77	76	70	77 (- 9)
300 mm lightweight concrete	390	64	68	70	70	70	70	64	71 (- 9)

For reasons of reciprocity the sum of the airborne sound reduction index R and the normalized impact sound pressure level L_n for homogeneous floor constructions depends only on frequency, if forced transmission is negligible [7] (see bibliography). This is normally valid for frequencies up to 1 kHz due to the influence of the stiffness of the top layer of the floor. Thus the normalized impact sound pressure level of a construction can be estimated from data on the sound reduction index of that construction.

For calculations in octave bands the relation is given by :

$$R + L_n = 43 + 30 \lg \frac{f}{[1\,\text{Hz}]} \text{ dB} \qquad \text{(B.3)}$$

where

f octave band centre frequency in Hertz.

For calculation of data in third-octave band width the expression is :

$$R + L_n = 38 + 30 \lg \frac{f}{[1\text{Hz}]} \text{ dB} \qquad \text{(B.4)}$$

where

f one-third octave band centre frequency in Hertz.

B.2 Equivalent weighted normalized impact sound pressure level $L_{n,w,eq}$ of homogeneous floor constructions

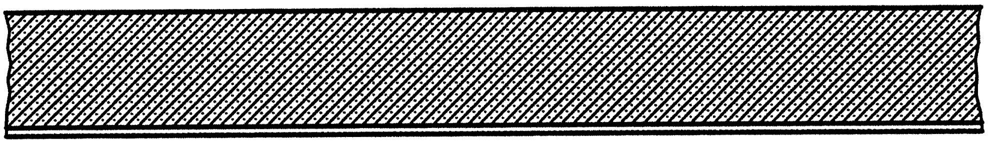
For homogeneous floor constructions the equivalent weighted normalized impact sound pressure level $L_{n,w,eq}$ used for the calculation following 4.3 can be calculated from the mass per unit area m' (in the range of 100 kg/m^2 to 600 kg/m^2) from [8] (see bibliography) :

$$L_{n,w,eq} = 164 - 35 \lg \frac{m'}{\left[1 \text{ kg/m}^2\right]} \text{ dB} \qquad \text{(B.5)}$$

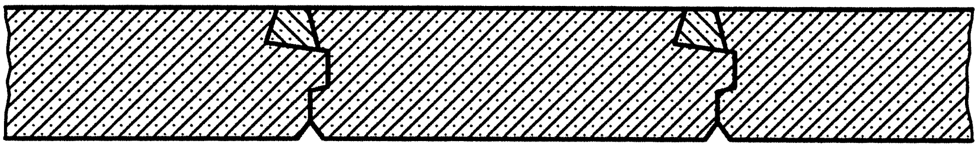
This equation is for homogeneous concrete floors ; for lightweight concrete or porous concrete the actual values will be somewhat lower, so equation B.5 is on the safe side in those cases. Figure B1 shows floor constructions which behave like homogeneous constructions.

