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Acoustics — Measurement of sound insulation in buildings and of building elements — Part V : Field measurements of airborne sound insulation of facade elements and facades

Acoustique — Mesurage de l'isolation acoustique des immeubles et des éléments de construction — Partie V : Mesurage sur place de l'isolation aux bruits aériens des éléments de façade et des façades

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FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up 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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 140/V was developed by Technical Committee ISO/TC 43, *Acoustics*, and was circulated to the member bodies in May 1976.

It has been approved by the member bodies of the following countries :

Australia	India	Romania
Austria	Israel	South Africa, Rep. of
Belgium	Italy	Spain
Canada	Japan	Sweden
Czechoslovakia	Korea, Rep. of	Switzerland
Denmark	Mexico	Turkey
Finland	Netherlands	United Kingdom
France	New Zealand	U.S.A.
Germany	Norway	U.S.S.R.
Hungary	Poland	

No member body expressed disapproval of the document.

Annexes A, C and E are integral parts of this International Standard.

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Acoustics — Measurement of sound insulation in buildings and of building elements — Part V : Field measurements of airborne sound insulation of facade elements and facades

0 INTRODUCTION

The purpose of this International Standard is

— to give procedures to measure the sound insulation properties of a facade with respect to outside noise such as traffic noise, thus making it possible to ensure that the constructions meet the desired acoustical conditions inside the building;

— to give field procedures to determine whether facades have met building specifications and to check where faults occurred in the facade construction.

1 SCOPE AND FIELD OF APPLICATION

This International Standard specifies field methods for measuring the sound insulation properties of facades under particular acoustical conditions and for determining the protection afforded by the facade to the occupants of the building.

NOTE — Laboratory measurements of facade elements and facades are dealt with in ISO 140/III.

The test specimen is located either in an outer wall (for example in the case of a window) or is the outer wall itself (for example a whole facade).

When determining the existing acoustical conditions, the measurements should preferably be carried out according to clause 3 with traffic noise (sound from different directions and with varying intensity).

When testing the sound insulation properties of facades, measurements can alternatively be performed according to clause 4 with loudspeaker noise (directed sound).

However, on account of the differences in the nature of the incident sound, the results of the two methods cannot be expected to agree fully.

2 REFERENCES

ISO 140/II, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part II : Statement of precision requirements.*

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

ISO/R 354, *Measurement of absorption coefficients in a reverberation room.*

ISO/R 1996, *Acoustics — Assessment of noise with respect to community response.*

IEC Publication 225, *Octave, half-octave and third-octave band filters intended for the analysis of sound and vibrations.*

3 MEASUREMENT WITH TRAFFIC NOISE

3.1 Principle

If the sound is incident on the test specimen from different directions and with varying intensity, as, for example, traffic noise in busy streets, the sound reduction index is obtained from the equivalent sound pressure levels measured as a function of frequency on both sides of the test specimen. This quantity is denoted by R_{tr} :

$$R_{tr} = L_{eq,1} - L_{eq,2} + 10 \lg \frac{S}{A} \text{ dB} \qquad \ldots (1)$$

where

$L_{eq,1}$ is the equivalent sound pressure level 2 m in front of the test specimen including the reflection effect of the test specimen;

$L_{eq,2}$ is the equivalent sound pressure level in the receiving room averaged over the room;

S is the area of the test specimen (see annex A);

A is the equivalent absorption area in the receiving room.

NOTE — Equation (1) is applicable when the line of traffic is sufficiently long and straight to ensure a fairly uniform distribution of incident sound. When the angle of elevation (observed from the point of least distance between the test specimen and the line of traffic) is more than about 20°, there will be a predominance of oblique angles of incidence and the results may differ from those obtained at ground floor level to the extent that the sound reduction index of the test specimen is dependent on the angle of incidence. When the angle of elevation exceeds 50°, equation (1) should not be used.

In cases where it is required to measure the protection afforded by the facade irrespective of its construction and surface area or its position relative to the noise sources, the standardized level difference $D_{nT,tr}$ should be used :

$$D_{nT,tr} = L_{eq,1} - L_{eq,2} + 10 \lg \frac{T}{T_0} \text{ dB} \qquad \ldots (2)$$

where

T is the measured reverberation time in the receiving room;

T_0 is the reference reverberation time, 0,5 s for dwellings.

