INTERNATIONAL STANDARD

ISO 16940

First edition
2008-12-01

Glass in building — Glazing and airborne sound insulation — Measurement of the mechanical impedance of laminated glass

Verre dans la construction — Vitrages et isolation aux bruits aériens — Mesurage de l'impédance mécanique du verre feuilleté

Reference number
ISO 16940:2008(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

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 16940 was prepared by Technical Committee ISO/TC 160, *Glass in building*, Subcommittee SC 2, *Use considerations*.

This first edition of ISO 16940 cancels and replaces ISO/PAS 16940:2004, which has been technically revised.

Glass in building — Glazing and airborne sound insulation — Measurement of the mechanical impedance of laminated glass

1 Scope

This International Standard describes a method for the measurement of the loss factor and the equivalent bending rigidity modulus of laminated glass test pieces. The aim is to compare the properties of interlayers. These two parameters (and others such as density and thicknesses of glass components) can be related to the sound transmission loss (STL) of the glazing itself.

NOTE The Cremer equation as shown in Annex C can be used to determine the sound transmission loss.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 12543-1:1998, *Glass in building — Laminated glass and laminated safety glass — Part 1: Definitions and description of component parts*

ISO 140-1, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 1: Requirements for laboratory test facilities with suppressed flanking transmission*

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

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12543-1 and the following apply.

3.1
laminated glass
assembly consisting of two sheets of glass joined together with the interlayer that will be characterized by the method of this International Standard

NOTE 1 Adapted from ISO 12543-1:1998, definition 3.1.

NOTE 2 The interlayer type and construction should be specified.

4 Test method

4.1 Measurement of mechanical impedance (MIM) of laminated glass

4.1.1 Principle

The loss factor and the equivalent bending rigidity modulus are determined from the measurement of the input impedance of a glass beam sample. The input impedance is the transfer function between the injected force in one point and the velocity. This transfer function has resonances corresponding to a maximum of the response of the system (resonance frequency).

4.1.2 Measurement

The input impedance is measured with an impedance head giving both parameters (force and velocity) at the fixation point of the tested structure. Tested samples are beams of dimensions (25 ± 2) mm × (300 ± 1) mm; this limits the number of resonances in a given frequency band compared with a plate sample. The glass panes shall be nominally 4 mm thick for comparison purposes. The input impedance is measured at the centre of the sample, i.e. at half-length. For the fixation, good balance between left and right sides is needed, and the centre part shall be precisely determined. The vibration mode of the sample shall be as shown in Figure 1, i.e. a bending vibration of two "free clamped" half-beams.

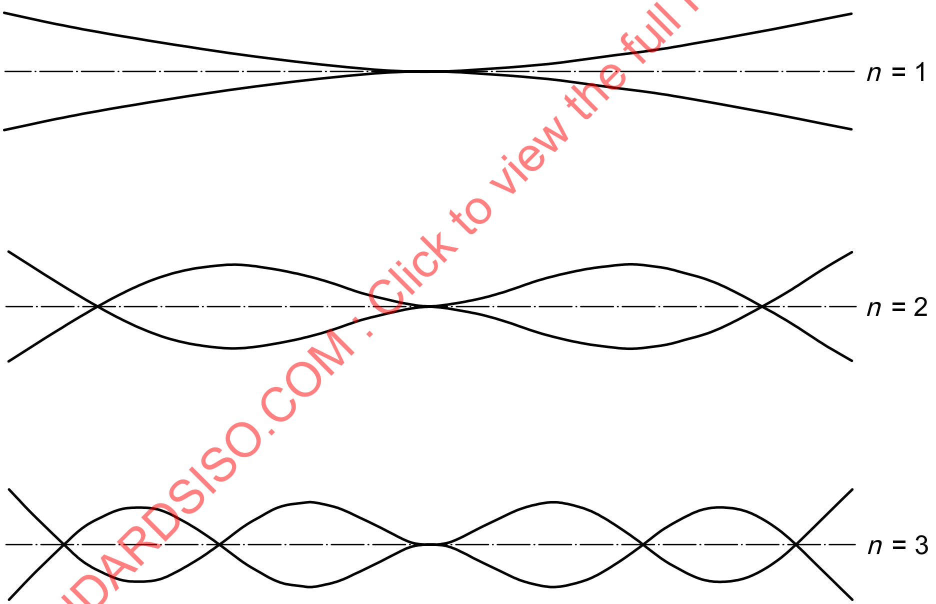


Figure 1 — Examples of vibration modes

The sample is glued (with a cyanoacrylic glue or equivalent) onto an impact button of 15 mm diameter. The impact button shall be flat (see Annex A).