Floor constructions without voids

in-situ concrete solid floor

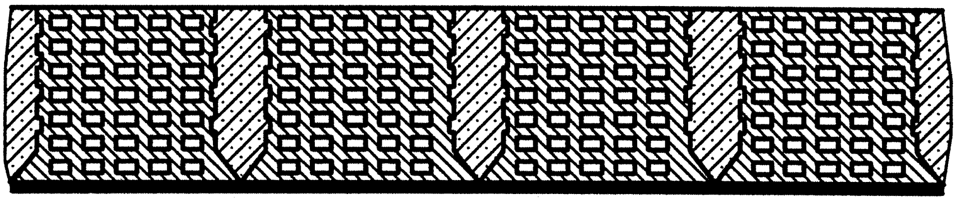


autoclaved aerated concrete solid floor

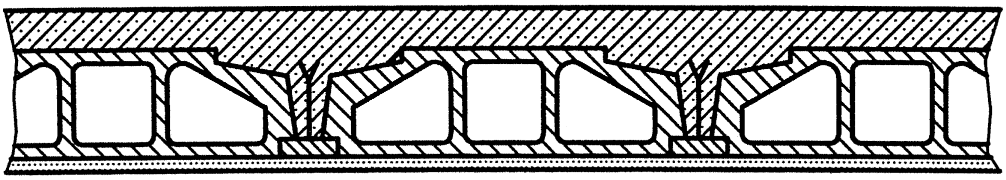


Floor constructions with voids

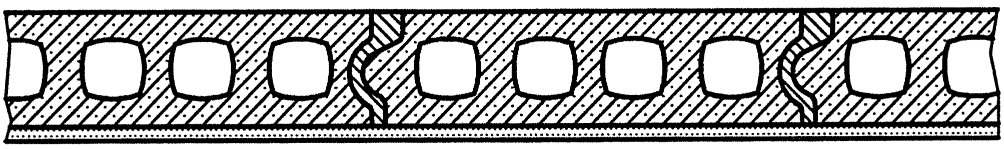
perforated brick floor



beam and pot



wide slab concrete floor



concrete beam floor

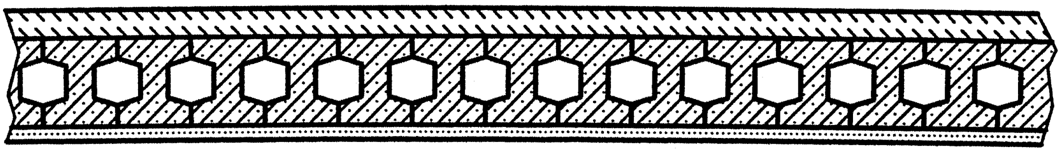


Figure B.1 - Types of basic floor constructions

Annex C
(informative)

Floating floors

C.1 Reduction of impact sound pressure level ΔL of floating floors

If no measured values for the reduction of impact sound pressure level ΔL of floating floors are available the following formulae can be applied :

a) the reduction of impact sound pressure level ΔL of floating floor screeds made of sand/cement or calcium-sulphate can be calculated by :

$$\Delta L = 30 \lg \frac{f}{f_o} \text{ dB} \tag{C.1}$$

where

f octave or third-octave band centre frequency in Hertz ;

f_o the resonance frequency of the system in Hertz according to :

$$f_o = 160\sqrt{\frac{s'}{m'}} \tag{C.2}$$

where :

s' is the dynamic stiffness per unit area of the resilient layer according to EN 29052-1 "Acoustics – Determination of dynamic stiffness – Part 1 : Materials used under floating floors in dwellings" measured without any pre-load, in Meganewtons per cubic metre ;

m' is the mass per unit area of the floating floor, in kilograms per square metre.

NOTE 1 The theory of impact sound insulation leads to the formula ΔL = 40 lg (f / f_o) which relates to infinite plates. However, experimental data show that for practical situations the above formula is on the safe side.

b) the reduction of impact sound pressure level ΔL for asphalt floating floors or dry floating floor constructions can be calculated from :

