BRITISH STANDARD

BS EN ISO 140-5:1998

Acoustics — Measurement of sound insulation in buildings and of building elements —

Part 5: Field measurements of airborne sound insulation of facade elements and facades

The European Standard EN ISO 140-5:1998 has the status of a British Standard

ICS 91.120.20

National foreword

This British Standard is the English language version of EN ISO 140-5:1998. It is identical with ISO 140-5:1998. It supersedes BS 2750-5:1980 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee EH/1, Acoustics, to Subcommittee EH/1/6, Building acoustics, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

Cross-references

Attention is drawn to the fact that CEN and CENELEC Standards normally include an annex which lists normative references to international publications with their corresponding European publications. The British Standards which implement these international or European publications may be found in the BSI Standards Catalogue under the section entitled "International Standards Correspondence Index", or by using the "Find" facility of the BSI Standards Electronic Catalogue.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN ISO title page, page 2, the ISO title page, page ii, pages 1 to 18, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

This British Standard, having been prepared under the direction of the Health and Environment Sector Board, was published under the authority of the Standards Board and comes into effect on 15 October 1998

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN ISO 140-5

August 1998

ICS 91.060.00; 91.120.00

Descriptors: See ISO document

English version

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)

Acoustique — Mesurage de l'isolation acoustique des immeubles et des éléments de construction — Partie 5: Mesurages in situ de la transmission des bruits aériens par les éléments de façade et les façades (ISO 140-5:1998)

Akustik — Messung der Schalldämmung in Gebäuden und von Bauteilen — Teil 5: Messung der Luftschalldämmung von Fassadenelementen und Fassaden am Bau (ISO 140-5:1998)

This European Standard was approved by CEN on 14 August 1998.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

Ref. No. EN ISO 140-5:1998 E

Foreword

The text of the International Standard ISO 140-5:1998 has been prepared by Technical Committee ISO/TC 43 "Acoustics" in collaboration with Technical Committee CEN/TC 126 "Acoustic properties of building products and of buildings", the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by February 1999, and conflicting national standards shall be withdrawn at the latest by February 1999.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Endorsement notice

The text of the International Standard ISO 140-5:1998 was approved by CEN as a European Standard without any modification.

NOTE Normative references to International Standards are listed in Annex ZA (normative).

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INTERNATIONAL STANDARD

ISO 140-5

Second edition
1998-08-15

Acoustics — Measurement of sound insulation in buildings and of building elements —

Part 5:
Field measurements of airborne sound insulation of façade elements and façades

Acoustique — Mesurage de l'isolation acoustique des immeubles et des éléments de construction —

Partie 5: Mesurages in situ de la transmission des bruits aériens par les éléments de façade et les façades

Reference number
ISO 140-5:1998(E)

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.

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.

International Standard ISO 140-5 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 2, *Building acoustics*.

This second edition cancels and replaces the first edition (ISO 140-5:1978), which has been technically revised.

ISO 140 consists of the following parts, under the general title *Acoustics — Measurement of sound insulation in buildings and of building elements:*

— *Part 1: Requirements of laboratory test facilities with suppressed flanking transmission;*

— *Part 2: Determination, verification and application of precision data;*

— *Part 3: Laboratory measurement of airborne sound insulation of building elements;*

— *Part 4: Field measurements of airborne sound insulation between rooms;*

— *Part 5: Field measurements of airborne sound insulation of façade elements and façades;*

— *Part 6: Laboratory measurements of impact sound insulation of floors;*

— *Part 7: Field measurements of impact sound insulation of floors;*

— *Part 8: Laboratory measurements of the reduction of transmitted impact noise by floor coverings on a heavyweight standard floor;*

— *Part 9: Laboratory measurement of room-to-room airborne sound insulation of a suspended ceiling with a plenum above it;*

— *Part 10: Laboratory measurement of airborne sound insulation of small building elements.*

Annex A and Annex B form an integral part of this part of ISO 140. Annex C to Annex F are for information only.

Descriptors: Acoustics, buildings, façades, airborne sound, acoustic insulation, tests, field tests, acoustic tests, acoustic measurements.

1 Scope

This part of ISO 140 specifies two series of methods (element methods and global methods) for measurement of the airborne sound insulation of façade elements and whole façades, respectively. The element methods aim to estimate the sound reduction index of a façade element, for example a window. The most accurate element method uses a loudspeaker as an artificial sound source. Other, less accurate, element methods use available traffic noise. The global methods, on the other hand, aim to estimate the outdoor/indoor sound level difference under actual traffic conditions. The most accurate global methods use the actual traffic as sound source. In addition, a loudspeaker may be used as an artificial sound source. An overview of the methods is given in Table 1.

The element loudspeaker method yields an apparent sound reduction index which, under certain circumstances [e.g. taking account of measurement precision (see **7.1**)], can be compared with the sound reduction index measured in laboratories in accordance with ISO 140-3 or ISO 140-10. This method is the preferred method when the aim of the measurement is to evaluate the performance of a specified façade element in relation to its performance in the laboratory.

The element road traffic method will serve the same purposes as the element loudspeaker method. It is particularly useful when, for different practical reasons, the element loudspeaker method cannot be used. These two methods will often yield slightly different results. The road traffic method tends to result in lower values of the sound reduction index than the loudspeaker method. In Annex D this road traffic method is supplemented by the corresponding aircraft and railway traffic methods.

The global road traffic method yields the real reduction of a façade in a given place relative to a position 2 m in front of the façade. This method is the preferred method when the aim of the measurement is to evaluate the performance of a whole façade, including all flanking paths, in a specified position relative to nearby roads. The result cannot be compared with that of laboratory measurements.

The global loudspeaker method yields the sound reduction of a façade relative to a position 2 m in front of the façade. This method is particularly useful when, for different practical reasons, the real noise source cannot be used. The result cannot be compared with that of laboratory measurements.