3.2 Equipment

The equipment shall be suitable for meeting the requirements of 3.4.

3.3 Test arrangement

For the test arrangement to be used in the field, it is not possible to standardize the area of the test specimen and the volume and shape of the receiving room.

3.4 Test procedure and evaluation

3.4.1 *Generation of sound field*

For sound excitation, the existing traffic noise, incident on the test specimen, is used.

3.4.2 *Measurement of the equivalent sound pressure levels*

The equivalent sound pressure level L_{eq} is defined by the formula :

$$L_{eq} = 10 \lg \frac{\frac{1}{T_i} \int_0^{T_i} p^2(t)\, dt}{p_0^2} \text{ dB} \qquad \ldots (3)$$

where

$p(t)$ is the time-variant sound pressure;

$p_0 = 20\ \mu\text{Pa}$ is the reference sound pressure;

T_i is the integrating time.

L_{eq} can be determined by an appropriate integrating device or (as an approximation) by a noise distribution analysis according to ISO/R 1996.

On account of the possible fluctuations of the traffic noise, the equivalent sound pressure levels $L_{eq,1}$ and $L_{eq,2}$ must be measured simultaneously on opposite sides of the specimen, for example by recording the sound signals with a two-track magnetic tape machine and by evaluating both signals within the same time intervals.

NOTE — When determining the difference of average sound pressure levels from simultaneous measurements, it is unimportant whether the actual readings are expressed in terms of L_{eq}, L_{50} or L_{10}. (L_{50} and L_{10} are the sound pressure levels exceeded in 50 % and 10 % of the observation time respectively.) In some cases one of these will be measured for other reasons and it will not be necessary to measure all three but only that which is the most convenient at the time. When specifically measuring sound insulation and not noise disturbance, it is preferable to use L_{eq}.

For determining the equivalent sound pressure level $L_{eq,1}$ the microphone should be placed about 2 m in front of the test specimen.

Alternatively, the microphone may be placed as close as possible (less than 2 cm) to the outer face of the test specimen with the axis parallel to it. In this case 3 dB are subtracted from the value of R_{tr} or $D_{nT,tr}$ calculated according to equations (1) and (2) respectively.

NOTES

1 When the microphone is placed as close as possible to the test specimen, several difficulties may arise, e.g. :

a) the level measurements will depend critically on the position of the microphone with respect to the outer face of the test specimen;

b) insufficiently large impedance of the test specimen (compliance of the window pane, absorption of facade material) may cause errors of unknown magnitude;

c) different microphone sensitivity and directivity on opposite sides of the test specimen.

2 If there is a balcony in front of the test specimen, the measurement with traffic noise cannot be applied for determining the sound reduction index of the test specimen.

However, the combined protection afforded, including the balcony, could be determined by placing the microphone 2 m in front of the balcony and by using equation (2).

The sound pressure level in the receiving room should be an average over space and time. This average may be obtained by using a number of fixed microphone positions or a number of stationary positions of a remotely controlled movable microphone. The microphone positions shall be out of the near field of the test specimen.

3.4.3 *Frequency range of measurements*

The sound pressure level should be measured using third-octave or octave band filters. The discrimination characteristics of the filters should be in accordance with IEC Publication 225.

Third-octave band filters having at least the following centre frequencies in hertz should be used :

100	125	160	200	250	315
400	500	630	800	1 000	1 250
1 600	2 000	2 500	3 150		

If octave band filters are used, as a minimum the series beginning with centre frequency 125 Hz and ending at 2 000 Hz should be used.

3.4.4 *Measurement and evaluation of the equivalent absorption area*

The correction term of equation (1) containing the equivalent absorption area may preferably be evaluated from the reverberation time measured according to ISO/R 354 and evaluated using Sabine's formula :

$$A = \frac{0{,}163\ V}{T} \qquad \ldots (4)$$

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 seconds.