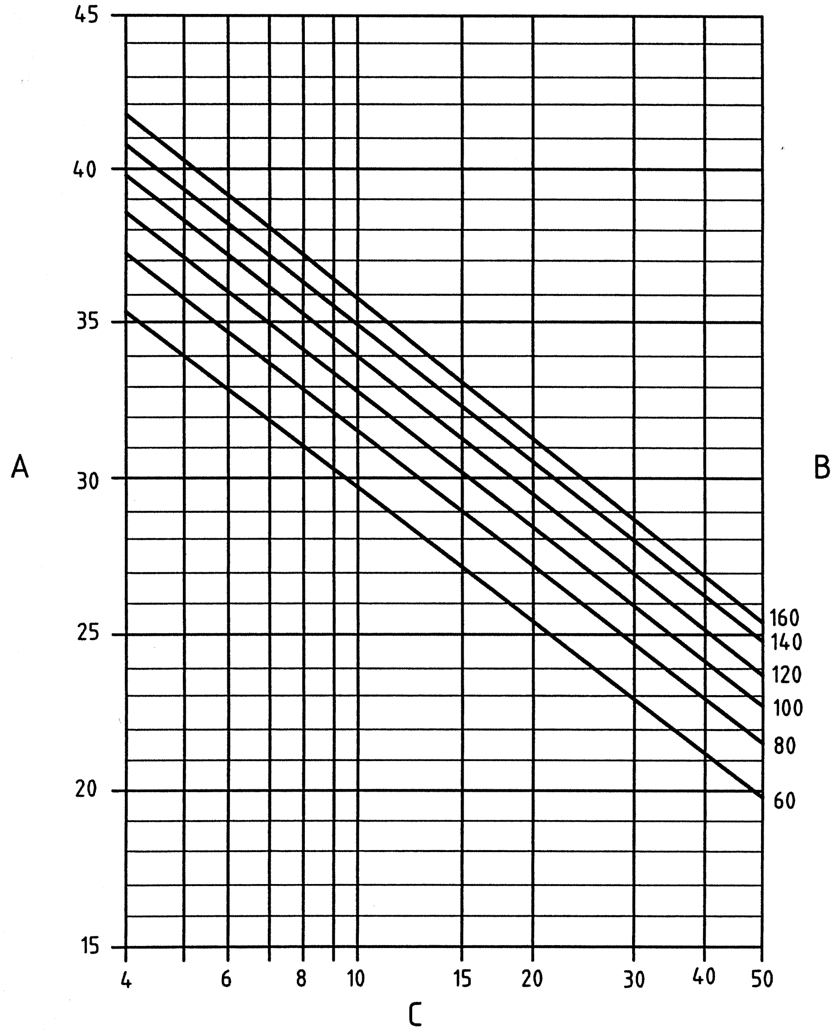
$$\Delta L = 40 \lg \frac{f}{f_o} \text{ dB} \tag{C.3}$$

NOTE 2 Due to the relatively high internal loss factor of the constructions mentioned, the reduction of impact sound pressure level ΔL increases with frequency according to the theory for infinite plates in most cases. This is confirmed by experimental data obtained under test conditions.

C.2 Weighted reduction of impact sound pressure level ΔL_w of floating floors

The weighted reduction of impact sound pressure level ΔL_w depends on the mass per unit area m' of the floating floor and the dynamic stiffness per unit area s' of the resilient layer according to EN 29052-1 "Acoustics – Determination of dynamics stiffness – Part 1 : Materials used under floating floors in dwellings" measured without any pre-load.

a) for floating floor screeds made of sand/cement or calcium-sulphate, values can be taken from Figure C.1.