Table 1 — Overview of the different measurement methods

No.	Method	Reference	Result	Field of application
	Element			
1	Element loudspeaker	Clause **5**	$R'_{45°}$	Preferred method to estimate the apparent sound reduction index of façade elements
2	Element road traffic	Clause **6**	$R'_{\mathrm{tr,s}}$	Alternative to method No.1 when road traffic noise of sufficient level is available
3	Element railway traffic	Annex D (informative)	$R'_{\mathrm{rt,s}}$	Alternative to method No.1 when railway traffic noise of sufficient level is available
4	Element air traffic	Annex D (informative)	$R'_{\mathrm{at,s}}$	Alternative to method No.1 when air traffic noise of sufficient level is available
	Global			
5	Global loudspeaker	Clause **5**	$D_{\mathrm{ls,2m,n}T}$ $D_{\mathrm{ls,2m,n}}$	Alternative to methods Nos. 6, 7 and 8
6	Global road traffic	Clause **6**	$D_{\mathrm{tr,2m,n}T}$ $D_{\mathrm{tr,2m,n}}$	Preferred method to estimate the global sound insulation of a façade exposed to road traffic noise
7	Global railway traffic	Annex D (informative)	$D_{\mathrm{rt,2m,n}T}$ $D_{\mathrm{rt,2m,n}}$	Preferred method to estimate the global sound insulation of a façade exposed to railway traffic noise
8	Global air traffic	Annex D (informative)	$D_{\mathrm{at,2m,n}T}$ $D_{\mathrm{at,2m,n}}$	Preferred method to estimate the global sound insulation of a façade exposed to air traffic noise

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 140. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 140 are encouraged to investigate the possibility of applying the most recent edition of the standards indicated below. Members of IEC and ISO maintain registers of currently valid international standards.

ISO 140-2:1991, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 2: Determination, verification and application of precision data.*

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

ISO 354:1985, *Acoustics — Measurement of sound absorption in a reverberation room.*

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

IEC 60651:1979, *Sound level meters.*

IEC 60804:1985, *Integrating-averaging sound level meters.*

IEC 60942:1991, *Sound calibrators.*

IEC 61260:1995, *Electroacoustics — Octave band filters and fractional — Octave band filters.*

3 Definitions

For the purposes of this part of ISO 140, the definitions given in ISO 140-3 and the following definitions apply.

3.1

average sound pressure level on a test surface, $L_{1,s}$

ten times the logarithm to the base 10 of the ratio of the surface and time average of the sound pressure squared to the square of the reference sound pressure, the surface average being taken over the entire test surface including reflecting effects from the test specimen and façade; it is expressed in decibels

3.2

average sound pressure level in a room, L_2

ten times the logarithm to the base 10 of the ratio of the space and time average of the sound pressure squared to the square of the reference sound pressure, the space average being taken over the entire room with the exception of those parts where the direct radiation of a sound source or the near field of the boundaries (wall, window, etc.) is of significant influence; it is expressed in decibels

3.3

equivalent continuous sound pressure level, L_{eq}

value of the sound pressure level of a continuous steady sound that, within the measurement time interval, has the same mean square sound pressure as the sound under consideration, the level of which varies with time; it is expressed in decibels

3.4

sound reduction index, R

ten times the logarithm to the base 10 of the ratio of the sound power W_1 incident on the test specimen to the sound power W_2 transmitted through the specimen:

$$R = 10 \lg \left(\frac{W_1}{W_2} \right) \text{ dB} \qquad \text{...(1)}$$

NOTE The expression "sound transmission loss" (TL) is also in use in English-speaking countries. It is equivalent to "sound reduction index".

3.5

apparent sound reduction index, R'

ten times the logarithm to the base 10 of the ratio of the sound power W_1 which is incident on the test specimen to the total sound power transmitted into the receiving room, if, in addition to the sound power W_2 radiated by the specimen, sound power W_3 radiated by flanking elements or by other components is significant:

$$R' = 10 \lg \left(\frac{W_1}{W_2 + W_3} \right) \text{dB} \quad \text{...(2)}$$

3.6

apparent sound reduction index, $R'_{45°}$

measure of the airborne sound insulation of a building element when the sound source is a loudspeaker and when the angle of sound incidence is 45°. The angle of sound incidence is the angle between the loudspeaker axis directed towards the centre of the test specimen and the normal to the surface of the façade. The apparent sound reduction index is then calculated from equation (3):

$$R'_{45°} = L_{1,s} - L_2 + 10 \lg \left(\frac{S}{A} \right) \text{dB} - 1{,}5 \text{ dB} \quad \text{...(3)}$$

where

- $L_{1,s}$ is the average sound pressure level on the surface of the test specimen, as defined in **3.1**;
- L_2 is the average sound pressure level in the receiving room, as defined in **3.2**;
- S is the area of the test specimen, determined as given in Annex A;
- A is the equivalent sound absorption area in the receiving room.

NOTE This equation is based on the assumption that the sound is incident from one angle only, 45°, and that the sound field in the receiving room is perfectly diffuse.

3.7

apparent sound reduction index, $R'_{tr,s}$

measure of the airborne sound insulation of a building element when the sound source is traffic noise and the outside microphone position is on the test surface. The apparent sound reduction index is then calculated from equation (4):

$$R'_{tr,s} = L_{eq,1,s} - L_{eq,2} + 10 \lg \left(\frac{S}{A} \right) \text{dB} - 3 \text{ dB} \quad \text{...(4)}$$

where

- $L_{eq,1,s}$ is the average value of the equivalent continuous sound pressure level on the surface of the test specimen including reflecting effects from the test specimen and façade;
- $L_{eq,2}$ is the average value of the equivalent continuous sound pressure level in the receiving room;
- S and A are as given in **3.6**.

3.8
level difference, D_{2m}

difference, in decibels, between the outdoor sound pressure level 2 m in front of the façade, $L_{1,2m}$, and the space and time averaged sound pressure level, L_2, in the receiving room:

$$D_{2m} = L_{1,2m} - L_2 \quad ...(5)$$

NOTE If traffic noise is used as the sound source, the notation is $D_{tr,2m,}$. If a loudspeaker is used, it is $D_{ls,2m}$.

3.9
standardized level difference, $D_{2m,nT}$

level difference, in decibels, corresponding to a reference value of the reverberation time in the receiving room:

$$D_{2m,nT} = D_{2m} + 10 \lg\left(\frac{T}{T_0}\right) \text{dB} \quad ...(6)$$

where T_0 = 0,5 s

NOTE If traffic noise is used as the sound source, the notation is $D_{tr,2m,nT}$. If a loudspeaker is used, it is $D_{ls,2m,nT}$.

3.10
normalized level difference, $D_{2m,n}$

level difference, in decibels, corresponding to the reference absorption area in the receiving room:

$$D_{2m,n} = D_{2m} - 10 \lg\frac{A}{A_0} \text{ dB} \quad ...(7)$$

where A_0 = 10 m^2

NOTE If traffic noise is used as the sound source, the notation is $D_{tr,2m,n}$. If a loudspeaker is used, it is $D_{ls,2m,n}$.

4 Equipment

4.1 General

The microphone shall have a maximum diameter of 13 mm.

The sound pressure level measurement equipment shall meet the requirements of a class 0 or 1 instrument according to IEC 60651 or IEC 60804. The measurement chain shall be calibrated by using a class 1 or better acoustical calibrator according to IEC 60942.