An alternative method of evaluating the equivalent absorption area into account is to measure the average sound pressure level produced by a sufficiently stable sound source the power output of which is known.

3.4.5 *Measurement procedure*

Each organization should determine a normal test procedure which complies with this International Standard.

The necessary criteria which affect the repeatability of the measurements are shown below :

On the outside,

– traffic noise source(s);

– position of the microphone relative to the test specimen.

On the inside,

– minimum distances between microphone and room boundaries, especially test specimen, with regard to near fields;

– number of microphone positions;

– averaging time of the levels;

– method for determining the equivalent absorption area, which involves a number of repeated readings in each position.

An example of typical test conditions is given in annex B.

3.5 Precision

It is required that the measurement procedure should give satisfactory repeatability. For the instrumentation and, in specific cases, for the complete measurement condition, this can be determined in accordance with the method shown in ISO 140/II.

It is recommended that different organizations in the same country should periodically perform comparison measurements on the same test object to check the repeatability and the reproducibility of their test procedures.

3.6 Expression of results

For the statement of the airborne sound insulation of the test specimen, the sound reduction index R_{tr} should be given at all frequencies of measurement, in tabular form and/or in the form of a curve. For graphs with the level in decibels plotted against frequency on a logarithmic scale, the length for a 10 : 1 frequency ratio should be equal to the length for 10 dB, 25 dB, or 50 dB on the ordinate scale.

3.7 Test report

With reference to this International Standard, the test report shall state :

a) name of organization that has performed the measurements;

b) date of test;

c) description of test specimen, if possible with sectional drawing and details of mounting;

d) indication of traffic situation and the equivalent sound pressure level $L_{eq,1}$;

e) a suitable plan of the building, showing the position of the test specimen in relation to the traffic flow;

f) volume and equivalent absorption area of the receiving room;

g) method applied for determining the equivalent sound pressure levels including the time intervals used and, in the case of a noise distribution analysis, the class width used;

h) type of filters used;

i) either the sound reduction index R_{tr} of test specimen or the standardized sound level difference $D_{nT,tr}$ as a function of frequency, whichever is appropriate;

j) the area S used for evaluation of R_{tr};

k) brief description of details of procedure and equipment (see 3.4.5).

4 MEASUREMENT WITH LOUDSPEAKER NOISE

4.1 Principle

The loudspeaker is located outside the building at an appropriate distance from the test specimen. The sound is incident on the test specimen mainly from one direction only.

The sound reduction index determined by this method is called R_ϑ and is given by the following equation :

$$R_\vartheta = L_1'' - L_2 + 10 \lg \frac{4\,S \cos\vartheta}{A}\ \text{dB} \qquad \ldots (5)$$

where

L_1'' is the average sound pressure level immediately in front of the test specimen without the reflecting effect of the test specimen (see 4.4.2);

ϑ is the angle of incidence (angle between the loudspeaker axis directed at the centre of the test specimen and the normal to the surface of the test specimen);

L_2 is the average sound pressure level in the receiving room;

S is the area of the test specimen (see annex A);

A is the equivalent absorption area in the receiving room.

4.2 Equipment

The equipment shall be suitable for meeting the requirements of 4.4.

4.3 Test arrangement

For the test arrangement to be used in the field, it is not possible to standardize the area of the test specimen and the volume and shape of the receiving room.

4.4 Test procedure and evaluation

4.4.1 *Generation of sound field*

The sound generated should be steady and have a continuous spectrum in the frequency range considered. Filters with a band width of at least one-third octave may be used.

The loudspeaker arrangement and its distance from the test specimen should be so chosen that the test specimen is excited as uniformly as possible. The loudspeaker should be placed as near as possible to the ground, preferably on the ground.

The local differences of sound pressure level over the surface of the test specimen should not exceed 5 dB.

The measurements shall be made at an angle of incidence of 45°. Other angles in the series 0°, 15°, 30°, 60° and 75° may be used in addition to 45°.

