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

Part 4:
Transmission of indoor sound to the outside

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

Partie 4: Transmission du bruit intérieur à l'extérieur

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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 15712-4 was prepared by CEN/TC 126, *Acoustic properties of building products and of buildings* (as EN 12354-4:2000), 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 4: Transmission of indoor sound to the outside

1 Scope

This European Standard describes a calculation model for the sound power level radiated by the envelope of a building due to airborne sound inside that building, primarily by means of measured sound pressure levels inside the building and measured data which characterize the sound transmission by the relevant elements and openings in the building envelope. These sound power levels, together with those of other sound sources in or in front of the building envelope, form the basis for the calculation of the sound pressure level at a chosen distance from a building as a measure for the acoustic performance of buildings.

The prediction of the inside sound pressure level from knowledge of the indoor sound sources is outside the scope of this European Standard.

The prediction of the outdoor sound propagation is outside the scope of this European Standard.

NOTE For simple propagation conditions an approach is given for the estimation of the sound pressure level in informative annex E.

This European Standard describes the principles of the calculation model, 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.

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 (including amendments).

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 140-5, *Acoustics – Measurement of sound insulation in buildings and of building elements – Part 5 : Field measurements of airborne sound insulation of façade elements and façades (ISO 140-5:1998).*

EN 20140-10, *Acoustics – Measurement of sound insulation in buildings and of building elements – Part 10 : Laboratory measurement of airborne sound insulation of small building elements (ISO 140-10:1991).*

EN ISO 7235, *Acoustics – Measurement procedures for ducted silencers - Insertion loss, flow noise and total pressure loss (ISO 7235:1991).*

3 Relevant quantities

The symbols used for the purposes of this European Standard are given in annex A.

3.1 Quantities to express building performance

3.1.1 Sound power level L_w

The sound power level of a substitute point sound source.

3.1.2 Directivity correction D_c

The deviation in decibels of the sound pressure level of a point sound source in a specified direction from the level of an omni-directional point source producing the same sound power level.

3.2 Quantities to express element performance

3.2.1 Sound reduction index R

The sound reduction index of an element for direct sound transmission as defined and determined according to EN ISO 140-3 or EN ISO 140-5.

3.2.2 Element normalized level difference $D_{n,e}$

The normalized level difference of a small building element as defined and determined according to EN 20140-10.

3.2.3 Insertion loss D (of an element)

The reduction in sound power level at a given location behind the element due to the insertion of the element into the duct in place of a hard-walled duct section as defined and determined according to EN ISO 7235.

NOTE For elements where this standard does not apply equivalent methods should be used.

3.2.4 Other relevant data

For the calculations additional information on constructions could be necessary, e.g. :

— the shape of the building envelope ;

— areas.

3.3 Other terms and quantities

3.3.1 Sound pressure level L_p

The sound pressure level at a specified reception point outside a building, due to the sound produced inside the building and by sources associated with the building as normally determined by measurements according to local requirements (specifying relevant positions, integration period and source conditions).

The sound pressure level is normally A-weighted.

3.3.2 Total attenuation due to propagation A_{tot}

The level difference between the radiated sound power and the sound pressure at a position at distance d from the building envelope, due to the total of all propagation effects, such as geometrical divergence, air absorption, ground effect, screening, etc.

3.3.3 Diffusivity term C_d

The level difference between the sound pressure level at 1 m to 2 m from the inside face of the relevant building element and the intensity level of the incident sound perpendicular to that element.

NOTE For a diffuse field and reflecting walls the diffusivity term is C_d = - 6 dB ; for other situations it can have a value between 0 dB and - 6 dB.

3.3.4 Inside sound pressure level $L_{p,in}$

The sound pressure level inside the building, 1 m to 2 m from the considered element or segment of the building envelope.

NOTE In the case of a diffuse sound field this corresponds to the average sound pressure level in the diffuse sound field.

3.3.5 Substitute point source

A point source for which the radiated sound is the same as that of a segment of the building envelope.

NOTE The segment may be composed of one or more building elements or of one or more openings.

4 Calculation model

4.1 General principles

The total sound pressure level at a reception point that is a chosen distance from a building is determined by the following contributions :

- the sound radiated by the elements of the building envelope due to the sound pressure level inside ;
- the sound radiated by individual sound sources, fixed in or onto the outside of the building ;
- the outdoor sound propagation (effects of distance, air absorption, ground effect, screening, reflections etc.).