The one-third-octave band filters and, if relevant, the octave band filters shall meet the requirements of IEC 61260.

The reverberation time measurement equipment shall meet the requirements of ISO 354.

4.2 Loudspeaker

The directivity of the loudspeaker in a free field shall be such that the local differences in the sound pressure level in each frequency band of interest are less than 5 dB, measured on an imaginary surface of the same size and orientation as the test specimen.

NOTE If the loudspeaker method is adapted to large test specimens, i.e. specimens where one dimension exceeds 5 m, differences up to 10 dB can be accepted. This should then be reported in the measurement report.

5 Measurement with loudspeaker noise

5.1 General

Two methods, the element and the global loudspeaker method, are described.

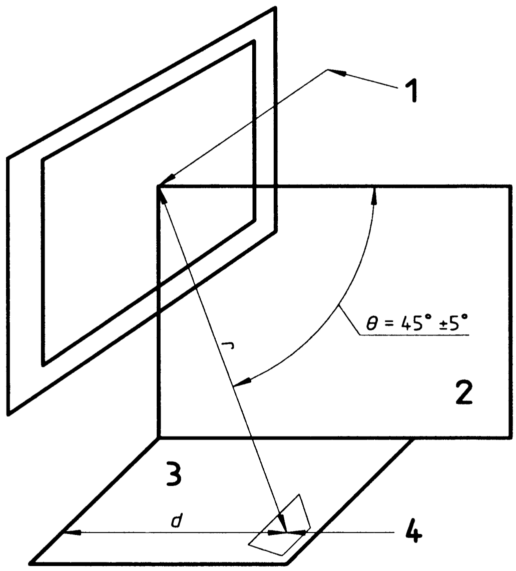
The element loudspeaker method will yield an estimate of the apparent sound reduction index which, under specified circumstances, can be compared with the sound reduction index for the corresponding façade elements obtained in laboratories.

The global loudspeaker method will quantify the airborne sound insulation of a whole façade or even a whole building in a specified situation. This result cannot be compared with laboratory measurements.

5.2 Principle

The loudspeaker is placed in one or more positions outside the building at a distance *d* from the façade, with the angle of sound incidence equal to (45 ± 5)° (see Figure 1).

The average sound pressure level is determined either directly on the test specimen (the element method) or 2 m in front of the façade (the global method), as well as in the receiving room. The apparent sound reduction index $R'_{45°}$ or the level difference $D_{\mathrm{ls,2m}}$ is calculated.



Key

1 Normal to the façade
2 Vertical plane
3 Horizontal plane
4 Loudspeaker

Figure 1 — Geometry of the loudspeaker method

5.3 Generation of sound field

The sound field generated shall be steady and have a continuous spectrum in the frequency range considered. If the measurements are made in one-third-octave bands, frequency bands with centre frequencies from at least 100 Hz to 3 150 Hz, preferably from 50 Hz to 5 000 Hz, shall be used. If the measurements are made in octave bands, frequency bands with centre frequencies from at least 125 Hz to 2 000 Hz, preferably from 63 Hz to 4 000 Hz, shall be used. In addition, the differences between the sound power levels in the one-third-octave bands belonging to an octave band shall not be greater than 6 dB in the 125 Hz octave band, 5 dB in the 250 Hz band, and 4 dB in bands of higher centre frequencies.

In all relevant frequency bands, the sound power level of the sound source shall be high enough to give a sound pressure level in the receiving room that exceeds the background noise level by at least 6 dB.

5.4 Position of the loudspeaker

Choose the position of the loudspeaker and the distance *d* to the façade so that the variation of the sound pressure level on the test specimen is minimized. This implies that the sound source is preferably placed on the ground. Alternatively, place the sound source as high above the ground as is possible in practice.

The distance r from the sound source to the centre of the test specimen shall be at least 5 m (d > 3,5 m) for the element loudspeaker method, and at least 7 m (d > 5 m) for the global loudspeaker method. The angle of the sound incidence shall be (45 ± 5)° (see Figure 1).

5.5 Measurements in the receiving room

5.5.1 *General*

Obtain the average sound pressure level in the receiving room by using a single microphone moved from position to position, or by an array of fixed microphones, or by a continuously moving or oscillating microphone. The sound pressure levels at the different microphone positions shall be averaged on an energy basis for all sound source positions. In addition, determine the background noise level L_b.

5.5.2 *Microphone positions*

As a minimum, five microphone positions shall be used in each room to obtain the average sound pressure level of each sound field. These positions shall be distributed within the maximum permitted space throughout each room, spaced uniformly.

The following separating distances are minimum values and should be exceeded where possible:

— 0,7 m between microphone positions;

— 0,5 m between any microphone position and room boundaries or objects in the room;

— 1,0 m between any microphone position and the sound source.

When using a moving microphone, the sweep radius shall be at least 0,7 m. The plane of the traverse shall be inclined in order to cover a large portion of the permitted room space and shall not lie in any plane within 10° of a room surface. The duration of a traverse period shall be not less than 15 s.

5.5.3 *Corrections for background noise*

Measure background noise levels to ensure that the observations in the receiving room are not affected by extraneous sound, such as noise from outside the test room, electrical noise in the receiving system, or electrical cross-talk between the source and receiving systems.

The background level should be at least 6 dB (and preferably more than 10 dB) below the level of the signal and background noise combined. If the difference in levels is smaller than 10 dB but greater than 6 dB, calculate corrections to the signal level according to equation (8):

$$L = 10 \lg \left(10^{L_{sb}/10} - 10^{L_b/10}\right) \text{ dB} \qquad \text{...(8)}$$

where

L is the adjusted signal level, in decibels;

L_{sb} is the level of signal and background noise combined, in decibels;

L_b is the background noise level, in decibels.

If the difference in levels is less than or equal to 6 dB in any of the frequency bands, use the correction 1,3 dB, corresponding to a difference of 6 dB. In that case indicate D_n, D_{nT} or R' values in the measurement report so that it is clear that the reported values are the limit of measurement [see i) of clause **9**].

5.5.4 *Measurement of reverberation time and evaluation of the equivalent sound absorption area*

The correction term in equation (6) containing the equivalent sound absorption area is evaluated from the reverberation time measured in accordance with ISO 354 and determined using Sabine's formula:

$$A = \frac{0{,}16\, V}{T} \qquad \text{...(9)}$$

where

- A is the equivalent absorption area, in square metres;
- V is the receiving room volume, in cubic metres;
- T is the reverberation time in the receiving room, in seconds.