NOTE Fixation balance is easier to achieve with inverted V buttons, but flat buttons have been chosen because they are more readily available.

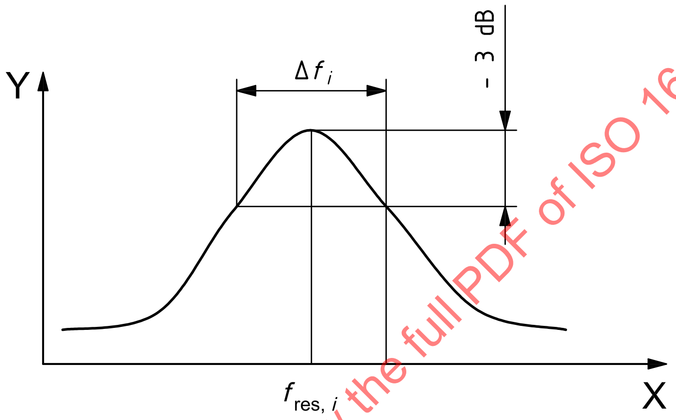
A white noise type force between 0 Hz and 5 000 Hz is used.

4.1.3 Determination of resonance frequencies and loss factors

When the transfer function corresponding to the input impedance is measured, resonance frequencies, $f_{\text{res},i}$, are noted as well as the resonance curves for each resonance frequency (i index corresponding to ith resonance). Bandwidths used are sufficient to get good accuracy. By default, 1,25 Hz bandwidths are used. The loss factor is then calculated using Equation (1):

$$\eta_i = \frac{\Delta f_i}{f_{\text{res},i}} \quad (1)$$

as shown in Figure 2, and is a function of the frequency.



Key

X frequency, f (Hz)

Y impedance, f/v

Figure 2 — Determination of the loss factor

If the outcome (see Annex D) does not allow readable data to be obtained at –3 dB on both sides of the peak, data at –2 dB shall be used by using Equation (2):

$$\frac{\Delta f}{f} = \frac{\Delta f}{f_{-2\text{dB}}} \times 1{,}31 \quad (2)$$

4.1.4 Test equipment

The measurement apparatus shall be set up as described in Annex A and composed of the following:

4.1.4.1 **Environmental chamber** or **air conditioned room**.

4.1.4.2 **White noise generator**.

4.1.4.3 **Power amplifier**.

4.1.4.4 **Shaker**.

4.1.4.5 **Impedance head**.

4.1.4.6 **Two measuring amplifiers**.

4.1.4.7 **FFT dual channel analyser**, plus calculation system.

The apparatus shall be set up consistent with the dimensions and masses of the samples.

The impedance head is an integrated system with a force transducer and an accelerometer. The force transducer is a transducer that generates an output voltage proportional to the input force. It is a piezoelectric sensor.

The accelerometer is a transducer generating an output voltage proportional to the input acceleration. It may be piezoelectric, strain gauge, etc.

The test equipment is shown in Annex A. A typical result is shown in Annex D.

Calculations may be done directly from the analyser, or automatically with specific software.

4.2 Test procedure

Measurements shall be carried out at (20 ± 1) °C. This parameter is very sensitive. The samples shall be kept for at least 1 h at the measurement temperature before performing the test.

The values of the resonance frequency and of the loss factor for the first three modes shall be noted.

The equivalent bending rigidity moduli for the first three modes should be calculated in accordance with Annex B.

The corresponding sound transmission loss curves should be calculated for the third mode in accordance with Annex C.