Legend

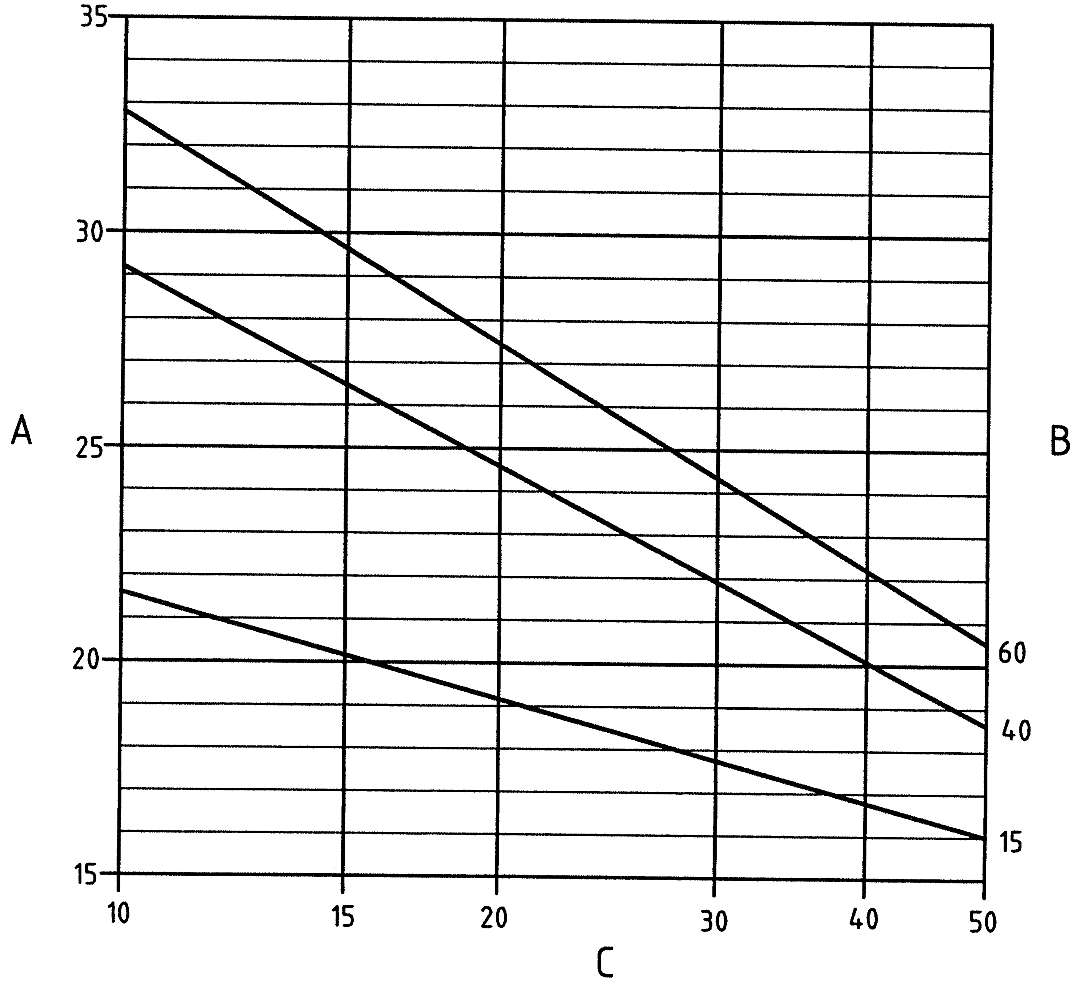
A Weighted impact sound reduction index ΔL_W in dB

B Mass per unit area of the floating floor in kgm^{-2}

C Dynamic stiffness per unit area s' of the resilient layer in MNm^{-3}

Figure C.1 - Weighted reduction of impact sound pressure level for floating floor screeds made of sand/cement or calcium-sulphate

b) for asphalt floating floors or dry floating floor constructions values can be taken from Figure C.2.



Legend

A Weighted impact sound reduction index ΔL_w in dB

B Mass per unit area of the floating floor in kgm^{-2}

C Dynamic stiffness per unit area s' of the resilient layer in MNm^{-3}

Figure C.2 - Weighted reduction of impact sound pressure level for asphalt floating floors or dry floating floor constructions

NOTE In case of two or more resilient layers the resulting total dynamic stiffness per unit area should be calculated by :

$$s'_{\text{tot}} = \left(\sum_{i=1}^{n} \frac{1}{s'_i} \right)^{-1} \quad \text{(C.4)}$$

Where

s'_i is the dynamic stiffness per unit area of the resilient layer i according to EN 29052-1 "Acoustics – Determination of dynamic stiffness – Part 1 : Materials used under floating floors in dwellings" measured without any pre-load.

This holds only if every resilient layer covers the whole area of the floor without any separations or cuttings, e.g. by heating or water supply pipes, electrical devices.

Annex D
(informative)

Laboratory measurement of flanking transmission

With the restriction that the transmission connected with a flanking structural element is dominated by the path Ff it is possible to characterize this transmission by laboratory measurements. This will be the case with flanking constructions like access floors. In this case the transmission will often be primarily structure-borne, though airborne transmission may be of influence. To express the results from such measurements it would be desirable to use an invariant quantity, that is a quantity which is independent of the measurement situation. From such a quantity the behaviour in the field could be extrapolated. However, such a quantity cannot be given in general, it is at most feasible to deduce such a quantity if the main transmission mechanism is known, i.e. primarily structure-borne or primarily airborne.