Following ISO 354, begin the evaluation of the reverberation time from the decay curve about 0,1 s after the sound source has been switched off, or from a sound pressure level a few decibels lower than that at the beginning of the decay. Use a range neither less than 20 dB nor so large that the observed decay cannot be approximated by a straight line. The bottom of this range shall be at least 10 dB above the background noise level.

The minimum number of decay measurements required for each frequency band is six. At least one loudspeaker position and three microphone positions with two readings in each case shall be used.

Moving microphones which meet the requirements of **6.3.2** may be used, but the traverse time shall be not less than 30 s.

NOTE If the reverberation time is extremely short (e.g. shorter than about 0,4 s), a moving microphone may be problematical.

5.6 Element loudspeaker method

5.6.1 *Test requirements*

If the purpose of the measurement is to obtain results as comparable as possible to those of laboratory measurements, carry out the following steps:

a) verify that the façade element under test is in accordance with the specified construction and is properly mounted according to the manufacturer's instructions;

b) estimate the sound reduction index of the façade to ensure that the sound transmission through the wall surrounding the test specimen does not contribute significantly to the sound pressure level in the receiving room.

If the purpose of the measurement is to compare the sound insulation of a window with the results of laboratory measurements, verify in addition that the area of the test opening is representative of that of the laboratories and that the niche opening and the window position in the niche do not deviate from the requirements given in ISO 140-3.

Annex C outlines some examples for carrying out these checks. In case of doubt about unacceptably high sound transmission through the wall surrounding the test specimen, the procedure described in Annex B shall be carried out.

5.6.2 *Measurements on the outer surface of the façade element*

Determine the average sound pressure level $L_{1,s}$ on the test surface. Carry out the measurements either with the microphone fastened directly on the actual test specimen with its axis parallel to the plane of the façade and directed upwards or downwards, or with its axis pointing in the direction normal to the test specimen. The distance from the test specimen to the centre of the microphone membrane shall be 10 mm or shorter, depending on the diameter of the microphone, if the axis of the microphone is parallel to the test surface, and 3 mm or shorter if the axis is normal to the test surface. If fastened, the microphone shall be fastened to the test specimen with a strong, adhesive tape. Equip the microphone with a hemispherical windscreen (see Figure 2).

If simultaneous measurements are carried out outdoors and indoors, only microphone types which, including cables, have been shown not to affect the sound insulation of the test specimen should be used if the microphone is fastened to the test specimen.

Choose between three and ten measurement positions depending on the difference in the sound pressure levels between the positions. Distribute the measurement positions evenly but asymmetrically on the measurement surface. It is recommended to begin with three measurement positions (n = 3). If the difference in the sound pressure level between two positions in one frequency is more than n, increase the number of measurement positions up to ten. If the test specimen is mounted in a recess of the façade, always choose ten measurement positions. If the difference in the sound pressure levels between the measurement positions is more than 10 dB, this shall be stated in the measurement report.

As an alternative to several fixed positions, a scanning microphone is allowed provided that the distance to the façade element can be kept constant and provided that the background noise is kept at least 10 dB below the signal level.

Average the n positions as given by equation (10):

$$L_{1,s} = 10\,\lg\left(10^{L_1/10} + 10^{L_2/10} + \ldots + 10^{L_n/10}\right) - 10\,\lg(n)\,\mathrm{dB} \qquad \ldots(10)$$

where L_1, L_2 ,..., L_n are the sound pressure levels in positions 1,2,..., n.

NOTE The differences in the sound pressure levels depend among other things on the height h above the ground, recesses, balconies and the position of the test specimen.

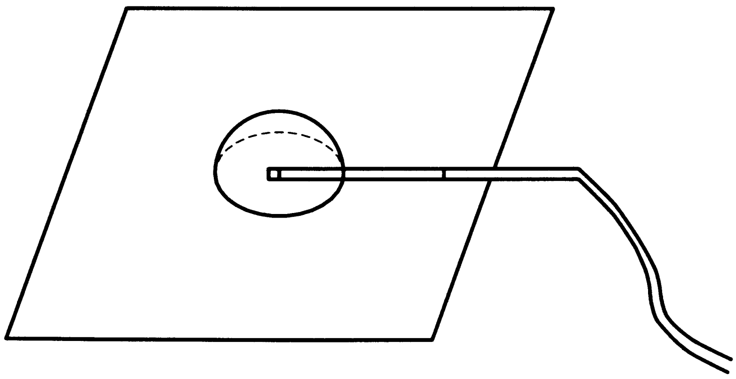


Figure 2 — Flush-mounted microphone

5.7 Global loudspeaker method

5.7.1 ***Test requirements***

There are no special requirements.

5.7.2 ***Measurements in front of the façade***

Place the microphone on the outside of the façade, in the middle. The distance shall be:

a) (2,0 ± 0,2) m from the plane of the façade, or

b) 1,0 m from a balustrade or other similar protrusion.

The height of the microphone shall be 1,5 m above the floor of the receiving room.

If the main part of the façade is a sloping construction such as a roof, choose the position not nearer to the roof than the projected part of the vertical part of the façade. If the room considered has more than one outside wall or is very large, see **5.7.3**. Denote the measured sound pressure level $L_{1,2m}$.

NOTE Because of uncontrolled interference effects, systematic errors will occur, particularly at low frequencies.

5.7.3 ***Large rooms or façades comprising more than one outside wall***

If the room is very large or if it has more than one outside wall, it is normally not possible to measure with one source position only. In those cases, use several source positions, each in full compliance with **5.4**. The number of positions is given by the directional characteristics of the loudspeaker and the area of the façade (see **4.2**).

5.7.4 ***Calculation of measurement results***

If several source positions have been used, calculate the level difference for each position and average them according to equation (11):

$$D_{\text{ls,2m}} = -10 \lg\left(\frac{1}{n}\sum 10^{-D_i/10}\right) \text{dB} \qquad ...(11)$$

where

n is the number of source positions;

D_i is the level difference for each source-receiver combination.

6 Measurements with road traffic

6.1 General

Two methods, the element and the global road traffic method, are described. The corresponding methods for railway and air traffic noise are described in Annex D.

The element road traffic method will yield an estimate of the apparent sound reduction index which, under specified circumstances, can be compared with the corresponding sound reduction index obtained in laboratories.

NOTE Due to background noise, this method is normally limited to measuring $R'_{\text{w}} < 40$ dB.

The global road traffic method will quantify the airborne sound insulation of a whole façade or even a whole building in a specified situation. This result cannot be compared with the sound reduction index obtained in a laboratory.

6.2 Principle

If the sound is incident on the test specimen from different directions and with varying intensity (e.g. traffic noise in busy streets), the sound reduction index or the level difference is obtained from the equivalent sound pressure levels measured as a function of frequency on both sides of the test specimen.