The sound radiation by the building envelope may be represented by the radiation of one or more substitute point sources. Each point source can represent the contribution of a segment of the building envelope or a group of individual sound sources. The number of point sources required to adequately represent a building depends upon the distance of each reception point from the building and the variation in propagation effects. Normally, the building envelope is represented by at least one point source for each side, i.e. walls and the roof, but often several point sources are required for each side.

The sound pressure level at a reception point outside the building is determined from the contributions of each substitute point source according to :

$$L_p = L_W + D_c - A_{tot} \quad (1)$$

where

L_p is the sound pressure level at a reception point outside the building due to the sound radiation of a substitute point source, in decibels ;

L_W is the sound power level of the substitute point source, in decibels ;

D_c is the directivity correction for the substitute point sources in the direction of the reception point, in decibels ;

A_{tot} is the total attenuation that occurs during sound propagation from the substitute point source to the reception point, in decibels.

The calculation model described in this standard is restricted to the calculation of the sound power level of the substitute point sources for the building elements and openings in the building envelope from data on :

- the inside sound pressure level ;
- the elements which form the building envelope.

The model will also give indications of the directivity correction that can be expected for various types of elements. The inside sound pressure level will normally be the equivalent sound pressure level over a specified period according to the relevant requirements. However, other types of levels can also be used, for instance the maximum level. The calculation of the inside sound pressure level is outside the scope of this European standard.

The calculation of the contribution of individual sound sources is outside the scope of this European standard.

The total attenuation A_{tot} due to propagation effects, necessary for the prediction of the sound pressure level at the reception point, can be estimated according to available methods for outdoor propagation, based on a point source approach. The calculation of these propagation effects is outside the scope of this European standard.

NOTE One such method is given in ISO 9613-2, where the total attenuation is indicated as A. The total attenuation follows from the addition of the attenuation due to various propagation effects, such as geometrical divergence, air absorption, ground effect, screening etc.

However, for simple propagation conditions an approach is given for the estimation of the sound pressure level in annex E.

4.2 Determination of substitute point sound sources

The elements contributing to the sound radiation are divided into two groups :

— plane radiators, such as structural elements of the building envelope, i.e. walls, roof, windows, doors, including small building elements with an area of typically less than 1 m^2, such as grids and openings ;

— larger openings, area typically 1 m^2 or more, i.e. large ventilation openings, open doors, open windows.

To calculate the sound propagation outside the building each element can be represented by a substitute point sound source. However, the building may also be divided into larger segments which are each represented by a substitute point sound source. For the segmentation the following rules apply :

— the sound propagation to the nearest reception points of interest (A_{tot}) is the same for all elements of a segment ;

— the distance to the nearest reception point of interest is larger than twice the largest dimension of the segment ;

— for the elements in a segment the same inside sound pressure level is applicable ;

— for the elements in a segment the same directivity is applicable.

If one or more of these conditions is not fulfilled, choose different segments for instance smaller segments, until these conditions are met.

Unless otherwise specified in the propagation model, the point source representing a vertical segment is positioned at half the width of the segment and 2/3 the height of the segment; for all other segments the position is at the centroid of the segment.

4.3 Determination of the sound power level for a substitute point source

For each segment the sound power level is determined from the following input data :

— sound pressure level inside : $L_{p,in}$;

— sound reduction index of large building element i of the building envelope : R_i ;

— element normalized level difference of small element i : $D_{n,e,i}$;

— insertion loss of silencing element for opening i : D_i ;

— area of building element or opening i : S_i.

For a **segment of structural elements of the building envelope** the sound power level for the substitute point source is determined by :

$$L_{\mathrm{w}} = L_{\mathrm{p,in}} + C_{\mathrm{d}} - R' + 10 \lg \frac{S}{S_{\mathrm{o}}} \tag{2}$$

where

$L_{\mathrm{p,in}}$ is the sound pressure level at 1 m to 2 m from the inside of the segment, in decibels ;

C_{d} is the diffusivity term for the inside sound field at the segment, in decibels ;

R' is the apparent sound reduction index for the segment, in decibels ;

S is the area of the segment, in square metres ;

S_{o} is the reference area, in square metres ; S_{o} = 1 m^2.