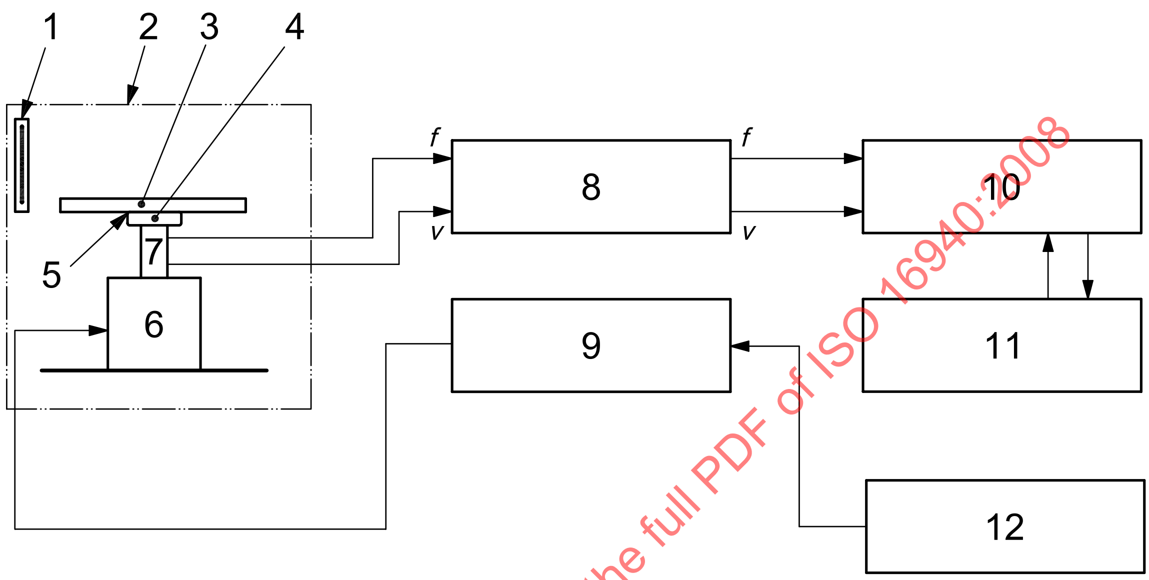
The weighted sound reduction index, R_w, in accordance with ISO 717-1, should be calculated and quoted to one decimal place.

4.3 Test report

The test report shall list the values of the resonance frequencies and loss factors for the first three modes.

Annex A
(normative)

Measurement set-up



Key

1 thermometer
2 environmental chamber
3 specimen
4 impact button
5 instantaneous adhesive
6 shaker
7 impedance head
8 measuring amplifiers of mechanical impedance
9 power amplifier
10 FFT analyser
11 computer
12 noise generator

Figure A.1 — Apparatus set-up

Annex B
(normative)

Determination of equivalent bending rigidity modulus

The equivalent bending rigidity modulus, $B_{\text{eq},i}$, shall be determined for each resonance frequency from Equation (B.1):

$$B_{\text{eq},i} = m_{\text{s}} \left(f_{\text{res},i} \frac{2\pi L^2}{\lambda_i^2} \right)^2 \tag{B.1}$$

where

m_{s} is the density per surface unit of the sample, in kg/m^2;

λ_i is a parameter (without dimension) given for free/clamped boundary conditions [1], [2] equal to:

1,875 10 for i = 1;

4,694 10 for i = 2;

7,854 76 for i = 3;

10,995 54 for i = 4;

L is the half-length of the beam, i.e. 150 mm.

NOTE The resulting equivalent bending rigidity modulus, $B_{\text{eq},i}$ ($f_{\text{res},i}$), is frequency dependent.

Annex C
(normative)

Calculation of sound transmission loss

The sound transmission loss, R, in the narrow band of a pane of the same glass combination shall be calculated using Equations (C.1), (C.2), (C.3) and (C.4). See ISO 140-1, ISO 140-3 and Reference [3].

$$\tau(\theta) = \frac{I_{\text{trans}}}{I_{\text{inc}}} = \frac{\left|p_t^2\right|}{\left|p_i^2\right|} = \left\{\left[1+\eta\left(\frac{\omega\rho_{\text{s}}}{2\rho c}\cos\theta\right)\left(\frac{\omega^2 B}{c^4\rho_{\text{s}}}\sin^4\theta\right)\right]^2 + \left[\left(\frac{\omega\rho_{\text{s}}}{2\rho c}\cos\theta\right)\left(1-\frac{\omega^2 B}{c^4\rho_{\text{s}}}\sin^4\theta\right)\right]^2\right\}^{-1} \tag{C.1}$$

where

I is the sound intensity, in W/m^2;

p is the sound pressure, in N/m^2;

η is the composite plate loss factor (dimensionless);

$\rho_{\text{s}} = \rho_{\text{m}} t$ is the plate surface density, in kg/m^2 (where ρ_{m} is the density of the plate material, in kg/m^3);

τ is the thickness of the plate, in m;

ρ is the density of air, in kg/m^3;

c is the speed of sound in air, in m/s;

θ is the angle of incidence;

B is the plate bending rigidity per unit width, in N·m;

$$\omega = 2\pi f \tag{C.2}$$

where

f is the frequency, in Hz;

$$\bar{\tau} = \frac{\int_0^{\text{lim}} \tau(\theta)\cos\theta\sin\theta\,\mathrm{d}\theta}{\int_0^{\text{lim}} \cos\theta\sin\theta\,\mathrm{d}\theta} \tag{C.3}$$

$$R = 10\lg\frac{1}{\tau}\,\text{dB} \quad (\text{with } \theta_{\text{lim}} = 75^\circ) \tag{C.4}$$

where R is the sound transmission loss.

The one-third-octave band data shall then be calculated.