4.4.2 *Measurement of the average sound pressure levels*

The average sound pressure level L_1'' is obtained from the sound radiation of the loudspeaker in the free field (i.e. in the absence of reflecting objects). The microphone should be placed at the same distance from the source as the surface of the test specimen. The sound pressure level should be averaged over an area corresponding to the surface of the test specimen. Except for the reflecting influence of the test specimen, this measurement should be carried out under the same acoustical conditions as during the actual measurements on the test specimen. It can be considered as calibration of the loudspeaker.

NOTE — If there is a balcony in front of the test specimen, the measurement will not yield the reduction index of the test specimen alone but rather the combined sound protection offered by the test specimen and the balcony under the given angle of incidence.

The sound radiation of the loudspeaker should not change between calibration and measurement of sound insulation.

NOTE — This may be checked by placing the microphone at a distance of about 1 m from the loudspeaker on the axis of radiation or by measuring the loudspeaker current.

The sound pressure level in the receiving room should be an average over space and time. This average may be obtained by using a number of fixed microphone positions or a continuously moving microphone with an integration of p^2. The microphone positions shall be out of the near field of the test specimen.

NOTE — An alternative method which may be advantageous in some cases is described in annex C.

When in any frequency band the sound pressure level in the receiving room is less than 10 dB above the background level, then the background level shall be measured just before and after the determination of sound pressure level due to the sound source and a correction as given in the table shall be applied.

TABLE — **Correction to sound pressure level readings**

Difference between sound pressure level measured with sound source operating and background level alone	Correction to be subtracted from sound pressure level measured with sound source operating to obtain sound pressure level due to sound source alone
dB	dB
3	3
4 to 5	2
6 to 9	1

The above corrections, if any, are to be made to the individual readings.

If the difference is less than 3 dB, i.e. the sound pressure level L_2 is less than the background level, a precise value of L_2 cannot be determined.

4.4.3 *Frequency range of measurements*

See 3.4.3.

4.4.4 *Measurement and evaluation of the equivalent absorption area*

Concerning the correction term of equation (5) containing the equivalent absorption area, see 3.4.4.

4.4.5 *Measurement procedure*

Each organization should determine a normal test procedure which complies with this International Standard.

The necessary criteria which affect the repeatability of the measurements are shown below :

On the outside,

- position of the loudspeaker relative to the test specimen;
- directivity of the loudspeaker;

- angle of incidence;
- calibration of loudspeaker.

On the inside,

- minimum distances between microphone and room boundaries, especially test specimen, with regard to near fields;
- number of microphone positions or, in the case of a moving microphone, the microphone path;
- averaging time of the levels;
- method for determining the equivalent absorption area, which involves a number of repeated readings in each position.

An example of typical test conditions is given in annex D.

4.5 Precision

See 3.5.

4.6 Expression of results

For the statement of the airborne sound insulation of the test specimen, the sound reduction index R_ϑ should be given at all frequencies of measurement, in tabular form and/or in the form of a curve. For graphs with the level in decibels plotted against frequency on a logarithmic scale, the length for a 10:1 frequency ratio should be equal to the length for 10 dB, 25 dB or 50 dB on the ordinate scale.

The angle of incidence should be indicated, for example R_{45}.

4.7 Test report

With reference to this International Standard, the test report shall state :

a) name of organization that has performed the measurements;

b) date of test;

c) description of test specimen, if possible with sectional drawing and details of mounting;

d) a suitable plan of the building, showing the position of the test specimen;

e) volume and equivalent absorption area of the receiving room;

f) loudspeaker arrangement, the angle ϑ of sound incidence as well as the position of the loudspeaker relative to the test specimen (i.e. the height of the test specimen, the distance of the loudspeaker from the facade and the lateral displacement or the angle of elevation φ and the angle of azimuth β, see annex E);

g) type of noise and filters used;

h) the sound reduction index R_ϑ of the test specimen as a function of frequency;

i) the area S used for the evaluation of R_ϑ;

j) brief description of details of procedure and equipment (see 4.4.5).

ANNEX A

AREA *S* OF TEST SPECIMEN

When determining the sound reduction index of a facade, *S* in equations (1) and (5) is the area of the whole facade as viewed from within the receiving room.