6.3 Test requirements

During the measurements the background noise in the receiving room shall be at least 10 dB below the measured equivalent sound pressure level. Use the existing traffic noise incident on the test specimen for sound generation. The measurement time shall include at least 50 passing vehicles.

On account of possible fluctuations in traffic noise, measure the equivalent sound pressure levels simultaneously on opposite sides of the specimen. Avoid quiet periods, i.e. periods when the traffic noise does not exceed the background noise by more than 10 dB.

NOTE Corrections for background noise according to **5.5.3** cannot normally be carried out.

6.4 Frequency range

When measurements are made in one-third-octave bands, frequency bands with centre frequencies of at least from 100 Hz to 3 150 Hz, preferably from 50 Hz to 5 000 Hz, shall be used. When measurements are made in octave bands, frequency bands with centre frequencies of at least from 125 Hz to 2 000 Hz, preferably from 63 Hz to 4 000 Hz, shall be used.

6.5 Element road traffic method

6.5.1 ***General***

If the purpose of the measurement is to compare the results with laboratory measurements or to obtain results which are representative of a façade element, follow, if possible, the procedure given in **5.6**. If, for practical reasons, that procedure is not applicable, the element road traffic method is an alternative. However, in all cases, the test requirements given in **5.6.1** shall be complied with.

NOTE Under some circumstances it may become necessary to apply the element road traffic method although the requirements stated in this part of ISO 140 are not fully complied with. If results of such measurements are reported, all deviations from this part of ISO 140 should be reported.

6.5.2 ***Generation of the sound field***

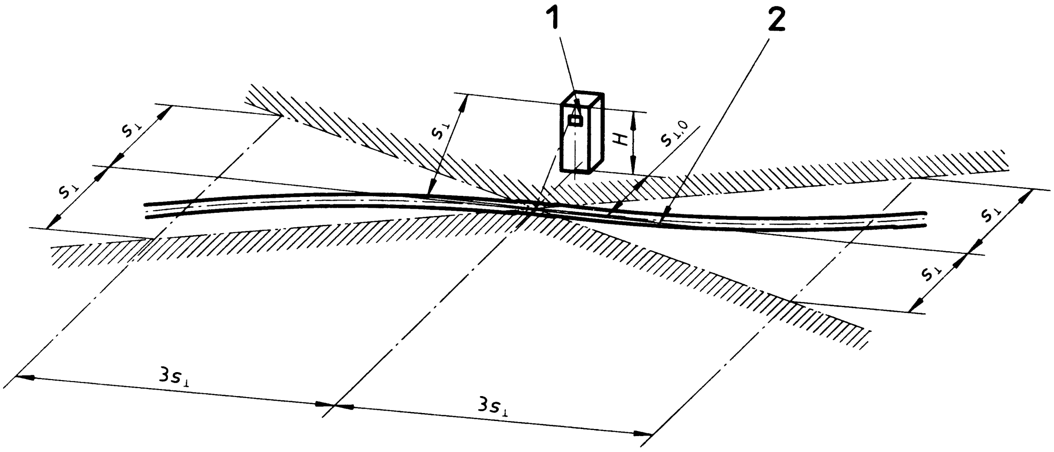
The measurement situation shall fulfil the following requirements.

a) The traffic shall flow approximately along a straight line within an angle of sight within ± 60° from the façade; within this angle, deviations from a straight line are allowed within ± 15° with the tangent to the traffic line at the intersection of the traffic line and the normal from the façade on the traffic line (see Figure 3).

b) The angle of elevation, observed from the point of least distance between the façade and the line of traffic, shall be less than 40°.

c) Free view of the whole façade shall be possible from the whole width of the traffic flow.

d) The minimum horizontal distance between the traffic line and the façade shall be at least three times the width of the façade to be tested, or 25 m, whichever is the largest (see note in **6.5.1**).



Key

1 Receiving point

2 Traffic line

NOTE $s_\perp$ is the distance between the receiving point and the traffic line;

$s_{\perp,0}$ is the horizontal distance between the receiving point and the traffic line;

H is the height difference between the receiving point and the traffic line.

Figure 3 — Conditions at long straight traffic lines

6.5.3 ***Measurement of the equivalent sound pressure levels***

Place the microphone on the outside of the test specimen as given in **5.6.2**. If the façade is flat without large recesses or balconies, use three microphone positions asymmetrically distributed over the measurement surface. If the façade has large recesses or balconies, use five microphone positions. Denote the measured sound pressure level $L_{1,\mathrm{eq},\mathrm{s}}$.

Carry out the measurements in the receiving room as given in **5.5**. If discrete microphone positions are used, it is permitted to use one position for each microphone position on the outside.

6.5.4 ***Measurement of reverberation time and evaluation of equivalent sound absorption area***

Proceed as given in **5.5.4**.

6.6 Global road traffic method

6.6.1 ***General***

There are no restrictions other than those given in **6.3**.

6.6.2 ***Generation of the sound field***

There are no special requirements.

6.6.3 ***Measurement of the equivalent continuous sound pressure levels***

Place the microphone on the outside of the façade, in the middle. The distance shall be:

a) (2,0 ± 0,2) m from the plane of the façade; or

b) 1,0 m from a balustrade or other similar protrusion.

The height of the microphone shall be 1,5 m above the floor of the receiving room.

If the main part of the façade is an oblique construction such as a roof, choose the position not nearer to the roof than the projected part of the vertical part of the façade. If the room considered has more than one outside wall, position the microphone in front of each of the façades. Denote the measured sound pressure level $L_{1,\mathrm{eq},2\mathrm{m}}$.

NOTE 1 Because of uncontrolled interference effects, systematic errors will occur, particularly at low frequencies.

Carry out the measurements in the receiving room as given in **5.5**.

NOTE 2 In addition to measurements in one-third-octave or octave bands, direct A-weighted measurements may be carried out.

6.6.4 ***Measurement of reverberation time and evaluation of equivalent sound absorption area***

Proceed as given in **5.5.4**.

In the case of direct A-weighted measurements, the reverberation time and absorption area at 500 Hz should be used when normalizing $D_{\mathrm{n}T}$ and D_{n} respectively.

6.6.5 ***Calculation of measurement results***

If several microphone positions on the source side have been used, calculate the level difference for each position and average according to equation (12):

$$D_{\mathrm{tr,2m}} = -10 \lg \left(\frac{1}{n} \sum 10^{-D_i/10} \right) \mathrm{dB} \qquad \text{...(12)}$$

where

n is the number of microphone positions on the source side;

D_i is the level difference for each source-receiver combination.