For the time being therefore the laboratory measurement of indirect transmission has the primary objective of intercomparison of different products in a standardized measurement situation. The measurement results are for that purpose expressed sufficiently as the flanking normalized impact sound pressure level L_{nf}, related to the specified laboratory situation.

$$L_{\mathrm{nf}} = L_2 + 10 \lg \frac{A}{A_\mathrm{o}} \text{ dB} ; \; A_\mathrm{o} = 10 \text{ m}^2 \qquad \text{(D.1)}$$

where

L_2 is the average impact sound pressure level in the receiving room due only to sound transmitted by the floor construction considered ;

A is the equivalent absorption area in the receiving room ; reference value A_o = 10 m^2.

For access floors this is determined in accordance with prEN ISO 140-12. For other flanking measurement methods are specified in prEN ISO 10848-1.

In the case of mainly structure-borne transmission the following equation can be used to determine the flanking impact sound pressure level L_{Ff} (with F = i) in an actual field situation from the product information L_{nf}.

$$L_{\mathrm{n,F=i,f}} = L_{\mathrm{nf}} + 10 \lg \frac{S_{\mathrm{F,lab}}\, l_{\mathrm{Ff}}}{S_\mathrm{F}\, l_{\mathrm{lab}}} + 10 \lg \frac{T_{\mathrm{s,F}}}{T_{\mathrm{s,F,lab}}} + 10 \lg \frac{T_{\mathrm{s,f}}}{T_{\mathrm{s,f,lab}}} \text{ dB} \qquad \text{(D.2)}$$

where :

S_F is the area of the excited floor in the actual field situation (F = i), in square metres ;

$S_{\mathrm{F,lab}}$ is the area of the excited floor in the laboratory situation (F = i), in square metres ;

l_{Ff} is the coupling length between elements F and f, in metres ;

l_{lab} is the coupling length between elements F and f in the laboratory situation, in metres ;

$T_{\mathrm{s,F}}$ is the structural reverberation time of element F in the field situation, in seconds ;

$T_{\mathrm{s,f}}$ is the structural reverberation time of element f in the field situation, in seconds ;

$T_{\mathrm{s,F,lab}}$ is the structural reverberation time of element F in the laboratory situation, in seconds ;

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

The last terms with the structural reverberation time should be neglected if the construction concerned has a high internal loss factor such as lightweight double leaf constructions.

NOTE 1 If airborne sound transmission is also of importance or even dominant, this relation is not valid. In the latter case a possible approach would be as for suspended ceilings ; see annex F of EN 12354-1 : 2000.

NOTE 2 For the use of this, and future improved relations, it would be necessary for some types of construction to perform additional laboratory measurements, to establish that the structure-borne transmission is indeed dominant.

Annex E
(informative)

Calculation examples

E.1 Situation

The impact sound pressure level L'_n between two dwellings is to be calculated for two rooms above each other, separated by a concrete floor slab covered with a floating floor. The volumes of the rooms are 50 m^3, the other construction details are given below.

Separating element :

floor — S_i = 5,00 m x 4,00 m = 20,0 m^2 ;

140 mm concrete, m' = 0,14 m x 2300 kg/m^3 = 322 kg/m^2 ;

floating floor : 35 mm concrete on 20 mm mineral wool slab with s' = 8 MN/m^3.

Flanking elements (identical on both sides) :

internal walls — S_j = 5,00 m x 2,50 m = 12,5 m^2 ; rigid cross junction ;

120 mm aerated concrete, m' = 0,12 m x 800 kg/m^3 = 96 kg/m^2 ;

external walls — S_j = 4,00 m x 2,50 m = 10,0 m^2 ; rigid T junction ;

100 mm brickwork, m' = 0,1 m x 1900 kg/m^3 = 190 kg/m^2.

E.2 Detailed model

E.2.1 Results

The resulting direct and flanking impact sound pressure levels are given per element and total, in octave bands and as a weighted value ; values are rounded to the nearest decibel. The details of the calculation are illustrated for the bold values in the next sections.