If the sound reduction index of only a part of the facade (for example a window) is to be determined, *S* is the area of that part of the facade as seen from within the receiving room. In the case of a window or a door, *S* is the area of the free opening in which the element (including a possible frame and sealing) is mounted. In both cases it shall be proved that the sound transmission through the rest of the facade is negligible.

The area *S* used shall be stated in the test report.

ANNEX B

EXAMPLE OF A TEST PROCEDURE FOR MEASUREMENTS WITH TRAFFIC NOISE

An example of a test procedure which will normally be expected to give satisfactory repeatability is given below for cases where the room volume exceeds 25 m^3 and the distance between the traffic noise sources and the test specimen is not less than 6 m :

The traffic noise sources must have a uniform distribution of sound incidence and sufficient sound power as a function of frequency for the measuring situation and the likely sound insulation of the test specimen.

The microphone should be placed about 2 m in front of the test specimen.

Six microphone positions randomly distributed throughout the room are taken, using an averaging time of 5 s in each frequency band at each position. No microphone position should be nearer than 0,5 m to the room boundaries or 1 m to the test specimen.

In the case of single vehicles passing the test specimen, for each of the six microphone positions the level difference is determined separately for each passing on the basis of a filtered tape loop analysis resulting in equivalent sound pressure levels for each frequency band. The averaging time shall be chosen according to the duration of the passing.

The equivalent absorption area should be determined from readings taken using three microphone positions with two reverberation time analyses at each position.

ANNEX C

OPEN-CLOSED METHOD

In field measurements, difficulties in determining the sound pressure level outside of the building may arise, for example due to weather conditions (wind, rain) or due to shadow effects of balconies.

In such cases it would be advantageous to determine the sound reduction index of a specimen such as a window or door by measurements in the receiving room only, with the test specimen open and closed. This so-called open-closed method is feasible if the test specimen is openable and if the sound reduction index of the outer wall is considerably higher than that of the test specimen.

The sound reduction index determined by this method using loudspeaker noise is called $R_{\vartheta,oc}$ and is given by the following equation :

$$R_{\vartheta,oc} = L_{2\ open} - L_{2\ closed} + 10 \lg \frac{T_{closed}}{T_{open}} \text{ dB} \quad \ldots (6)$$

where T_{closed} and T_{open} are the reverberation times measured in the room with the test specimen closed and open.

The correction term

$$10 \lg \frac{T_{closed}}{T_{open}} \text{ dB}$$

takes into account that the equivalent absorption area in the receiving room is changed when the test specimen is opened.

If this influence is to be evaluated from the average sound pressure level produced by a standard source, the correction term should be replaced by

$$10 \lg \frac{A_{open}}{A_{closed}} \text{ dB}$$

where A_{open} and A_{closed} are the equivalent absorption areas of the room with the test specimen open and closed.

If only a part of the test specimen (not less than one-third of the full area S of the test specimen) is openable, a further correction term

$$10 \lg \frac{S}{S_{open}} \text{ dB}$$

must be added to equation (6), where S_{open} is the area of the part of test specimen which can be opened.

ANNEX D

EXAMPLE OF A TEST PROCEDURE FOR MEASUREMENTS WITH LOUDSPEAKER NOISE

An example of a test procedure which will normally be expected to give satisfactory repeatability in cases where the room volume exceeds 25 m^3 is given below :

For a test specimen at ground floor level, the loudspeaker is placed on the ground at an angle of incidence of 45°, the axis of the loudspeaker being directed to the centre of the test specimen.

The loudspeaker is placed at an adequate distance to ensure uniform sound level over the surface of the test specimen.

The loudspeaker is fed with white noise in one-third octave bands.

Six microphone positions randomly distributed throughout the room are taken, using an averaging time of 5 s in each frequency band at each position. No microphone position should be nearer than 0,5 m to the room boundaries or 1 m to the test specimen.

As an alternative, the sound field sampling procedure can be carried out using a rotating microphone device having a sweep radius of 0,7 m. In this case the plane of the traverse is inclined in relation to the room boundaries and the device should have a traverse time equal to the averaging time, which should be a minimum of 30 s.

The equivalent absorption area should be determined from readings taken using three microphone positions with two reverberation time analyses at each position.