7 Precision

7.1 General

The measurement procedure shall give satisfactory repeatability. This shall be determined in accordance with the method given in ISO 140-2 and should be verified from time to time, particularly when a change is made in the procedure or instrumentation.

NOTE 1 Numerical requirements for repeatability are given in ISO 140-2.

NOTE 2 As the sound insulation of windows and small façade elements depends on the dimensions, the sound insulation in practice could differ considerably if a construction has an area other than the one tested in the laboratory. It is unlikely that test specimens (especially window panes) the areas of which have a ratio of up to 2 : 1 will show differences in sound insulation greater than 3 dB in the single-number quantity. With an area greater than that which has been tested, a lower sound insulation will generally result.

7.2 Element loudspeaker method

If the variation in the sound pressure levels between the different outdoor microphone positions is less than 10 dB, the value of the weighted apparent sound reduction index $R'_{45°,\mathrm{w}}$ obtained by this method, can be 0 dB to 2 dB higher than the value of the corresponding sound reduction index R_{w} measured in a laboratory, assuming that mounting conditions, including niche size, and test specimen type and size are identical. In discrete frequency bands, the deviations may become greater, especially at frequencies below 250 Hz. In addition, the reproducibility of such measurements shall be taken into account. As a comparison, laboratory measurements have been shown to have a reproducibility, as defined in ISO 5725-1, of about 2 dB for the R_{w} value.

7.3 Global loudspeaker method

The reproducibility has been shown to be about 2 dB.

7.4 Element and global road traffic methods

The precisions of the element and global road traffic methods are not known.

8 Expression of results

For the statement of the airborne sound insulation of a façade element and a façade, the standardized level difference D_{nT} or the apparent sound reduction index R' shall be given at all frequencies of measurement, to one decimal place, in tabular form and/or in the form of a curve. Graphs in the test report shall show the level in decibels plotted against frequency on a logarithmic scale, using the following dimensions:

— 5 mm for a one-third octave band,

— 20 mm for 10 dB.

The use of a form in accordance with Annex E is preferred. This being a short version of the test report, state all information of importance regarding the test object, the test procedure, and the test results.

If octave band values are to be calculated from the one-third-octave bands, these values shall be calculated from the three one-third-octave band values in each octave band, using equation (13):

$$X_{\mathrm{oct}} = -10 \lg \left(\sum_{n=1}^{3} \frac{10^{-X_{1/3\mathrm{oct}}/10}}{3} \right) \quad \text{...(13)}$$

where X is the normalized level difference, the standardized level difference, or the apparent sound reduction index.

9 Test report

The test report shall state:

a) reference to this part of ISO 140;

b) name of the organization that has performed the measurements;

c) identification of test site;

d) name and address of the organization or person who ordered the test (client);

e) date of test;

f) description of façade elements and of façade;

g) volume of receiving room;

h) area of test surface;

i) apparent sound reduction index, standardized level difference, or normalized level difference, as a function of frequency, and the corresponding weighted values;

j) Information on background noise;

k) Information about which test method has been used.

l) any deviations from this part of ISO 140.

For the evaluation of single-number ratings, see ISO 717-1.

Annex A (normative) Determination of area S

When determining the sound reduction index for a façade element, e.g. for a window or a door, the area S is equal to the area of the free opening where the window or the door is mounted. The area S that is used shall be given in the measurement report.

When determining the sound reduction index for the whole façade of a receiving room, the area S is equal to the area of the part of the façade which can be seen from the receiving room.

Annex B (normative) Control of sound transmission through the wall surrounding the test specimen

Cover the test specimen and only the test specimen on the inside with 10-cm-thick mineral wool covered with at least two 13-mm-thick plaster boards, and then measure the sound insulation. If the measurements show an improvement in the sound insulation which is less than 6 dB throughout the whole frequency range or parts of it, the sound transmission through the surrounding wall is unacceptably high. In that case accurate comparisons with laboratory measurements cannot be made for those frequencies for which the improvement is less than 6 dB.

Annex C (informative) Examples of verification of test requirements

C.1 Evaluation of a test specimen

To find out if a test specimen is identical to the one tested in the laboratory, the following checks may be carried out:

— type of window construction;

— thickness and type of glass;

— number of panes;

— airspace between panes;

— type of gas in a sealed glazing unit;

— number of seals;

— the existence of a dust seal (in windows between the coupled sashes);

— type and material of the frame.

C.2 Verification of mounting

To ascertain that the mounting is carried out according to the manufacturer's instructions, one or more of the following tests may be carried out:

— visual examination;

— total or partial dismounting;

— acoustical check, e.g. by testing the test specimen after the space between the frame and the wall has been taped over. If there is a difference in the sound insulation, there is a leak.

Annex D (informative) Measurements with aircraft and railway traffic noise

D.1 Introduction

Air traffic noise in the neighbourhood of airports normally penetrates into buildings through a number of different propagation paths during each aircraft operation. This happens at the same time as the frequency composition of the noise varies. Thus the described methods of measurements of air traffic noise reduction in buildings are based on time-integrated noise descriptors. Railway traffic noise is dealt with simultaneously as it has a similar time pattern.

D.2 General

Two methods, the element and the global traffic method, are described.

The element method yields an estimate of the apparent sound reduction index which, under specified circumstances, can be used to estimate the noise reduction of one particular element of a building. However, this method is to be used with care as the measurement precision is not known.

The global method quantifies the airborne sound insulation of a whole façade or even a whole building relative to a position 2 m in front of the façade. This result cannot be compared with that of laboratory measurements.

D.3 Definitions

For the purposes of this annex, the following definitions apply.

D.3.1
sound exposure level

the sound exposure level of a discrete noise event is given by equation (D.1):

$$L_E = 10 \lg \frac{1}{t_0} \int_{t_1}^{t_2} \frac{p^2(t)}{p_0^2} \, dt \qquad \text{...(D.1)}$$

where

$p(t)$ is the instantaneous sound pressure;

$t_2 - t_1$ is a stated time interval long enough to encompass all significant sounds of a stated event;

p_0 is the reference sound pressure, with $p_0 = 20$ µPa;

t_0 is the reference duration, with $t_0 = 1$ s.

NOTE Sound exposure level is also called "single event sound pressure level".

D.3.2
sound exposure level difference, D_{E2m}

difference between the outdoor sound exposure level, $L_{E1,2m}$, and the space-averaged sound exposure level, L_{E2}, in the receiving room:

$$D_{E2m} = L_{E1,2m} - L_{E2} \qquad \text{...(D.2)}$$

NOTE If air traffic is used as sound source, the notation is $D_{at,E2m}$. If railway traffic noise is used, it is $D_{rt,E2m}$.