Frequency			125 Hz	250 Hz	**500** Hz	1 kHz	2 kHz	4 kHz	L_{nw} dB
L_n	floor	L_{nDd}	57	50	**41**	36	30	26	42
	Internal wall	L_{nDf}	42	38	**36**	31	24	22	31
	Internal wall	L_{nDf}	42	38	**36**	31	24	22	31
	External wall	L_{nDf}	42	39	**34**	28	21	16	30
	External wall	L_{nDf}	42	39	**34**	28	21	16	30
L'_n	total		58	51	**44**	39	32	29	43

$L'_{nw}(C_I)$ = 43 (1) dB, so e.g. $L'_{nw} + C_I$ = 43 + 1 = 44 dB.

E.2.2 Detailed steps for separating floor and flanking walls

E.2.2.1 Transfer of input data of elements to in situ values :

partition floor, m' = 322 kg/m^2, f_c = 134 Hz, S = 20,0 m^2

Frequence		125	250	**500**	1 k	2 k	4 k	Hz
input :	$L_{n,s}$ floor (see annex B)	70,8	73,1	**73,6**	74,4	75,1	75,0	dB
	R_s floor (see annex B of EN 12354-1 : 2000)	35,1	38,7	**48,6**	56,9	64,5	71,3	dB
calculated :	10lg ($T_{s,situ}$/$T_{s,lab}$)	- 1,5	- 1,6	**- 1,6**	- 1,5	- 1,4	- 1,3	dB
result :	$L_{n,situ}$ (see equation (13))	69,3	71,5	**72,0**	72,9	73,7	73,7	dB
	$R_{i,situ}$ (see equation (14))	36,6	40,3	**50,2**	58,4	65,9	72,6	dB

floating floor, m' = 80 kg/m^2, s' = 8 MN/m^3

Frequence		125	250	**500**	1 k	2 k	4 k	Hz
input :	ΔL (see annex C)	12,0	22,0	**31,0**	37,0	44,0	48,0	dB
result :	ΔL_{situ} (see equation (15))	12,0	22,0	**31,0**	37,0	44,0	48,0	dB

internal wall, m' = 96 kg/m^2, f_c = 390 Hz, S =12,5 m^2, l_{ij} = 5,00 m

Frequence		125	250	**500**	1 k	2 k	4 k	Hz
input :	R_f (see annex B of EN 12354-1 : 2000)	36,4	32,7	**29,4**	36,8	45,0	46,7	dB
calculated	10lg ($T_{s,situ}$/$T_{s,lab}$)	- 3,7	- 3,2	**- 2,1**	- 2,1	- 1,9	- 1,5	dB
result :	$R_{f,situ}$ (see equation (14))	40,1	35,9	**31,5**	38,9	46,9	48,2	dB

external wall, m' =190 kg/m^2, f_c = 298 Hz, S =10,0 m^2, l_{ij} = 4,00 m

Frequence		125	250	**500**	1 k	2 k	4 k	Hz
input :	R_f (see annex B of EN 12354-1 : 2000)	40,6	35,2	**36,6**	47,1	55,9	63,1	dB
calculated	10lg ($T_{s,situ}$/$T_{s,lab}$)	- 3,4	- 3,0	**- 2,4**	- 2,1	- 1,8	- 1,5	dB
result :	$R_{f,situ}$ (see equation (14))	44,0	38,2	**39,0**	49,2	57,7	64,6	dB

E.2.2.2 Transfer of input data of junctions to in situ values :

Internal wall, l_{Df} = 5 m, S_j = 12,5 m^2, S_i = 20,0 m^2

See equation (E.2) of annex E of EN 12354-1 : 2000 around corner with $m_{\perp i}/m_i$ = 96/322 : K_{Df} = 10,3 dB

Frequence	125	250	**500**	1 k	2 k	4 k	Hz
floor : a_{situ} (see equation (17))	16,7	17,2	**17,2**	18,0	19,0	20,6	dB
wall : a_{situ} (see equation (17))	4,8	5,3	**7,1**	7,2	8,1	9,7	dB
$10\lg\left(l_{ij} / \sqrt{a_{floor}}\sqrt{a_{wall}}\right)$ (equation (16))	- 2,5	- 2,8	**- 3,4**	- 3,6	- 3,9	- 4,5	dB
$D_{v,Df,situ}$ (see equation (16))	12,8	13,1	**13,7**	13,9	14,2	14,8	dB