The apparent sound reduction index for the segment follows from the data on the composing elements i by :

$$R' = -10 \lg \left[\sum_{\mathrm{i}=1}^{\mathrm{m}} \frac{S_{\mathrm{i}}}{S} 10^{-R_{\mathrm{i}}/10} + \sum_{\mathrm{i}=\mathrm{m}+1}^{\mathrm{m}+\mathrm{n}} \frac{A_{\mathrm{o}}}{S} 10^{-D_{\mathrm{n,e,i}}/10} \right] \tag{3}$$

where

R_{i} is the sound reduction index of element i, in decibels ;

S_{i} is the area of element i, in square metres ;

$D_{\mathrm{n,e,i}}$ is the element normalized sound level difference for a small element i, in decibels ;

A_{o} is the reference absorption area, in square metres; A_{o} = 10 m^2 ;

m is the number of large elements of the segment ;

n is the number of small elements of the segment.

Information on the inside sound pressure level and diffusivity of the sound field is given in annex B, based on the type of enclosed space and internal conditions for the elements of the building envelope.

NOTE 1 In the case of an ideal diffuse sound field and non-absorbing elements C_{d} = - 6 dB; for industrial spaces and segments which are non-absorbing at the inside a value of C_{d} = - 5 dB is generally more appropriate.

NOTE 2 The contribution of structure-borne sound to the sound radiation is not incorporated into the model. It could roughly be incorporated through an adjusted sound reduction index ; some indications are given in annex C.

Information on the sound reduction index to be used is given in annex C.

For a **segment of openings** the sound power level for the substitute point source is determined by :

$$L_{\mathrm{w}} = L_{\mathrm{p,in}} + C_{\mathrm{d}} + 10\,\lg \sum_{\mathrm{i}=1}^{\mathrm{o}} \frac{S_{\mathrm{i}}}{S} 10^{-D_{\mathrm{i}}/10} \qquad (4)$$

where

S_i is the area of opening i, in square metres ;

S is the area of the segment being the total area of the openings in that segment, in square metres ;

D_{i} is the insertion loss for a silencing element for opening i, in decibels ;

o is the number of openings of the segment.

The calculation of the sound power level is performed in frequency bands, based on acoustic data for the elements in frequency bands (one-third octave bands or octave bands). The calculation is performed at least for the octave bands from 125 Hz to 2 000 Hz or for the one-third octave bands from 100 Hz to 3150 Hz.

NOTE 3 The calculations can be extended to higher or lower frequencies if acoustic data are available for such larger frequency range. However, especially for the lower frequencies no information is currently available on the accuracy of the calculations.

NOTE 4 For rough indications it could be sufficient to apply the model directly to A-weighted levels and single number ratings of the performance of building elements according to EN ISO 717-1. Guidelines for this are given in annex F.

4.4 Determination of the directivity correction for a substitute point source

The directivity correction D_{c} contains the inherent directivity of the radiating elements and openings as given by the directivity index D_{I}. It can also contain the effect of the vicinity of hard surfaces (reflection and screening) as given by the solid angle index D_{Ω}.

For a specific direction the directivity correction is determined from :

$$D_{\mathrm{c}} = D_{\mathrm{I}} + D_{\Omega} = D_{\mathrm{I}} + 10\,\lg \frac{4\pi}{\Omega} \qquad (5)$$

where

Ω is the solid angle into which radiation occurs, in steradians.

Whether or not the solid angle index is included in the directivity correction depends on the propagation model used. When reflections on the ground and other surfaces are taken into account by image sources, the solid angle index D_{Ω} = 0 dB. However, when the reflecting surfaces are the building envelope itself, it is recommended to include the effect of these surfaces in the solid angle index. In giving the directivity correction the value of the included solid angle index is therefore to be stated clearly.

Information on the directivity correction is given in annex D.

4.5 Limitations

Although large, homogeneous building elements, for instance a complete side wall, can have specific radiation patterns, favouring certain directions ; these effects are not taken into account in the model.

The possible contribution of structure-borne sound by machinery in the building is not included in the model, although an approximate approach is indicated in annex C.

5 Accuracy

The accuracy of prediction of the model depends on many factors: the accuracy of the input data, the fitting of the situation into the model, the type of elements involved, the geometry of the situation, the type of quantity to be predicted and the workmanship. It is therefore not possible to specify the accuracy in general for all types of situations and applications. Data on the accuracy will have to be gathered in the future by comparing the results of the model with a variety of field situations.

In applying the predictions it is advisable to vary the input data, especially in complicated situations and with rare elements with questionable input data. The resulting variation in the results gives an impression of the expected accuracy for situations where good workmanship can be assumed.