D.3.3
standardized sound exposure level difference, $D_{E2m,nT}$

level difference corresponding to a reference value of the reverberation time in the receiving room:

$$D_{E2m,nT} = D_{E2m} + 10 \lg \left(\frac{T}{T_0} \right) \text{dB} \qquad \text{...(D.3)}$$

where $T_0 = 0{,}5$ s.

NOTE If air traffic noise is used as sound source, the notation is $D_{at,E2m,nT}$. If railway traffic is used, it is $D_{rt,E2m,nT}$.

D.3.4
normalized sound exposure level difference, $D_{E2m,n}$

level difference corresponding to a reference value of the absorption area in the receiving room:

$$D_{E2m,n} = D_{E2m} - 10 \lg \left(\frac{A}{A_0} \right) \text{dB} \qquad \text{...(D.4)}$$

where $A_0 = 10$ m^2.

NOTE If air traffic noise is used as sound source, the notation is $D_{at,E2m,n}$. If railway traffic is used, it is $D_{rt,E2m,n}$.

D.3.5
apparent sound reduction index, $R'_{at,s}$

measure of the airborne sound insulation of a building element when the sound source is air traffic noise and the outside microphone position is on the test surface; it is calculated from equation (D.5):

$$R'_{at,s} = L_{E1,s} - L_{E2} + 10 \lg\left(\frac{S}{A}\right) \text{dB} - 3 \text{ dB} \quad \text{...(D.5)}$$

where

- $L_{E1,s}$ is the average value of the sound exposure level on the surface of the test specimen including reflecting effects from the test specimen and façade;
- L_{E2} is the average value of the sound exposure level in the receiving room;
- S is the surface area of the test specimen;
- A is the sound absorption area in the receiving room.

D.3.6
apparent sound reduction index, $R'_{rt,}$

measure of the airborne sound insulation of a building element when the sound source is railway traffic noise and the outside microphone position is on the test surface; it is calculated from equation (D.6):

$$R'_{rt,s} = L_{E1,s} - L_{E2} + 10 \lg\left(\frac{S}{A}\right) \text{dB} - 3 \text{ dB} \quad \text{...(D.6)}$$

where

- $L_{E1,s}$ is the average value of the sound exposure level on the surface of the test specimen including reflecting effects from the test specimen and façade;
- L_{E2} is the average value of the sound exposure level in the receiving room;
- S and A are as given, in **D.3.5**.

D.4 Instrumentation

See **4.1**.

D.5 Measurements

D.5.1 *General*

Aircraft or railway noise is used as the sound source. The sound pressure level is measured simultaneously outdoors and indoors at specified positions. Then the relevant noise descriptor is calculated.

D.5.2 *Test requirements*

The sound pressure levels from the traffic, both outdoors and indoors, shall be sufficient to ensure that the measurements are unaffected by background noise within the frequency range of interest.

D.5.3 *Frequency range*

If the measurements are made in one-third-octave bands, use frequency bands with centre frequencies from at least 100 Hz to 3 150 Hz, preferably from 50 Hz to 5 000 Hz. If the measurements are made in octave bands, use the frequency bands with centre frequencies from at least 125 Hz to 2 000 Hz, preferably from 63 Hz to 4 000 Hz.

D.5.4 ***Element method***

D.5.4.1 *General*

If the purpose of the measurement is to compare the results with laboratory measurements or to obtain results which are representative of a façade element, follow, if possible, the procedure given in **5.6**. If, for practical reasons, that procedure is not applicable, this element air or railway traffic method is an alternative. However, the test requirements given in **5.6.1** shall in all cases be complied with.

NOTE Under some circumstances it may become necessary to apply the element air or railway traffic method although the requirements stated in this part of ISO 140 are not fully complied with. If the results of such measurements are reported, all deviations from this part of ISO 140 should be reported.

D.5.4.2 *Generation of the sound field*

There are no restrictions other than those given in **D.5.2**.

D.5.4.3 *Measurement of the sound exposure level*

Place the microphone on the outer surface of the test specimen as given in **5.6.2**. If the façade is flat without large recesses or balconies, use three microphone positions asymmetrically distributed over the measurement surface. If the façade has large recesses or balconies, use five microphone positions. Measure the sound exposure level for at least five noise events. The microphone may be moved between the noise events. Denote the measured sound exposure level for the event i as $L_{\mathrm{E1}i,\mathrm{s}}$.

In the receiving room, use as a minimum five microphone positions uniformly distributed within the maximum permitted space throughout the room. A moving microphone can be used in those cases where the duration of the noise event is about equal to or longer than the traverse period. When using a moving microphone, the sweep radius shall be not less than 0,7 m. The plane of the traverse shall be inclined in order to cover a large portion of the permitted room space and shall not lie in any plane within 10° of a room surface. The duration of a traverse period shall be not more than 15 s.

The following separating distances are minimum values and should be exceeded where possible:

— 0,7 m between microphone positions;

— 0,5 m between any microphone position and room boundaries or objects in the room;

— 1,0 m between any microphone position and the test specimen.

Measure the sound exposure level for the same events as for the outdoor measurements. If discrete microphone positions are used, it is permitted to use one position for each microphone position on the outside. Denote the measured sound exposure level for the event i as $L_{\mathrm{E2}i}$.

D.5.4.4 *Measurement of reverberation time and evaluation of equivalent sound absorption area*

Proceed as specified in **5.5.4**.

D.5.4.5 *Calculation of measurement results*

Calculate the apparent sound reduction index $R'_{\mathrm{at,s}}$ or $R'_{\mathrm{rt,s}}$ and the weighted apparent sound reduction index $R'_{\mathrm{at,s,w}}$ or $R'_{\mathrm{rt,s,w}}$ according to the method given in ISO 717-1. If several noise events were used, calculate the apparent sound reduction index for each position and average them according to

$$R'_{\mathrm{s}} = -10\ \lg\left(\frac{1}{n}\sum 10^{-R'_i/10}\right)\ \mathrm{dB} \qquad \text{...(D.7)}$$

where

n is the number of noise events;

R'_i is the apparent noise reduction index for the i-th noise event.

NOTE The apparent sound reduction index can only be used to estimate the sound insulation of a particular façade element when there is no significant flanking transmission.

D.5.5 ***Global method***

D.5.5.1 *Generation of the sound field*

There are no restrictions other than those given in **D.5.2**.

D.5.5.2 *Measurement of the sound exposure level*

Place the microphone on the outside of the façade, in the middle of the width, at a distance of (2,0 ± 0,2) m from the plane of the façade. The height of the microphone shall be 1,5 m above the floor of the receiving room.