External wall, l_{Df} = 4 m, S_j = 10,0 m^2, S_i = 20,0 m^2

See equation (E.3) of annex E of EN 12354-1 : 2000 around corner with $m_{\perp i}/m_i$ = 190/322 : K_{Df} = 6,0 dB

Frequence	125	250	**500**	1 k	2 k	4 k	Hz
floor : a_{situ} (see equation (17))	16,7	17,2	**17,2**	18,0	19,0	20,6	dB
wall : a_{situ} (see equation (17))	6,4	7,0	**8,1**	8,8	10,1	12,1	dB
$10\lg\left(l_{ij} / \sqrt{a_{floor}}\sqrt{a_{wall}}\right)$ (see equation (16))	- 4,1	- 4,4	**- 4,7**	- 5,0	- 5,4	- 6,0	dB
$D_{v,\,Df,situ}$ (see equation (16))	10,1	10,4	**10,7**	11,0	11,4	12,0	dB

Determination of direct and flanking sound transmission ; equations (19), (20) :

Direct transmission (equation (19)) :

Frequence	125	250	**500**	1 k	2 k	4 k	Hz
$L_{n,situ}$	69,3	71,5	**72,0**	72,9	73,7	73,7	dB
ΔL_{situ}	12,0	22,0	**31,0**	37,0	44,0	48,0	dB
$L_{n,d}$	57,3	49,5	**41,0**	35,9	29,7	25,7	dB

Flanking transmission over internal wall (equation (20)) :

Frequence	125	250	**500**	1 k	2 k	4 k	Hz
$L_{n,situ}$	69,3	71,5	**72,0**	72,9	73,7	73,7	dB
ΔL_{situ}	12,0	22,0	**31,0**	37,0	44,0	48,0	dB
$R_{i,situ}$	36,6	40,3	**50,2**	58,4	65,9	72,6	dB
$R_{f,situ}$	40,1	35,9	**31,5**	38,9	46,9	48,2	dB
$D_{v,Df,situ}$	12,8	13,1	**13,7**	13,9	14,2	14,8	dB
$5\lg(S_i/S_j)$	1,0	1,0	**1,0**	1,0	1,0	1,0	dB
$L_{n,Df}$	41,7	37,6	**35,6**	30,7	24,0	22,1	dB
NOTE Values in the table with results have been rounded.							

Flanking transmission over external wall (equation (20)) :

Frequence	125	250	**500**	1 k	2 k	4 k	Hz
$L_{n,situ}$	69,3	71,5	**72,0**	72,9	73,7	73,7	dB
ΔL_{situ}	12,0	22,0	**31,0**	37,0	44,0	48,0	dB
$R_{i,situ}$	36,6	40,3	**50,2**	58,4	65,9	72,6	dB
$R_{f,situ}$	44,0	38,2	**39,0**	49,2	57,7	64,6	dB
$D_{v,Df,situ}$	10,1	10,4	**10,7**	11,0	11,4	12,0	dB
$5 \lg (S_i/S_j)$	1,5	1,5	**1,5**	1,5	1,5	1,5	dB
$L_{n,Df}$	42,0	38,6	**34,4**	28,9	20,9	16,2	dB
NOTE Values in the table with results have been rounded.							

E.2.3 Structural reverberation time floor at 500 Hz octave (see annex C of EN 12354-1 : 2000) :

Calculations for this octave band with f = 400 Hz (lower one-third octave band)

Laboratory

with m' = 322 kg/m^2 and f_c = 134 Hz, equation (C.4) gives : α_k = 0,154 ;

with η_{int} = 0,006 ; σ = 1,2 ; S_{lab} = 10 m^2 and $\Sigma\, l_k$ = 12,8 m, equation (C.1) gives : η_{tot} = 0,037 ;

thus $\boldsymbol{T_{s,lab}}$ **= 0,149 s** (The estimation according to equation (C.5) would give $T_{s,lab}$ = 0,14 s)

Field

Borders with

internal wall : K_{ij}= 1,3 ; 10,3 and 10,3 dB (see equation (E.2) of EN 12354-1 : 2000), thus equation (C.2) gives

α_k = 0,388

external wall : K_{ij} = 6,0 and 6,0 dB (see equation (E.3) of EN 12354-1 : 2000), thus equation (C.2) gives α_k = 0,274

This results in (equation C.1) η_{tot} = 0,053 and $\boldsymbol{T_{s,situ}}$ **= 0,104 s**.

So the terms for the sound reduction index, impact sound pressure level and the junction transmission are :

floor : **10 lg (**$\boldsymbol{T_{s,situ}/T_{s,lab}}$**) = 10 lg 0,104/0,149 = -1,6 dB**

$\boldsymbol{a_{situ}}$ **= 17,2 m**

Following the same procedure it also follows that :

Internal wall : $\boldsymbol{a_{situ}}$ **= 7,1 m**

External wall : $\boldsymbol{a_{situ}}$ **= 8,1 m**

E.3 Simplified model

Situation :

The same building situation as in E.1 is evaluated.

Input data :

— mass per unit area of the concrete floor : m' = 0,14 m x 2300 kg/m^3 = 322 kg/m^2 ;

— dynamic stiffness per unit area of the mineral wool slab : s' = 8 MN/m^3 ;

— mass per unit area of the floor screed : m' = 80 kg/m^2.

Calculated values :

— equivalent weighted normalized impact sound pressure level of the concrete floor slab : from annex B :

$L_{n,w,eq}$ = 164 - 35 lg(m'/m'_0) with m'_0 = 1 kg/m^2
= 164 - 35 lg (322/1) = 76,2 dB ≈ 76 dB

— weighted impact sound improvement index of the floating floor :

with the dynamic stiffness per unit area s' = 8 MN/m^3 of the mineral wool slab and the mass per unit area m' = 80 kg/m^2 of the floor screed follows from Figure C.1 :

ΔL_w = 33 dB

— correction K for flanking transmission :

mean surface mass of the homogeneous flanking elements, not covered with resilient layers, m' = 0,25 [(2 x 190) + (2 x 100)] kg/m^2 = 145 kg/m^2 ; so from Table 1 :

K = 2 dB

— weighted normalized impact sound pressure level between the two rooms :

from equation (21) :

$L'_{n,w} = L_{n,w,eq} - \Delta L_w + K$ = (76 - 33 + 2) dB = 45 dB

— weighted standardized impact sound pressure level between the two rooms

with volume of the receiving V = 50 m^3, from equation (3) :

$L'_{nT,w} = L'_{n,w}$ - 10 lg (V/30) = (45 - 2,2) dB = 42,8 dB ≈ 43 dB

Bibliography

[1] Cremer, L., Heckl, M. : Structure Borne Sound, 2nd edition, Springer Verlag, Heidelberg 1988.

[2] Cremer, H. + L., "Theorie der Entstehung des Klopfschalls", Frequenz **1** (1948), 61-71.

[3] DIN 4109, Schallschutz im Hochbau, Deutsches Institut für Normung e.V., Berlin, November 1989.

[4] Gerretsen, E., "Calculation of airborne and impact sound insulation between dwellings", Applied Acoustics **19** (1986), 245-264.

[5] Gerretsen, E., "A calculation model for the impact sound insulation of floors with floating and soft coverings (in Dutch)", report F 38, Stichting Bouwresearch, Rotterdam 1990.

[6] Gôsele, K., Gieβelmann, K., "Berechnung des Trittschallschutzes von Rohdecken", Fottschritte der Akustik DAGA '76, VDI-Verlag Düsseldorf, 1976.

[7] Heckl, M., Rathe, E.J., "Relationship between the transmission loss and the impact noise insulation of floor structures", JASA **35** (1963), 1825-1830.

[8] ÖNORM B 8115, Schallschutz und Raumakustik im Hochbau, Österreichisches Normungsinstitut, Wien, 1992.

[9] Gerretsen, E., "European developments in prediction models for building acoustics", Acta Acustica **2** (1994), 205-214.

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