If the main part of the façade is a sloping construction such as a roof, choose the position not nearer to the roof than the projected part of the vertical part of the façade. If the room considered has more than one outside wall of façade, position the microphone in front of the façade with the highest outside noise level. Denote the measured sound exposure level $L_{E1,2m}$.

NOTE 1 Because of uncontrolled interference effects, systematic errors will occur at low frequencies.

NOTE 2 When air traffic noise is used as sound source, it often happens that the outdoor microphone is screened differently than the façade. In these cases systematic differences can occur compared to cases when this is not so.

Carry out the measurements in the receiving room as given in **5.5**. If discrete microphone positions are used, it is permitted to use one position for each noise event.

Measure the sound exposure level for at least five noise events.

NOTE 3 In addition to measurements in one-third-octave or octave bands, direct A-weighted measurements may be carried out.

D.5.5.3 *Measurement of reverberation time and evaluation of equivalent sound absorption area*

Proceed as specified in **5.5.4**.

D.5.5.4 *Calculation of measurement results*

If several noise events were used, calculate the level difference for each event and average according to

$$D_{E2m} = -10 \lg\left(\frac{1}{n}\sum 10^{-D_i/10}\right) \text{dB} \qquad \text{...(D.8)}$$

where

n is the number of noise events;

D_i is the level difference for the i-th noise event.

D.6 Precision

The measurement precision is not known. Thus the measurement results should be used with great care.

In addition, see **7.1**.

D.7 Expression of results

See clause **8**.

D.8 Test report

See clause **9**.

Annex E (informative)
Form for the expression of results reported in one-third-octave bands

This annex gives an example of a form for the expression of results for the field measurement of airborne sound insulation of façade elements and of façades. The curve of reference values shown in the form is taken from ISO 717-1. The latest version of that standard is applied. The reference curves should be supplemented or at least replaced by the shifted reference curve according to the procedure described in ISO 717-1. The example is given for R'_{45}. The form can be used for other values accordingly.

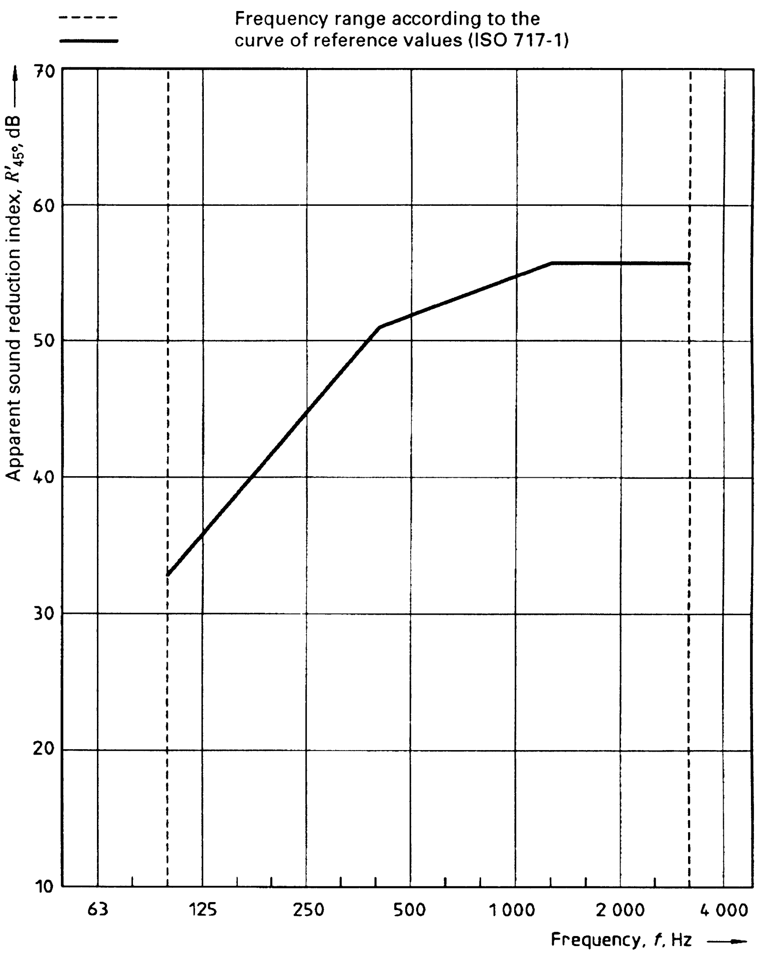
Apparent sound reduction index according to ISO 140-5
Field measurements of airborne sound insulation of façade elements and façades

Client: Date of test:

Description and identification of the building construction and test arrangement:

Area *S* of test specimen: m²
Receiving room volume: m³

Frequency *f* Hz	$R'_{45°}$ (one-third octave) dB
50	
63	
80	
100	
125	
160	
200	
250	
315	
400	
500	
630	
800	
1 000	
1 250	
1 600	
2 000	
2 500	
3 150	
4 000	
5 000	



Rating according to ISO 717-1:

$R'_{45°,w}(C;C_{tr})$ = (;) dB; $C_{50\text{-}3150}$ = dB; $C_{50\text{-}5000}$ = dB; $C_{100\text{-}5000}$ = dB

Evaluation based on field measurement results obtained by an engineering method $C_{tr,50\text{-}3150}$ = dB; $C_{tr,50\text{-}5000}$ = dB; $C_{tr,100\text{-}5000}$ = dB

No. of test report: Name of test institute:

Date: Signature:

Annex F (informative)
Bibliography

[1] ISO 140-10:1991, *Measurement of sound insulation in buildings and of building elements — Part 10: Laboratory measurements of sound insulation of small building elements.*

[2] ISO 5725-1:1994, *Accuracy (trueness and precision) of measurement methods and results — Part 1: General principles and definitions.*

Annex ZA (normative)
Normative references to international publications with their relevant European publications

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.

Publication	Year	Title	EN	Year
ISO 140-2	1991	Acoustics — Measurement of sound insulation in buildings and of building elements — Part 2: Determination, verification and application of precision data	EN 20140-2	1993
ISO 140-3	1985	Acoustics — Measurement of sound insulation in buildings and of building elements — Part 3: Laboratory measurements of airborne sound insulation of building elements	EN ISO 140-3	1995
ISO 354	1985	Acoustics — Measurement of sound absorption in a reverberation room	EN ISO 354	1993
ISO 717-1	1996	Acoustics — Rating of sound insulation in buildings and of building elements — Part 1: Airborne sound insulation	EN ISO 717-1	1996

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